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High Value Vegetables in Southeast Asia: Production, Supply and Demand

24-26 January 2012
Chiang Mai, Thailand



Edited by R. Holmer, G. Linwattana, P. Nath, and J.D.H. Keatinge

- Thailand Department of Agriculture (DOA)
- AVRDC – The World Vegetable Center
- ASEAN-AVRDC Regional Network (AARNET)
- Horticultural Science Society of Thailand (HSST)
- Vegetable Science International Network (VEGINET)

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AVRDC – The World Vegetable Center is an international nonprofit research institute committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of nutritious, health-promoting vegetables.

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High Value Vegetables in Southeast Asia: Production, Supply and Demand

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The Nourished Millennium: How vegetables put global goals for healthy, balanced diets within reach

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ABSTRACT

About 3 billion people in the world are malnourished due to imbalanced diets or a lack of food. Those without sufficient food are undernourished and have weakened immune systems; undernourished children may be stunted with impaired cognitive development. More than 70% of malnourished children live in Asia. People unable to consume a balanced diet suffer from micronutrient malnutrition; they may be overnourished, and prone to develop chronic diseases such as anemia, blindness, cardiovascular disease, diabetes and cancer. In Asia and the Pacific, almost 600 million malnourished people add a considerable burden to already overstretched healthcare systems.

Many nations adopted the United Nations Millennium Declaration in 2000 and agreed to the time-bound targets (the Millennium Development Goals), yet progress toward these goals has been uneven. Some countries in Asia (including Vietnam, Nepal, India, Cambodia, Bangladesh and China) have made significant strides, and Thailand and Sri Lanka have made some progress—however, the challenges to improve child and maternal health and eliminate chronic malnutrition remain, with many rural-urban disparities.

Managing global malnutrition is complex, especially with the potential consequences of climate uncertainty and social unrest. While biofortification, food fortification, dietary supplements, and other interventions can improve nutrition, the easiest way to enhance the quality of nutritionally deficient diets is for the poor to grow nutritious foods locally.

Vegetables are a key source of micronutrients to improve the health of the malnourished poor, particularly vulnerable women and children. With locally available, high nutrient content vegetables, communities can ensure good nutrition through balanced diets and also increase household incomes. Vegetables such as mungbean, kangkong, moringa, sweet potato leaves and bitter gourd, as well as the more commonly known tomato, onion and cabbage, can provide wholesome and nutritious meals to contribute toward eliminating malnutrition and improving livelihoods amongst the poor.

Keywords

malnutrition, vegetables, health, micronutrients, balanced diets

INTRODUCTION

The world's population is about seven billion (UN-DESA 2011) - almost one billion people are undernourished (FAO 2011a), almost two billion are overweight or obese (WHO 2011a) and globally malnutrition affects more than two billion people. While many of the world's population are undernourished and hungry or over-supplied with calories, those who are malnourished have the so-called 'hidden hunger' resulting from micronutrient deficiencies, and lack of iron, vitamin A and zinc are among the top ten leading causes of death through disease in developing countries.

Iron and zinc deficiencies are one of the most common forms of malnutrition. Iron deficiency results in anemia which affects particularly women of child bearing age causing the deaths of an estimated 50,000 young women a year in pregnancy and childbirth, and impedes cognitive development in children. Iron deficiency between six months and two years old impairs the mental development of about half the children in the developing world. Iron deficiency in adults is so widespread that it is lowering the energy of nations and the productivity of workforces – with estimated losses of up to 2% of GDP in the worst affected countries. Zinc deficiency has many deleterious effects on human health as the mineral is essential for growth and lack of zinc can compromise the human immune system with then multiple consequences. Folate (vitamin B9) deficiency causes approximately 200,000 severe birth defects every year and is associated with approximately one in every ten adult deaths from heart disease, while iodine deficiency in pregnancy causes as many as 20 million babies a year to be born mentally impaired. Vitamin A deficiency compromises the immune systems of approximately 40% of the children under five years old in developing countries and leads to the early deaths of an estimated one million young children each year. Vitamin and mineral deficiencies should not be assessed individually as the causes and outcomes often overlap and interact. About half of all children with vitamin and mineral deficiencies have multiple deficiencies – an immeasurable burden on individuals, their families, and education and national health systems (Huffman et al. 1999; UNICEF and The Micronutrient Initiative 2004).

In Southeast Asia, the burden of micronutrient deficiencies is substantial. From data reported by UNICEF and The Micronutrient Initiative (2004), in Cambodia about 63% of children under five years old were estimated to have iron deficiency anemia, as well as 58% of women aged between 15 and 49 years old. This contrasts with the situation in Thailand where only 22% of the children under-five years of age and 27% of women of child-bearing age were deemed to be anemic. In both Cambodia and LaoPDR up to 42% of children under six years old were estimated to have sub-clinical vitamin A deficiency, while in Vietnam this was as low as 12% of children under six years old.

The data presented by the UNICEF (2011) shows that while the mortality rate of children under five years old in Southeast Asia has more than halved between 1990 and 2010 and seven of the ASEAN countries may reach their respective targets for Millennium Development Goal 4, only three countries are likely to reach the level of the most successful countries in the world with respect to these goals—ensuring that fewer than five children in every thousand die before reaching their fifth birthday (Table 1). If child mortality is used as a proxy indicator for malnutrition, it is clear that many countries in the region are making positive efforts to address the nutritional needs of their populations, but also that there is still much to be done.

Vegetables are an important source of minerals and vitamins. Both the global vegetables such as tomato (*Solanum lycopersicum*), cabbage (*Brassica oleracea*), onions (*Allium cepa*) and peppers (*Capsicum annuum*), and traditional vegetables such as moringa (*Moringa oleifera*), kangkong (*Ipomoea aquatic*), perilla (*Perilla frutescens*), anemone (*Nymphoides hydrophylla*), bitter gourd (*Momordica charantia*) and jute mallow (*Corchorus olitorius*) contain micronutrients to a greater or lesser extent depending on the species. Compared to cabbage, tomato contains somewhat more β-carotene, vitamin E and iron but has lower antioxidant activity (Yang and Keding 2009). However, moringa can have 38 times the amount of β-carotene, 24 times the amount of vitamin C, 17 times the amounts of vitamin E, folates and iron and eight times the amount of antioxidant activity exhibited by commercially-available tomatoes.

Southeast Asian diets have been influenced by traditional beliefs, religion and culture. Usually these diets are low in fat, high in fiber and with plenty of vegetables, relatively low in calories, and prepared in a manner that tempts the palate; Southeast Asian cuisine is usually considered to be satisfying and healthy. Traditionally rice and starchy foods, vegetables, fruit, legumes and nuts are consumed daily with fish often being a source of animal protein. Poultry and eggs are also consumed, with red meat consumed less frequently. Data (FAOSTAT 2011) challenges this traditional view, indicating that while vegetable consumption per capita per day exceeds the World Health Organization’s recommended daily consumption of 400 g per person in LaoPDR, Myanmar and Vietnam, the other countries in the region do not meet this target level of consumption.

The Asia-Pacific region was on track to achieve the Millennium Development Goal of halving the prevalence of extreme poverty by 2015, but recent dramatic rises in the price of rice and other staples have pushed millions of people back into hunger and poverty (Zeeuw and

Prain 2011). Each country's vulnerability can be considered in the context of its MDG achievement to assess how far it is at risk for each goal. Based on the child malnutrition indicator, the countries at greatest risk in Southeast Asia are LaoPDR and Cambodia and Nepal (ESCAP-ADB-UNDP 2010) while other countries remain vulnerable. The region's food supply system is more fragile and imbalanced than was previously thought. Large numbers of people in the Asia-Pacific were already undernourished prior to the recent price rises, relying on monotonous diets dominated by a few starchy staples. With a basic need for starchy food to reduce hunger, the poor have had to reduce their dietary diversity even further; many more millions in the region are now affected by the consequences of micronutrient malnutrition.

Food vs nutritional security

'Food security' is a much overused phrase indicating that there is a sufficient amount of quality food available. Unfortunately, dietary diversity and the role of fruits and vegetables to ensure a balanced diet are subsumed by the drive to assuage the world's immediate hunger through starch-based diets and, where possible, some protein. The starchy crops are often grown in monocultures, readily scaled up to fulfill the increasing demand from those who focus on 'food' security. While the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences, unfortunately economic drivers force the reality towards reduced food diversity for the poor.

Price volatility makes smallholder farmers and poor consumers increasingly vulnerable to poverty and hunger. FAO (2011b) clearly state that even short term fluctuations in prices can have a long term effect on development. Interestingly, the FAO monthly food price index averaged 215 points in November 2011, marginally down from October and is only just below its June 2008 high food prices crisis peak. Unfortunately, this food price index measures monthly change in the prices of a basket of only cereals, oilseed, dairy products, meat and sugar, and does not take into account the vegetables and fruit that can help assure a balanced diet.

Sharp rises in the price of staple foods are the most obvious symptoms of fundamental problems in our food supply systems, which national, regional or global changes in energy costs and climate will only further exacerbate. Greater investment in food systems that address diets rather than simply food supply is needed. For example, in times of high prices, cutting back on nutritious food in the first 1,000 days of a child's life can affect mental and physical development and, ultimately, future earning capacity.

The food crisis in the Asia–Pacific region manifested itself mainly in higher agricultural commodity prices including grains, pulses, animal products, fruit and vegetables. This, for example with rice, had a devastating effect on millions of the poorest in the region who rely on it as their major staple food. Between November 2007 and May 2008, global rice prices increased by 140 percent, despite production reaching an all-time high in 2007 and despite the absence of any significant increase in demand and fairly stable rice stocks. Politically-driven export restrictions triggered a sharp increase in the price of rice, which only stabilized and started to fall after restrictions were lifted and precautionary rice purchases were no longer required (Weinberger et al. 2009). Rising energy prices, reduced staple food stock levels and exchange rate movements certainly helped to drive the food prices up.

In spite of the substantially reduced level of poverty in this region which was on track to achieve the Millennium Development Goal (MDG) of halving the prevalence of extreme poverty by 2015 (in 2005–2006, on average 16% of the population of Asia and the Pacific—about 542 million people—were hungry), the Asian food price crisis in 2007-2008 nevertheless resulted in about another 40 million people in the region going hungry. Many of those who were not hungry nonetheless were likely to have spent a much larger proportion of their income on the staple foods and thus reducing yet further their consumption of vegetables and fruit (Cambodia Development Resource Institute 2008; Overseas Development Institute 2008).

Women, children and the vulnerable

Women in developing countries have challenges which are driven by culture as well as gender-related differences. There is usually an unequal balance in power and influence between men and women, women are often affected by cultural and social factors that tend to reduce opportunities for education and employment and tend to focus on domestic and child-bearing roles.

Poverty tends to have more serious consequences on the health of women: reduced access to healthcare, practices within the household where nutritious foods are often preferentially served to men leading to malnutrition in women and children, and risks that accompany pregnancy and childbirth.

WHO (2009) reported that about half the women who died in 2004 were from low income countries (as opposed to 16% from high income countries) with almost half of those deaths attributed to lower respiratory infections, heart disease, diarrhea, strokes, HIV/AIDS, maternal conditions, neonatal infections, prematurity and low birth weight—this is in contrast to the deaths in high income countries where a quarter of the deaths are attributed to heart disease and strokes. Globally, about 80% of maternal deaths are due to complications in pregnancy, childbirth or the postpartum period, with indirect causes (20%) of maternal death including diseases that complicate pregnancy or are aggravated by pregnancy, such as malaria, anemia and HIV/AIDS. Women also die because of poor health at conception and during pregnancy and from pregnancy-aggravated pre-existing conditions.

Poor maternal health and diseases that have not been adequately treated before or during pregnancy contribute to the death of the mothers, and also to premature birth and low birth weight. About 17% of babies born have low birth weight (WHO 2011b), and of the approximately 133 million babies who are born alive each year there are almost 3 million neonatal deaths. The pattern of babies' deaths is similar to the pattern of maternal deaths: large numbers in low-income countries (74 deaths per 1000 births) compared to high-income countries (7 deaths per 1000 births) (Table 2). Although the underlying causes differ, poor maternal health remains a major factor and even those infants who survive maternal or neonatal complications have high morbidity with disabilities that include cerebral palsy, mental retardation or visual or auditory impairment and may die later in infancy and childhood.

Pregnant and lactating women and young children less than three years old are most vulnerable to malnutrition. Evidence shows that beyond the age of 2 or 3 years, the effects of chronic malnutrition are irreversible. This means that to break the intergenerational transmission of poverty and malnutrition, children at risk must be reached during their first two years of life (The Mother and Child Health and Education Trust 2011).

Children who are malnourished and do not reach their optimum height or who have experienced bouts of weight loss during childhood are affected in many ways. As adults they may not reach their optimum size and thus may have reduced physical capacity for work. Malnutrition also affects the development of the brain which often results in a lower IQ and furthermore malnourished children are also at greater risk of infection due to impaired immune systems. The degree of cognitive impairment is directly related to the severity of stunting and iron deficiency anemia. These children have low cognitive test scores, delayed enrolment and are more often absent from school than well-nourished children. Vitamin A deficiency reduces immunity and increases the incidence and gravity of infectious diseases—this again impacting education.

The loss in economic productivity from malnourishment is calculated as 1.38% of reduced productivity for every 1% decrease in height while 1% reduced productivity is estimated for every 1% drop in iron status (Haddad and Bouis 1991). If stunting in early childhood can be prevented and more than a third of that 1% increase in adult stature made possible, a lifetime of economic loss can be mitigated.

The other vulnerable sectors of the population are also severely affected by the consequences of malnutrition. The elderly, those with chronic diseases, communities living in conflict situations, and those coping with environmental challenges are all affected. Malnutrition can result in reduction in energy levels for physical work, greater susceptibility to infectious disease, anemia, blindness and other consequences of micronutrient malnourishment.

In developed countries, the population often is able to make a choice of whether to eat a nutritious diet. In many developing countries there may be no choice and thus malnourishment is a common part of daily life. Poverty is an important factor, and often yields a higher burden on women, children and the vulnerable, yet empowering communities through information, education and appropriate tools can bring about the changes needed to make a more nutritious diet available to overcome these impediments to healthy and productive lives.

Risk mitigation

Populations in developing countries are particularly vulnerable to risk of serious changes in their health and economic status. Risk in terms of food security are often well and graphically documented, less so the risks due to malnutrition. Food and nutritional security are at risk from climatic events and changes, civil disturbances, global economic fluctuations and, perhaps more poignantly, a lack of information and support for change.

Mitigating the risks that the poor in developing countries face is a complex issue, but part of the solution to provide nutritional security is to help the poor to grow their own nutrition, by growing (and therefore consuming) more vegetables and fruit. This will allow the poor to continue consuming this healthy diversity in spite of the rising prices which have meant that fresh produce may no longer be easily purchased and consumed (Aguilar 2005; Cambodia Development Research Institute 2008).

Global climatic uncertainty is a major risk. Weather variability has always been a risk to farmers, but current climatic fluctuations and changes further exacerbate the risk. To ensure farmers and households are more nutritionally resilient when confronted with warmer or cooler temperatures, drought or flooding, salinity, or a combination of these factors, there must be fruit and vegetables types and varieties that can withstand these challenges. These climatic events have already been seen in Southeast Asia, causing significant loss of life, damage to infrastructure and land, and reduced crop production and yield. The Philippines, Thailand, Vietnam and Malaysia have been particularly badly hit by typhoons and floods in recent years, and in Southeast Asia coastal areas such as the Irrawaddy delta in Myanmar, the lower reaches of the Chao Phraya in Thailand, and the Mekong and Red River Deltas in Vietnam are conspicuously vulnerable.

With climate change, pests and pathogens of the crops will also evolve, adapt and change their distribution affecting the crops and the quantity and quality of their yields. Plants suffering from abiotic stresses may be more vulnerable to pests and diseases, their pollinators may be less common, and consequently yields may be affected. Plant breeding is a key intervention to help farmers and households reduce their risk by developing plants that will perform well under these constraints (de la Peña and Hughes 2007). Many wild relatives of cultivated varieties of both fruit and vegetables may possess genes which make them more adaptable and tolerant to harsher environments in which they can thrive. For example, *Solanum chilense*, a wild relative of the cultivated tomato, is indigenous to the desert areas of northern Chile and found to be adapted to extreme aridity, soil salinity, and to low temperatures (Chetelat et al. 2009). Two wild nightshade species from the same region (*S. sitiens* and *S. lycopersicoides*) also share such traits. Gene transfer from these wild species could facilitate the development of drought and salt tolerant traits in standard tomato varieties. With adapted varieties and targeted crop management techniques, yields of diverse and nutritious vegetables and fruit should remain available and affordable so that commodity supply uncertainties and price rises will not be a major risk (Keatinge et al. 2009; AVRDC 2010).

Vegetables and fruit are both food and important parts of national culture. Keatinge et al. (2011) describe the social and political consequences of the inability to obtain key vegetables (onions) causing the downfall of two state governments in India and trade tensions between India and Pakistan. Similarly, chili pepper prices in Indonesia rose ten-fold in early 2011, costing more than beef per kg in Jakarta (Firdaus 2011) and resulted in the Indonesian government urging Indonesians to grow their own chilies.

Given that the concept of security is often broadened away from food security, to include economic security and environmental security, threats can include overpopulation, population movements, deforestation, crime and disease, as well civil unrest and international conflicts (McKay, 2009), the support of healthy, contributing members of society who are well nourished becomes increasingly critical to national governments. The dynamics of urban and rural populations must also be considered and mechanisms to ensure food and nutritional security for both sectors of the population are vital.

Interventions to improve nutritional security

Nutritional security requires the availability and affordability of the essential vitamin and mineral micronutrients for human health as part of a balanced diet. Dietary supplements, fortification of food products, biofortification and assuring a diversity of vegetables and fruit in the diet are possible ways forward to ensure nutritional security.

Dietary supplements in the form of tablets and powders have been used to combat malnutrition in developing countries where the most effective way of controlling vitamin A deficiency has been through delivery of high-dose supplements as food fortification has not yet ensured coverage levels similar to supplementation in most affected areas. Achieving substantial reductions in child mortality means that all children 6–59 months old living in affected areas need to receive high-dose supplements every 4–6 months. Vitamin A supplementation has been carried out for decades in some of Southeast Asian countries, including Indonesia, the Philippines and Vietnam and is particularly effective where there is a strong child immunization program. Myanmar was successful in ensuring supplementation with vitamin A of about 97% of children at least once a year (Huffman et al. 1999; UNICEF 2007).

Infants are born with stores of vitamin A sufficient only for the first few days of life. Although newborns with healthy, well-nourished mothers receive sufficient vitamin A from breast milk to protect them from deficiency, in developing countries this is often not the case and new mothers must also be given vitamin A supplementation to ensure that their deficiency does not affect their infant's development—this activity lags behind supplementation for children and in Southeast Asia in 2004 for example, only 12 priority countries surpassed 50 per cent coverage, including Myanmar and Vietnam (UNICEF 2007). Dietary inadequacies can also be prevented by using complementary food supplements such as moringa leaf powder (PROTA 2004), water dispersible or crushable micronutrient tablets, micronutrient sprinkles added to food just before feeding, or fortified spreads added to food just before feeding or eaten as snacks (Nestel et al. 2003).

While vitamin A tablets have been used to good effect in countries with a strong national immunization program, some countries, for example Malaysia, do not have vitamin A supplementation, relying instead on food-based strategies. Food fortification is a very effective strategy to increase intake of vitamin A and is widely used to prevent deficiencies of multiple nutrients. However, effective food fortification generally requires technical capacity and centrally processed and widely distributed foods that are amenable to fortification. Foods that are fortified include sugar (sugar fortification has been carried out in Latin America for several decades), salt (iodized salt is common in many countries, reducing the incidence of goitre and other complaints associated with iodine deficiency), oil, milk, margarine, infant foods and various types of flour. In many of the countries in Southeast Asia, fortification of flour is a successful way to tackle the issues of iron and folate deficiency, although in the countries assessed, the fortification of flour is only mandatory in Indonesia. Foods fortified with vitamin A are available in Malaysia and the Philippines, with some progress towards fortification in Indonesia, Thailand and Vietnam (UNICEF 2007).

These approaches can be effective answers to deficiency but are not particularly sustainable (Keatinge et al. 2011). Another option includes the biofortification of staple crops but this is a high-cost and may be a high-risk and long-term strategy. Several crops have been the subject of intense research to develop varieties that are high in specific nutrients. Both conventional breeding and genetically modified crops have been considered for this purpose. Golden rice is biofortified with provitamin A (beta-carotene) and zinc and is due to be released in the Philippines in 2013—this rice was produced through genetic modification and has encountered many hurdles along the way (Levitt 2011). There are also plans to develop sorghum with increased levels of lysine, vitamin A, iron and zinc through transgenic processes (Africa Harvest 2010).

All plant breeders should be focusing on producing crops that are sufficiently nutritious. Unfortunately in the private sector there is a greater focus on long shelf-life and appearance, rather than intrinsic, health-promoting characteristics. Conventional breeding and selection has improved the nutritional quality of some crops: orange fleshed sweet potato has been shown to be an excellent source of vitamin A and is in the process of widespread adoption in countries such as Mozambique and Uganda (Naico and Lusk 2010). However, as obesity is a growing global problem, providing a carbohydrate-based source of vitamin A is perhaps not a perfect solution. Biofortification of maize with provitamin A carotenoids has been successful (Howe and Tanumihardjo 2006), but the impact on vitamin A deficiency has yet to be quantified.

Common sense indicates a sensible solution would be to increase dietary diversity to include more pulses, additional green leafy and orange vegetables, and other diverse nutrient-dense foods. De Pee and Bloem (2009) recommend dietary diversity with fruit and vegetables to overcome vitamin A deficiency even though ensuring bioavailability and bioconversion of carotenoids in the fruit and vegetables into vitamin A can sometimes be a challenge. Eating fruit and vegetables as part of an overall strategy to overcome micronutrient malnutrition is particularly important as fruit and vegetables are sources of a whole range of additional vitamins, minerals and other beneficial dietary components such as folate that make important contributions to human health (Yang and Keding 2009; Keatinge et al. in press)

In order to provide a sustainable solution to tackle these micronutrient deficiencies, home gardens are a primary tool to raise awareness and tackle malnutrition simultaneously (Talukder et al. 2010). A home garden is an area, usually around or adjacent to, the home where diverse vegetables and fruit can be grown throughout the year to meet family nutritional requirements and sometimes excess produce can be sold to generate extra family income. Home gardening with vegetables and fruit can usually be undertaken by most of the rural and urban poor irrespective of their level of land resources, educational status, cash investment capacity or gender. The land needed for home gardens is small, labor requirements can usually be fulfilled by family members, and both waste water and household organic wastes can be recycled for irrigation and used as compost respectively.

A food based approach to combat malnutrition requires diet diversity with sufficient amounts of carbohydrate, proteins and fats/oils, as well as the diverse products of the home garden supplying vital micronutrients. The produce of home gardens contributes substantially to the nutritional health of the families, especially those that are malnourished or poor (Berti et al. 2004; Talukder et al. 2010; Holmer 2011; Keatinge et al. 2011). An additional advantage of home gardens is that it empowers women who are usually the ones looking after such gardens – they give women greater authority and control over the quality of their family’s diet (Ruel and Levin 2001).

Keatinge et al (2011) demonstrate that in India a 6m x 6m home garden can provide much of the vitamin requirement (A and C) for a family of four year-round. The inclusion of a range of traditional vegetables in such gardens brings further advantage as many of these have the advantage of natural high nutrient-density (Yang and Keding 2009). Home garden designs are available, taking into account local conditions and dietary preferences (Fig. 1) however it is natural that individuals will adapt home gardens to suit their own needs. With information and education, these adapted home gardens will be able to contribute substantially to a family’s nutritional needs.

In order to maximize the nutritional gains from these home gardens and the diversity of nutritious vegetable produce, ways of preparing the foods that maximize nutrient bioavailability to the consumer should be used as often as possible. The majority of the poor in developing countries cannot afford to consume sufficient meat for their nutritional requirements and therefore their iron intake is often from less expensive plant sources. Many people do not choose to consume meat and animal products due to health-related, environmental, personal preference or religious reasons. Absorption of plant-based iron by the human body is lower than that of iron from meat (Hunt 2003). Although the total iron intake from vegetables and other plant sources may meet dietary recommendations, the low bioavailability of plant-based iron may still cause iron deficiency among these population. Yang et al. (2002) showed that vegetables can be grouped into three categories based on their iron bioavailability before and after cooking, adding vegetables with high iron bioavailability with or without cooking (for example, tomato) to a meal can enhance bioavailable iron intake. In addition certain vegetables such as tomato and moringa leaves can enhance iron bioavailability from the meal when added during cooking (Vijayalakshmi et al. 2003), and bioavailability from legumes such as mungbean can be improved by more than 10% by soaking, pressure cooking, fermenting and sprouting (AVRDC 1995) which reduces the level of phytic acid which is anti-nutritional for iron, calcium, zinc and copper.

The home gardens, and by extension school and community gardens, serve both to empower women and can teach children about healthy foods and growing healthy crops. The abundant good quality crops for the household empower the women to manage the diets of their families (Yang and Hanson 2009), and extra income through sales of excess produce may enhance the women's and household's standing in the community through the exchange of home produce with neighbors. School gardens are becoming particularly important in some areas of Southeast Asia. In the Philippines, home garden and village vegetable production is being promoted to enhance subsistence diets and diversify local economies, and is also promoted through schools (Johnson et al. 2008). An ambitious program to establish vegetable gardens at all 42,000 public schools in the country (AVRDC 2011) is being started which will contribute to the nutritional health of the children in the country.

Focus on vegetables and fruit

Consuming nutrient dense fruit and vegetables is a key step to overcoming micronutrient malnutrition and ensuring that the food consumed is also appetizing. While vegetables are commonly consumed as part of the main meal, and usually cooked, fruit may be eaten as snacks, and are often consumed raw.

Both traditional and global fruits are important in local diets. Many fruit are tree crops and in the case of traditional or indigenous tree fruits, it is important to set priorities for which species to promote and to engage in participatory domestication for the improvement of yield, quality and germplasm delivery to farmers (Jamnadass et al. 2011). Both indigenous and exotic fruits are cultivated in Southeast Asia and can contribute both to improved nutrition and to income generation, however the indigenous species are those most often cultivated by smallholders. Traditional fruit in the region include durian (*Durio* spp.), rambutan (*Nephelium lappaceum*), jackfruit (*Artocarpus heterophyllus*), wax/Malay apple (*Syzygium malaccense*), custard apple (*Annona* spp.), persimmon (*Diospyros* spp.), mangosteen (*Garcinia mangostana*), banana (*Musa* sp.) and dragon fruit (*Hylocereus* spp.). The nutritional contents of these fruit are not well characterized having a diversity of species and types. The available data shows a wide diversity both in terms of the range of nutrients in the fruit and amount of those nutrients, as with the exotic fruits (Table 3).

There is even greater diversity in the range of available vegetables in the region. There are currently almost 60,000 accessions of vegetables in AVRDC – The World Vegetable Center's genebank and of these about 12,000 accessions from some 200 species of indigenous vegetables.

The exotic vegetables such as tomato, onion, cucumber, carrots and peppers are ubiquitous in most Southeast Asian countries. These vegetables have gained prominence and are often readily available in rural and urban markets. They are usually of consistent appearance, attractive to the eye and have been adopted into national cuisines. Of more interest nutritionally are the traditional vegetables such as mungbean, kangkong, moringa, sweet potato leaves and bitter gourd, and the even less common species such as Bird's nest fern (*Asplenium* spp.) anemone, sesbania (*Sesbania grandiflora*) and Chinese cedar (*Toona sinensis*) (Table 3). The nutrients in some of these traditional species are considerably higher than in the exotic species which have often been bred for commercial qualities such as long shelf life at the expense of taste and nutrition.

To reduce risks and to benefit from the higher nutritional contents, these crops must be grown under appropriate crop management conditions which minimize the need for external inputs and maximize quality yields. With sensible agricultural practices, for small-scale production and home gardens the compost and organic inputs can be provided by the household, requiring minimal recourse to purchased fertilizers. The use of leguminous species (such as mungbean) in appropriate rotations will also enhance the soil health of the home garden.

Pests and diseases must be controlled—an ideal way is through the use of resistant varieties. Unfortunately, the search for biotic and abiotic stress tolerance is occurring mainly in commercial vegetable and temperate fruit species. The opportunities to enhance traditional crops which are important to local communities in developing countries have not been taken up to any large extent (Keatinge et al 2010). Indigenous vegetables such as amaranth (*Amaranthus* spp.), kangkong and Malabar spinach (*Basella alba*) are infested by few pests and diseases and can thrive with very limited external production inputs. However, for the more susceptible crops, simple net shelters can give protection from insect pests, especially to seedlings, thus reducing pest disease incidence.

To manage pests and diseases on eggplant, for example, a combination of cultural control (keeping weeds under control, using trap crops e.g. okra to manage leafhoppers and border crops to reduce infestation by whiteflies), host plant resistance, mechanical control (using 30-mesh nylon net to protect seedlings from infestation by eggplant fruit and shoot borers) and behavioral control (yellow and blue sticky traps to attract whiteflies and thrips respectively) can give good pest control (Srinivasan 2009). Where some form of pesticide is required, neem or other natural pesticides can be used and will have minimal impact on the environment or consumers. In eggplant production, neem soil drenches or foliar application can control whiteflies, while soil application of neem cake can reduce the incidence of stem borers and sex pheromone lures can be used to control the fruit and shoot borer. Similarly, in tomato production, sex pheromone traps and a combination of *Bacillus thuringiensis* (Bt), *Helicoverpa armigera* nuclear polyhedrosis virus (HaNPV) and neem extract applications also provide good control of the tomato fruit borer (Srinivasan et al. 2010). Cultural control, host plant resistance and sex pheromone traps, as part of a crop management package which also includes biopesticides and parasitoids can provide effective control of many of the pests that cause losses in vegetable production. Control measures for bacterial and fungal diseases (Lin and Wang 2010; Chen et al. 2010) include rotations, pathogen-free planting materials, resistant varieties, grafting onto resistant rootstocks, sanitation and other crop management practices. While some of these crop management practices do require inputs, most of the technologies are easily within the reach of the poor, thus ensuring quality, nutritious produce.

Water use is also a major concern in many regions and opportunities to utilize domestic waste water (untreated household wastewater that has not come into contact with sewage) for vegetable production in a home garden maximize the use of this precious resource. Where water may be contaminated with fecal organisms or other infectious agents, for example in cities or villages where sewage runoff may have contaminated the water, or where the sewage water is sometimes used directly as a source of irrigation water, care must be taken in the application of water to the crops, especially where the crops may not be cooked before consumption, for example salads and herbs that may be eaten raw (Stephenson et al. 2000; Walker et al. 2007). Where water is a critical, limiting factor, drip irrigation could be considered to maximize crop yield per unit of water (Palada et al. 2011). The cost of a small-scale drip irrigation kit is not considered prohibitive when it is distributed over the cropping periods of two years, with the cost of other inputs remaining the same but total labor use under drip irrigation is usually less, although an increase in yield due to better water management may require additional labor for harvesting. Transformation of existing agricultural practices with drip irrigation in dry areas has a strong positive impact on profits (and therefore household security) with minimal environmental impact and thus has great potential to contribute to sustainable agricultural development (Woltering et al. 2011). Maximizing the use of the available water minimizes production risks, and thus contributes to the stability of household food supplies in areas where water is a major limiting factor.

CONCLUSION

Achieving the Millennium Development Goals on target are a major challenge which appears to be impossible to overcome, yet every step towards the elusive goals improves the lives and livelihoods of many millions of people. In Southeast Asia there has been substantial progress towards improving maternal and child health, and improving nutrition thus equipping children better to reap the successes of education. Nonetheless it is clear that much remains to be done. The recent financial and food crises were an alarm for which the ultimate cause is not widely acknowledged: the reliance on very few crops to feed an ever-increasing number of people. With fewer crop types, there is less diversity, less resilience and more risk. The risk is not only to production and thus national and regional economies, but also to human nutrition and health.

Where there is relative affluence, and families can purchase the food of choice, this choice is often poorly made, resulting in another extreme of imbalanced diets leading to obesity and the associated health problems. There are diverse fruits and vegetables available, both traditional and exotic, which can be included as part of the daily diet—and their production, use and consumption must be promoted. There are many different ways of producing these crops. Vegetables can be grown in rural villages or in urban areas, in a home garden, or commercially. Different production and postharvest practices can be used to reduce risks (including those of injudicious use of inputs, climatic events and variation and crop price fluctuations), increase profits and improve livelihoods. More investment is needed, more commitment by national and international agencies and governments, and more information and education about the risks of not eating a balanced and diverse diet. Unless we have balanced, health-promoting diets, we cannot nourish the hopes and dreams of millions of people in Southeast Asia.

References

ACAGA. 2011. http://www.custardapple.com.au/index.php?option=com_content&view=article&id=48&Itemid=55 (accessed 11 December 2011)

Africa Harvest. 2010. ABS Project: Technology Development. http://biosorghum.org/articles.php?id=56 (accessed 11 Dec 2011).

Aguilar AVJ. 2005. Rice in the Filipino diet and culture. Discussion Paper Series No. 2005–15, Manila: Philippines Institute of Development Studies.

AVRDC. 1995. Effect of cooking on in vitro bioavailability of iron in mungbean. In AVRDC 1994 Progress Report. Pp 239-243. AVRDC Publication number 95-434, Shanhua, Taiwan.

AVRDC. 2010. Prosperity for the poor and health for all: Strategic Plan 2011–2025. 41pp. Shanhua: AVRDC.

AVRDC. 2011. *Gulayan sa Paaralan*: Vegetables go to school in the Philippines. *'Fresh' News from AVRDC – The World Vegetable Center*, July 15 2011. http://www.avrdc.org/fileadmin/pdfs/newsletter/15-July-2011.pdf (accessed 8 December 2011).

Berti PR, Krasevec J, FitzGerald S. 2004. A Review of the effectiveness of agriculture interventions in improving nutrition outcomes. *Public Health Nutrition* 7: 599-609.

Cambodia Development Resource Institute. 2008. Survey Report: Impact of high food prices in Cambodia. 97pp. http://documents.wfp.org/stellent/groups/public/documents/ena/wfp189739.pdf (accessed 2 December 2011)

Chetelat RT, Pertuzé RA, Faúndez L, Graham EB, Jones CM. 2009. Distribution, ecology and reproductive biology of wild tomatoes and related nightshades from the Atacama Desert region of northern Chile. Euphytica 167:77-93

Chen C-h, Sheu Z-m, Chen W-y, Wang T-c. 2010. Managing fungal diseases of tomato. Pp69-84 in Srinivasan R (Ed) Safer tomato production methods: A field guide for soil fertility and pest management. AVRDC – The World Vegetable Center, Shanhua, Taiwan. AVRDC Publication number 10-740. 97pp.

de la Peña R, Hughes Jd'A. 2007. Improving vegetable productivity in a variable and changing climate. *Journal of Semi-Arid Tropical Agricultural Research* 4: 22

de Pee S, Bloem MW. 2009. Current and potential role of specially formulated foods and food supplements for preventing

malnutrition among 6- to 23-month-old children and for treating moderate malnutrition among 6- to 59-month-old children. *Food and Nutrition Bulletin* 30: S434-S463

ESCAP-ADB-UNDP. 2010. Achieving the Millennium Development Goals in an Era of Global Uncertainty. Asia-Pacific Regional Report 2009/10. Economic and Social Commission for Asia and the Pacific. 116pp

FAO. 2011a. The State of Food Insecurity in the World 2011. 50pp. Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO. 2011b. The November FAO Food Price Index nearly unchanged from October
Release date: 08/12/2011 http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/ (accessed 12 December 2011)

FAOSTAT. 2011. FAOSTAT online. http://faostat.fao.org/site/339/default.aspx (accessed December 2011)

Firdaus I. 2011. Indonesians fired up by the soaring price of chili pepper. China Post, February 11th, 2011

Haddad LJ, Bouis HE. 1991. The Impact of Nutritional Status on Agricultural Productivity: Wage Evidence from the Philippines. *Oxford Bulletin of Economics and Statistics* 53: 45–68

Holmer, R.J. 2011. Vegetable gardens benefit the urban poor in the Philippines. *Appropriate Technology* 38: 49-51

Howe JA, Tanumihardjo SA. 2006. Carotenoid-biofortified maize maintains adequate vitamin a status in Mongolian gerbils. *Journal of Nutrition* 136: 2562-7.

Huffman SL, Baker J, Shumann J, Zehner ER. 1999. The Case for Promoting Multiple Vitamin/Mineral Supplements for Women of Reproductive Age in Developing Countries. LINKAGES Project, Academy for Educational Development Washington DC. 40pp.

Hunt JR. 2003. Bioavailabililty of iron, zinc, and other trace minerals from vegetarian diets. *American Society for Clinical Nutrition* 78: 6335-6395
Jamnadass RH, Dawson IK, Franzel S, Leakey RRB, Mithofer D, Akinnifesi FK, Tchoundjeu Z. 2011. Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallhoders' agroforestry systems: a review. *International Forestry Review* 13: 1-17.
Johnson GI, Weinberger K, Wu MH. 2008. The Vegetable Industry in Tropical Asia: An overview of production and trade, with a focus on Thailand, Indonesia, the Philippines, Vietnam, and India [CD-ROM]. Shanhua, Taiwan: AVRDC - The World Vegetable Center. 56 pp. (Explorations series; no.1).
Keatinge JDH, Chadha ML, Hughes Jd'A, Easdown WJ, Holmer RJ, Tenkouano A, Yang RY, Mavlyanova R, Neave S, Afari-Sefa V, Luther G, Ravishankar M, Ojiewo C, Belarmino M, Ebert A, Wang JF, Lin LJ. (in press). Vegetable Home, School, Community and Disaster Recovery Gardens and their Impact on the Attainment of the Millennium Development Goals: Retrospective and Perspective for Research and Development. *Food Security*.
Keatinge, JDH, Ledesma D, Hughes Jd'A, de la Peña R. 2009. A strategic look to the future for vegetable research: The World Vegetable Center and its partners. Global Climate Change: Imperatives for Agricultural Research in Asia-Pacific (pp. 113–119). Tsukuba: JIRCAS.
Keatinge JDH, Yang R-Y, Hughes Jd'A, Easdown WJ, Holmer R. 2011. The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals. *Food Security* 3:491–501
Keatinge JDH, Waliyar F, Jamnadas RH, Moustafa A, Andrade M, Drechsel P, Hughes Jd'A, Kadirvel P, Luther K. 2010. Re-learning old lessons for the future of food – by bread alone no longer: Diversifying diets with fruits and vegetables. *Crop Science* 50: S51–S62
Levitt T. 2011. Can GM-free biofortified crops succeed after Golden Rice controversy? *The Ecologist* http://www.theecologist.org/News/news_analysis/1159571/can_gmfree_biofortified_crops_succeed_after_golden_rice_controversy.html (accessed 11 Dec 2011)
Lim TK. 1996. Durian 1. Characteristics and Cultivars. Agnote 639 No. D29 http://www.nt.gov.au/d/Primary_Industry/Content/File/horticulture/639.pdf (accessed 11 December 2011)
Lin LJ, Hsiao YY, Kuo CG. 2009. Discovering indigenous treasures: Promising indigenous vegetables from around the world. AVRDC – The World Vegetable Center Publication No. 09-720. AVRDC – The World Vegetable Center, Shanhua, Taiwan. 317 p.
Lin C-h, Wang J-f. 2010. Managing bacterial diseases of tomato. Pp61-68 in Srinivasan R (Ed) Safer tomato production methods: A field guide for soil fertility and pest management. AVRDC – The World Vegetable Center, Shanhua, Taiwan. AVRDC Publication number 10-740. 97pp
McKay J. 2009. Food and Health Considerations in Asia-Pacific Regional Security. *Asia Pacific Journal of Clinical Nutrition* 18: 654-663
Morton J. 1987. Fruits of warm climates. Morton JF, Miami, FL.
Naico ATA, Lusk JL. 2010. The Value of a nutritionally enhanced staple crop: Results from a choice experiment conducted with orange-fleshed sweet potatoes in Mozambique. *Journal of African Economies* 19:536-558
Nestel P, Briend A, de Benoist B, Decker E, Ferguson E, Fontaine O, Micardi A, Nalubola R. 2003. Complementary Food Supplements to Achieve Micronutrient Adequacy for Infants and Young Children. *Journal of Pediatric Gastroenterology and Nutrition* 36: 316–328
Overseas Development Institute. 2008. Rising food prices: a global crisis. Briefing Paper #37. 4pp London, UK. http://www.odi.org.uk/resources/docs/1630.pdf (accessed 2 December 2011)
Palada M, Bhattarai S, Wu DL, Roberts M, Bhattarai M, Kimsan R, Midmore D. 2011. More Crop Per Drop: Using Simple Drip Irrigation Systems for Small-scale Vegetable Production. AVRDC – The World Vegetable Center, Shanhua, Taiwan. AVRDC Publication No. 09-729. 83 pp.
PROTA. 2004. Plant Resources of Tropical Africa 2: Vegetables Moringa oleifera Lam. Pp392-395; In: Grubben GJH, Denton OA, Messiaen CM, Schippers RR, Lemmens RHMJ, Oyen LPA. Eds.; PROTA Foundation: Wageningen, Netherlands. 668pp
Ruel MT, Levin CE. 2001. Assessing the potential for food-based strategies to reduce vitamin A and iron deficiencies: A review of recent evidence. Food Consumption and Nutrition Division Discussion Paper no 92. International Food Policy Research Institute, Washington DC, 2000. See also Food Nutr Bull 22: 94-95.
Srinivasan R. 2009. Insect and mite pests on eggplant: a field guide for identification and management. AVRDC – The World Vegetable Center, Shanhua, Taiwan. AVRDC Publication number 09-726. 64pp
Srinivasan R, Su F-c, Lin M-y, Hsu Y-c. 2010. Insect and mite pests on tomato: identification and management. Pp23-59 in Srinivasan R (Ed) Safer tomato production methods: A field guide for soil fertility and pest management. AVRDC – The World Vegetable Center, Shanhua, Taiwan. AVRDC Publication number 10-740. 97pp
Stephenson LS, Latham MC, Ottesen EA. 2000. Malnutrition and parasitic helminth infections. *Parasitology* 121: S23-S38
Talukder A, Haselow N, Osei A, Village E, Reario D, Kroeun H, SokHoing L, Uddin A, Dhungel S, Quinn V. 2010. Homestead food production model contributes to improved household food security and nutrition status of young children and women in poor populations: Lessons learned from scaling up programs in Asia (Bangladesh, Cambodia, Nepal, Philippines). Field Action Science Reports, factsreports.org
The Mother and Child Health and Education Trust. 2011. Impact of Malnutrition. http://motherchildnutrition.org/malnutrition/about-malnutrition/impact-of-malnutrition.html (accessed 12 December 2011)
UN-DESA. 2011. World Population Prospects: the 2010 Revision United Nations Department of Economic and Social Affairs http://esa.un.org/unpd/wpp/Excel-Data/population.htm (accessed 09 December 2011)
UNICEF. 2007. Vitamin A Supplementation: A decade of progress. The United Nations Children's Fund, New York, US
UNICEF. 2011. Levels and trends in child mortality. Report 2011. UNICEF New York 19pp
UNICEF and The Micronutrient Initiative. 2004. Vitamin and mineral deficiency. A global damage assessment report. The Micronutrient Initiative, Ottawa, Canada and United Nations Children's Fund, New York, USA. 7pp
Vijayalakshmi P, Amirthaveni S, Devadas RP, Weinberger K, Tsou SCS, Shanmugasundaram S. 2003. Enhanced bioavailability of iron from mungbeans and its effects on health of schoolchildren. Shanhua, Taiwan: AVRDC - The World Vegetable Center, Technical Bulletin No. 30, AVRDC Publication 03-559. 32 pp.

Walker SP, Wachs TD, Gardner JM, Lozoff B, Wasserman GA, Pollitt E, Carter JA. 2007. Child development: risk factors for adverse outcomes in developing countries. *Lancet* 369: 145-157
Weinberger KM, Easdown WJ, Yang R-y, Keatinge JDH. 2009. Food crisis in the Asia-Pacific region. *Asia Pacific Journal of Clinical Nutrition* 18: 507-515
WHO. 2009. Women's health Fact sheet N°334
http://www.who.int/mediacentre/factsheets/fs334/en/index.html (accessed 4 December 2011)
WHO. 2011a. Obesity and overweight Fact sheet N°311. World Health Organization, Rome, Italy.
WHO. 2011b. Maternal mortality http://www.who.int/making_pregnancy_safer/topics/maternal_mortality/en/ (accessed 12 December 2011)
Woltering L, Ibrahim A, Pasternak D, Ndjeunga J. 2011. The economics of low pressure drip irrigation and hand watering for vegetable production in the Sahel. *Agricultural Water Management* 99: 67-73
Yang RY, Hanson PM. 2009. Improved food availability for food security in Asia-Pacific region. Asia Pacific Journal of Clinical Nutrition18:633-637
Yang R-y, Keding GB. 2009. Nutritional contributions of important African Indigenous Vegetables. In: Shackleton CM, Pasquini M, Drescher AW (Eds.). African Indigenous Vegetables in urban agriculture. Earthscan. Virginia, USA. Pp. 105-143.
Yang RY, Tsou SCS, Lee TC. 2002. Effect of cooking on in vitro iron bioavailability of various vegetables. In: Lee TC and Ho CT (Eds.) Bioactive Compounds in Foods: effect of processing and storage. pp130-142. American Chemical Society, Washington, D.C.
Zeeuw H, Prain G. 2011. Effects of the global financial crisis and food price hikes of 2007/2008 on the food security of poor urban households. *Urban Agriculture Magazine* 25: 36-38

TABLES AND FIGURES

Table 1. Mortality rate of children under five years old in Southeast Asia linked to the target for Millennium Development Goal 4 (Reducing child mortality), and compared with countries most at risk, and best-performing countries. Data source UNICEF (2011).

Country	Under-five mortality rate per 1,000 live births		
	2010	MDG goal targets for 2015	Average annual rate of reduction (percent)
Brunei Darussalam	7	4	2.7
Cambodia	51	40	4.3
Indonesia	35	28	4.4
LaoPDR	54	48	4.9
Malaysia	6	6	5.5
Myanmar	66	37	2.6
Philippines	29	20	3.6
Singapore	3	3	4.9
Thailand	13	11	4.5
Vietnam	23	17	4.0
Afghanistan	149	70	1.7
Niger	143	104	3.9
Finland	3	2	4.2
Japan	3	2	3.5
Developed countries	7	5	3.8
Developing countries	63	32	2.2

Table 2. Neonatal, infant and children under five years old mortality in Southeast Asia in 2010, compared with average figures for developing and developed countries.

Country	Neonatal deaths (thousands)#	Infant deaths (thousands)#	Under five years old deaths (thousands)#	Population*	Total deaths (% of the population)
Brunei Darussalam	0	0	0	422,700	0
Cambodia	7	14	16	13,395,682	0.28
Indonesia	73	115	151	237,641,326	0.14
LaoPDR	3	6	8	6,348,800	0.27
Malaysia	2	3	3	28,334,135	0.03
Myanmar	26	43	56	48,337,000	0.26
Philippines	32	52	66	94,013,200	0.16
Singapore	0	0	0	5,183,700	0
Thailand	7	9	11	65,519,000	0.04
Vietnam	18	28	34	85,846,997	0.09
Developed countries	53	83	99		
Developing countries	3,019	5,346	7,515		

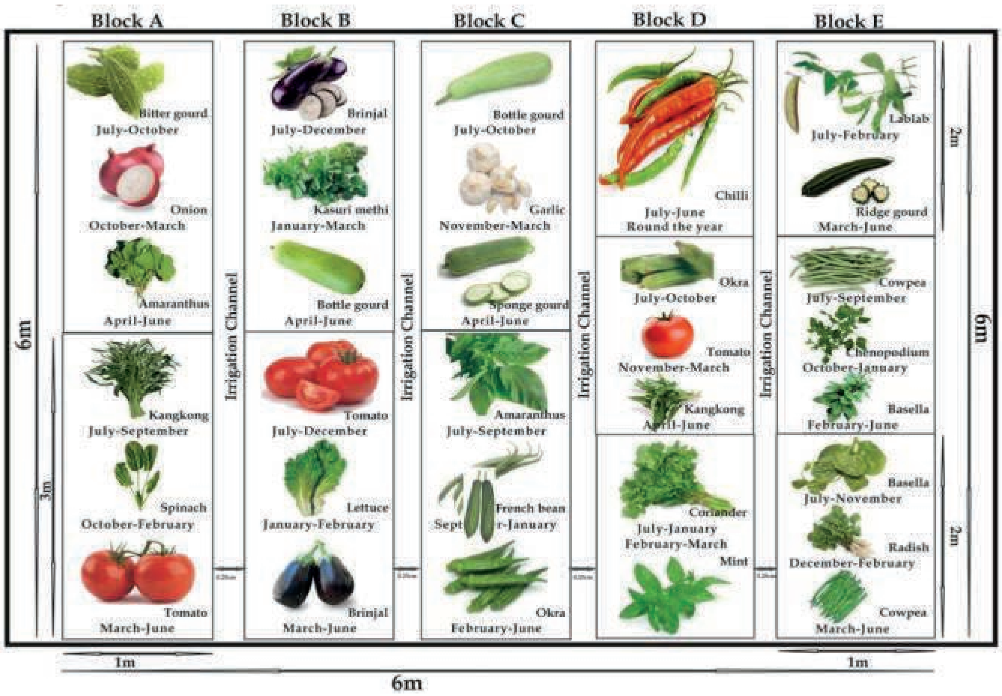
Data source UNICEF 2011. * Population data from Department of Statistics, Brunei; National Institute of Statistics, Cambodia; Badan Pusat Statistik, Indonesia; Population and Housing Census 2005 estimate (LaoPDR); Department of Statistics, Malaysia; UN estimates (Myanmar); National Statistics Office, Philippines; Department of Statistics, Singapore; UN estimates (Thailand); Department of Population and Labour Statistics, Vietnam

Table 3. Nutritional contents of common Southeast Asian traditional fruits and traditional and exotic vegetables.

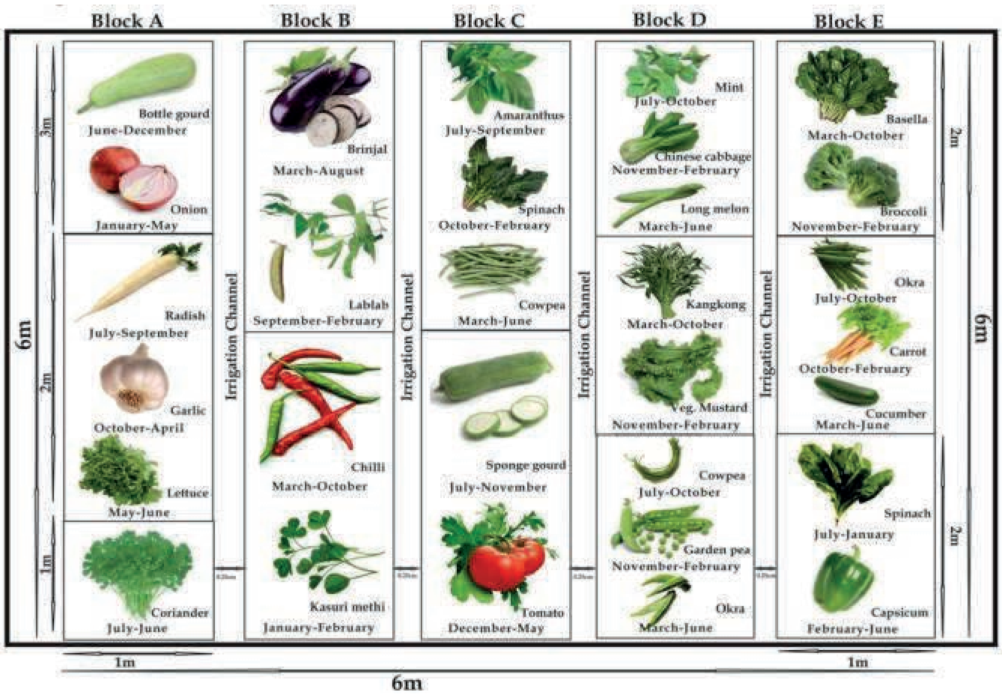
Crop	Protein (g)	Vitamin A (mg)	Vitamin C (mg)	Calcium (mg)	Iron (mg)
Custard apple	1.17-2.47	0.007-0.018	15-44.4	17.6-27	0.42-1.14
Mangosteen	0.5-0.6	n/a	1-2	0.01-8	0.2-0.8
Persimmon	0.7	n/a	11	6	0.3
Wax apple	0.5-0.7	0.003-0.008	6.5-17	5.6-5.9	0.2-0.82
Jackfruit (pulp)	1.3-1.9	n/a	8-10	22	0.5
Rambutan	0.46		30	10.6	
Durian	2.5-2.8	0.018	23.9-25	7.9-9	0.73-1
Moringa (leaves)	8.6	19.7	274	584	10.7
Okra (fruit)	1.8	0.4	37	44	0.9
Kangkong (leaves)	2.4	0.4	40	220	2.5
Common cabbage	1.7	0.4	49	52	0.7
Mungbean (grain)	23.8	0.02	15	55	2.8
Tomato	0.9	0.2	30	9	0.6
Sweet pepper	4.4	2.5	93	188	2.1
Bird's nest fern (*Asplenium australasicum*)	2.8	n/a	Very high	Low	Low
Anemone (*Nymphoides hydrophylla*)	0.7	Medium	Low	Low	Low
Sesbania (*Sesbania grandiflora*) leaves	8	Very high	Very high	High	Very high
Chinese cedar (*Toona sinensis*)	6.3-9.8	Medium	Very high	High	High

Data source: ACAGA 2011; Lim 1996; Morton 1987; Yang and Keding 2009; Lin et al. 2009.

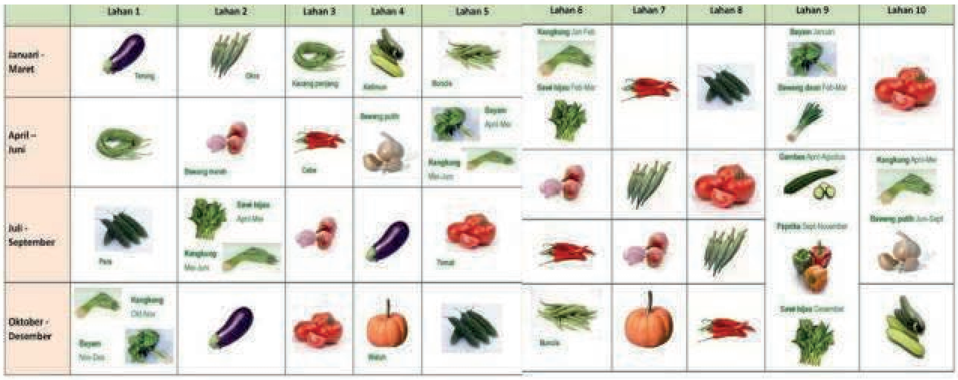
Home garden model from Jharkhand, India



Home garden model from Punjab, India



Home garden model for East Java, Indonesia



Home garden model for Bali, Indonesia

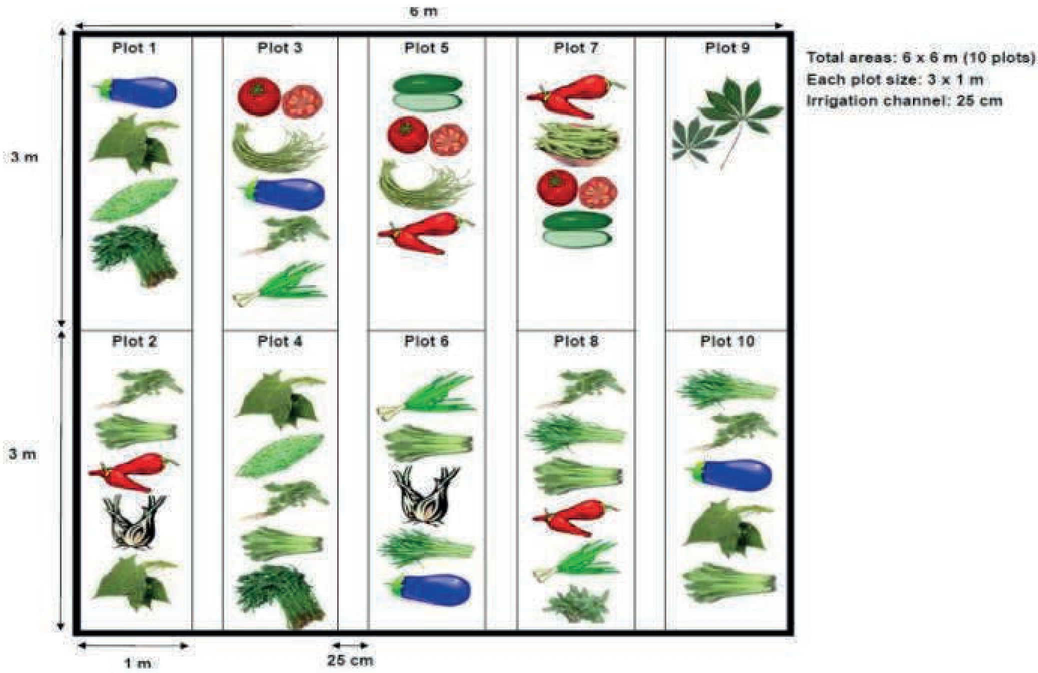


Figure 1. Home garden layouts from AVRDC – The World Vegetable Center. The layouts from Jharkhand and the Punjab are used by thousands of poor families, while the layouts for Bali and East Java are in the testing phase for appropriateness and adoptability.

Growing role of vegetables in food security and nutrition in Asia

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ABSTRACT
Vegetables play an important role in promoting household food security and nutrition, and provide a sustainable solution to micronutrient malnutrition which is affecting the health of 2 billion people on the planet, especially children. Vegetable production generates employment and income of small scale farmers especially women, while safeguarding the natural resource base. The sector offers one of the highest impacts to reducing poverty and hunger, and a great potential for achieving sustained improvements in the nutrition status of the poor. On the other hand, production of vegetables is considerably lower than the estimated recruitments, and much of the potential of the expansion of vegetable cultivation remains largely untapped, in part due to government policies and priorities on increasing domestic production of main staples in a framework of attaining calorie based food security. However, countries wish to consider balanced approaches and explore opportunities for crop diversification to increase production of nutritionally-rich vegetable crops that will not undermine the larger goal of sustaining increased productions of cereal, but will aim at ensuring the availability of a diversified range of vitamins and micronutrient rich products at an affordable price to satisfy essential human dietary requirements. On consumption side, average per capita vegetable consumption stands nearly at a half of optimum consumption level, due to lack of availability and high price, and the lack of awareness of nutritional value of vegetables. Hence, there is a need to increase the availability of vegetables at an affordable price and to promote the awareness and advocacy. In order to be able to move on all these fronts, significant investments in strengthening research and development, capacity building, and advocacy and education are needed and regional cooperation and concerted efforts through partnerships must be further strengthened.

Keywords
Vegetables, productivity, income generation, nutritional security, climate change.

INTRODUCTION
In a world of 7 billion people, FAO estimated that a total of 925 million people were undernourished in 2010, which was slightly reduced, when compared with 1.02 billion in 2009, but remained higher than pre-2008 level. WHO estimates that 10 million children die before their 5th birthday every year, and that one third of these deaths are associated with undernutrition. One in three children in developing countries under the age of five (178 million children) are stunted due to chronic undernutrition and 148 million children are underweight. Micronutrient malnutrition or “hidden hunger” is affecting around 2 billion people (nearly 30% of the world population) with serious public health consequences.

Although the world produces sufficient food to meet the demand of everyone to satisfy calorie requirement, yet it is not accessed equally. When food price of nutritionally rich food products and vegetables increases and become volatile it affects specifically poor consumers who spend as much as 70% of their house hold income on food.

Agriculture remains the largest contributor to the employment and livelihoods of nearly 70% of the people in developing countries who represent the largest portion of the poor and undernourished population. The agriculture sector is far more than just a food producer. It produces food not only for direct consumption at household level and contributes to national food security, but also generates employment and income, while safeguarding the natural resource base, upon which the majority of mankind relies. This sector offers the highest impact to reducing poverty and hunger and has the greatest potential for achieving sustained improvements in the nutrition status of the poor.

Despite the fastest economic growth, there were 578 million undernourished people in the Asia-Pacific region in 2010, which represented 62% of the world total. Ninety-one % of them live in just 6 countries (India, China, Pakistan, Bangladesh, Indonesia, and Philippines). In spite of the significant efforts in combating undernutrition and malnutrition in many countries of the region, the absolute numbers remained almost at the same level of 20 years ago. The achievement of the Millennium Development Goal (MDG) to halve the proportion of extreme hunger from 20% in base year 1990 to 10% in 2015 became very uncertain, considering the rate which remained at 16% in 2010.

The global population is growing at the rate of about 6 million each month, and is projected to reach around 9.1 billion by year 2050 (FAO). Most of this growth will be in the developing world. The size of the Asian population will reach nearly 5 billion (56% of the world population) by that time. At the same time, rapid urbanization is taking place in Asia also. At present, already 50% of world population lives in cities, which is expected to reach 60% in 2030 and nearly 70% by 2050. To meet the demand of this larger, more urban and richer (on an average) population, FAO estimates that the world food production (net of food used for liquid biofuels) must increase by 70% (100% in developing countries alone). If we fail to achieve this goal, world hunger situation would be worsened and global security and world peace would be seriously threatened.

FAO expects that globally 90% of (80% in developing countries) of the growth in crop production will have to come from intensification, particularly varietal improvement and crop intensification. This would pose a major challenge for agricultural research both in public and private-sector.

More serious challenges, however, are projected to come from existing constraints if we fail to solve the problems, such as soaring food prices and volatility, stagnation of expansion or decline of arable land, scarcity of water resources, frequent occurrence of natural disasters, high crude oil price leading to high costs of agricultural inputs and transport, competition in the use of land and water with bio-energy crops and decline of investment in agriculture.

Vegetable production and dietary imbalance in Asian countries

Addressing the needs of adequate and nutritionally-balanced and safe food for rapidly growing and increasingly urbanized population of Asia is a daunting challenge for all of us. In this context, per capita income growth and the shift of consumer preference towards more diverse and nutritious foods are the major driving factors taking place. Vegetables are an excellent resource for overcoming micronutrient deficiencies as well as providing smallholder farmers with much higher income and more jobs per hectare than staple crops (WHO-FAO 2004; AVRDC 2006). For poor households, vegetables and fruits are often the only sources of micronutrients in the family diet. Low fruit and vegetable intake is largely responsible for micronutrient deficiencies that aggravate the risk of mortality and morbidity throughout the life course. A continued dietary deficit in micronutrients and vitamins may emerge as a more serious nutritional problem than a lack of energy in Asia over the coming decades. Starchy foods still account for the bulk of share of the source for dietary energy in most South Asian countries, especially in Bangladesh, Nepal and India where the rate of undernutrition is identically high (Table 1).

Worldwide the harvested area under vegetable crops rose to 54.7 million ha increasing at an annual rate of 2.49% over the period 2001-2009 (Table 2). South Asian countries notably Bangladesh and Nepal had the highest rate of increase in cropped area under vegetables followed by China. Global production of vegetables reached 941.85 million tons, increasing at an average annual rate of 3.02% over the same period. China ranked top in the world with 48.8% share of world vegetable production in 2009 (Table 3). India was the second largest producer of vegetables contributing 9.7% to global production in 2009. Except China, elsewhere in East Asia production of vegetables mostly stagnated during the past decade with negative growth rates recorded in Japan and the Republic of Korea. Next to China, South Asian countries, Bangladesh, India, and Nepal recorded higher growth rates in vegetable production. Asia accounted for about 76% of the global production of vegetables in 2009.

China ranked top in the world in production of vegetables followed by a distant second India (Table 3). In some countries, for example in Vietnam, vegetables are the second most important crop after rice. Vegetables traditionally occupy pre-eminence in Asian diets for a variety of reasons. The region boasts of a rich biodiversity with more than 80 different types of vegetables that can be grown year round. High labor intensity in vegetable production provides good scope to generate employment opportunities for small scale farmers in the informal sector. Overall, in addition to such dietary benefits and income generating avenues, vegetable production offers substantial opportunities for value addition and growth of export-oriented small and medium scale agri-business operations.

Region-wise, Eastern Asia had the highest level of vegetable production driven by record increase in production in China followed by a distant second Southern Asia (Table 4). Yields were the highest in East Asia varying from around 19 t/ha in China to 37 t/ha in the Republic of Korea.

Status of vegetable supply scenario and consumption level

Global supply of vegetables (per capita per year) has increased from 77 kg in 1987 to 120 kg in 2007, however, it will be considerably less if we take into account 20-30% or more of production lost between the farm gate and the plate—in postharvest handling, transportation, and storage. The FAO/WHO expert consultation (2004) on diet, nutrition and the prevention of chronic diseases recommended a daily intake of 400 g (defined as consuming five servings) of fruits and vegetables (excluding potatoes and other starchy tubers) to prevent heart disease, cancer, diabetes and obesity.

It is worth mentioning that tthe estimated levels of current fruit and vegetable intake vary considerably from less than 100 g per day in less developed countries to about 450 g in Western Europe. As evident from Table 6, annual per capita supply of vegetables ranged from 62.4 kg in Southern Asia to 260.9 kg in Eastern Asia. Per capita vegetable supply is the highest in Asia compared to other regions of the world and even higher than world average (Table 5). Within Asia, Eastern Asia tops the list followed by Western Asia and Central Asia (Table 6). Per capita availability of vegetables is the lowest in South Eastern Asia followed by Southern Asia. What is interesting to note is that consumption rose among poor consumers. Demand is also growing due to urbanization, improvement in connectivity, and increasing income levels. According to FAO, the share of domestic consumption rose from 85% to 90% of total national production. However, world vegetable production is still far from meeting even the basic nutritional needs of most countries. The situation is particularly dire in countries that are already food insecure. Lack of local supplies and affordable prices are major causes of low consumption.

Issues and challenges

In many countries in Asia, Government agricultural policy is heavily placed on the attainment of self-sufficiency in staple food and increased production of cereals such as rice and wheat to achieve calorie based food security, with a limited attention to the importance of crop diversification and value of vegetables as a sustainable solution to micronutrient malnutrition.

While, demand for vegetables is increasing due to population increase, economic growth, increasing income level, rapid urbanization, improvement in connectivity, etc., the productivity of vegetables remains still low in South and Southeast Asia varying from 7.4 t/ha to 13 t/ha, as against the level of 19 t/ha in China and 37 t/ha in the Republic of Korea. Though, some countries in Asia have achieved a good growth in the production of vegetables, the production remains very low especially in SAARC and ASEAN countries. As a result, their domestic vegetable production is still very far from desired level to secure adequate supply to domestic consumers at an affordable price and to raise vegetable consumption to FAO/WHO recommended level, which is the root cause of under- and malnutrition in these countries.

Vegetables are generally sensitive to environmental extremes. Climate change is likely to aggravate this further. Erratic rainfall and high temperature spells driven by climate change may reduce productivity and production of vegetables. Suitable land availability for vegetable cultivation is another issue of great concern. Due to conflict of interest with other sectors (like fisheries) and competition for land and water within subsector, vegetables are being pushed in marginal and less fertile areas lessening its productivity and production. The excessive pressure for staple production and subsequently land deficit, is leading to erosion of plant genetic resources of the region. Unfortunately, vegetables are still not the priority Research & Development (R&D) areas for the majority of the governments in the region. It is a challenging task to include vegetables R&D in the main stream of the R&D. Input supply systems mainly the quality seed is weak. Farmers often do not receive quality and healthy seeds in time with affordable prices. In spite of huge efforts in the last 30 years, the success in vegetable input supply systems is not up to the mark. In addition to that production costs are on rise compared to output prices making vegetable production less attractive to the poor farmers. Marketing facilities for vegetable crops are extremely under-developed and even in some very remote areas do not exist, depriving farmers getting remunerative prices for their produces.

The opportunities to increase production of vegetables clearly lie in smallholder farming systems with greater involvement of women farmers for efficient utilization of spaces adjacent to homesteads. The more people produce the more people will have access to fresh vegetables for their own daily consumption. Technology development should focus on addressing constraints in fitting diverse vegetable crops in cereal-based cropping systems and bringing unutilized homestead areas under intensive vegetable cultivation. Exploring additional opportunities and untapped potentials can help achieve sustained growth in vegetable production to enhance its contribution to national incomes.

Options for increasing vegetable production

Asia's highly urbanized population could be turned into an advantage by promoting urban and peri-urban horticulture. Profitability and sustainability of urban and peri-urban agriculture and horticulture (UPA/H) in general, and that of vegetable production, in particular, is virtually guaranteed by the nearby existence of large populations, relatively low transportation and packaging costs and low postharvest losses. Urban and peri-urban agriculture has been rapidly expanding, often as an informal sector. What is needed is the integration of UPA/H in national food and nutrition security strategies and provision of adapted urban and peri-urban extension systems mainly through development of connectivity and communication technologies - including smoothening of input supply systems.

The Asia-Pacific region is endowed with a rich diversity of vegetable crops that can be grown in a range of environments from temperate to tropical climates. But erratic rainfall and high temperature spells driven by climate change may reduce productivity and production of vegetable crops. Movement of crops along the temperature gradient—from tropical to sub-tropical and sub-tropical to temperate—is a natural coping strategy to adapt to temperature changes. The other strategy relies on adjusting crop management technologies to allow for escape of the most sensitive developmental stages of vegetable crop plants from the deleterious effects of high temperatures.

Many of the challenges facing agriculture currently and in the future will require more innovative and integrated applications of existing knowledge, science and technology (formal, traditional and community-based), as well as new approaches for agricultural and natural resource management[1]. Enhancing productivity and expanding the cultivation of vegetable crops across the Asia-Pacific region will require substantial achievements in R&D to effectively address ongoing constraints as well as to address emerging concerns driven by climate change.

Of particular concern will be ensuring product quality and safety in an environment where insect pests and diseases are often a major threat. This will require research, demonstration and training to disseminate Good Agriculture Practices (GAP) including IPM in order to reduce the reliance on conventional pesticide spraying.

[1] IAASTD Report 2008

Technology and support service systems should be tailored to the distinct nature and specific needs of each category of vegetable production systems. Attempts to introduce uniform solutions will be counter-productive. Simple, affordable, and accessible technologies must be available to increase the resilience of smallholder vegetable farmers to cope with increased problems due to high temperatures, drought, salinity, and flooding. Vegetable production in Asia as elsewhere in the world is centered on a few well-domesticated species for which production practices are standardized and value chains well developed. Such activities serve as the key prerequisite for vegetable based enterprise development on the one hand, however, on the other hand it lead to the under utilization of the waste reservoir of the continent's indigenous vegetable specious with untapped potential. Indigenous vegetables offer a range of advantages. They are easy to grow, require minimal extra inputs, and can fit into year-round production systems. These attributes make them highly suited to smallholder farmers in Asia. They have also immense value as a measure of adaptation to changing environments due to climate change.

Enhanced investment in capacity building and in education will benefit and lead to a nation of more aware producers and consumers who eat more vegetables. Continuous capacity building and education are key components of sustainable vegetable production.

Cultivation of vegetables in off-season is an emerging practice to ensure adequate year-round supply of fresh vegetables. Off-season vegetable cultivation also allows growing non-conventional varieties and high-value crops that are in high demand in international markets. Greenhouse crop production including cultivation in plastic covered tunnels is viable technologies that allow for off-season vegetable production and streamlining of insect pest and disease management. These technologies are already widely practiced in China. More concerted efforts are needed to assist farmers in adopting these technologies.

Production of vegetables according to organic farming principles is steadily expanding in Asian countries. The demand for organically produced vegetables is constantly growing especially in the developed countries and city markets, providing a market opportunity and added value to be further developed where ever feasible.

Postharvest losses especially in vegetables are presently in the range of 20 – 30% or more and contribute directly to higher costs and reduced availability of these commodities. Postharvest losses continue to pose challenges and substantially reduce the food availability; but also represent economic losses as well as a considerable waste of water and energy used to grow and harvest the produce that has been lost. Most of the existing marketing systems for vegetables are quite fragmented and supply chains are inadequate for handling perishable commodities. Improved farmers' organization and community based production systems in rural areas could be an option for poor farmers to have more access to market outlets. Promoting decentralized marketing and proximity production systems including home gardens will help reducing postharvest losses by shortening the production-supply-consumption chain as much as possible.

With diverse agro-ecological settings across the region, it is not impossible to increase vegetable production and consumption provided appropriate policies are in place to promote investment and design both long-term and short-term interventions involving participation by both public and private sectors. In this respect WHO and FAO have jointly elaborated a framework for action[2] to promote vegetable and fruit consumption in support to Governments' health and nutrition policies. In addition, seed policy is also a key policy document which can help shape the development in any segment of field crops including vegetables.

Improving vegetable marketing systems and increasing its efficiency through investment in strengthening the value chains and upgrading physical facilities in rural markets can provide significant incentive for farmers to increase production of vegetables. In many Asian countries, the structural inefficiency is a great barrier to improving the vegetable marketing system. The vegetables co-operative marketing institutions may play an important role in providing market accessibility to the small farmers. Concerted efforts through public-private partnership (PPP) in this regard would not only remove imperfections in the vegetable marketing system but would

[2] http://www.who.int/dietphysicalactivity/fruit/en/

also help in raising the quality of production by making available critical inputs to the farmers and ensuring the implementation of Good Agriculture Practices.

From the perspective of generating income the vegetable sector holds significant potential provided adequate investments are made in improving postharvest management and development of agro-processing industries and strengthening the vegetable value chain. There is an opportunity to significantly increase the supply of high quality and safe fresh and processed vegetables for local and export markets. This would require awareness creation and training about international food safety standards as established by Codex Alimentarius and the promotion of product labeling and traceability, following the guidelines and protocols of private sector trade initiatives such as GLOBALGAP.

Recommendations

Efforts should be directed at the development and implementation of value chain approach, including Good Agricultural Practices (GAP) in vegetable crop production systems to ensure products quality and safety, promote agro-processing , linking them with market and take advantage of income generating potential by offering a diversified range of fresh and processed vegetables for both local and export markets.

In order to achieve sustainable growth in production of vegetables, equal emphasis should be given to four available options: increasing productivity; expansion of area where ever required and possible; increasing cropping intensity and ensuring product quality and safety.

Sustainable crop intensification and climate change adaptation programme in vegetables should be promoted through enhancing agricultural research and investment including varietal improvement, seed production, water-saving technology and other low cost crop intensification and farming technologies.

Emphasis should be given to fitting vegetables in the cropping pattern/farming systems of the smallholder farm families with adequate consideration for overcoming the challenges posed by ever changing and dynamic production systems. Concerted efforts should be focused on making vegetable crop production systems more diverse by motivating farmers to include a wide range of vegetable crops in their farming systems so that supply of adequate family nutrition is ensured and the risk of crop losses due to adverse climatic conditions minimized.

Small scale vegetable growers should be supported to enhance their group activities to strengthen bargaining power, access to skill development and training, credit, crop insurance, market and other support services.

All proven approaches to increasing and sustaining vegetable production should be mobilized through public sector, private sector, and public-private partnership efforts:

- Promotion of urban-, and peri-urban vegetable production practices including homestead vegetable production throughout the year with micro-garden systems on rooftops, balconies and patios, when space and land area are scarcely available
- Promotion of organic vegetable cultivation, when economically feasible and sustainable, to capture market niches with added value
- Support of soilless vegetable production systems, where ever possible, to reduce pressure on crop lands and to address the needs of landless rural and urban poor.
- Support for advanced technologies for vegetable production intensification and off-season vegetable production including greenhouses cultivation and hydroponics
- Motivating farmers to cultivate a broad range of cultivars, including early maturing varieties to take the advantage of better market prices
- Promote Integrated Pest management (IPM) in vegetable production. Use vegetable cultivars with multiple insect pest and diseases resistances to reduce the use of pesticides.

Urgent attention must be focused on improving postharvest management, reduction of postharvest and processing losses through more public sector investment in improving rural connectivity, infrastructure in rural markets facility including cool-chain storage and transportation; development of improved postharvest management and cost-effective processing technologies; and training of different stakeholders involved in vegetable supply chain.

Concerted efforts must be focused on eliminating existing loopholes in input supply systems for vegetable crops, where delay in access to required inputs to match crop growth periods acts as a drag on improving productivity. This has particular implications for the small scale producers in rural, urban and peri-urban horticulture often affecting women vegetable growers whose productivity is hampered by the non-availability of adapted inputs at the right time resulting in reduced income and less supply of vegetables for household consumption and associated malnutrition at family level.

Suitable interventions should be designed for improving market efficiency that stimulates incentives for increasing production of vegetables. Such measures may include efforts at increasing household consumption of vegetables through training and demonstration of vegetable-based recipes for inclusion in family diets; establishing school gardens as a means to create awareness about growing and consuming vegetables and fruits for health; improving physical facilities in rural markets; and developing capacity of women farmers to have access to markets.

Focused efforts must be continued on conservation and use of lesser known traditional vegetable species and varieties to avoid the further erosion of plant biodiversity.

There should be a national and regional commitment for long-term investment in vegetable research and development to enhance the diversity and increase the yield potential of vegetable crops.

Priority should be given to capacity building and training especially for women farmers in rural areas in the context of increasing migration of male members in the family to urban centers in search of jobs.

Nutrition education at household level should be promoted for the preparation and consumption of a variety and diversity of vegetables. Food based nutrition approach as well as bio-fortification programme with vegetables as the key commodity, should be promoted to maximize the value and contribution of vegetables for food security and nutrition.

The focus on continued increase of vegetable production must not be at the expense of quality with the use of hazardous chemicals and unsafe production practices that may frustrate the whole effort to tailor vegetable production to ameliorating the existing scenario of undernourishment and malnutrition. This will require substantial national investment in capacity building for GAP and quality control from plough to plate, along the value chain.

Promote vegetable consumption through advocacy and public awareness on the value of vegetables as a key for healthy life and only sustainable solution to combat with the problem of micro nutrient deficiency, which affects the health of nearly 2 billion people including a large number of children.

Increasing production and consumption of vegetables can significantly contribute to enhancing nutrition security and health; particularly in developing countries where the prevalence of undernutrition and malnutrition is still pervasive. But much of the tremendous potential of the expansion of vegetable cultivation remains largely untapped, in part due to government policies refocused on increasing domestic production of main staples in framework of attaining calorie based food security. However, countries must consider balanced and nuanced approaches and explore opportunities to increase production of nutritionally-rich vegetable crops that will not undermine the larger goal of sustaining increased production of food cereals but will aim at ensuring the availability of a diversified range of products for a healthy and sustainable diet.

Regional cooperation and partnership on the promotion of vegetables be strengthened with an aim to share knowledge and experience, learn from best practices and lessons, and promote concerted efforts towards the attainment of common goals to achieve food security and nutrition. FAO has been assisting member countries in this area and FAO's efforts will continue.

References

AVRDC. 2006. Vegetables Matter. AVRDC-The World Vegetable Center, Shanhua, Taiwan.

FAO. 2009. FAOSTAT Rome.

IAASTD. 2008. Synthesis Report of the International Assessment of Agricultural Knowledge , Science and Technology for Development (IAASTD)

Jelle Bruinsma. 2009. The Resource Outlook to 2050: By how much do land, water and crop yields need to increase by 2050? Paper presented at the FAO Expert Meeting, 24-26 June 2009, Rome on "How to Feed the World in 2050".

TABLES

Table 1: Extent of dietary imbalance in selected countries of South Asia, 1990-1992 to 2003-2005

Country		Under Nutrition (%)	Dietary Energy from starchy staple (%)		
			1990-1992	1995-1997	2003-2005
Bangladesh		46	85	84	82
India		48	66	64	60
Maldives		30	51	45	40
Nepal		45	79	77	73
Pakistan		38	56	53	51

Source: FAOSTAT, 2011

Table 2: Harvested Area under Vegetable Crops in Selected Countries of Asia (000 ha)

Country	2001	2005	2006	2007	2008	2009	AGR, %
Bangladesh	306	389	422	453	455	455	5.08
India	5616	5616	6110	5905	6549	6623	2.08
Pakistan	347	385	421	419	435	435	2.87
Nepal	153	170	198	208	229	236	5.57
Myanmar	279	301	308	309	311	311	1.37
Thailand	351	383	376	375	391	388	1.26
Vietnam	582	671	671	671	671	671	1.79
Philippines	572	582	628	639	628	628	1.17
China	17166	22151	23000	23717	24080	24827	4.72
Japan	456	432	406	439	409	404	-1.50
Korea Republic of	422	364	326	318	307	307	-3.90
Korea DPR	308	323	322	319	319	319	0.44
World	44953	50824	52327	52705	53710	54739	2.49

AGR – Annual Growth Rate, Source: FAO Statistical Yearbook, 2008 and 2010

Table 3: Production of Vegetables in Selected Countries of Asia (000 ton)

Country	2001	2005	2006	2007	2008	2009	AGR, %
Bangladesh	1794	2568	2905	3197	3362	3362	8.17
India	73992	68883	77446	77243	90118	90757	2.59
Pakistan	4693	5032	5449	5509	5481	5481	1.96
Nepal	1508	1891	2233	2375	2602	2812	8.10
Myanmar	3382	3906	4010	4068	4087	4087	2.40
Thailand	3090	3342	3346	3389	3706	3728	2.37
Vietnam	6645	7991	7991	7991	7991	7991	2.33
Philippines	4887	5353	5721	5988	5342	5325	1.08
China	321824	423932	432222	451633	457830	459558	4.55
Japan	12710	11801	11263	12700	10963	10600	-2.24
Korea Republic	11938	11413	11243	11907	11278	11278	-0.71
Korea DPR	3757	3992	3876	3756	3756	3756	0.00
World	742541	869041	895615	908838	931857	941849	3.02

AGR – Annual Growth Rate, Source: FAO Statistical Yearbook, 2008 and 2010

Table 4: Harvested Area (million ha) and Production (million tons) of Vegetables in Asia

Region	1991		2001		2009	
	Area	Production	Area	Production	Area	Production
Central Asia	-	-	0.45	7.47	0.57	13.48
Eastern Asia	9.16	163.35	20.48	408.37	23.82	549.79
Southern Asia	6.14	64.05	7.54	100.13	8.94	124.15
South-Eastern Asia	2.23	17.95	2.95	27.25	3.28	33.47
Western Asia	1.46	28.42	1.96	39.51	2.05	44.66
Asia	18.99	273.77	33.38	582.73	38.66	765.55

Source: FAOSTAT 2011

Table 5: Status of Vegetable Supply in the World (kg/capita/yr)

Continent	1987	1997	2007
Asia	74.87	103.67	143.68
Africa	50.53	51.97	57.49
Americas	69.90	75.05	82.07
Europe	108.27	106.84	116.77
World	76.56	93.37	119.53

Source: FAOSTAT 2011

Table 6: Status of Vegetable Supply Scenario in Asia (kg/capita/yr)

Region	1987	1997	2007
Central Asia	-	79.53	153.87
Eastern Asia	101.23	169.61	260.87
Southern Asia	49.80	51.36	62.40
South-Eastern Asia	36.73	44.27	52.48
Western Asia	167.21	150.36	154.23
Asia	74.87	103.67	143.68

Source: FAOSTAT 2011

Breeding of leafy amaranth for adaptation to climate change

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ABSTRACT
Heavy rainfall in connection with typhoons inflicted severe damage on leafy vegetables in recent years. In response to these natural events, cultivation of leafy vegetables under plastic houses to avoid losses due to heavy rainfall is now more common in Taiwan. As temperatures can reach up to 40 ^{o}C in plastic houses during summer months, amaranth and water spinach are the only crop choices that do well under such extreme conditions. White rust caused by *Albugo bliti* O. Kuntze often renders amaranth unusable for commercial purposes during the period from June to October. Improving the performance of leafy vegetables after typhoons by reducing the damage caused by white rust is a major breeding aim for leafy amaranth in Taiwan. The amaranth cultivar 'Tainung No. 1' has been released by the Taiwan Agricultural Research Institute and it presents interesting agricultural traits such as high yield, short cultivation period, heat and cold tolerance, and white rust resistance. The amaranth cultivar 'Tainung No. 2' has been selected from the progeny of 'Tainung No. 1' after crossing the latter with a local cultivar having characteristics such as short cultivation period, heat and cold tolerance and tender leaves. White rust incidence of the amaranth line 04-110 was only 3.9% compared with an incidence of 47.0% in the local cultivar in trials conducted in 2005 in Hsilo, central Taiwan. In other regional trials conducted in Pingtung in southern Taiwan in 2007, no white rust incidence of amaranth line 04-110 was observed, while two local cultivars presented a disease incidence of 87% and 96%, respectively. Single-pustule isolates of white rust were collected twice from major commercial cultivation areas and this resulted in 10 isolates that were used as inocula for screening for white rust tolerance. Line 04-110 was shown to be resistant to eight isolates and tolerant to two isolates of white rust.

Keywords
Leafy amaranth, *Albugo bliti*, single-pustule isolates, amaranth breeding

INTRODUCTION
Leafy amaranth is an important leafy vegetable during the summer months in Taiwan. According to wholesale data over a 5-year period, about 73.6% of the total amount of leafy amaranth entering the marketplace annually is traded from May to October. During this period, the trade volume of leafy amaranth exceeds that of Chinese kale, celery, and mustard. Only cabbage, Chinese cabbage, pak choi, lettuce and water spinach reach higher trading volumes during the summer months (http://amis.afa.gov.tw/v-asp/top-v.asp).

Typhoons, which regularly strike Taiwan during summer, are often associated with heavy rainfall of up to 3000 mm and subsequent flooding, as was the case with Typhoon Morakot, which hit southern Taiwan in August 2009. Such extreme weather conditions inflict heavy yield losses on leafy vegetable production fields and lead to high crop prices during summer months. To avoid severe crop damage and yield losses from heavy rainfall, an increasing number of producers have moved the cultivation of leafy vegetables from the open field to plastic houses in recent years, especially in Taoyuan County near Taipei City.

Under plastic houses temperatures can easily reach 40°C in summer and most leafy vegetables cannot grow normally under these conditions. When measuring the membrane thermostability of vegetable leaves of 59 species or varieties of vegetable crops under heat stress, water spinach proved to be heat tolerant and amaranth moderately heat tolerant, while the majority of vegetable crops was either heat sensitive or only slightly heat tolerant (Kuo et al. 1992).

Amaranth uses the C4-cycle photosynthetic pathway that assures high photosynthetic activity and water use efficiency under high temperatures and high radiation intensity and is, therefore, an ideal crop for abiotic stress conditions under changing climates. For further adaptation to climate change, a short cultivation period is an important breeding goal that allows quick market supply with leafy vegetables soon after a typhoon and keeps prices at a reasonable level for consumers. Similar to water spinach, amaranth requires only 21-23 days from sowing to harvest during the summer season. It grows faster than pak choi, which has a growth period of about 25-30 days. Amaranth is sensitive to low temperatures and the growth period will extend to 50-60 days if harvest is required in January or February when the temperature ranges from 10 – 20 ℃.

White rust of amaranth, a fungal disease caused by *Albugo bliti* (Biv.) Kuntze, is a serious problem during the summer season under hot and humid conditions, not only in Taiwan, but also in Southeast Asia (Grubben and Van Sloten 1981; BOSTID 1984). In the field, close to 100% of amaranth plants might be infected with white rust, which usually forms white pustules on the leaf surface, considerably reducing the commercial value of the crop and increasing labor costs for the elimination of infected leaves. Most plants will survive, even under heavy white rust infestation. Fungicides are available for the control of white rust, but as sprays may not be applied during a 2-week period prior to harvest, chemical control proves to be difficult for a crop with a short 21-day growth period as fungicides would need to be applied at the one or two true leaf stage and remain effective for a 2-week period under high inoculum pressure. Therefore, the most practical way to control white rust in amaranth is to select and develop resistant cultivars.

In this paper we describe amaranth breeding efforts conducted by the Taiwan Agricultural Research Institute with its headquarters located in Wufeng, Taichung, central Taiwan. The leafy amaranth cultivar ‘Tainung No. 1’ was released in August 2000 and is characterized by high yield, short cultivation period, white rust resistance and cold tolerance. The leafy amaranth cultivar ‘Tainung No. 2’ was registered in November 2004 and has many desirable traits such as high yield, short cultivation period, tender leaves and cold tolerance. Amaranth line 04-110 has shown to be resistant to white rust in different regional field trials and after artificial inoculation with different isolates in growth chambers.

MATERIALS AND METHODS

The amaranth cultivar ‘Tainung No. 1’ had been selected from ‘TVI 3509 Bayam’ originally introduced from Indonesia, and underwent mass selection for seven generations from 1990 to 2000. ‘Tainung No. 2’ had been selected from a cross of ‘Tainung No. 1’ with the local cultivar ‘Yellow Leaf’ followed by mass selection for seven generations from 1995 to 2003. The amaranth line 04-110 was selected for white rust resistance after selfing the AVRDC line VI033488, formerly known as TOT 2242 for four generations and sib-mating for another two generations. ‘Yellow Leaf’ is a major cultivar in Taiwan with bright yellow-greenish leaf color. ‘Red’ is another leafy amaranth cultivar with diffused red color in green leaves. ‘Deep Red’ is a red-colored leafy amaranth with a higher proportion of red color compared with ‘Red’. ‘Tender Stem’ is another major amaranth cultivar in southern Taiwan with green, big, smooth leaves. These four commercial cultivars served as control cultivars for the experiments described here.

Regional trials of leafy amaranth cultivars

Regional trials were conducted in two commercial leafy vegetable growing areas each in central Taiwan: (a) Hsilo (23°48'02"N 120°27'39"E) and (b) Wufeng (23°27'15"N 120°44'56"E), and in southern Taiwan: (a) Tainan City, (22°57'0"N 120°12'0"E) and (b) Pingtung City (22°41'43"N 120°28'40"E) with three replications in randomized complete block design (RCBD). The plot area of each treatment was 7.2 m^2 and a seed amount of 7.2 g was broadcast; plant density was not adjusted by thinning. The harvest area was 2.4 m^2 and only plants with a height of more than 20 cm were considered for marketable yield. The cultivation period ranged from 19-25 days between July to October and from 23-27 days from March to June due to the lower temperatures experienced in spring (March-April). The harvest time for 'Tainung No. 1' and 'Tainung No. 2' was the same as with the control cultivars, but differed for 04-110 as this line needed more time to reach marketable size.

Evaluation of 'Tainung No. 1' for white rust resistance

'Tainung No. 1' and the local cultivar 'Yellow Leaf' were evaluated concerning disease spread and disease severity of white rust by random sampling of 40 plants of each treatment after harvest in central Taiwan, Citong Township. The plants were cultivated under plastic houses and rated for disease severity on a scale of 0 to 4 based on the number of diseased leaves: 0 = no symptoms; 1 - 4 = one to four leaves infected, respectively:

ni = number of plants in each class; N=40

$$\text{Disease severity} = \frac{n_0 x_0 + n_1 x_1 + n_2 x_2 + n_3 x_3 + n_4 x_4}{40 \times 4}$$

Diseased leaves were collected from Hsilo Township and the leaf pustules were washed with distilled water by using a brush. 'Tainung No. 1' and the local cultivar 'Yellow Leaf' were broadcast on 2, 4, and 7 August 2000 in three replications at Wufeng (TARI). Suspension solution with white rust zoospores was sprayed in the evening hours (17:30-18:30) of 7, 8, and 9 August and plants were covered with a 16-mesh green net.

Leaf tenderness test of 'Tainung No. 2'

The diameter of 10 randomly selected plants from each of three replicated plots of 'Tainung No. 2' and 'Yellow Leaf' was measured at 1 cm above the cotyledons using a Mitutoyo digital caliper. The rheological value as an indicator of leaf tenderness of 'Tainung No. 2' and 'Yellow Leaf' was measured using a Fudoh rheometer. The Fudoh rheometer readings were analyzed with the Rheosoft program attached to the rheometer.

Evaluation of 04-110 for white rust resistance in the field

In regional field trials 50 plants were sampled per treatment. The white rust scale used differed from the one used for 'Tainung No. 1'. Rust incidence was rated on a scale from 0 to 4 based on the average of three leaves per plant: 0 = no symptoms; 1 = less than 5 pustules; 2 = more than 5 pustules and less than 1/10th of leaf area affected; 3 = more than 1/10th , but less than half of leaf area affected; 4 = more than half of leaf area affected.

ni = number of plants in each class; N=50

$$\text{Disease severity} = \frac{n_0 \times x_0 + n_1 x_1 + n_2 x_2 + \cdot \cdot \cdot + n_{12} x_{12}}{50 \times 12}$$

Single pustule isolates (SPI) of white rust

Amaranth leaves infected with white rust were collected from northern Taiwan: Luzhou District (25°04' 54"N 121°28'26"E), Bade City (24°55'43"N 121°17'4"E); from central Taiwan: Hsilo Township, and from southern Taiwan: Tainan City and Pingtung City. The geographic coordinates of the latter locations are given above in the section on regional trials. Single pustule isolates were cut out with a knife and placed in a 1.5 ml Eppendorf tube, adding 200 μl cool distilled water, and followed by shaking on a Vortex shaker for about 10 seconds. The concentration of zoospores was determined after 30 minutes using a hemacytometer. The 10 highest SPI concentrations from 20 samples were selected for inoculation. The underside of two leaves of 7-day-old seedlings was inoculated with 10 μl per leaf. The ten selected SPIs were inoculated on four plants each. The inoculated plants were placed into a dew chamber for one day keeping the relative humidity above 95% and the temperature at 25 °C, without light. Temperature and relative humidity were adjusted and monitored using Hobo® Pro v2.

After 24 hr in the dew chamber, the plants were placed in plastic bags with two square windows (10 cm x 10 cm each) of bonded, nonwoven fabric for ventilation and isolation and transferred to a growth chamber with 12 hrs light, 25 °C and 90% relative humidity. After seven to nine days in the growth chamber, clear white and creamy white pustules had formed. The creamy white pustules were discarded and the clear white pustule isolates were chosen for further multiplication. After two subsequent generations, ten isolates were kept, two from Luzhou District, two from Bade City, four from Hsilo Township, one from Tainan City, and one from Pingtung City.

Evaluation of 04-110 for white rust resistance with single pustule isolates in the growth chamber

One line and five cultivars were screened for white rust resistance in the growth chamber: 04-110, 'Red', 'Deep Red', 'Yellow Leaf', 'Tainung No. 1', and 'Tainung No. 2'. Twenty seeds were broadcast in 4-inch plastic nursery pots containing peat moss mixed with slow release fertilizer Hi-Control 14-12-14, designed for 70 days at a ratio of 10:1 (v:v). A completely randomized design with three replicates was used in this experiment. Reverse osmosis water was used for irrigation to avoid damping off. Thinning to 10 plants was done when the seedlings were 7 days old. Two true leaves were inoculated with one drop (10 μl) per leaf at a concentration of 10^5 zoospores per ml. The plants were exposed to the same conditions (isolation, dew chamber and growth chamber) as described for the SPI procedure. The total number of pustules on all plant leaves was counted as indication of white rust resistance after seven days in the growth chamber. The following disease incidence scale was used: R (resistant) - less than 5 pustules; T (tolerant) - 5-10 pustules; S (susceptible) - 11-30 pustules; VS (very susceptible) - >30 pustules.

RESULTS AND DISCUSSION

Regional trials of 'Tainung No. 1' and 'Tainung No. 2'

'Tainung No. 1' showed a higher yield than the local cultivar 'Yellow Leaf' in all eight locations where the regional trials were conducted (Table 1). In three locations the 'Yellow Leaf' cultivar did not produce any marketable yield, hence statistical differences could not be calculated. The regional trial conducted in Hsilo in 1996 (sowing date: 16 July) was affected by Typhoon Herb (29 July to 1 August), resulting in low marketable yield of only 9.4 t/ha of 'Tainung No. 1', while 'Yellow Leaf' sustained very serious damage from the typhoon and did not have any marketable yield. Thanks to the rapid growth of 'Tainung No. 1', this cultivar produced 19.7 and 19.5 t/ha marketable yield in Hsilo (March 1997) and Pingtung (October 1997), respectively, while 'Yellow Leaf' did not have any marketable yield at the same harvest date. The regional trial conducted in March 1997 (sowing date 20 March) suffered from lower temperatures compared with the other trials, hence 27 days were needed from sowing to harvest. The cultivar 'Tainung No. 1' matured about one week earlier compared with 'Yellow Leaf'.

As evidenced in the regional trials, 'Tainung No. 1' has a relatively short cultivation period, produces high yield, and is heat and cold tolerant. Given its short growth cycle, this cultivar is very suitable for rapid leafy vegetable production after typhoon damage and heavy rainfall. In summer, 'Tainung No. 1' matures two to three days earlier than other cultivars and seven to ten days earlier in winter. The shorter cultivation period reduces the risk of damage by typhoons and increases the crop index during the summer season.

Table 1. Marketable yield[z] of 'Tainung No. 1' and 'Yellow Leaf' in regional trials in Taiwan from 1995 to 1998

Location	Date of sowing	Days to harvest	'Tainung No. 1' (t/ha)	'Yellow Leaf' (t/ha)
Hsilo	1995/8/10	19	27.7[a]	9.2[b]
Wufeng	1995/8/10	21	36.0[a]	31.5[b]
Wufeng	1995/10/3	23	42.9[a]	38.4[b]
Hsilo	1996/7/16	23	9.4	0
Hsilo	1996/8/20	21	18.7[a]	11.5[b]
Hsilo	1997/3/20	27	19.7	0
Pingtung	1997/10/20	21	19.5	0
Tainan	1998/3/17	23	29.8[a]	12.8[b]

[z] = only plants with a height exceeding 20 cm are considered for marketable yield

Means in each row followed by the same letter are not statistically different as shown by the t-test at the $p \leq 0.05$ significance level.

White rust disease spread and disease severity of 'Tainung No. 1'

'Tainung No. 1' presented a lower white rust disease spread and disease severity than the local cultivar 'Yellow Leaf' (Table 2). This effect was not only observed under field conditions, but also in the growth chamber where the seedlings were inoculated at different growth stages (age of seedling) (Table 3). Disease spread and disease severity were more pronounced at later seedling stages when seedlings had reached at least seven days (Table 3). Lower disease incidence of young seedling stages (less than 5 days old) may be due to the relatively small leaf area providing only minimal contact with the suspension solution. As the growth period of leafy amaranth is only 19 to 23 days during summer, a few days difference in seedling age is having a huge impact on disease incidence. Seedlings inoculated at the 7-11 day-old seedling stage may reach a disease spread of 95% at 10 days after inoculation. Due to this exponential disease spread, it will be very hard to control white rust through fungicide applications given the short growth period of amaranth and the withholding period of 14 days for chemical sprays before harvest. Resistant or tolerant cultivars can reduce the frequency of chemical sprays, especially during long rainfall periods. Up to now, 'Tainung No. 1' was mostly used for organic amaranth cultivation due to its resistance to white rust and its short growth cycle.

Table 2. White rust disease spread and disease severity of 'Tainung No. 1' in regional trials in Hsilo Township in June 2000

Cultivar	Disease spread (%)	Disease severity (%)
Yellow Leaf	77.5	30.5
Tainung No. 1	5.6	1.4

Table 3. White rust disease spread and disease severity of 'Tainung No. 1' as affected by age of seedlings when inoculated in Wufeng Township in June 2000

Age of seedlings (days) when inoculated	Disease spread (%)		Disease severity (%)	
	Tainung No. 1	Yellow Leaf	Tainung No. 1	Yellow Leaf
9-11	4.2[b]	95.0[a]	1.1[b]	49.1[a]
7-8	5.9[b]	70.1[a]	1.7[b]	26.0[a]
5-6	5.0[b]	22.5[a]	1.3[b]	6.1[a]
3-4	0[b]	5.7[a]	o[b]	1.6[a]
1-2	0[a]	0[a]	0[a]	0[a]

Data were transformed for comparison of means using the square root of each score. Means in each row followed by the same letter are not statistically different as shown by the t-test at the $p \leq 0.05$ significance level

Regional trials and leaf tenderness of 'Tainung No.2'

'Tainung No.2' is a progeny of a cross of 'Tainung No. 1' and 'Yellow Leaf' with important agricultural traits such as heat tolerance, cold tolerance, short growth cycle, and high yield (Table 4). 'Tainung No.2' has a bright yellow greenish leaf color, while 'Tainung No.1' shows green leaf color. 'Tainung No.2' is characterized by higher leaf tenderness than the local cultivar 'Yellow Leaf' (Table 5). 'Tainung No.2' is suitable for cultivation near cities like Bade City or in the Luzhou District.

Table 4. Marketable yield[z] of 'Tainung No. 2' in regional trials in Taiwan from 1999 to 2002

Location	Date of sowing	Days to harvest	Tainung No. 1 (t/ha)	Yellow Leaf (t/ha)
Hsilo	May 1999	25	27.6[a]	17.3[b]
Hsilo	Aug. 1999	19	14.0[a]	9.6[b]
Tainang	Sept. 1999	25	25.3[a]	18.8[b]
Pingtung	Sept. 1999	25	28.8[a]	24.1[b]
Citong	Feb. 2002	21	15.3[a]	10.7[b]

[z] = only plants with a height exceeding 20 cm are considered for marketable yield

Means in each row followed by the same letter are not statistically different as shown by the t-test at the $p \leq 0.05$ significance level

Table 5. Tenderness of leafy amaranth 'Tainung No.2' compared with 'Yellow Leaf'

Cultivar	Tenderness (g/cm^2)
Tainung No. 2	2110[b]
Yellow Leaf	3022[a]

Means in each column followed by the same letter are not statistically different as shown by the t-test at the $p \leq 0.05$ significance level

Regional trials of the line 04-11

Marketable yield of 04-110 did not differ from that of 'Deep Red' or 'Red' in regional trials (Tables 6, 7), but white rust disease spread and disease severity was lower (Tables 6, 7, 8). Although 04-110 showed a lower disease spread and disease severity than 'Red' and 'Deep Red', disease incidence increased under successive cultivation in regional trials conducted in August and September 2006 in Hsilo Township (Table 7). Successive cultivation of leafy amaranth all year round is a common production trend in commercial production areas in Taiwan. Such practice dramatically increases the risk of white rust disease infection in leafy amaranth production fields. White rust in amaranth and cruciferous crops is not only an airborne fungal disease, but also spreads through the soil (Bames 1968; Kolte et al. 1998). This has been confirmed for amaranth monoculture fields at Hsilo in central Taiwan (Lee and Hsieh 2003). Infected cotyledons and diseased leaves of seedlings were the main sources of secondary inocula with a maximum production at the 3-4 leaf stage. Rotation with other crops, resistant cultivars and minimal use of fungicide sprays constitute integrated methods to control white rust in amaranth.

Table 6. Regional cultivar trials in Hsilo Township from July to August 2005

Cultivar (Line)	Marketable yield (t/ha)	White rust disease spread (%)	White rust disease severity (%)
Deep Red	26.0	94.0	47.0
04-101	23.6	18.0	3.0
04-110	27.4	18.0	3.9
LSD 0.05	NS	1.1	25.6

Table 7. Successive regional cultivar trials in Hsilo Township on the same location from August to September 2006

Duration of experiment	Cultivar (Line)	Marketable yield (t/ha)	White rust disease spread (%)	White rust disease severity (%)
4-25 August 2006	Deep Red	28.9	95.3	21.6
	Red	26.0	98.0	24.1
	04-110	28.9	6.0	0.8
	LSD 0.05	3.8	26.3	4.1
6-27 September 2006	Deep Red	21.9	100.0	35.1
	Red	22.0	100.0	33.5
	04-110	22.4	56.7	7.7
	LSD 0.05	3.1	20.3	8.9

Data were transformed for comparison of means using the square root of each score

Evaluation of 04-110 for white rust resistance by inoculation with purified single pustule isolate (SPI)

Amaranth cultivars differed in their susceptibility / resistance to different SPIs (Table 9). Line 04-110 was tolerant to SPI 9754 and SPI 9741 and resistant to eight other SPIs (Table 9). ‘Tainung No. 1’ was resistant to all SPIs, but ‘Tainung No. 2’ was either susceptible or tolerant to the various SPIs, but not resistant to any. ‘Red’ or ‘Deep Red’ had a similar disease reaction and were either susceptible or highly susceptible to all SPIs tested. ‘Yellow Leaf’ was susceptible to most SPIs, except SPI 9738 (tolerant).

Table 8. Regional cultivar trials in Pingtung and Hsilo in 2007

Location/Date of sowing	Cultivar (Line)	White rust disease spread (%)	White rust disease severity (%)
Pingtung / 21 April	Deep Red	96.0	38.4
	Tender Stem	87.0	32.5
	04-110	0.0	0.0
Pingtung / 26 May	Deep Red	53.0	15.7
	Tender Stem	96.0	36.0
	04-110	0.0	0.0
Hsilo / 22 June	Red	98.7	37.9
	04-110 (lot 1)	0.6	0.2
	04-110 (lot 2)	0.6	0.2

From the results obtained, it is possible to divide the 10 SPIs into four groups or races: (1) group 1 includes SPI 9701, 9717, 9718, 9735, 9716, and 9739 – the cultivars ‘Yellow Leaf’, ‘Deep Red’, ‘Red’, and ‘Tainung No. 2’ were all susceptible or very susceptible to these SPIs, while ‘Tainung No.1’ and 04-110 were resistant to all SPIs; (2) group 2 includes SPI 9754 and 9741 - the cultivars ‘Yellow Leaf’, ‘Deep Red’, ‘Red’, ‘Tainung No. 2’ were all susceptible to these SPIs, while ‘Tainung No.1’ was resistant and line 04-110 tolerant to these two SPIs; (3) group 3 includes SPI 9732 SPI - the cultivars ‘Yellow Leaf’, ‘Deep Red’, and ‘Red’ were susceptible to this SPI, ‘Tainung No. 2’ was tolerant and ‘Tainung No.1’ and line 04-110 were resistant; (4) group 4 includes SPI 9738 – the cultivars ‘Deep Red’ and ‘Red’ were susceptible to this SPI, ‘Yellow Leaf’ and ‘Tainung No. 2’ were tolerant, and ‘Tainung No.1’ and line 04-110 were resistant.

Different biological white rust races (*A. candida*) have also been reported in cruciferous crops based on susceptibility to different host species, where each crop species is susceptible to its own specific race (Pound and Williams 1963; Ferreira and Boley 1991). While young seedlings without fully expanded cotyledons are usually susceptible to most races, older plants are more race-specific. Cultivars within the same crop may vary in their susceptibility to the different white rust races (Fan et al. 1983; Ferreira and Boley 1991).

The red amaranth line 04-110 is more resistant to white rust than the local cultivars 'Red' or 'Deep Red'. This may lead to a reduction of fungicide sprays and, consequently, to reduced production costs, once this line has been registered and released to farmers.

Table 9. Average white rust pustule number and disease severity in the amaranth line 04-110 inoculated with purified single pustule isolate (SPI) extracted from infected leaves collected in northern, central and southern Taiwan

SPI \Cultivar	Yellow Leaf	Deep Red	Red	Tainung No. 1	Tainung No. 2	04-110
9701 (Luzhou	22.5(S)	29.7(S)	26.8(S)	0.0(R)	24.3(S)	3.4(R)
9717 (Luzhou)	23.9(S)	33.1(VS)	27.9(S)	1.1(R)	19.1(S)	3.2(R)
9718 (Bade)	14.9(S)	20.4(S)	18.3(S)	1.1(R)	16.9(S)	1.6(R)
9735 (Bade)	16.0(S)	20.2(S)	13.6(S)	0.0(R)	14.7(S)	0.0(R)
9716 (Hsilo)	27.8(S)	23.5(S)	30.3(VS)	0.6(R)	12.3(S)	0.0(R)
9732 (Hsilo)	20.7(S)	12.0(S)	15.6(S)	0.0(R)	7.7(T)	0.0(R)
9738 (Hsilo)	6.0(T)	25.0(S)	20.2(S)	0.0(R)	9.9(T)	0.9(R)
9754 (Hsilo)	20.6(S)	19.8(S)	22.9(S)	0.5(R)	13.3(S)	6.8(T)
9739 (Tainan)	29.1(S)	22.9(S)	30.1(VS)	0.0(R)	20.6(S)	1.6(R)
9741 (Pingtung)	29.1(S)	29.7(S)	48.2(VS)	0.5(R)	11.3(S)	8.8(T)

CONCLUSION

Heavy rainfall and flooding in the aftermath of typhoons are major abiotic stress conditions for the production of leafy vegetables during summer. Heavy rainfall combined with high relative humidity is conducive for the production of white rust zoospores and subsequent infection of amaranth leaves. As white rust resistant cultivars are not yet widely used in commercial amaranth production in Taiwan, most amaranth fields show high infection rates during the summer months. Crop damage from heavy rainfall and flooding can be avoided when leafy vegetables are cultivated under plastic houses. On the other hand, cultivation in plastic houses may lead to heat stress and low light intensity which again has a negative impact on yield.

'Tainung No. 1' and 'Tainung No. 2' developed by the Taiwan Agricultural Research Institute are both heat tolerant and have a relatively short growth period all year round. 'Tainung No. 1' and the breeding line 04-110 are both resistant to white rust under field conditions or when inoculated in growth chambers with SPIs collected from different production sites in Taiwan. However, when amaranth was grown successively on the same plot, white rust disease spread and severity was much more pronounced compared with single cropping. Therefore, crop rotation, the use of resistant cultivars and selective fungicide sprays, when required are recommended as good agricultural practices for successful control of white rust in amaranth.

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References

Barnes EH. 1968. White rusts of crucifers. In: Atlas and manual of plant pathology. p. 138-142.

BOSTID (Board on Science and Technology for International Development). 1984. Amaranth: modern prospects for an ancient crop. 74 p.

Fan Z, Rimmer SR, Stefansson BR. 1983. Inheritance of resistance to *Albugo candida* in rape (*Brassica napus* L.) *Can. J. Genet. Cytol.* 25:420-424.

Ferreira SA, Boley RA, 1991. Albugo candida. http://www.extento.hawaii.edu/kbase/crop/type/a_candi.htm.

Grubben GJH, Van Sloten DH. 1981. Genetic resources of amaranths. IBPGR, Rome.

Kolte SJ, Sachan JN, and Rimmer SR. 1998. A new simple technique for development of seedling infection of white rust of rapeseed-mustard from oospores of *Albugo candida*. *Indian Phytopath*. 51:287-289.

Kuo CG, Chen HM, Sun HC. 1992. Membrane thermostability and heat tolerance of vegetable leaves. In: Adaptation of food crops to temperature and water stress. P. 160-168. Shanhua, AVRDC.

Lee ML, Hsieh WH. 2003. Inoculum sources of amaranth white rust and its disease development. *Plant Pathology Bulletin* 12(3): 163-172.

Pound GS. and Williams PH. 1963. Biological races of *Albugo candida*. *Phytopathology* 53:1146-1149.

Pepper (*Capsicum* spp.) germplasm management under Thailand conditions

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ABSTRACT
Pepper (*Capsicum* spp.) germplasm at Tropical Vegetable Research Center, Kasetsart University, Kamphaeng Saen, Nakhon Pathom, Thailand are about 2,348 accessions which were collected domestically and also introduced from abroad. Evaluation on agronomic and horticultural traits as well as the screenings for resistance to anthracnose (*Colletrotichum* spp.), cucumber mosaic virus (CMV), chili veinal mottle virus (ChiVMV), root knot nematode (*Meloidogyne* spp.) and fruit fly (*Bactrocera latifrons*) have been done through the multidisciplinary efforts to enhance the utilizations of the pepper germplasm. Database on the evaluated germplasm was created through the support from BIOTEC, NSTDA and can be accessed on line at www.biotec.or.th/germplasm. Collaborative projects on pepper with specific topics i.e. double haploid, introduction and the use of male sterility in hot pepper and cayenne type hybrid seed production, embryo rescue in the interspecific hybridization among *Capsicum annuum C. chinense* and *C. baccatum* were conducted with the Departments of Horticulture, Plant Pathology, and Entomology of Kasetsart University, Ubonrachathani University, Maejo University, Chiang Mai University and the Department of Agriculture, Ministry of Agriculture and Cooperatives.

Keywords
Pepper, *Capsicum*, germplasm, anthracnose, virus, CMV, ChiVMV, nematode, fruit fly

INTRODUCTION
Pepper (*Capsicum* spp.) germplasm conserved at Tropical Vegetable Research Center (TVRC), Kasetsart University, Kamphaeng Saen, Nakhon Pathom, Thailand are introduced from international institutions as well as collected from the whole country. To date, the Center has assembled about 2,348 accessions of *Capsicum* spp. These collections comprise cultivated species, i.e. *Capsicum annuum, C. frutescens, C. chinense, C. baccatum* and *C. pubescens*. They are wide range of fruit morphology and region of origin but they are good source of pest and disease resistance. The major diseases contributing to low yield in pepper are cucumber mosaic virus (CMV), chili veinal mottle virus (ChiVMV) and anthracnose (*Colletotrichum*

spp.). CMV and ChiVMV were found to be the most important viruses infected pepper plants throughout Thailand (Chiemsombat and Kittipakorn 1997; Chiemsombat et al. 1998) Anthracnose was reported as significant pathogens that caused yield of pepper losses up to 80% (Poonpolgul and Kumphai 2007). The pest that found to be serious attack to pepper is fruit fly (*Bactrocera latifrons*) females that lay eggs under the epidermis of pepper fruit. The mature maggots inside the fruit feed on the core and wall of fruit caused yield losses. Root knot nematode (*Meloidogyne* spp.) is another pest that infested the root of pepper caused the root swollen and bearing knots or galls. The affected plants are stunted and eventually wilt and die.

To examine the potential of pepper germplasm conserved at TVRC as the source of desirable traits and resistance to diseases and pests, characterization seed multiplication for further research as well as evaluation for resistance to diseases and pests were the aims of this study.

MATERIALS AND METHODS

Morphological study and seed multiplication

A total of 614 accessions of Capsicum germplasm belongs to five domesticated species were planted at the experimental field at TVRC, Kasetsart University, Kamphaeng Saen, Nakhon Pathom, Thailand for several seasons. These germplasm comprised 55 accessions from AVRDC - The World Vegetable Center, Taiwan, 285 accessions from GRIN/SINGER, USA, 152 accessions from Thailand collections and 122 accessions from other countries that maintained at TVRC. Each accession was grown in the net cage for morphological study and seed production (Fig. 1). Characterization is recorded on the characters which can be easily seen followed the descriptor list of the former International Board for Plant Genetic Resources (IBPGR) and now the International Plant Genetic Resources Institute (IPGRI). Seeds were harvested and they were cleaned and dried prior to storage.

Figure 1. Net cage for producing good quality seed and preserving genetic constitution of the pepper germplasm

Evaluation for anthracnose resistance

Seventy four accessions of pepper germplasm were used for anthracnose (*Colletotrichum capsici*) resistant evaluation. Red fruits of pepper were examined by spraying spore suspension of *Colletotrichum* isolate at 200 spores/sq.mm on attached fruits, which were incubated for 2 days by covering with plastic bag. After incubation the symptom of disease was checked and evaluated based on percent of infected fruit area. Reaction types were classified as

R = Resistant (< 20% area infection)
MR = Moderately resistant (21-40% area infection)
MS = Moderately susceptible (41-60% area infection)
S = Susceptible (> 60% area infection)

Evaluation for virus resistance

Five hundred and seven accessions and 529 accessions of pepper germplasm were examined for CMV and ChiVMV resistance, respectively. Twenty-four pepper seedlings of each accession were grown in plastic tray under greenhouse condition. Inoculum of CMV and ChiVMV was mechanical inoculated to pepper seedlings at 3-5 leaves stage and repeated inoculation has been done after 1 week of the first inoculation. Symptom on the infected plants was determined after 4 weeks of inoculation and indirect ELISA according to Clark and Adams (1977) was used to detect the virus in leaf samples. Reaction types were based on percent of infected plants as follows:

I = Immune (0% infection)
R = Resistant (1-10% infection)
MR = Moderately resistant (11-30% infection)
MS = Moderately susceptible (30-50% infection)
S = Susceptible (51-100% infection)

Evaluation for nematode resistance

Forty six accessions of pepper germplasm were evaluated for nematode (*Meloidogyne* spp.) resistance. Seedlings were raised in peat moss substrate in 104 hole-plastic trays. Thirty–day-old pepper seedlings were transplanted in sandy loam in small pot and the inoculum suspension contained 1000 $\pm$ 100 eggs were inoculated in each plant. The inoculated plants were moved into the screen covered cage. Evaluation for nematode gall index was done on 40 day-old plants. Root gall index were classified into 5 types as

1 = Highly resistant (very few galls)
2 = Very resistant (< 25% galls)
3 = Moderately resistant (25-50% galls)
4 = Slightly resistant (51-75% galls)
5 = Susceptible (>75% galls)

Evaluation for fruit fly resistance

Thirty hundred fifty seven accessions of pepper germplasm were tested for the resistance to Malaysian fruit fly (*Bactrocera latifrons*). Each accession comprised ten plants were grown under the 20 fine meshes net house. Forty pairs of the 14-21 days-old were released into the net house with 20 accessions of potted pepper plants to determine the infestation of fruit fly on pepper fruits. The resistance was measured by fruit yield loss (YLF), thus it was separated into

HR = Highly resistant (0 %YLF)
R = Resistant (1-25 %YLF)
MR = Moderately resistant (16-50 %YLF)
MS = Moderately susceptible (51-75 %YLF)
S = Susceptible (75-100 %YLF)

RESULTS AND DISCUSSION

Morphological study and seed multiplication

Information of horticultural characters can be recorded only 602 accessions of pepper germplasm due to more variation of fruit characters and no fruit set of some accessions especially in *C. pubescens.* The collecting information and the data of characterization are recorded in passport data and in computerized data base. The amount of seeds to produce should be enough to cover the need for active and working collections. After harvesting seeds at physiological maturity stage the seeds are extracted cleaned and dried. Decreasing seed moisture contents to be 5-8% is necessary for longevity of the seeds in storage. They are packed in aluminum foil with the label of accession number, date of packing, germination test and other related information on the cover to prevent misidentification of the accessions. The germplasm seeds are reserved in medium term storage about 10 ºC with 50% relative humidity.

Seed production of pepper germplasm with the amount of seeds more than 5 gram were 444 accessions and the amount of seeds less than 5 gram were 121 accessions. There were 49 accessions of pepper germplasm could not get any seeds due to the plants and fruits were damaged by diseases and pests. Some accessions whether were unable to fruit set or set fruits but no seeds.

Evaluation for anthracnose resistance

Anthracnose disease scores as evaluated at full mature red fruit stages were found to be resistance level varied considerably from 0-17.93% of disease incidence, were 43 accessions. Among these accessions, 16 accessions showed no symptom of disease incidence and accession number, its species, origin and the available of seed for requested are shown in Table 1. The other accessions rated as moderately resistant, moderately susceptible and susceptible were 14, 12 and 5 accessions, respectively.

Table 1. Sixteen accessions of pepper germplasm that showed no symptom of anthracnose incidence

Acc.no.	Scientific name	Origin	Seed available
CA743	*Capsicum chinense*	Hungary	-
CA747	*Capsicum baccatum*	Hungary	**
CA822	*Capsicum annuum*	-	**
CA892	*Capsicum annuum*	Japan	-
CA924	*Capsicum baccatum*	Japan	-
CA927	*Capsicum annuum*	Japan	**
CA985	*Capsicum annuum*	Thailand	-
CA1032	*Capsicum frutescens*	Thailand	*
CA1131	*Capsicum annuum*	Thailand	**
CA1180	*Capsicum annuum*	Thailand	**
CA1245	*Capsicum annuum*	AVRDC	**
CA1251	*Capsicum annuum*	AVRDC	**
CA1299	*Capsicum baccatum*	AVRDC	-
CA1302	*Capsicum annuum*	AVRDC	**
CA1394	*Capsicum annuum*	Japan	*
CA1429	*Capsicum annuum*	Thailand	**

Evaluation for virus resistance

Screening of 507 accessions of pepper germplasm for CMV and 529 accessions for ChiVMV resistant sources under greenhouse conditions, several immune or highly resistant accessions were successfully identified after 4 weeks of inoculation. It was found that only one accession, CA2106, introduced from AVRDC-The World Vegetable Center was exhibited immune response (no symptom) to CMV. ChiVMV caused symptoms varying from vein mottling, vein banding necrosis, leaf distortion, green spot and green flecking in 520 accessions, thus there were only 9 accessions showed highly resistant or immune response (Table 2). However, it was found that two accessions showed resistance to CMV and ChiVMV. The first was CA1828 was resistance to CMV and the other one was CA1029 was resistance to ChiVMV. The rest of the accessions were moderately resistant, moderately susceptible and susceptible.

Table 2. ChiVMV highly resistant accessions and their species, origin and seed available for requested

Acc.no.	Scientific name	Origin	Seed available
CA446	*Capsicum annuum*	AVRDC	**
CA860	*Capsicum annuum*	Thailand	**
CA1131	*Capsicum annuum*	Thailand	**
CA1184	*Capsicum annuum*	AVRDC	**
CA1195	*Capsicum annuum*	AVRDC	**
CA1258	*Capsicum annuum*	AVRDC	**
CA1338	*Capsicum annuum*	Thailand	*
CA1611	*Capsicum annuum*	India (GRIN)	-
CA1622	*Capsicum frutescens*	Mexico (GRIN)	-

Evaluation for nematode resistance

The pepper germplasm showed different severity of galling caused by root knot nematode (*Meloidogyne* spp.). Symptoms of infestation varied among the tested plants from a few galls to 100 percent galls. From this study, eleven accessions considered as highly resistant or fewer gall infection (Table 3). The infection rates lower than 25% was found in 13 accessions of pepper germplasm (Table 4). It can be noticed that most of the accessions that resistance to root knot nematode belonged to *C. frutescens*. If those accessions are confirmed the resistance by evaluating in the field, it will be a great interest for breeding program and utilizing as rootstocks.

Table 3. Highly resistant accessions of pepper germplasm to root knot nematode

Acc.no.	Scientific name	Origin	Seed available
CA516-A	*Capsicum annuum*	-	*
CA735	*Capsicum frutescens*	Phillipines	*
CA756	*Capsicum annuum*	Hungary	**
CA787	*Capsicum annuum*	-	*
CA1299	*Capsicum baccatum*	AVRDC	-
CA1336	*Capsicum frutescens*	Thailand	*
CA1343	*Capsicum frutescens*	Thailand	-
CA1345	*Capsicum frutescens*	Thailand	-
CA1352	*Capsicum frutescens*	Thailand	-
CA1361	*Capsicum frutescens*	Thailand	-
CA1486	*Capsicum frutescens*	Laos	-

Table 4. Very resistant accessions of pepper germplasm to root knot nematode

Acc.no.	Scientific name	Origin	Seed available
CA516-B	*Capsicum annuum*	-	-
CA747	*Capsicum baccatum*	Hungary	**
CA1165	*Capsicum annuum*	Thailand	*
CA1182	*Capsicum annuum*	AVRDC	*
CA1347	*Capsicum frutescens*	Thailand	-
CA1380	*Capsicum frutescens*	Thailand	-
CA1386	*Capsicum frutescens*	Thailand	-
CA1399	*Capsicum frutescens*	Thailand	-
CA1400	*Capsicum frutescens*	Thailand	-
CA1429	*Capsicum frutescens*	Thailand	**
CA1487	*Capsicum frutescens*	Laos	*
CA1726	*Capsicum annuum*	Mexico (GRIN)	**
CA1779	*Capsicum frutescens*	Brazil (GRIN)	-

Evaluation for fruit fly resistance

Fruit fly (*Bactrocera latifrons*) females lay eggs under the epidermis of pepper fruit and mature maggots inside the fruit feed on the core and wall of fruit caused yield losses. Seventeen accessions from 357 accessions of pepper germplasm tested under net house conditions were found to be resistance to fruit fly infestation as the yield lost in the range of 1-25% (Table 5). The other accessions rated as moderately resistant, moderately susceptible and susceptible were 41, 148 and 151 accessions, respectively.

Table 5. Resistant accessions of pepper germplasm to fruit fly infestation

Acc.no.	Scientific name	Origin	Seed available
CA1131	*Capsicum annuum*	Thailand	**
CA1187	*Capsicum annuum*	Thailand	*
CA1317	*Capsicum frutescens*	Bolivia	*
CA1340	*Capsicum annuum*	Thailand	*
CA1373	*Capsicum annuum*	Thailand	**
CA1394	*Capsicum annuum*	Japan	*
CA1429	*Capsicum frutescens*	Thailand	**
CA1631	*Capsicum annuum*	Spain (GRIN)	*
CA1632	*Capsicum annuum*	Mexico (GRIN)	**
CA1633	*Capsicum chinense*	Bolivia (GRIN)	*
CA1634	*Capsicum chinense*	Costa Rica (GRIN)	**
CA1657	*Capsicum baccatum*	Peru (GRIN)	**
CA1683	*Capsicum sp.*	Peru (GRIN)	*
CA1747	*Capsicum annuum*	India (GRIN)	**
CA1801	*Capsicum annuum*	Mexico (GRIN)	*
CA1829	*Capsicum annuum*	Mexico (GRIN)	**
CA1857	*Capsicum annuum*	GRIN	**

CONCLUSION

A total of 602 accessions of pepper germplasm was recorded for the morphological characters and 565 accessions can be produced the seeds for further uses. Evaluations for disease and pest resistance it was found that 16 accessions showed no symptoms of anthracnose incidence, one and nine accessions were highly resistance or immune to CMV and ChiVMV, respectively. Highly resistant accessions of pepper germplasm to root knot nematode were found 11 accessions and the very resistant accessions were 13 accessions. Pepper accessions exhibiting fruit yield loss caused by fruit fly less than 25% was found 17 accessions. It is interesting to note that only one accession, CA1131, showed resistance to anthracnose, CMV and fruit fly and moderately resistance to ChiVMV. Database on the evaluated germplasm was created through the support from BIOTEC, NSTDA and can be accessed on line at www.biotec.or.th/germplasm.

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References

Chiemsombat P,Kittipakorn K. 1997. Confirmation of potentially important pepper viruses. In: AVRDC 1997. Collaborative vegetable research in Southeast Asia. Proceedings of AVNET-II Final Workshop, Bangkok, Thailand, 1-6 Sep 1996. Publication No. 420-431, 451pp.

Chiemsombat P, Sae-Ung N, Attathom S, Patarapuwadol S, Siriwong P. 1998. Molecular taxonomy of new potyvirus isolated from chilli pepper in Thailand. Archives of Virology 143:1855-1863.

IPGRI, AVRDC and CATIE. 1995. Descriptors for Capsicum (*Capsicum* spp.). International Plant Genetic Resources Institute, Rome, Italy; the Asian Vegetable Research and Development Center, Taipei, Taiwan, and the Centro Agronomico Tropical de Investigacion y Ensenanze, Turrialba, Costa Rica. 45 pp.

Poonpolgul S, Kumphai 2007. Chilli pepper anthracnose in Thailand. In: Oh Dae-Guen, Kim Ki-Taek (eds.) Abstracts of The First International Symposium on Chili Anthracnose.National Horticultural Research Institute, Rural Development of Adminstration, Republic of Korea.

Breeding for disease resistance of melon in Taiwan

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ABSTRACT

Melon (*Cucumis melo* L.) is very popular in Taiwan. The tropical and subtropical climates render the possibility of the production of this fruit year-round. However, the warm weather, especially during the warm seasons also favors the development of many diseases. Powdery mildew (*Podosphaera xanthi*) is one of the most serious diseases, even becomes a limiting factor in melon production. Although powdery mildew can be controlled by chemical spray, it is not an encouraged approach due to the economic and safety considerations. When leaf disc inoculation method was used in the screening test, most commercial cultivars of melons in Taiwan were found to be susceptible to powdery mildew. A breeding program for obtaining muskmelon varieties resistant to the disease, and also having high fruit quality was, therefore, initiated. Assessment of powdery mildew resistant by artificial inoculation has been development. There are different types of melon lines which are resistant to powdery mildew have been bred, and a new variety 'Tainung No. 10' was released in 2006. In the future, some breeding lines with different resistant gene will be pyramided. Soil decline problem due to continuous monoculture has become another major factors limiting production of melon in Taiwan. One of the serious responses of soil problem is sudden wilt of melon plants. Moreover, the primary pathogens for melon vine decline are fungi *Monosporascus cannonballus*. This disease cannot be well controlled by chemicals. Sudden wilt results in severe economic losses in melon industry in Taiwan. A study was conducted to overcome this soil-borne disease in melon. There are three step strategies were performed: 1) improvement of steam-treatment of soil; 2) development of grafted techniques; 3) breeding of resistant variety. According to the results of steam-treatment of soil experiments, it is suggested that the method is effective for resolving the problem of soil decline caused by continuous monoculture of oriental melon. Besides, the artificial inoculation technique in early seedling stage is evaluated. After assessment of this disease resistance has been established, the outputs of resistant breeding lines may be efficient.

Keywords

Cucumis melo, breeding of disease resistance, *Podosphaera xanthi*, *Monosporascus cannonballus*

INTRODUCTION

Melon (*Cucumis melo* L.) is a kind of Cucurbitaceae family, which is grown in the tropical and subtropical regions worldwide. The world production of melon was estimated at 23 million tons in 2010 (FAOSTAT 2011). And it is the fourth item of total cucurbit crop production. The major produces are China, Turkey, Iran, the Unite State and Spain. The estimated production value is more than $1.2 billion. It is a highly morphological diversity species with variations in both vegetative and fruit characteristics (Robinson and Decker-Walters 1997). It is also a popular fruit product with high value for the consumer market in Taiwan. Therefore, there are two main types of melon are grown in Taiwan. One is the thick skin melon produced in Tainan City, Yunlin and Chiayi County, the other one is the thin skin oriental melon produced in

Kaohsiung City, Pintung, Yunlin and Chiayi County. The major production seasons are spring and autumn and the average yield is about 15 to 18 tons/hectare. However, during these ten years, the total production area for melon has declined more than 50% from 2001 to 2010. The estimated planted area was around 5000 hectare and the yield is about 70 thousand tons in 2010 (COASTAT 2010). Although the decreasing rate is related with many uncertain factors, including biotic and abiotic stress, it is worth to effort on resistant breeding. Therefore, the main topics of this paper are: 1) to present a breeding program of powdery mildew in melon, 2) to draft a integrated control technology to overcome the melon vine decline problem and to figure a resistant breeding program.

Breeding strategies of powdery mildew in melon

Powdery mildew is one of the most serious fungal diseases, even becomes a limiting factor in melon production around the world. The disease is primarily caused by two pathogens: *Podosphaera xanthii* (Castag.) Braun & N. Shish (syn. *Sphaerotheca fuliginea* (Schlecht. ex Fr.) Poll; *S. fusca* (Fr.) Blumer emend. Braun) and *Golovinomyces cichoracearum* (D. C.) Huleta (syn. *Erysiphe cichoracearum* DC ex. Mecat) (Jahn et al. 2002). However, *P. xanthii* is the only one indentified fungus as the pathogen of melon powdery mildew problem in Taiwan (Huang et al. 2002). Although the disease can be controlled by chemical spray, it is not an encouraged approach due to the economic and safety considerations. A breeding program for obtaining melon varieties resistant to the disease, and also having high fruit quality was, therefore, initiated from 1998 in TARI.

According to many reports, the races of P. xanthii on melon seem to be complicate. There are seven races of *P. xanthii* which have been identified in melon by the differential host set , including IRAN-H, Vedrantais, PMR 45, WMR 29, Edisto 47, PI414723, PMR5, Pi124112 and MR-1 (Pitrat et al. 1998). Moreover, many putative races also have been reported in some melon production areas (McCreight et al. 2006). Because of the complex virulent of *P. xanthii* in the open field, the infection in this condition was not uniform and screening of resistance was not stable. Breeding for resistance should be based on a system of inoculation of specific race of *P. xanthii*.

Therefore, a leaf-disk method was developed for disease assessment of melon powdery mildew caused by P. xanthii race 1 by collaboration with INRA, French. Ten to fourteen days after inoculating with P. xanthii race 1 in melon seedling stage, the symptoms can be scored on a scale of 0 to 9 (0 = no detectable fungal growth; 1 = isolated colonies cover less than 10% of the leaf disc area; 3 = less than 50% of the leaf disc area covered by sporulation; 5 = between 50 % - 80% of the leaf disc area covered by sporulation; 7 = 100% leaf disc area covered with weak sporulation; 9 = 100% leaf disc area covered with heavy sporulation). The susceptibility response to powdery mildew of the inoculated melon is identified by disease ratings: score 0 to 2 is resistant and score 3 to 9 is susceptible (Mohamed et al. 1995). In our experiments, there was a positive correlation among leaf- disk assay, seedling inoculation in growth chamber and natural infection of melon plants in open field. The relative coefficients (r2) were 0.9709 and 0.7924, respectively (p=0.05). The leaf-disk assay is feasible to apply to powdery mildew resistant breeding program of melon in Taiwan (Huang et al. 2002).

Nineteen commercial cultivars of melon were collected to evaluate the disease response of powdery mildew (*P xanthii* race 1) in 2004. It has been found that only three of these varieties, i.e. Autumn waltz No.2, Chengfang, and Mihua, were resistant; the other 16 varieties were susceptible. This result implies most of the melon cultivars in Taiwan were susceptible to powdery mildew (*P. xanthii* race 1). Then assessment of 36 inbred lines ($S_8 \sim S_{12}$) developed by TARI to the same pathogen were also performed. Among them, 21 inbred lines were resistant, and the other 15 ones were susceptible. Therefore, one of the resistant lines '99004' was a S_{12} inbred line with resistance to race 1 of *P. xanthii* from the progenies of the hybrid between TVI6274 and TVI8140, was served as the maternal parent, and '99009' was an inbred line with high fruit quality of S_9 from the hybrid 'Emerald Sweet' of Known-you seed Co. in Taiwan was selected to be the other parent. Then The resistance to powdery mildew hybrid 'Tainung No. 10' was derived from a cross between '99004' and '99009' in 2006 (Wang et al. 2004).

Based on this result, the inheritance of resistance to powdery mildew (*P. xanthii* race 1) in the resistant inbred line '99004' (S_{12}) has been further studied. For this purpose, cross hybridization between inbred line '' 99004 and the susceptible inbred line '99009' (S_9), were made to create suitable experiment populations. Finally the parents and their progeny, including F_1, F_2, BC_R, and BC_S, were inoculated with powdery mildew to see the response in every single plant. The segregation ratios of resistance vs. susceptibility obtained from these experiment indicated that the resistance trait of inbred line '99004' seems being under the control of a single dominant gene (Wang et al. 2004).

For understanding the race information of powdery mildew of melon in Taiwan, the race identification was conducted by the leaf-disk inoculation of melon differential hosts. From 2001 to 2004, *P. xanthii* race 1 was isolated from Wufeng, Lunbei, Tainan, and Bade. The host included sensitive cultivars of 'Golden light', 'Honey world', and 'Hsianghwa', and the mild powdery mildew spot of resistant variety 'Tainung No. 10'. In spring 2005, *Podosphaera xanthii* race 5 was isolated from sensitive symptom of Tainung No. 10, and race 1, 5 from the sensitive cultivar Hsianghwa. At the same time, both races were isolated form Tainan. When these 2 races were inoculated on leaf disc of Hsianghwa and Tainung No. 10, Hsianghwa showed sensitive reaction on these 2 races; nevertheless, Tainung No. 10 was resistant to race 1 but sensitive to race 5. In the total 181 isolates, there were 138 isolates belong to race 1 but 43 isolates to race5. The results showed that there were at least 2 races of *P. xanthii* on melon in Taiwan, but race 1 are more common (Huang and Wang 2007).

Integrated control technology of vine decline in melon

Melon vine decline is an increasingly destructive disease of melon. It could be a complex of soil borne diseases that have become major yield-limiting factor worldwide (Martyn and Miller, 1996). Despite the complex situation, the primary pathogens responsible for melon vine decline are the soil borne fungi *Monosporascus cannonballus* (Fita et al, 2008). Nowadays, it also has been an important problem for melon production in Taiwan (Su and Lin 2001). *M. cannonballus* causes brown discoloration of the roots of melon in the early stage, then can evolve into rot, and even lead to necrosis of the whole root system. Vine decline are observed in the late stage when the high requirement of water by fruit increases (Fita et al. 2007). The symptom of this disease in melon plant is variable based on the climate condition and the cultural practices. However, the assessment methodology of this disease is highly difficult. Furthermore, there are limit number of resistant germplasm to the disease (Fita and Pico 2009) to develop resistant cultivars recently. Therefore, the integrated control technology of vine decline in melon has already initiated.

M. cannonballus caused root rot/vine decline of melon. Sudden wilt of most infected plants occurred in the field at 2 weeks before harvesting. According to the report, the germination of ascospore of *M. cannonballus* and germling attachment to plant roots were highly specific. It was only in genera and species of plants belonging to Cucurbitaceae (*Cucurbita, Citrullus and Cucumis*). Additional the numbers of ascospore germplings attached to cultivars of melon were minimally 3-times higher than on root system of all other cucurbit genera or species. None ascospore germination occurred in the rhizosphere of alfalfa, cotton, wheat, corn, sorghum and broccoli (Stanghellini et al, 2009). Field survey results showed that the host range of *M. cannonballus* included muskmelon, Japanese cantaloupe, oriental pickling melon, cucumber, wax gourd and bottle gourd as rootstock for watermelon in Taiwan. Besides the muskmelon, which was usually seriously damaged, the root rot/vine decline in other 5 cucurbit plants were limited to some locations in Fangyuan of Changhua County or in the greenhouse (Lin et al. 2008).

Soil decline due to continuous monoculture has become a major factors limiting production of melon in the greenhouse in Taiwan. The plant showed the symptom of vine decline before fruit harvesting and *M. cannonballus* was estimated to be the major biotic problem to melon vine disease. A study was conducted in a commercial greenhouse in Chaiyi, Taiwan, to determine effects of steam treatment of soil on the growth, yield and quality of 'Grill' melon. The soil in the greenhouse was used for production of 'Grill' melon for two crops per year for more than three years. A self-propelled soil disinfector was used for steaming the soil up to a depth of 15 cm for four hours. Results showed that the temperature in the steamed soil at the depth of 10 cm reached 60 °C for a period of 1.5 h., compared to the non-steaming treatment (control). Plants of melon grew vigorously in the steam-treated soil with a significant increase in leaf size. Also, steaming of soil significantly reduced the incidence of wilting plants. The average weight, length, diameter and flesh thickness of fruits of melon plants grown in steam-treated soil were higher than fruits from plants grown in untreated soil. The yield of melon plants grown in steam-treated soil was increased by 38.1%, compared to the control. This study suggests that steam-treatment of soil is an effective method for resolving the problem of vine decline caused by soil decline of oriental melon as a greenhouse crop (Wang et al. 2011).

Grafting has been successfully applied to resolve soil borne diseases in many horticultural crops. It is also suitable for melon to control the vine decline disease. Several Cucurbits and their inter-specific hybrids have been used as rootstocks for melon. Some rootstocks have been reported to positively affect yield and fruit quality (Bletsos 2005). And, the melon tongue root inarching grafts, used squash as rootstock, were studied for their efficacy in controlling vine decline of melon. The above-ground rootstock tissues were excised at the grafting union by razor 3 weeks after transplanting. The survival rates of the rootstock plants were more than 80%. These results provided the basis for disease management of vine decline of melon by graft culture. In 2005, the field experiments conducted at Chigu (Tainan), the grafts on squash rootstock gave a stable, positive performance on disease management. Although the root of rootstock plants was also infected by *M. cannonballus*, they displayed a relatively low root rot index of 1.1 and 1.6 in the two fields, respectively. Fifty-four percent of the total root numbers were found to derive from the rootstock plant. By harvest time, the grafts showed a phenomenon of temporary wilting in which the plants wilted during the day and would recover at night or in a later time under certain circumstances. A normal harvest of high quality fruit of muskmelon was possible (Su and Lin 2008).

CONCLUSION

Because melon is an important crop in Taiwan, it should be receive more research resources to resolve the decreasing rate of production caused by biotic stress, especially diseases. The climate is warm and humid, therefore the environment is suitable to many kinds of pathogens. Diseases might be the major cause of problems in melon production. The resistant breeding methods for powdery mildew in melon have been established since 1999. To date, three resistant cultivars (*P. xanthii* race1) were developed and released. Actually, these resistant cultivars showed vigorous growth in the open field. To address this complex race situation, cultivars resistant to other races must be bred. For melon vine decline disease, an integrated control strategy has been published; these technologies can be applied now in melon production. However, collection of resistant germplasm and utilization of these resources are the high priority of Taiwan's research program. The final objective of breeding for disease resistance is to pyramid multiple resistances in melon to enhance adaption in the future.

References

Bletsos FA. 2005. Use of grafting and calcium cyanamide as alternatives to methyl bromide soil fumigation and their effects on growth, yield, quality and *Fusarium* wilt control in melon. Phytopathology 153:155-161.

Council of Agriculture (COA). 2010. Agricultural Statistics Yearbook. COA, Executive Yuan. Taipei, Taiwan. 332.

FAOSTAT. 2012. FAOSTAT Database Results 2010. http:// www.fao.org.

Fita A, Pico B. 2009. 'Piel de Sapo' breeding lines tolerant to melon vine decline. HortScience 44:1458-1460.

Fita A, Pico B, Nuez F. 2007. Melon roots under stress: Melon vine decline. Plant Stress 1:93-104.

Fita A, Pico B, Dias RCS, Nuez F. 2008. Effects of root architecture on response to melon vine decline. J. Hort. Sci. Biotechol. 83:616-623.

Huang JH, Wang YH. 2007. The race of Podosphaera xanthii causing melon powdery mildew in Taiwan. J. of Taiwan Agricultural Research 56:307-315.

Huang JH, Wang YH, Lo CT. 2002. Development of leaf-disk method for screening melon varieties resistant to *Sphaerotheca fuliginea* race 1. J. of Agricultural Research of China 51: 49-56.

Jahn M, Nunger HM, McCreight JD. 2002. Breeding cucurbit crops for powdery mildew resistance. In: Belanger RR, Bushnell WR, Dik AJ, Carver LW (Eds.) The Powdery Mildews, a comprehensive treatise. APS Press, St. Paul, MN, USA. pp. 239-248.

Lin YS, Su JF, Lin KM. 2008. The Host Range of Monosporascus cannonballus in Taiwan. Plant Pathol. Bull. 17:25-34.

Martyn RD, Miller ME. 1996. Monosporascus root rot vine decline: An emerging disease of melon worldwide. Plant Dis. 80:716-725.

McCreight JD. 2006. Melon-powdery mildew interactions reveal variation in melon cultigens and *Podosphaera xanthii* race 1 and 2. J. Amer. Soc. Hort. Sci. 131:59-65.

Pitrat M, Dogimont C, Bardin M. 1998. Resistance to fungal diseases of foliage in melon. Cucurbitaceae 98:167-173.

Robinson R W, Decker-Walters DS. 1997. Cucurbit, Crop Production Science in Horticulture 6. CAB International, New York.

Stanghellini ME, Alcantara TP, Ferrin DM. Germination of *Monosporascus cannonballus* ascospores in the rhizosphere: A host-specific response. Phytopathology 99: S123.

Su JF, Lin YS. 2001. The disease development and xylem-tylose formation of root rot and vine decline of muskmelon. Plant Pathol. Bull. 10: 205.

Su JF, Lin YS. 2008. The Grafting Management in Root Rot/Vine Decline of Muskmelon. Plant Pathol. Bull. 17:35-41.

Wang YH, Su JF, Yang CK, Lin YW, Lin CY, Wei ML. 2011. Effects of steam treatment of soil on green house for oriental melon in a commercial greenhouse. J. of Taiwan Agricultural Research 60:167-177.

Wang YH, Huang JH, Lin TK, Wang ST, Hsiao CH. 2004. Genetic studies and screening for resistance to powdery mildew in melon. J. of Agricultural Research of China 53:1-8.

Genetic improvement of adopted okra cultivars for YVMV disease resistance involving wild relatives in genus A*belmoschus*

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ABSTRACT

Okra [*Abelmoschus esculentus* (L.) Moench] is an important vegetable crop grown in tropical and sub tropical regions throughout world. Since its domestication, improvement has been the continuous quest like other plant commodity specially the resistance for biotic and abiotic stresses. In India it is grown almost in every part in various seasons excepting winter season has resulted in the prevalence of Yellow vein mosaic virus disease (YVMV), which is transmitted through a vector as white fly. Its epidemic form causes serious threat to quality and productivity of fruits. Therefore to develop cultivar having resistance to YVMV disease from sources namely wild species *Abelmoschus manihot* ssp *manihot* and *Abelmoschus tetraphyllus* and tolerant cultivar of cultivated species like US7109 has been taken up at this university. The efforts to transfer gene for resistance to YVMV disease from wild species to cultivated cultivars *viz.,* Hisar Unnat and Varsha Uphar, have progressed in generating use full advance lines. Hisar is ideally suited for screening against YVMV infection and more so in congenial environment, the rainy season. The studies conducted since 2000 revealed that Varsha Uphar is poor cross compatible with wild relative comparison to cultivar Hisar Unnat. The partial fertile F_1 plant obtained in the cross of Hisar Unnat with the wild sub species *manihot* were further back crossed and even involved for three way crosses for improving the fruit shape and colour characters. Our studies have indicated that the resistance to YVMV is controlled by two complimentary genes whose track has been either from wild ssp *manihot* or the symptomless carrier cultivar namely IC 1542. The concentrated efforts in this have lead to the development of several promising recombinants inbred lines.

Keywords

Okra, wild species, Yellow vein mosaic virus disease, Resistance

INTRODUCTION

Okra with considerable area under cultivation in both African and Asian countries is considered as important component of diet for nutritional balanced food mainly on account having large extent of socio-economic potential world over due to its robust nature, dietary fiber and distinct amino acid composition being rich in lysine and tryptophan unlike those in cereals and pulses. Moreover, the increased demand, due to alarming population growth globally with intense pressure on land use and natural resources particularly for plant species are required to be diversified in food chain (Hughes 2009). It is crucial vegetable crop to contribute towards nutritional security for food and even so far income diversification in the substance farming system which predominant in the developed as well as underdeveloped countries. However, okra has been considered until –recently a minor crop with little attention for its genetic improvement in the International Research Programme (Duzyaman 1997).

Since its domestication as vegetable crop in tropical and subtropical region, it has found diversified utility as vegetable in the fresh staple but some times in canned formed of tender green pods for its high mucilage content with relatively good nutritional value and is rather a good compliment in developing countries where there is a great elementary in balance.

Okra originally included in the genus *Hibiscus* section *Abelmoschus* is presently accepted as distinct genus on the basis of its cadiucaus nature of the calyx. Four of the species of the *Abelmoschus* are reported to be cultivated in different geographical areas over the world. The cultivation of most popular species *Ablemoschus esculentus* is based mainly on traditional cultivars. Most breeding programmes are focused for genetic improvement of the crop for biotic and abiotic stresses particularly as the crop can be grown all round the year accepting few winter months. Okra despite being a robust crop, the yield losses under large scale commercially production are very high on account of several biotic stresses particularly for the most destructive viral disease namely Yellow Vein Mosaic Virus (YVMV) and it is the limiting factor for the successful cultivation for this crop in rainy seasons in India. Ever since its first report as early as 1924 (Kulkarni 1924), there has been continuous quest and attempt by several workers (Singh et al. 1962; Dhankhar et al. 1997, 1999; Nerkar and Jambhale 1985; Thakur 1976) as the losses due to virus disease may extend to 94 percent depending upon the stage of crop growth (Shastry and Singh 1974). Disease is transmitted by insect vector identified as whitefly (*Bemisia tabaci* Gen.) and being a viral disease can not be controlled satisfactorily by application of any of chemical means.

The inheritance of this disease has been studied by number of research workers since 1962. These are contradictory report with no definite conclusion for nature of resistance to yellow vein mosaic virus disease in okra, which may be due to complexity of the disease and more so on getting congenial environment for the establishment of its vector, the whitefly. Nevertheless, the efforts are continuing to over this deadly viral disease by involving wide and wild relatives as a source of resistance at several institutions. A systematic study has also been under taken to transfer the genes for resistance to YVMV in the still popular cultivar Hisar Unnat and Varsha Uphar, which now has shown breakdown for last decade. Therefore, the focused efforts are intensively being pursued to improve Hisar Unnat in respect of its tolerance to YVMV as the cultivar Varsha Uphar was poorly compatible with wild relatives *A. manihot* ssp. *manihot*.

MATERIALS AND METHODS

Two prominent varieties of okra namely Hisar Unnat and Varsha Uphar identified and released at National Level in the year of 1992 and 1996, respectively had wide adaptation all over the country until these succumbed to the deadly YVMV disease. However, in the absence of suitable resistant varieties of okra, both are still being cultivated in most part of the okra growing region in India in different seasons. Both of the varieties were crossed with *A. manihot* ssp *manihot* and *A. tetraphyllus* , however, the material for the present study comprised of the material derived from the cross between the cultivar Hisar Unnat and wild species *Abelmoschus manihot* ssp *manihot*, which is being maintained at this University for the last two decade. The F_1 between two genotypes were attempted in both ways i.e. Hisar Unnat as female as well as pollen parent as early as during rainy season 1999. Further, the F_1 plants exhibiting partial fertility were back crossed with recurrent parent “Hisar Unnat” in rainy season, 2000. The BC_1 generation plants were observed under natural epiphytotic conditions in rainy season 2001 for resistance along with fruit characters.

Under field conditions following Singh et al. (1962) disease symptoms were recorded that begin with the yellowing of the veins on the new emerging leaves. With regards to the intensity and distribution of the disease four distinct type of infection are noticeable on the plant. In the severe form, the disease may appear very early in the season on the young plant, where all the veins on the leaves may turn completely yellow, which subsequently turn brown leading to drying up and shedding of leaves. Such plant rarely comes to flower and thus leading to severe losses to crop. In second type of severe infection, the older leaves on the main stem remain green, whereas the top leaves and flowering part of the secondary branches exhibit clear symptoms of infection. On such plants, though fruits are formed in good numbers but are uniformly yellow at the tender picking stage and as such are unmarketable. Both of these types of infections fall under the category of susceptible genotype. In the case of mild infection two types of infections are observed. The first, where leaves do not show yellowing of vein, however, the fruits, which are otherwise well developed show slightly yellowing. In the second type the plant remain healthy almost until the end of fruiting period, however, a few small young shoots may appears as tertiary branches or on the basal portion of the main stem with only veins clearing as yellow but the tissues between the vein remain unaffected and green plants of this last category are practically capable of giving yield equivalent to those obtained from completely symptom free plants.

The BC_1 progeny traceable as BC_1-3 was further crossed with genotype "US7109" identified source of tolerance to YVMV with dark green fruit. The F_1 thus obtained as three parent cross was further back crossed with recurrent parent as US 7109 to improve fruit colour. The segregating progenies were observed for desirable fruit shape, size and colour along with resistance to YVMV under field condition. The further progression and advancement of the segregating material has been closely observed over the years under various seasons and the four lines (Line No. 10, 15, 16 and 25) derived as resistant (0-5%) were evaluated for fruit and plant characters. Ultimately one promising line with desirable fruit characters and the resistance to YVMV was evaluated for yield potential during rainy season of 2009 and 2010 against the check in plot size of 3.6 x 2.0 meters with row to row spacing as 60 cm and between plants within row as 30 cm.

RESULT AND DISCUSSION

The improvement programme depicting the crosses attempted with released from CCS Haryana Agricultural University, Hisar and the success in terms of derived lines:

Lines	*A. manihot* ssp *manihot*	*A. tetraphyllus*
Hisar Unnat	19 lines	Nil
Varsha Uphar	3	Nil

The F_1 plants between Hisar Unnat and wild species *Abelmoschus manihot* ssp. *manihot* exhibited heterosis for morphological characters namely stem height, branches per plant, flower and leaf size, however, were partially fertile. The hybrid plants though free from YVMV disease through out the season but beared fruits, which were intermediate for most of the fruit traits. The F_1 plants on back crossing to Hisar Unnat resulted in fruits with 4-6 seeds of which 30 percent were found as viable as already reported (Dhankhar et al. 2005). Three parent cross progenies derived from the second back cross with recurrent parent as US 7109 resulted in the fruits with adequate number of seeds and desirable fruit traits (attractive shape ands size and dark green in colour). The progeny on observation for the various morphological and fruit traits, when found stable and uniform, were isolated as Line No 10, 15, 16 and 25 (Fig. 1).

BC$_1$-3 x US 7109 (Third parent)
↓
F$_1$ x US 7109
↓
↓ ↓ ↓
BC$_1$-6 BC$_1$-7 BC$_1$-9 Selfing
↓ ↓ ↓
BC$_1$-6-7 BC$_1$-7-6 BC$_1$-9-2 Selected and
further selfing
↓ ↓ ↓
BC$_1$-6-7-1 BC$_1$-6-7-2 BC$_1$-7-6-1 BC$_1$-9-2-2 Selected and
↓ ↓ ↓ further selfing

Figure 1. Homozygous lines obtained numbered as Line No.15, 16, 25 and 10.

On evaluation (Table 1), line No. 15 with dark green fruit recorded fruit length as 16.0 cm, fruit diameter as 2.0 cm and number of fruits being 21 per plant at internodel length of 3.5 cm with a pedicel length 4.0 cm, which makes convenient to harvest the fruit from plant. Stem length for this line was 70.0 cm with an average 3.0 branches per plant, which are parallel with upright height tendency along with main stem resulting in close canopy of plant with leaves having long petiole and deeply lobed, which make it suitable for better penetration of light. The assessment of this advanced line No 15 during rainy season of 2009 and 2010 against the most popular commercial variety Varsha Uphar identified it statistically at par for fruit yield (130.0 q/ha) and average fruit number per plant (33.0) (Table 2). However, based on colour, shape and size of fruit this line has advantage over Varsha Uphar in terms of smoothness, where in the VU, it is generally felt that under water stress condition fruits may give non smooth pods where in the seed positions within the pods is expressed visibly to large extent, besides, the breakdown of its resistance to YVMV.

Table 1. Characteristics of yellow mosaic virus resistant line of okra developed from interspecific cross

Character	Line number of *A. esculentus* x *A. manihot* ssp *manih*ot				
	Line No 25	Line No 10	Line No 16	Line No 15	Varsha Uphar
Habit	Tall	Medium tall	Medium tall	Medium tall	Tall
Height (cm)	95.2	85.8	72.4	70.0	100.0
Number of branches/plant	3.4	3.0	2.6	3.0	2-3
Internodal length (cm)	4.8	5.7	3.9	3.5	5.5
Fruit length (cm)	13.2	20.5	15.5	16.0	18.0
Fruit diameter (cm)	2.2	1.7	2.1	2.0	2.2
Fruit number	26.2	22.4	21.6	21.0	20
Number of locules/fruit	5.0	5.0	5.0	5.0	5.0
Fruit colour	Green	Green	Dark Green	Dark green	Green
Fruit surface	Smooth	Smooth	Smooth	Smooth	Smooth
Pedicel length (cm)	3.7	4.2	4.1	4.0	3.0
Petiole length (cm)	20.3	19.5	16.6	18.5	19.3

Disease reaction (YVMV)	0-5%	0-5%	0-5%	0-5%	20-25%

Table 2. Mean performance of advance line No 15 against check variety Varsha Uphar for yield, fruit number and disease incidence over the year 2000 and 2010.

Genotype	Mean yield (q/ha)	Fruit umber/plant	Incidence (%) of YVMV
Line No 15	130.3	33.2	2.5
Varsha Uphar	128.4	30.3	22.5

References

Dhankar, S.K., Dhankar, B.S. and R.K. Yadava. 2005. Inheritance of resistance to yellow vein mosaic virus in an inter-specific cross of okra (*Abelmoschus esculentus*). *Indian J. Agric. Sci*. **75**: 87-89.

Dhankhar, B.S., Saharan B. S. and Pandita, M.L. 1997. Okra 'Varsha Uphar' is resistant to YVMV. *Indian Horticulture* **41** (4): 50-1.

Dhankhar, B.S., Saharan B. S. and Sharma, N.K. 1999. 'Hisar Unnat': new YVMV resistant okra. *Indian Horticulture* **44** (1): 2, 6.

Duzyaman, E. 1997. Okra: botany and horticulture. *Horti. Rev*. **21**: 42-68.

Hughes, J. 2009. Just famine foods? What contribution can underutilized plant make to food security? *Acta Horticulture*. **806**: 39-47

Kulkarni, G.S. 1924. Mosaic and other related disease of crops in Bombay presidency. *Poona Agric. Coll. Mag*. **16**: 6-12.

Nerkar, Y.S. and Jambhale, N.D. 1985. Transfer of resistance to yellow vein mosaic from related species into okra (*Abelmoschus esculentus* (L.) Moench). *Indian Journal of Genetics and Plant Breeding*. **45** (2): 261-70.

Sastry, K.S.M. and Singh, J.S. 1974. Effect of yellow vein mosaic virus infection on growth and yield of okra. *Indian Phytopathology*. **17**: 294-7.

Singh, H.B., Joshi, B.S., Khanna P.P. and Gupta, P.S.1962. Breeding for field resistance to yellow vein mosaic in bhindi. *Indian Journal of Genetics and Plant Breeding*. **22** (2): 137-44.

Thankur, M.R. 1976. Inheritance of resistance to yellow vein mosaic in a cross of okra species, *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. m*anihot*. *Journal of Society for Advancement in Breeding Research in Asia and Oceania*. **8** (1):69-73.

Adaptability and horticultural characterization of *Moringa* accessions under Central Philippines conditions

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ABSTRACT

This study was conducted to determine the adaptability and describe the horticultural characteristics of *Moringa oleifera* Lam. accessions under central Philippines conditions. Eighteen *Moringa* accessions obtained from AVRDC – The World Vegetable Center were evaluated in observational trials at Central Philippine University, Iloilo City, Philippines in 2009. The accessions originated from India (3), Laos (1), Philippines (1), Taiwan (1), Tanzania (1), Thailand (10), and USA (1). Three-month-old seedlings were transplanted in non-replicated plots at a spacing of 2 m between rows and 1.5 m between plants. Data were recorded on growth and stand survival, plant height, stem diameter, number of branches, fresh leaf yield, pod and seed production, and incidence of insect pests and diseases. Percentage seed germination ranged from 40 to 100%, with eight accessions having 100% and eight accessions 80% germination. Two accessions from Thailand had poor germination (40%). All seeds that germinated developed into healthy seedlings with 80 to 100% survival. At 28 weeks after second pruning, accessions Mo-2 (USA) and Mo-40 (India) produced the tallest plants (5.6 and 5.1 m, respectively), whereas Mo-34 (India) produced the shortest plants (2.9 m). Mean stem diameter ranged from 3.5 cm (Mo-34) to 8.5 cm (Mo4-Thailand). Mo-38 (Thailand) produced the highest number of branches (5.3), whereas Mo-33 (Philippines) showed the lowest number of branches (2.0) per plant. Two accessions from Thailand resulted in the highest leaf fresh weight, which exceeded 2 kg/plant from two prunings. Eight accessions produced leaf fresh biomass that exceeded 1 kg/plant. Mo-3 (Taiwan) developed the highest number of pods, whereas Mo-34 produced the highest number of seeds. Red mites (*Tetranychus urticae*), Coccinellid beetles (Coccinellidae), leaf-footed bug (*Leptoglossus phyllopus*) and whiteflies (*Bemisia* sp.) were present, but caused only minor damage to plants. Stem rot was the only disease observed in a few plants.

Keywords

Indigenous vegetables, drumstick tree, horticultural traits, germination, stand establishment.

INTRODUCTION

The multiple uses and high micronutrient density of *Moringa oleifera* Lam., commonly known as *malunggay* in the Philippines and by several names elsewhere, have led to growing interest in this crop and resulted in its extensive cultivation worldwide. A small, fast-growing evergreen that reaches up to 12 m high, *Moringa* is characterized by its spreading, open crown of drooping, fragile branches, feathery foliage of tripinnate leaves, and thick, corky, whitish bark.

It has edible leaves, flowers, fruits, roots, and seed oil, and has been traditionally used for herbal medicine. It is also a source of dye, used as livestock forage, and for water purification (Palada 1996; Palada and Chang 2003). In some countries, it is grown mainly as an ornamental and in hedgerows and hedges (Little and Wadsworth 1964; Palada 1996).

Moringa has been observed to tolerate temperature fluctuations from -1 to 48°C. It is drought tolerant (Troup 1921) and is known to thrive in places that have annual rainfall of as much as 1800 mm (Ramachandran et al. 1980). It grows well from sea level to 1,200-m elevation (Jahn et al. 1986) in most light to medium-textured soils, but best growth occurs in sandy loams (Ramachandran et al. 1980) with a pH between 5.5 and 7.5 (Francis and Liogier 1991).

Germination is epigeal and occurs between 7 to 30 days after sowing. Although seedling growth is rapid, germination percentage is usually low. Propagation is also possible with cuttings, but studies show that trees propagated from seeds produce longer roots (Sharma and Raina 1982).

Moringa pods and leaves are the most nutritious parts of the plant (from www.nap.edu). The edible, tender pods have a taste similar to asparagus. The tender leaves taste like watercress and, along with its flowers, are consumed cooked or raw (Bodner and Gereau 1988). They are rich in protein, minerals, beta-carotene, thiamin, riboflavin, and other vitamins particularly vitamins A and C (Dahot 1988). Gram for gram, *Moringa* leaves contain 7 times the Vitamin C in oranges, 4 times the calcium in milk, 4 times the Vitamin A in carrots, 2 times the protein in milk/yogurt, and 3 times the potassium in bananas (Fuglie 2001 from http://deepfitness.com/3244/*Moringa*-Leaf-Powder—The-Worlds-Greatest-UnknownSupplement.aspx; Fuglie 1999). The immature seeds, which taste like peanuts after frying, are also consumed cooked or raw (Dastur 1964). They contain 19 to 47% oil (Ibrahim et al. 1974) and are rich in palmitic, stearic, behemic, and oleic acids and can be used for human consumption, illumination, and in cosmetics and soaps. The oil, also known as ben oil, is valued for its power of absorbing and retaining odors, and is used by watchmakers as a lubricant (Verma et al. 1976). The crushed seeds can be used to remove turbidity and reduce bacterial contamination from drinking water (Sutherland 1989; Yongbai 2005) while leaf extracts can increase root nodulation, nodule weight, and *Rhizobium* nitrogenase activity in mungbean (Bandana 1987). The roots are used as a condiment or garnish after peeling, drying, and mixing with vinegar (Martin and Ruberte 1979).

The medicinal uses of *Moringa* are well-documented. The juice extracted from leaves has strong antibacterial and antimalarial properties (Chopra et al. 1956) and are taken for diabetes and high blood pressure control (Vietmyer 2006).

Leaf extracts were found to exhibit antimicrobial activity including inhibition of growth of *Staphylococcus aureus* strain isolated from food and animal intestines. It can also be a potential substitute for antibiotics in broiler production (Yang et al. 2006). The flowers and roots contain pterygospermin, an antibiotic that is highly effective in the treatment of cholera (Lizzy et al. 1968); it inhibits growth of gram positive and gram negative bacteria. The root bark contains the alkaloids moringine and spirochine that act on the nervous system (from www.nap.edu). Ben oil is used in the treatment of gout and rheumatism (Singh et al. 1983). The numerous medicinal properties and uses of *Moringa* are likewise enumerated by Holst (2000) and Fahey (2005). Research conducted at AVRDC – The World Vegetable Center revealed that the four *Moringa* species (*M. oleifera*, *M. peregrina*, *M. stenopetala* and *M. drouhardii*) studied contain high amounts of antioxidants and nutrients, high antioxidant activity, and low oxalate content. *M. peregrina* has the highest antioxidant content while *M. oleifera* has the highest nutrient values (Yang et al. 2006).

There are numerous *Moringa* accessions in the germplasm bank of AVRDC – The World Vegetable Center in Shanhua, Taiwan. However, their adaptability to other conditions, specifically under the tropical climate in Central Philippines where the plant is mainly grown in the backyard as leafy vegetable, has never been tested. This study will help in determining which among the various accessions has the best yield and is able to adapt well under local soil, weather, pest and disease conditions, and can be rapidly regenerated using stem cuttings. This study was conducted to determine the adaptability and horticultural characteristics of different

Moringa accessions under local conditions. The different phases of the study under corresponding specific objectives are as follows:

Observation nursery

This study was conducted to describe: 1) the percentage germination and survival of the different *Moringa* accessions under Central Philippine University (CPU) conditions; 2) horticultural characteristics of the various *Moringa* accessions; 3) susceptibility to insect pests and/or diseases; 4) regeneration capacity of the various *Moringa* accessions by stem cutting; and 5) coppicing capacity of *Moringa* accessions.

Adaptability trial

This study is being conducted to determine: 1) which *Moringa* accessions will grow well under CPU Zarraga Farm conditions; 2) horticultural characteristics of various *Moringa* accessions; 3) susceptibility to insect pests and/or diseases of the different *Moringa* accessions; and 4) coppicing capacity of the different Moringa accessions.

Propagation study

This study is being conducted to determine: 1) percentage germination and survival of different *Moringa* accessions; 2) early growth horticultural characteristics of *Moringa* accessions; and 4) regeneration capacity of the various *Moringa* accessions by stem cutting propagation.

MATERIALS AND METHODS

Only five seeds each were supplied from the first batch of *Moringa* accessions from AVRDC-Taiwan. Because this amount is not enough for a replicated field trial, these seeds were grown inside a greenhouse then transplanted later in the field for observation purposes.

Observation nursery

Moringa seeds were sown in small plastic bags containing a mixture of 1:1:1 garden soil, commercial organic fertilizer, and sand. The seedlings were transferred to larger pots containing 2 kg of the same potting mixture at 2 to 3 weeks after sowing. The potted plants were grown under greenhouse conditions for 3 months to study the horticultural characteristics at the seedling and early developmental stages.

The observational nursery was established in October 2009. When the seedlings from the first batch of seeds were four months old, these were transferred to bigger pots while waiting for the availability of an area inside the campus. Two and a half months later, the potted plants were pruned 75 cm above the soil surface to facilitate transplanting to the field. Holes were made on prepared raised seedbeds. A kilogram of organic fertilizer was placed into each hole, and then covered with soil to avoid direct contact with the plant roots. The individually labeled plants were planted in the holes then sufficiently covered with soil. The pruned stems were cut 30 cm long, placed in a shady place for 3 days for conditioning, then planted in small pots for possible vegetative regeneration.

Adaptability trial

Greenhouse study. Potted seedlings of the different *Moringa* accessions were used in the greenhouse study. Each accession had 5to 10 potted plants. Accessions with low germination percentage were regenerated in a non-replicated greenhouse propagation trial.

Field study. The experimental area was thoroughly prepared prior to transplanting. The potted seedlings of the different accessions from the greenhouse study were planted in single rows on 60-cm wide well-prepared raised beds. Plants were spaced 2 m between rows and 1.5 m within rows, which is equivalent to 3,333 plants/ha. Each row was planted with 5 seedlings.

Fertilization. For faster plant establishment two kilograms of organic fertilizer were applied at the bottom of the holes in the seedbed just before transplanting the *Moringa* seedlings. No additional fertilizer was applied when plants were fully established.

Watering. Seedlings were watered immediately after transplanting to promote early root development. During dry months watering was done regularly.

Crop protection. Thorough tillage of the experimental area suppressed early weed growth. The weed-free field was maintained by applying organic mulch around the base of the young trees and by hand-pulling or hoeing the area between beds and rows. Although *Moringa* is resistant to most pests and diseases, some outbreaks may occur under certain conditions. Pests such as red mites, aphids, leafminers, whiteflies, and caterpillars were controlled using botanical concoctions. Proper drainage was maintained to avoid waterlogging; this cannot be tolerated by *Moringa* and can encourage/enhance *Diplodia* root rot infection.

Pruning and harvesting. Six months after field transplanting, the plants were pruned 30 cm from the ground level. The stem cuttings/shoots were used for the vegetative propagation study under greenhouse conditions. Green leaves in the pruned branches were harvested by snapping the leaf petioles from the branches.

Experimental treatments and design

Eighteen *M. oleifera* accessions from AVRDC germplasm collection were used as treatments. A local *Moringa* variety was included as control. The *Moringa* accessions are presented in Table 1.

In the observational nursery (field) trial the accessions were planted in non-replicated single rows. No experimental design was used for this trial. In the greenhouse study, the accessions were arranged in a completely randomized design. The field study, on the other hand, utilized a randomized complete block design with two replications.

Data collection

The following data were collected from the greenhouse and field studies.

Greenhouse study

1. Percent germination and plant survival within 2 to 4 weeks.

$$\% \text{ Germination} = \frac{\text{No. of seedlings that emerged}}{\text{No. of seeds sown}} \times 100$$

$$\% \text{ Survival} = \frac{\text{No. of alive seedlings 1 mo after emergence}}{\text{No. of seedlings that emerged}} \times 100$$

A seed was considered to have emerged when at least 2 cm of its epicotyl was above the soil level. A seedling was considered to have survived if it was alive and healthy one month after emergence.

2. Plant height. Plant height was measured at biweekly intervals starting one week after emergence from the soil level in the pot to the last node.

3. Number of leaf petioles. This was counted at biweekly intervals starting 2 weeks after emergence until just before field planting.

Field study

1. Plant height. This was measured starting 2 weeks after transplanting at weekly intervals during the first three months, thereafter at monthly intervals until the first pruning.
2. The number of developed leaf petioles was counted starting 2 weeks after transplanting at 3-week to monthly intervals until the first pruning.
3. The number of side shoots or branches that developed after pruning was determined.
4. Growth habit, either erect or prostate, was determined.
5. Stem diameter was measured at monthly intervals.
6. Leaf color, either green, light green or dark green, was determined.

7. The number of days to flower formation and pod development was assessed. This was recorded when a plant had developed at least one branch of fully developed/well-formed close flowers while that for the pod was counted when at least one plant had developed one pod at least 5 cm long.
8. Leaf yield. Green leaves was snapped off from the stems after pruning and then weighed.
9. Incidence of pests and diseases. Pests that infested and diseases that infected the plants were recorded.

Propagation study
The same growth parameters were measured from propagated stem cuttings obtained from mother plants. However, percent germination and percent survival were
calculated using the formula:

% Germination = No. of stem cuttings with at least one healthy shoot ÷ no. of cuttings planted x 100

% Survival = No. of alive stem cuttings x 100 No. of cuttings which germinated

Data analysis

All quantitative data were statistically analyzed using ANOVA for CRD and RCBD at the 5% level of significance. Significant differences between and among means were determined using DMRT at the 5% level of significance. Susceptibility to pests and/or diseases was categorized as susceptible, moderately susceptible, or not susceptible.

RESULTS AND DISCUSSION

Field and propagation studies are still in progress; only results of greenhouse and observational studies are reported here.

Greenhouse study and observational trial
The number of days from sowing (seeding) to seedling emergence varied with accessions and ranged from 6.3 to 10.6 days (Table 2). Accession Mo-34 (La Mu E) from India was the earliest to emerge and Mo-40 (PKM-1) from India was the latest.

The percentage seed germination ranged from 40 to 100%, with eight accessions having 100% and eight accessions with 80% germination (Table 3). Two accessions from Thailand had poor germination (40%). All seeds that germinated developed into healthy seedlings with 80 to 100% survival (Table 3).

At 28 weeks after second pruning (Table 4), accessions Mo-2 (USA) and Mo-40 (India) produced the tallest plants (5.6 and 5.1 m, respectively), whereas Mo-34 (India) produced the shortest plants (2.9 m).

Mean stem diameter (Table 5) ranged from 3.5 cm (Mo-34) to 8.5 cm (Mo-4, Thailand). Mo-38 (Thailand) produced the highest number of branches (5.3), whereas Mo-33 (Philippines) showed the lowest number of branches (2.0) per plant.

Two accessions from Thailand resulted in the highest leaf fresh weight, which exceeded 2 kg/plant from two prunings (Table 5). Eight accessions produced leaf fresh biomass that exceeded 1 kg/plant. Based on this yield and the plant population, these accessions have yield potential of 3 to 6 t/ha of fresh leaf biomass. Results of previous evaluation trials at AVRDC indicated that at high plant population density (44,444 plants/ha) accessions Mo-29 (India), Mo-34 (India) and Mo-35 (Tanzania) produced 60-70 t/ha of young shoot biomass from two harvests (Palada et al. 2007). Mo-3 (Taiwan) developed the highest number of pods, whereas Mo-34 produced the highest number of seeds.

Plant survival under waterlogged conditions

Moringa plants are very sensitive to water logging and typically will not survive under prolonged flooding or water logged conditions. In the Philippines frequent rainfall brought about by typhoons during monsoon season results in fields being flooded for several days. In the field trial, most of the *Moringa* accessions survived the intermittent flooded condition of the field. It was observed that plants tolerated the waterlogged soil conditions for several days and when water receded and soil moisture decreased, plants developed new shoots.

Data of Table 6 show that 84% of the accessions had 100% plant survival. Only three accessions (Mo-4, Mo-12 and Mo-40) had less than 100% survival. Between accessions the rate of recovery and regrowth (development of new shoots) varied (data not shown). Although most of the accessions survived the flooded conditions, after frequent rainfall this factor delays normal growth and development of plants. *Moringa* accessions with high tolerance to flooding are therefore ideal and suitable for areas with high annual rainfall. The results reported here are different from studies conducted at AVRDC, Taiwan where in general, plant survival of most accessions was below 100% (Palada et al. 2012).

Incidence of pests and diseases

Throughout the field trial few insect pests were identified. Red mites (*Tetranychus urticae*), Coccinellid beetles (Coccinellidae), leaf-footed bug (*Leptoglossus phyllopus*) and whiteflies (*Bemisia* sp.) were present, but caused only minor damage to plants. Stem rot was the only disease observed in a few plants.

CONCLUSION

This preliminary evaluation trial suggests that there are promising *Moringa* accessions adapted for Central Philippines conditions with potential for high leaf biomass production. Accessions from Thailand and India possess desirable horticultural traits such as leaf fresh weight, stem diameter and number of side branches. These accessions should be propagated and multiplied for commercial production. This will be the next step in the R&D program at Central Philippine University.

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Literature cited

Bandana B, Srivastava RC, Mathur SN. 1987. Nodulation and nitrogenase activity in Vigna mungo in response to seed-soaking and root-dressing treatments of Moringa leaf extracts. Indian Journal of Plant Physiology 30(4):362-367.

Bodner CC, Gereau R. 1988. A contribution to Bontoc Ethno Botany 42(3):307-369

Chopra RN, Nayar SL, Chopra IC. 1956. Glossary of Indian medicinal plants. New Delhi: Council of Scientific and Industrial Research.

Dahot MU. 1988. Vitamin contents of the flowers of Moringa oleifera. Pakistan Journal of Biochemistry, 21(1-2), 21-24.

Dastur JF. 1964. Useful plants of India and Pakistan. Bombay: D.B. Taraporevala Sons and Co.

Fahey JW. 2005. Moringa oleifera: A review of the medical evidence of its nutritional, therapeutic and prophylactic properties. Part 1. Trees for Life Journal, 1(5). Retrieved December 15, 2009 from http://www.TFLJournal.org/article.php/20051201124931586

Francis JK, Liogier HA. 1991. Naturalized exotic species in Puerto Rico. Gen. Tech. Rep. So-82. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Fuglie LJ. 2001. The miracle tree: The multiple attributes of Moringa. Retrieved December 15, 2009 from http://www.echotech.org/bookstore/advanced_search_result.php?keywords=Miracle+Tree.

Holst S. 2000. Moringa: Nature's medicine cabinet. Sherman Oaks, California, USA: Sierra Sunrise Publishing citing Fuglie LJ. 1999. The miracle tree: Moringa oleifera: Nutrition for the Tropics. Dakar, Senegal. Church World Service.

Ibrahim SS, Ismael M, Samuel G. 1974. Benseeds: A potential oil source. Agricultural Research Review, 52(9):47-50.

Jahn SAA, Musnad HA, Burgstaller H. 1986. The Tree that purifies water: Cultivating Moringaceae in the Sudan, Unasylva, 38(2), 23-28.

Little, EL Jr, Wadsworth, FS. 1964. Common trees of Puerto Rico and the Virgin Islands. Agric Handb. 249. Washington, D.C: U.S. Department of Agriculture.

Lizzy KS, Narashima R, Puttaswamy TL. 1968. Chemotherapy of bacterial infections. Part 4: Potential anticholera agents. Indian Journal of Experimental Biology 6(3):168-169.

Vietmyer N. 2006. Lost crops of Africa. Volume II, Vegetables.Washington, D.C.: The National Academies Press. Retrieved September 28, 2009 from www.nap.edu.

Martin FW, Ruberte RM. 1979. Edible leaves of the Tropics (2nd ed.). Mayaguez, PR: U.S. Department of Agriculture, Science, and Education Administration, Agricultural Research, Southern Region.
Palada MC. 1996. Moringa oleifera: A multipurpose tree with horticultural potential in Southeastern USA. Hortscience, 31(5):794-797.
Palada MC, Chang LC. 2003. Suggested cultural practices for Moringa. AVRDC International Cooperators' Guide. AVRDC publication # 03-545.
Palada MC, Chang LC, Yang RY, Engle LM. 2007. Introduction and varietal screening of drumstick tree (Moringa spp.) for horticultural traits and adaptation in Taiwan. Acta Hort. 752:249-254.
Palada MC, Wu DL, Ebert AW. 2012. Horticultural characterization and propagation of Moringa germplasm at AVRDC – The World Vegetable Center. Paper presented at the Regional Symposium: High-value vegetables in Southeast Asia: Production, supply and demand. Chiang Mai, Thailand, 24-26 January 2012.
Ramachadran CPKV, Gopalakrishnan PK. 1980. Drumstick (Moringa oleifera): A multipurpose Indian vegetable. Economic Botany, 34(3): 276-283.
Sharma GK, Raina V. 1982. Propagation techniques of Moringa olefeira Lam. In: Khosla PK (ed.). Improvement of forest biomass. Proceedings of a Symposium: 1980 November 20-21; Solan, India: Indian Society of Tree Scientists.
Singh, U, Wadhwani AM, Johri BM. 1983. Dictionary of economic plants in India. (2nd ed.). New Delhi: Indian Council of Agricultural Research.
Sutherland JP, Folkard, GK, Grant WD. 1989. Seeds of Moringa species as naturally occuring flocculants for water treatment. Science, Technology, andDevelopment 7(3):191-197.
Troup RS. 1921. The Silviculture of Indian Trees. Clarendon Press, Oxford, UK.
Verma SC, Banerji R, Misra G, Ngam SK. 1976. Nutritional value of Moringa. Current Science. 45(21): 769-770.
Yang RY, Chang, L.C., Hsu, J.C., Weng, B.B.C., Palada, M.C., Chadha ML, Levasseur V. 2006. Nutritional and functional properties of *Moringa* leaves – From germplasm, to plant, to food, to health. *Moringa* and other highly nutritious plant resources: Strategies, standards and markets for a better impact on nutrition in Africa. Accra, Ghana, November 16-18, 2006.
Yang RY, Tsou, SCS, Lee TC, Chang LC, Kuo G, Lai P.Y. 2006. *Moringa,* a novel plant rich in antioxidants, bioavailable iron, and nutrients. pp.224-239. In C.T. Ho (ed.). Challenges in chemistry and biology of herbs. Washington. D.C.: American Chemical Society.
Yongbai, KA. 2005. Studies on the potential use of medicinal plants and macrofungi (lower plants) in water and waste water purification. Retrieved September 28, 2009 from www.biotech.kth.se/iobb/news/kenneth04.doc

TABLES

Table 1. *Moringa* germplasm accessions selected for horticultural characterization study at CPU, Iloilo, Philippines. 2009.

Acc. No.	Genus	Species	Pedigree Cultivar	Country
Mo-2	*Moringa*	*oleifera*	Virgin Islands	USA
Mo-3	*Moringa*	*oleifera*	La-Mu	Taiwan
Mo-4	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-6	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-7	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-8	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-9	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-12	*Moringa*	*oleifera*	Ma Rum Khaw Nheaw	Thailand
Mo-14	*Moringa*	*oleifera*	Ma Rum Khaw Jaw	Thailand
Mo-15	*Moringa*	*oleifera*	Ma Rum Khaw Nheaw	Thailand
Mo-20	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-29	*Moringa*	*oleifera*	TNAU-1	India
Mo-33	*Moringa*	*oleifera*	Davao Malunggay	Philippines
Mo-34	*Moringa*	*oleifera*	La Mu E	India
Mo-35	*Moringa*	*oleifera*	RCA Moringa	Tanzania
Mo-37	*Moringa*	*oleifera*	Vientiane Pak-Ihum	Lao PDR
Mo-38	*Moringa*	*oleifera*	Ma Rum C	Thailand
Mo-40	*Moringa*	*oleifera*	PKM-1	India

Table 2. Number of days from sowing to seedling emergence in *Moringa* accessions. CPU, Iloilo, Philippines. 20 June 2009. Observational nursery, greenhouse.

Acc. No.	Pedigree Cultivar	Country	No. days emergence
Mo-2	Virgin Islands	USA	7.4
Mo-3	La-Mu	Taiwan	7.6
Mo-4	Ma Rum	Thailand	8.5
Mo-6	Ma Rum	Thailand	8.0
Mo-7	Ma Rum	Thailand	8.6
Mo-8	Ma Rum	Thailand	8.0
Mo-9	Ma Rum	Thailand	7.5
Mo-12	Ma Rum Khaw Nheaw	Thailand	8.0
Mo-14	Ma Rum Khaw Jaw	Thailand	8.0
Mo-15	Ma Rum Khaw Nheaw	Thailand	9.8
Mo-20	Ma Rum	Thailand	7.8
Mo-29	TNAU-1	India	7.3
Mo-33	Davao Malunggay	Philippines	8.3
Mo-34	La Mu E	India	6.3
Mo-35	RCA Moringa	Tanzania	6.4
Mo-37	Vientiane Pak-Ihum	Lao PDR	9.8
Mo-38	Ma Rum C	Thailand	10.3
Mo-40	PKM-1	India	10.6

Table 3. Germination and plant survival of *Moringa* accessions. CPU, Iloilo, Philippines

Acc. No.	Country	Germination (%)	Survival (%)
Mo-2	USA	100	100
Mo-3	Taiwan	100	100
Mo-4	Thailand	100	80
Mo-6	Thailand	40	100
Mo-7	Thailand	100	100
Mo-8	Thailand	80	100
Mo-9	Thailand	80	100
Mo-12	Thailand	40	100
Mo-14	Thailand	80	100
Mo-15	Thailand	100	100
Mo-20	Thailand	100	100
Mo-29	India	80	100
Mo-33	Philippines	80	80
Mo-34	India	80	100
Mo-35	Tanzania	100	100
Mo-37	Lao PDR	80	100
Mo-38	Thailand	80	80
Mo-40	India	100	100

Total: 18 accessions with 30 seeds per accession

Table 4. Mean plant height of *Moringa* accessions CPU, Iloilo.

Acc. No.	Country	19 WA1P* (m)	28 WA2P** (m)
Mo-2	USA	2.86	5.59
Mo-3	Taiwan	2.90	4.26
Mo-4	Thailand	2.14	4.80
Mo-6	Thailand	2.20	4.22
Mo-7	Thailand	2.18	3.59
Mo-8	Thailand	2.55	3.89
Mo-9	Thailand	2.02	3.39
Mo-12	Thailand	2.18	2.95
Mo-14	Thailand	2.10	3.53
Mo-15	Thailand	1.92	3.92
Mo-20	Thailand	2.73	4.09
Mo-29	India	3.03	3.75
Mo-33	Philippines	2.74	3.58
Mo-34	India	3.25	2.88
Mo-35	Tanzania	3.64	3.32
Mo-37	Lao PDR	2.65	4.00
Mo-38	Thailand	2.04	3.31
Mo-40	India	2.24	5.08

*19 weeks after 1st pruning; **28 weeks after 2nd pruning

Table 5. Mean stem diameter, number of branches and leaf fresh weight of *Moringa* accessions.

Acc. No.	Country	Stem Diameter (cm)	No. of Branches	Leaf fresh weight (kg)
Mo-2	USA	8.4	2.8	1.78
Mo-3	Taiwan	5.1	2.6	0.77
Mo-4	Thailand	8.5	3.0	2.34
Mo-6	Thailand	5.6	2.5	1.80
Mo-7	Thailand	5.5	3.8	0.72
Mo-8	Thailand	5.2	3.8	1.15
Mo-9	Thailand	5.8	4.0	0.76
Mo-12	Thailand	4.8	3.5	0.80
Mo-14	Thailand	4.6	2.5	2.11
Mo-15	Thailand	5.7	3.4	1.64
Mo-20	Thailand	6.1	2.8	1.54
Mo-29	India	5.2	2.5	0.65
Mo-33	Philippines	5.4	2.0	1.00
Mo-34	India	3.5	3.0	0.56
Mo-35	Tanzania	4.9	3.0	0.88
Mo-37	Lao PDR	5.7	3.2	1.53
Mo-38	Thailand	5.7	5.3	1.33
Mo-40	India	7.1	4.0	1.63

Table 6. Plant survival of *Moringa* accessions after several typhoons. CPU, Iloilo, 10 Nov 2011.

Acc. No.	Pedigree Cultivar	Country	No. of seedlings	Surv. (%)
Mo-2	Virgin Islands	USA	5	100
Mo-3	La-Mu	Taiwan	5	100
Mo-4	Ma Rum	Thailand	4	75
Mo-6	Ma Rum	Thailand	5	100
Mo-7	Ma Rum	Thailand	5	100
Mo-8	Ma Rum	Thailand	5	100
Mo-9	Ma Rum	Thailand	5	100
Mo-12	Ma Rum Khaw Nheaw	Thailand	3	75
Mo-14	Ma Rum Khaw Jaw	Thailand	5	100
Mo-15	Ma Rum Khaw Nheaw	Thailand	5	100
Mo-20	Ma Rum	Thailand	4	100
Mo-29	TNAU-1	India	5	100
Mo-33	Davao Malunggay	Philippines	4	100
Mo-34	La Mu E	India	5	100
Mo-35	RCA Moringa	Tanzania	5	100
Mo-37	Vientiane Pak-Ihum	Lao PDR	5	100
Mo-38	Ma Rum C	Thailand	4	100
Mo-40	PKM-1	India	5	60
	Local variety	Philippines	5	100

FAO at work: Case studies of vegetable integrated pest management and farmer education in Asia

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ABSTRACT

Pesticide use in vegetable production among smallholder farmers in Asia remains unnecessarily high. Enduring concern over farmer health and environmental pollution caused by indiscriminate use of pesticides calls for safer and more sustainable crop protection strategies. New concerns over food safety in relation to pesticide residues on fresh and processed vegetables intended for domestic and export markets provide momentum for further development and application of Integrated Pest Management (IPM) as part of Good Agricultural Practices promotion efforts. At the same time, climate change is facilitating the spread of new invasive pest species, often prompting farmers to use more pesticides. FAO has been working with Asian governments, civil society organizations and the private sector to develop robust IPM strategies for a range of economically important vegetable crops during the last decade. Case studies of successfully employed vegetable IPM strategies, resulting into major crop production improvements and reductions in pesticide use, will be detailed in this paper. Apart from assistance to governments to strengthen pesticide regulatory systems, FAO also continues to assist National IPM Programmes in the Asia region to implement farmer IPM training, using the innovative and successful Farmers Field School approach. This paper will therefore also outline training achievements to date and results from this important training work, aimed at turning vegetable *farmers* into IPM experts.

Keywords

IPM, Asia, Pesticide misuse, FFS, Vegetables, Good Agriculture Practices

INTRODUCTION

Vegetables are an important part of a complete diet of Asians, adding valuable nutrients that would otherwise be insufficiently available in staple food crops such as rice, wheat or maize. Recent figures from FAO confirm their multiple importances in most Asian countries (FAOSTAT 2012). However, the realization of optimal yields, particularly in the warm humid lowlands, is often constrained by pests and diseases. Intensification of horticultural production and climate change contribute to increased pressure of pest and diseases (Kiritani 2006, Thomson et al. 2010). Use of chemical pesticides remains the mainstay of crop protection in horticultural production in Asia. Indiscriminate use of chemical pesticides is directly attributed to the rapid increase in resistance development, resurgence and secondary pest outbreaks (Dutcher 2007). To name but a few of the serious other problems associated with indiscriminate use of pesticides, the Asia region is facing challenges of overuse and misuse (Srinivasan 2008), inappropriate labeling (EJF 2002), product quality issues (Van der Wulp et al. 2008), environmental pollution (Becker et al. 2011) and serious health hazards to farmers and consumers (Settle and Whitten 2000; Mancini et al. 2009). Increasingly, consumers in urban communities are aware of the dangers of toxic residues on vegetables. Asian consumers demand safe and healthy fresh vegetables free from—or with minimum levels—of pesticide residues.

Ecologically-oriented Integrated Pest Management has a proven track record as an effective alternative to chemical-oriented pest management (IAASTD 2009). IPM has evolved in many developing countries from a mix of various technical components (Smith and Reynolds 1966, Kongan 1998) to a farmer-led program (FAO 2002). This approach encouraged the development of non-chemical methods that promote the growing of a healthy crop and at the same time protecting natural enemies, thus ensuring natural pest population regulation below economically-important levels. A participatory approach towards IPM demands that farmers need to be educated in the language of ecology to better appreciate the advances in an ecological pest management approach. In the last decade, advances in participatory training for IPM in a number of Asian countries took the form of farmer education through Farmer Field Schools (FFSs) and follow-up learning/study activities. The FFS is lauded as the most appropriate and effective extension and education methodology for training farmers in natural resource management practices, such as those called for in IPM (Swanson and Rajalahti 2010).

To argue the case for the need for scaling up efforts to 'turn more farmers into IPM experts', several successful IPM case studies are presented below, based on field work supported by the FAO Asia Regional IPM Programme during the period 2002-2012.

MATERIALS AND METHODS

Scope and rationale for the FAO Regional Vegetable IPM Programme in Asia

The above described problems associated with misuse and overuse of pesticides in vegetable production in tropical Asia provide the rationale for FAO implementing a Regional Programme for the development and application of IPM in vegetable production systems in several Asian countries. The FAO Programme operates currently in 10 member countries (Bangladesh, Cambodia, China PR, Indonesia, Lao PDR, Nepal, Philippines, Thailand and Vietnam), with work initiated in 2011 in Asia's youngest nation, Timor Leste. The FAO Programme works with National IPM Programmes that assist farmers through training to better understand vegetable crop ecology and to minimize use of pesticides in their local crop production systems. The Programme has, since 1996, carried out applied research, extension and farmer education activities to promote and support the development and application of vegetable IPM by Asian smallholder farmers. The Programme recently completed its 2nd phase (2002-08), with assistance continuing to date as part of several FAO implemented regional follow up projects (Ketelaar and Kumar 2011).

Training strategy and methodology

The standard training approach employed in all FAO Regional IPM supported National Programmes is the so-called 'Farmers Field School (FFS)' approach. Farmers Field Schools are 'schools without walls' which are held in farmers' fields. Typically, a group of about 25 to 30 vegetable farmers meet on a weekly basis and grow and study together in a vegetable crop of local relevance and choice from sowing to harvest (FAO 2002; Ketelaar and Kumar 2011).

RESULTS AND DISCUSSION

Brassica IPM in highland production systems in Thailand

Despite heavy reliance on chemical pesticides, farmers cannot control the diamondback moth (DBM), *Plutella xylostella,* in intensive crucifer production areas in Thailand's north-eastern highlands. Surveys done in 2004 to document natural biological control revealed the presence of the parasitoids *Cotesia plutellae, Macromalon orientale* and *Diadromus collaris*. These, having a combined overall parasitism rate of 42.3%, were insufficient to suppress DBM populations. Since the DBM parasitoid *Diadegma semiclausum* was not found, the Thai Government with the technical and financial support from the FAO-IPM and a DANIDA-funded IPM project proceeded in 2005 to introduce it from the Cameron Highlands in Malaysia as per internationally agreed guidelines (IPPC-ISPM-3). Whereas *D. semiclausum* established easily in organic farms in Doi Angkhang (Chiangmai highlands), its introduction for establishment in intensively-sprayed crucifer production areas in the Phetchabun highlands needed careful planning in conjunction with IPM Farmer Field School (IPM-FFS) training. In 2005, 533 parasitoid adults (57% female) were released and 100 cocoons left out in FFS fields. Patches of crucifers were planted during off-season periods to provide year-round food for DBM, the latter as host for the parasitoids. In this field site, farmers participated in two rounds of consecutive IPM-FFS. After participation and aided by high levels of biological control from parasitoids, farmers reduced pesticide use from 18-20 times to less than two times per crop. Subsequently, more parasitoid releases took place area-wide (400 ha) in joint efforts with up-scaling of IPM-FFS training to 100 farmers. Continuous surveys done until 2010 consistently confirmed the spread and establishment of the parasitoid over 800 ha with satisfactory parasitism rates (80%) in fields where farmers practice IPM. Farmers now can produce higher quality crucifers with no concern of unacceptable pesticide residues, and have gained access to more lucrative domestic and international markets. That *D. semiclausum* can readily establish area-wide in intensively-sprayed crucifers in Phetchabun clearly illustrates the importance of coupling IPM-FFS training with parasitoid releases where crops are sprayed heavily (Upanisakorn et al. 2011). Similar result was reported from Da Lat, Vietnam, where FFS-based farmer training coupled with introduction of parasitoids supported by FAO in the early 1990s, has resulted in decline of pesticide use and increased income of smallholder farmers (Nga and Kumar 2008)

Potato IPM in lowland rice-based production systems in Vietnam

Potato is an important food crop in Vietnam, which is increasingly providing raw materials for the food-processing industry and stable income to the smallholder farmers in the Red-River Delta region. However, the increasing labor costs have been one of the major causes for sluggish growth. To address the issue, FAO initiated an innovative pilot project implemented by the Vietnam National IPM Program/ Plant Protection Sub Department, with the purpose to promote rice-potato farm system development. The project was implemented in Thai Giang village, Thai Thuy district and Vu An village, Kien Xuong district in Thai Binh province with guidance from the Thai Binh’s Department of Agriculture and Rural Development (DARD) and Plant Protection Sub-department (PPSD) during the period 2009-2011. A series of action research activities were carried out comparing potatoes grown using rice stubbles as mulch (minimum tillage, MT and compared with normal soil-mulched potato (farmer tillage, FT). Plant growth parameters were studied to compare the performances of these two methods. Results from 3 years of study revealed that the MT performed better than the FT treatments for all variables studied. Due to the use of mulch, pesticide use, most notably herbicide, was reduced to 1 spray per season in the MT over 2 sprays per season in FT treatment. The average yield (tons/ha) in MT was 22.72 ± 0.24 compared to 20.39 ± 0.20 in FTI treatment which was found to be significantly higher ($F=898.42$; $df= 1,11$; $p<0.001$). An average 10% yield gain in MT was achieved over FT (Fig. 1).

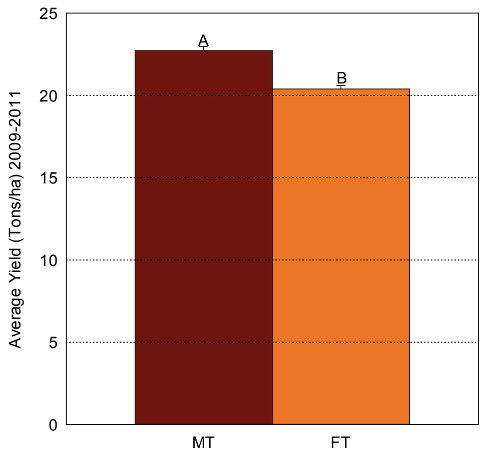

Figure 1. The average potato yield (tons/ha) from 2009-2011

Similarly the other parameters *i.e.*, cluster per ha was significantly better ($F=2818.954$; $df=1, 11$; $p<0.001$) in MT over FT treatment. Coming back to the main objective of the study in reducing the labor input and cost, the MT on a hectare basis saved 192 man-day, reducing costs with 1,162.00 US$/ha.

When the overall cost benefit was calculated, it was found that the net profit for farmers was in range of 1,615-2,026 US$ per ha. Clearly, the FAO intervention has been an important innovation in rice-based lowland cropping systems in Vietnam. It has added a new possibility of growing potatoes in labor-strived rural communities and ensured adoption of use of plant-biomass for mulching. This practice also promoted better soil health and structure as plant-biomass is worked back into the soil in preparation for the next wet season rice crop and eliminated the traditional practice of burning rice stubbles post-harvest, thus reducing air pollution and carbon releases. This minimum tillage innovation can thus also be marked as an interesting climate change mitigation practice, as recently recognized in a policy directive (3119/QD-BNN-KHCN; 16 December 2011) by the Vietnamese Ministry of Agriculture and Rural Development.

CONCLUSION

The problems associated with misuse and overuse of pesticides in vegetable production in South and Southeast Asia remain serious and acute. The realization that farmers will have to double today's production levels so as to feed the expected 9.2 billion global population in 2050 calls for crop production intensification efforts. The challenge will be for governments to regulate and promote crop intensification practices that reduce the need for pesticide inputs and follow a 'save and grow' approach (FAO 2011). With global warming now an established reality, it is likely that farmers will face a range of new pest and diseases. Without appropriate training in Integrated Production and Pest Management, farmers will continue to try to control these pests through higher inputs of agro-chemicals without –or too late- realizing the negative consequences. The key to development and sustainable establishment of vegetable IPM is the ability of farmers to understand local ecosystems and implications of their management interventions on such ecosystems. Reduction of chemical pesticides in vegetable production is possible but can only become a reality if farmers become 'ecosystem literate' and feel confident that they can manage vegetable production with lesser inputs of chemical pesticides. Developing farmers into Vegetable IPM Experts will thus remain a crucially important task if vegetable IPM is to establish itself sustainably among Asia's many millions of smallholder vegetable growers. No doubt the job is daunting. FAO and the Asian Institute of Technology (AIT), a Thailand based inter-governmental postgraduate teaching, research and development institute, remain committed to support its member countries in their future efforts to innovate environmentally safe and sustainable technologies for biotic stress management and upscale farmer IPM training programmes in Asia.

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References

Becker, L., Martin Scheringer, M., Schenker, U., and Hungerbühler, K. 2011. Assessment of the environmental persistence and long-range transport of endosulfan, Environmental Pollution. J. Envpol. 159: 1737-1743.

Dutcher, J. D. 2007. A Review of Resurgence and Replacement Causing Pest Outbreaks in IPM, pp 27-43. In: General Concepts in Integrated Pest and Disease Management. Ciancio, A. Ciancio and K. G. Mukerji (eds.). Springer Netherlands.

EJF, 2002. Death in Small Doses: Cambodia's Pesticides Problems and Solutions. Environmental Justice Foundation, London, UK

FAO, 2002. From Farmer Field School to Community IPM: Ten years of IPM training in Asia. FAO-RAP, Bangkok, Thailand.

FAO, 2011. Save and Grow: A policymaker's guide to the sustainable intensification of smallholder crop production. Rome, Italy.

FAO, 2012. FAOSTAT database. Accessed on 05 February 2012.

Ketelaar, J. W. & P. Kumar. 2011. Asian Smallholder Vegetable Farmers as IPM Experts Experiences from the FAO Regional Vegetable IPM Programme (2002-2010). In: Horticulture and Livelihood Security Prem Nath and P. B. Gaddagimath (eds.), Scientific Publishers, India. .

IAASTD, 2009. Agriculture at the crossroads. In: B.D. McIntyre, H.R. Herren, J. Wakhungu & R.T. Watson (eds.), Washington, DC.

Kiritani, K. 2006. Predicting impacts of global warming on population dynamics and arthropod populations in Japan. Popul Ecol. 48: 5-12.

Kogan, M. 1998. Integrated Pest Management: Historical Perspectives and Contemporary Developments. Annu Rev Entomol. 43:243-270.

Mancini, F. Jiggins, J. and O'Malley, M. 2009. Reducing the incidence of pesticide poisoning by educating farmers on Integrated Pest Management in South India. Int. J. Occup. Environ. Health. 15:143-151.

Nga, L. T. and Kumar P. 2008. Contributions of parasitoids and Bacillus thuringiensis to the management of Diamondback Moth in highland crucifer production in Da Lat, Vietnam. J. Asia-Pacific Entomol. 11: 59–64.

Settle, W. H. and Whitten, M. J. 2000. The Role of Small Scale Farmers in Strengthening the Link between Sustainable Agriculture and Biodiversity. Proc. The XXI Congress of Entomology, Iguassu, Brazil, 20-26 August.

Smith, R.F. and Reynolds, H.T. 1966. Principles, definitions and scope of Integrated Pest Control. Proc. FAO Symposium on Integrated Pest Control, FAO, Rome. pp. 11-17.

Srinivasan, R. 2008. Integrated Pest Management for eggplant fruit and shoot borer (*Leucinodes orbonalis*) in south and Southeast Asia: Past, Present and Future. J Biopest. 1:105 – 112.

Swanson, B.E. & Rajalahti, R. 2010. Strengthening agricultural extension and advisory systems: Procedures for assessing, transforming, and evaluating extension systems. In: Agriculture and Rural Development Discussion Paper 45. Washington DC, the International Bank for Reconstruction and Development and World Bank.

Thomson, L. J., Macfadyen, S., and Hoffmann, A. A. 2010. Predicting the effects of climate change on natural enemies of agricultural pests. Bio Control. 52:296-306.

Upanisakorn, A., Sammawan, S., Ketelaar, J.W., Lim, G.S. 2011. Introduction and establishment of *Diadegma semiclausum* in conjunction with farmer field school for diamondback moth control in intensively sprayed crucifer production in northeastern Thailand. Proc. The 6th International Workshop on Management of the Diamondback Moth and Other Crucifer Insect Pests, AVRDC, Taiwan. pp 260-265.

Van der Wulp, H., Louanglath, K., and Taipangnavong, T. 2008. Back to Office Report on Mission to Northern Lao PDR. FAO-IPM Programme, FAO-RAP, Bangkok (Unpublished). 19 pp.

Towards developing a sustainable management strategy for legume pod borer, *Maruca vitrata* on yard-long bean in Southeast Asia

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ABSTRACT

Legume pod borer, *Maruca vitrata,* is a serious production constraint on yard-long bean which is grown over 7% of the total vegetable production area in Southeast Asia. It can cause up to 80% yield loss on various host plants, and because it is hidden within the pods, it is difficult to control with chemical pesticides. However, farmers rely heavily on the use of chemical pesticides to control *M. vitrata*. Intensive and indiscriminate use of pesticides leads to the development of resistance in *M. vitrata* to chemical pesticides, degrades the environment, kills natural enemies, and causes resurgence of secondary insect pests. To reduce pesticide residues in vegetable legumes and to promote better human health, an integrated pest management strategy based on sex pheromones, natural enemies, and bio-pesticides is being developed based on applied research. Since phenotypic variations have been observed among populations of *M. vitrata* in Southeast Asia and sub-Saharan Africa, *M. vitrata* populations present in Southeast Asia with reference populations from sub-Saharan Africa have been characterized. The inconsistency in the performance of sex pheromone lures has become an obstacle in implementing trap-based pest monitoring of *M. vitrata*. Appropriate pheromone blends for each geographical region are being developed based on the variations in pheromone production and reception in *M. vitrata*. With a more systematic effort, novel species-specific parasitoids of *M. vitrata* have been identified in Lao PDR, Taiwan, Thailand and Vietnam. Studies have indicated the potential susceptibility of *M. vitrata* to *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, *Maruca vitrata* multiple nucleopolyhedrovirus, and neem.

Hence, an IPM strategy based on sex pheromones, natural enemies, and biopesticides will soon be validated in pilot project sites in Southeast Asia, especially Thailand and Vietnam to manage *M. vitrata*.

Keywords

Maruca vitrata, integrated pest management, yard-long bean

INTRODUCTION

Vegetable legumes are one of the important crops in Southeast Asia. They are important source of plant proteins in the human diet and considered as the ‘meat of the poor’ (Heiser 1990). They are rich in essential micronutrients, especially iron and folic acid, which are particularly important for women of child-bearing age and other vulnerable groups such as infants and young children, adolescent boys and girls and pregnant women. Leguminous crops fix atmospheric nitrogen in the soil, thus improving soil fertility. Legumes can be used as high quality livestock fodder, and are planted to control soil erosion. Yard-long bean (*Vigna unguiculata sesquipedalis*) is the most popular vegetable legume in Southeast Asia, accounting for almost seven percent of the total vegetable production area in the region (Ali et al. 2002). It is estimated to be cultivated on more than 150,000 ha in total, in Indonesia, Thailand, and Vietnam (Chinh et al. 2000; Sarutayophat et al. 2007). Other grain and vegetable legumes are being cultivated on an area of 1.4 m ha in Southeast Asia.

Vegetable legumes are highly susceptible to insect pests and diseases. Among the documented pests, legume pod borer (LPB), *Maruca vitrata* (F.) (syn. *M. testulalis*) (Lepidoptera: Pyralidae), is considered the most serious pest of yard-long bean, mungbean, and soybean in Southeast Asia (Sharma 1998; Ulrichs et al. 2001a; Soeun 2001). *M. vitrata* larvae feed on flowers and pods (Sharma 1998). First instar larvae prefer to feed on flowers rather than pods or leaves. The mature larvae are capable of damaging pods, and occasionally the peduncle and stems (Taylor 1967). Up to 80% yield losses have been reported in cowpea due to *M. vitrata* damage (Singh et al. 1990). Losses in cowpea pod yield ranged from 17–53% in Taiwan (Liao and Lin 2000). In Bangladesh, the damage to lablab bean was 18%, even in pesticide-sprayed fields, and it was 20–30% pod damage in mungbean (Zahid et al. 2008). About 25% pod damage in yard-long bean was estimated in Indonesia (Hammig et al. 2008).

At present, farmers rely almost exclusively on the application of chemical insecticides to combat *M. vitrata*, but without satisfactory control results. The window for effective pesticide application is very brief, as *M. vitrata* larvae are exposed on leaves only for a short time after hatching. Cambodian farmers sprayed up to 20 times per season with up to five different pesticides mixed together per tank per spray on major vegetables including yard-long bean (Sodavy et al. 2000). In Bangladesh, the country bean is being sprayed at weekly or biweekly intervals—sometimes every day—to control *M. vitrata* (Hoque et al. 2002). The destruction of indigenous biodiversity, development of pesticide resistance, and environmental deterioration are direct consequences of pesticide abuse. Occupational health hazards to farm workers are an additional dimension of pesticide overuse. *M. vitrata* resistance to commonly used pesticides has been documented in Southeast Asia (Ulrichs et al. 2001a). The overuse of pesticide also increases production costs, thus reducing profits for farmers. Pesticide residues hamper the export market potential for vegetable legumes. In a 2004 survey conducted in the United Kingdom, almost 45% of green bean samples, including yard-long bean from Thailand and Bangladesh, had at least one kind of pesticide residue above the legal limit (PAN UK 2009).

Thus, vegetable legume growers in different regions of Asia urgently need alternative management strategies to control *M. vitrata*. Therefore, an IPM strategy must be developed and deployed. AVRDC – The World Vegetable Center has recently initiated a project in collaboration with its research and development partners in Benin, Germany, India, Kenya, Lao PDR, Malaysia, Taiwan, Thailand and Vietnam to develop an IPM strategy for managing *M. vitrata* in Southeast Asia and sub-Saharan Africa. This paper reviews some key findings towards developing a sustainable IPM strategy in this project.

Population composition of *M. vitrata*

The Indo-Malaysian region is considered to be the most probable region of origin for the genus *Maruca*, including *M. vitrata,* which is found throughout the tropics (CABI 2005). Although 11 species have been documented in the genus (ZipcodeZoo.com), only two other species, *M. amboinalis* and *M. nigroapicalis,* have been described; they were observed in the Indo-Malaysian and Tonkin area, and the latter never was found again after the first description (CABI 2005). Kirti and Gill (2005) also confirmed the occurrence of *M. amboinalis*, and differentiated it from *M. vitrata* based on the external genitals. As *M. vitrata* is thought to have evolved in Southeast Asia and possibly spread across Asia and into Africa, local *M. vitrata* populations from the project countries are being characterized to confirm the identity of the pest species that damage food legumes.

The male genitalia of *M. vitrata* has long and strongly curved uncus, slightly dilated at distal end, tegument dome-shaped, valva with a short harpe; female genitalia with corpus bursae dropper shaped, signum missing, ductus bursae membranous, with a collar at distal end. The male genitalia of *M. amboinalis* has uncus with slightly dilated at distal end, tuba analis longer than uncus, valva with costa and harpe marked by a small, weakly curved projection; female genitalia has an oblong corpus bursae with a slight constriction in outer wall in middle, moderately long and distally rounded ductus bursae, ovipositor with rounded and well defined lobes, each lobe densely setose with varying sizes of setae (Kirti and Gill 2005). When the adult specimens of *Maruca* sp. from Benin, Kenya, Lao PDR, Taiwan, Thailand and Vietnam were examined, all had the wing venation and the external genital structures (Figure 1) of *M. vitrata*, and hence the *Maruca* species infesting vegetable legumes could be confirmed as *M. vitrata*.

A total of 41 different larval populations on the host plants *Sesbania cannabina*, *S. grandiflora, S. rostrata, S. vesicaria, Vigna unguiculata, V. u.* subsp. *sesquipedalis, V. radiata, V. cylindrica, Phaseolus* sp*., P. vulgaris, Cajanus cajan, Psophocarpus tetragonolobus, Pterocarpus santalinus, Canavalia* sp*., Pueraria phaseoloides, Dolichos lablab, Lonchocarpus cyanescens* and *Tephrosia bracteola* from Benin, India, Kenya, Lao PDR, Taiwan, Thailand and Vietnam, with Indonesia (as a reference sample) were collected by AVRDC and the collaborating partners. Mitochondrial gene, cytochrome c oxidase I (*coxI*) was used as a candidate gene to compare the larval populations of *M. vitrata*. The results have shown that there is no difference among the *M. vitrata* populations based on the host plants. However, single nucleotide polymorphisms (SNPs) have been observed in the *coxI* sequences of different *M. vitrata* populations, although the functional significance of these SNPs among the *M. vitrata* populations is still unknown.

The nuclear internal transcribed spacer 2 (ITS2) region of rDNA was also used for diversity analysis. Although several pairs of primers have been tried for the PCR, only about 135 bp high quality sequence of ITS2 could be obtained from all *M. vitrata* accessions. Since this short sequence contains several SNPs, it will complement the diversity analysis based on *cox1* gene sequences. As a third candidate gene, *M. vitrata* elongation factor 1α (EF1α) was also tried for characterizing the *M. vitrata* populations. The EF1α gene specific primer pairs amplified a PCR product covering 1193 bp of the intron-less EF1α gene for 22 *M. vitrata* samples, but did not reveal any sequence polymorphisms among the *M. vitrata* populations.

Refining the sex pheromone lures

Sex pheromone traps mimicking the pheromone of female insects attract males which are trapped and eventually killed. This reduces mating and production of next generation of insects. The major component of *M. vitrata* sex pheromone was identified as (E,E)-10,12-hexadecadienal (Adati and Tatsuki 1999), whereas (E,E)-10,12-hexadecadienol, and (E)-10-hexadecenal were identified as minor components (Downham et al. 2003). Re-examination of *M. vitrata* sex pheromone revealed the presence of two new components, (*E*)-10-hexadecenol and (*Z,Z,Z,Z,Z*)-3,6,9,12,15-tricosapentaene (Hassan 2007). Variations have been observed in the responses of *M. vitrata* males to the synthetic sex pheromone lures over various geographical regions. A synthetic sex pheromone lure consisting of (E,E)-10,12-

hexadecadienal, (E,E)-10,12-hexadecadienol, and (E)-10-hexadecenal was developed and attracted male *M. vitrata* moths in Benin and Ghana, while (E,E)-10,12-hexadecadienal alone was most effective in Burkina Faso (Downham et al. 2004). Neither pheromone was effective in Taiwan and Thailand, while a variant blend was effective in India (Hassan 2007). Hence, a thorough investigation into the sex pheromone components among *M. vitrata* populations from different geographical origins is needed to refine the pheromone based pest management strategy. Collaborating partners in Germany, India and Kenya are currently identifying the major and minor components of sex pheromone among the *M. vitrata* populations from target countries.

Sex pheromone biosynthesis in insects usually is regulated by hormonal and neural factors such as pheromone biosynthesis activating neuropeptide (PBAN) (Iglesias et al. 2002). Several PBAN from different insects have been characterized (Rafaeli 2002). However, the role of PBAN in relation to a specific pheromone blend is not known in *M. vitrata*. Identification of genotypic variation in PBAN among distinct *M. vitrata* populations from different countries is in progress to determine its contribution in sex pheromone polymorphism, if any. Pheromone perception in insects is mediated by pheromone binding proteins (PBPs) present in the insect antennae that bind to the pheromone compounds (Vogt et al. 2002). PBPs have been identified from several insects, and multiple PBPs occur in a single insect species. These PBPs could discriminate different components in an insect pheromone. Lack of a particular PBP in an insect population might make that population non-responsive to a specific pheromone blend. Because different *M. vitrata* populations respond differently to the multi-component pheromone, variations may exist in the PBPs of various *M. vitrata* populations, which is being characterized.

Thus, understanding the pheromone polymorphism, diversity in PBAN and/or PBPs could enable us to develop specific pheromone blends for a particular *M. vitrata* population in a given region to monitor and/or mass-trap the pest population.

Exploration for species-specific natural enemies of *M. vitrata*

Although a substantial number of parasitoid species have been reported to attack *M. vitrata* in tropical Asia and Africa (Waterhouse and Norris 1987; Sharma 1998; Ulrichs et al. 2001b; Huang et al. 2003; Arodokoun et al. 2006), they have not been exploited successfully in biological control programs. This is largely due to the low level of parasitism observed with all recorded species of parasitoids. However, a few parasitoids have been identified in recent years that could control *M. vitrata*. Huang et al. (2003) found that the parasitism of *M. vitrata* by *Apanteles taragamae*, could reach as high as 63% in Taiwan. *Bassus asper* was the most prevalent parasitoid in the Philippines with parasitism rates up to 17.1% (Ulrichs et al. 2001b). A braconid parasitoid, *Phanerotoma leucobasis,* could inflict about 30% parasitism in Benin (Arodokoun et al. 2006). Although these natural enemies could cause higher parasitism under field conditions, most of them are generalists; the performance of generalist parasitoids in a new habitat is highly variable, as the host range is not definite. Some countries may not allow the introduction of generalist parasitoids for biological control programs. To address these issues, explorations are being made in Lao PDR, Malaysia, Taiwan, Thailand and Vietnam to identify species-specific parasitoids of *M. vitrata*.

Although *A. taragamae* and *Nemorilla maculosa* (a tachinid fly) were reported to be the major parasitoids of *M. vitrata* in Taiwan (Huang et al. 2003; Srinivasan et al. 2009), *Therophilus marucae* (Braconidae: Hymenoptera) (Figure 2), besides *T. javanus* emerged as a major parasitoid in a recent survey during May – June 2011 in Southern Taiwan. It is a larval parasitoid and the field parasitism rate was up to 38%. The same parasitoid is also known to exist predominantly in Lao PDR and Vietnam. However, an egg-larval parasitoid, *Phanerotoma philippinensis* (Braconidae: Hymenoptera) (Figure 3) has been identified as a major parasitoid of *M. vitrata* in Thailand. In a monitoring survey during March – July 2011 at Nakhon Pathom area, the field parasitism ranged between 2 and 21%. Mass-culturing methods currently are being developed for these parasitoids with an objective to explore their use in managing *M. vitrata*.

Identification and/or development of promising bio-pesticides against *M. vitrata*

Different *B. thuringiensis* (Bt) δ-endotoxins have already been evaluated against *M. vitrata* at AVRDC. The results showed that Cry1Ab was the most potent toxin, followed by Cry1Ca (Srinivasan 2008). Hence, commercial Bt formulations containing Cry1Ab and/or Cry1Ca should be effective against *M. vitrata*. The commercial Bt formulations such as Crymax® and Redcat® (*B. t.* subsp. *kurstaki*) and Xentari® and Zitarback F.C.® (*B. t.* subsp. *aizawai*) were bioassayed against *M. vitrata* in Taiwan and Thailand. In Taiwan, both Crymax® and Xentari® are equally effective against *M. vitrata*, recording similar LC_{50} values. However, in Thailand, Redcat® was more effective than Zitarback F.C.® which recorded a three-fold higher LC_{50}. The toxicity of isolates and commercial formulations of entomopathogenic fungi such as *B. bassiana* and *M. anisopliae* is being assayed against *M. vitrata* by our collaborative partners.

Variable results have been obtained with the application of neem-based pesticides against *M. vitrata*. The commercial neem formulation (Biofree–I®) in Taiwan did not cause the mortality of *M. vitrata*. However, a neem formulation in Thailand (Thai neem 111) recorded a median lethal concentration of about 2300 ppm. Currently, we are assessing the oviposition repellence and chronic toxicity of neem formulations.

AVRDC – The World Vegetable Center identified a nuclear polyhedrosis virus (NPV) that infects *M. vitrata* in Taiwan in 2005. It was the world's first recorded instance of an NPV specifically infecting *M. vitrata*. The NPV was characterized based on ultra-structural morphology, restriction endonuclease cleavage patterns, and sequences of the coding region of polyhedrin gene, and named MaviMNPV (Lee et al. 2007). Laboratory bioassays revealed that the first instar *M. vitrata* larvae were the most susceptible stage to MaviMNPV and the median lethal concentrations (LC_{50}s) increased with increasing larval instars (Lee et al. 2007). Formulations of this NPV have been found to be effective against *M. vitrata* on food legumes either alone or in combination with *B. thuringiensis* and neem under laboratory and field conditions in Taiwan and Benin (Tamo et al. 2007; Srinivasan et al. 2009). The formulations of MaviMNPV were evaluated against *M. vitrata* on hyacinth (lablab) bean. After five rounds of spraying at 15-day intervals, the pod damage was significantly lower in treatments containing MaviMNPV formulations (8.38-9.79%) than that of the control (18.29%). Such a control efficacy was similar with those of Xentari® (8.11%) and carbaryl (9.71%) (Srinivasan et al. 2009). In another field trial at Thailand, Redcat® and Zitarback F.C.® recorded lower damages (3.57 and 3.10%, respectively) which was on par with cypermethrin (3.76%) compared to the untreated check (6.48%). Hence, bio-pesticides have promising potential against *M. vitrata* and thus reducing the damage in vegetable legumes. Currently, efforts are underway in identifying the effectiveness of bio-pesticides either alone or in combinations against *M. vitrata*.

CONCLUSION

An integrated pest management (IPM) strategy will be formulated based on the refined sex pheromone lures, species – specific parasitoids and promising biopesticides identified from the on-going research activities. This IPM strategy will be validated in small-scale on-station field trials in Taiwan, Thailand and Vietnam. In addition to the on-station trials, a few on-farm field trials will also be conducted in farmers' fields in Thailand and Vietnam to validate the strategy. If necessary, the component technologies will be adjusted to suit to the local conditions, and promoted among the vegetable legume growers in Southeast Asia.

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References

Ali, M., Umar Farooq and Ying Yen Shih. 2002. Vegetable Research and Development in the ASEAN Region: A Guideline for Setting Priorities. P.20-64. In: Kuo, C. G. (ed.). 2002. Perspectives of ASEAN Cooperation in Vegetable Research and Development: Proceedings of the Forum on the ASEAN-AVRDC Regional Network on Vegetable Research and Development (AARNET), Shanhua, Taiwan, 24-26 September 2001. Asian Vegetable Research and Development Center. AVRDC Publication No. 02-539, 151 p..

Adati T, Tatsuki S. 1999. Identification of female sex pheromone of the legume pod borer, *Maruca vitrata* and antagonistic effects of geometrical isomers. *J. Chem. Ecol.* 25:105–116.
Arodokoun DY, Tamò M, Cloutier C, Brodeur J. 2006. Larval parasitoids occurring on *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae) in Benin, West Africa. *Agric. Ecosyst. Environ.* 113: 320–325.
CAB International, 2005. Crop Protection Compendium, 2005 Edition. Wallingford, UK: CAB International. www.cabicompendium.org/cpc (Selected texts for *Maruca vitrata*). http://www.runetwork.de/html/fr/articles/document.html?Action=displayDocument&id=8752
Chinh NT, Dzung DT, Long TD, Tam HM, Ramakrishna A, Johansen C. 2000. Legumes in Viet Nam: Constraints and Opportunities. In. http://www.icrisat.org/text/research/nrmp/cdlegumes/e-book/09.pdf. p.111–125.
Downham MCA, Hall DR, Chamberlain DJ, Cork A, Farman DI, Tamo M, Dahounto D, Datinon B, Adetonah S. 2003. Minor components in the sex pheromone of legume pod-borer: *Maruca vitrata* development of an attractive blend. *J. Chem. Ecol.* 29: 989–1012.
Downham MCA, Tamo M, Hall DR, Datinon B, Adetonah S, Farman DI. 2004. Developing pheromone traps and lures for *Maruca vitrata* in Benin, West Africa. *Entomol. Exp. Appl.* 110: 151–158.
Hammig MD, Shepard BM, Carner GR, Dilts R, Rauf A. 2008. Area-wide pest management for non-rice food crops in Southeast Asia. p. 326-350. In: Koul O, Cuperus G, Norman Elliott (eds.), Area-wide Pest Management: Theory and Implementation, CABI, UK. 480 p.
Hassan MN. 2007. Re-investigation of the female sex pheromone of the legume pod-borer, *Maruca vitrata* (Lepidoptera: Crambidae). PhD Dissertation submitted to University of Greenwich, UK. 244 p.
Heiser CB. 1990. Seed to civilization: The story of food. Harvard University Press. 254 p.
Hoque M, Mollik SR, Nazimuddin M, Alam SN, Khorsheduzzaman M, Jasmine HS, Sultana NA, Rahman M, Ahmed B, Rajotte E, Luther G. 2002. Survey of bean pod borer (*Maruca testulalis*), whitefly and aphids and their natural enemies on country bean (*Lablab purpureus*). Tenth Annual Report of the Integrated Pest Management Collaborative Research Support Program (IPM CRSP). http://www.oired.vt.edu/ipmcrsp/communications/annrepts/annrep03/Bangladesh/8BangladeshY_10_ANNUAL_REPORT1.pdf#page=10. p. 123–124.
Huang CC, Peng WK, Talekar NS. 2003. Parasitoids and other natural enemies of *Maruca vitrata* feeding on *Sesbania cannabina* in Taiwan. *Biol. Control* 48: 407–416.
Iglesias F, Marco P, Francois MC. 2002. A new member of the PBAN family in Spodoptera littoralis: molecular cloning and immunovisualisation in scotophase hemolymph. *Insect Biochem. Mol. Biol.* 32: 901–908.
Kirti JS, Gill NS. 2005. Taxonomic studies on Indian species of Genus *Maruca* Walker (Lepidoptera: Pyralidae). *Zoos' Print J.* 20(7): 1930-1931.
Lee ST, Srinivasan R, Wu YJ, Talekar NS. 2007. Occurrence and characterization of a nucleopolyhedrovirus from *Maruca vitrata* (Lepidoptera, Pyralidae) isolated in Taiwan. *BioControl* 52: 801–819.
Liao CT, Lin CS. 2000. Occurrence of the Legume Pod Borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) on Cowpea (*Vigna nguiculata* Walp) and its Insecticides Application Trial. *Plant Prot. Bull*. 42: 213–222.
Pesticide Action Network (PAN) UK, 2009. Pesticide residues in green beans. http://www.pan-uk.org/Projects/Food/beans.html (accessed on March 11, 2009).
Rafaeli A. 2002. Neuroendocrine control of pheromone biosynthesis in moths. *Int. Rev. Cytol.* 213: 49–92.
Sarutayophat TC, Nualsri Q, Santipracha, Saereeprasert V, 2007. Characterization and genetic relatedness among 37 yardlong bean and cowpea accessions based on morphological characters and RAPD analysis. *Songklanakarin J. Sci. Technol.* 29: 591–600.
Sharma HC. 1998. Bionomics, host plant resistance, and management of the legume pod borer, Maruca vitrata – a review. *Crop Prot.* 17: 373–386.
Singh SR, Jackai LEN, Dos Santos JHR, Adalla CB. 1990. Insect pests of cowpeas, pp. 43–90, *in* Singh SR (ed.). Insect Pests of Tropical Legumes. John Wiley & Sons, Chichester, United Kingdom.
Sodavy P, Sitha M, Nugent R, Murphy H. 2000. Situation Analysis on Farmers' Awareness and Perceptions of the Effect of Pesticides on their Health. FAO COMMUNITY IPM PROGRAMME, Field document. p.16. http://www.communityipm.org/toxictrail/Documents/Cambodia-SituationAnalysis.pdf
Soeun M. 2001. Legumes in rice-based cropping systems in Cambodia: Constraints and opportunities. p. 4-10. In: Gowda CLL, Ramakrishna A, Rupela OP, Wani SP. (Eds.), Legumes in rice-based cropping systems in tropical Asia: Constraints and Opportunities, ICRISAT, India. 142 p.
Srinivasan R. 2008. Susceptibility of legume pod borer (LPB), *Maruca vitrata* to δ-endotoxins of *Bacillus thuringiensis* (Bt) in Taiwan. *J. Invertebr. Pathol.* 97: 79–81.
Srinivasan R, Tamo M, Lee ST, Lin MY, Huang CC, Hsu YC. 2009. Towards developing a biological control program for legume pod borer, *Maruca vitrata*. In: Sanjeev Gupta, M. Ali and B.B. Singh (eds.), Grain Legumes: Genetic Improvement, Management and Trade, Indian Society of Pulses Research and Development, Kanpur, India. pp.183-196.
Tamo M, Goergen G, Agboton C, Srinivasan R. 2007. Putting agro-biodiversity to work: the cowpea story. In: Proc. of XVI International Plant Protection Congress. pp. 354-355.
Taylor TA. 1967. The bionomics of *Maruca testulalis* Gey. (Lepidoptera: Pyralidae), a major pest of cowpeas in Nigeria. *J. West Afr. Sci. Assoc.* 12: 111–129.
Ulrichs C, Mewis I, Schnitzler WH, Burleigh JR. 2001a. Effectivity of synthetic insecticides against *Maruca vitrata* F. and the parasitoid *Bassus asper* CHOU & SHARKEY in the Philippines. *Mitteilungen der Deutschen Gesellschaft fur allgemeine und angewandte Entomologie* 13(1-6): 279–282.
Ulrichs C, Mewis I, Schnitzler WH, Burleigh JR. 2001b. Parasitoids of the bean podborer, *Maruca vitrata* F. (Lepidoptera: Pyraustinae), a pest of *Vigna sesquipedalis* in the Philippine lowlands. *Mitteilungen der Deutschen Gesellschaft fur allgemeine und angewandte Entomologie* 13(1-6): 283–288.
Vogt RG, Rogers ME, Franco MD, Sun M. 2002. A comparative study of odorant binding protein genes: differential expression of the PBP1-GOBP2 gene cluster in *Manduca sexta* (Lepidoptera) and the organization of OBP genes in *Drosophila melanogaster* (Diptera). *J. Exp. Biol.* 205: 719–744.
Waterhouse DF, Norris KR, 1987. *Biological control: Pacific prospects*. Inkata Press, Melbourne, Australia. 454 p.
Zahid MA, Islam MM, Begum MR. 2008. Determination of economic injury levels of *Maruca vitrata* in mungbean. *J. Agric. Rural Dev*. 6(1&2): 91–97.

Figure 1. Genitalia of *Maruca vitrata*

Figure 2. *Therophilus marucae*, a larval parasitoid of *Maruca vitrata*

Figure 3. *Phanerotoma philippinensis*, an egg – larval parasitoid of *Maruca vitrata*

Area-wide promotion and adoption of fruit fly IPM: innovative experiences of curriculum development for Farmers Field Schools

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ABSTRACT

The Asian region (East, Southeast, and South) is among the top three regions worldwide in terms of annual exports and imports of fresh fruits and vegetables. The productivity and quality of many of the fruits and vegetable crops are seriously reduced by tephritid fruit flies (*Bactrocera dorsalis* & *Bactrocera cucurbitae*). Tephritid fruit flies can cause *direct* damage to fruits and vegetables leading to 90-100% losses depending on locality, variety and season and *indirect* loss by reducing the trade potential due to strict quarantine regulations. Until recently, area-wide fruit fly IPM promotion efforts in Asia have focused largely on introduction of the sterile male technique, without attention to farmer education on promotion of an integrated management approach. Adoption of fruit fly IPM among smallholder farmers has been negligible and impact on control of fruit fly populations limited.

The Asian Fruit Fly IPM Project, which is a newly-established collaborative effort among various development partners (AIT, FAO-IPM and associated National IPM Programmes in Greater Mekong Subregion) and private sector (Biological Control Research Laboratory, India), aims to promote the adoption of area-wide Integrated Pest Management and educate farmers on the ecology and management of Fruit Flies through participation in Farmer Field Schools.

Since Project inception in September 2010, various capacity building training and action research activities were conducted at regional and country-level. These activities have led to country-specific project interventions, strategic design of effective 1-2-3 IPM strategies: 1) using protein bait; 2) sanitation; and 3) lures for population monitoring) and the innovative development of fruit fly IPM training curricula and materials (see http://ipm.ait.asia).

This paper will outline pilot experiences of area-wide fruit fly IPM and present the innovative farmer education initiatives developed in all 4 Greater Mekong Subregion project member countries (Cambodia, Lao PDR, Thailand and Vietnam).

Keywords

Bactrocera Fruit Flies, IPM, Farmers Field Schools, Greater Mekong Subregion

INTRODUCTION

Improving productivity and quality of fruits and vegetables enhances food security, employment and trade opportunities. The Asian region (East, Southeast, and South) is among the top three regions worldwide—for both exporters and importers of fruits and vegetables. The Mekong River basin countries are important producers of a range of fruits and vegetables for domestic consumption and international trade. In 2004, Asian countries produced 178 million tons of tropical fruits which amounted to 66% of the total global production and earned 2.5 billion US$ (Somsri et al. 2007).

Several factors, however, constrain fruit and vegetable production in the Mekong River basin, Tephritid fruit flies (FF) (*B. dorsalis, B. correcta* & *B. cucurbitae*) cause direct damage to fruits and vegetables (Clark et al. 2005), potentially leading to 90-100% losses depending on locality, variety and season. In addition, to the direct losses, fruit fly infestation results in serious losses in trade value and opportunity due to strict quarantine regulations imposed by most importing countries.

The Asian Fruit Fly IPM Project (http://ipm.ait.asia) funded by Taiwan ICDF (www.icdf.org) is a newly established regional consortium of research and development institutions (Asian Institute of Technology, Bangkok), United Nations agencies (FAO IPM Programme), private sector (Biological Control Research Laboratory, India), and national government IPM and extension programmes in Cambodia, Laos, Thailand and Vietnam. In partnership, efforts are underway to improvise the existing FF IPM technologies, innovate IPM strategies, and subsequently extend these locally-adapted IPM strategies to the farmers. The Farmers Field School (FFS) approach is used for training farmers and to empower them to raise healthy and profitable fruits and vegetable crops.

This paper outlines pilot activities to develop innovative FFS curricula for some important fruit and vegetable crops and presents initial results from the pilot FFS carried out primarily in Cambodia on bitter gourd and guava. Also future plans and challenges would be elaborated to highlight the role of grower's education using FFS as a means for adapting area-wide IPM for fruit fly IPM in the region and beyond.

MATERIALS AND METHODS

Background Preparation: Following official approval of the project a Regional Inception and Planning Workshop was organized in Bangkok from 1-3 September 2010. All project stakeholders, including scientists from Asia, Australia and Hawaii, participated in this workshop with the purpose to analyze results of previous fruit fly projects and develop work plans for the project. It was clear that limited efforts had been made so far in the region for community and/or farmer education on fruit fly IPM. Most past projects focused primarily on collecting basic information, *i.e.* species taxonomy, with the exception of ACIAR-funded efforts on using protein baits in Vietnam and in other countries. Workshop outputs then led to development of Country Strategy Papers by each of the four countries and subsequent GIS map assisted area selection for project site interventions (see http://ipm.ait.asia).

A Regional Training on IPM for Fruit Flies was organized in Tien Giang, Vietnam in December 2010. This Training was organized by FAO and AIT, in collaboration with the Southern Fruit Research Institute and MARD's Plant Protection Department (see http://ipm.ait.asia/?page_id=667). Upon return from the regional training, IPM Trainers with farmers undertook baseline surveys (BS) and information collected was analyzed for fine-tuning project intervention and training work plans. A short-duration (7-10 days) Training of Trainers (TOT) was organized in each of the participating country to equip IPM Trainers with basic information on fruit flies (life cycle, ecology, biology, management, monitoring, etc.). This was followed by the development of curricula for the FFS on selected crops (one fruit and one vegetable crop) in each country and adaptation of field exercises and population monitoring guides in local languages. Most of these curricula also included other biotic and abiotic stress affecting crop health as fruit flies were not the only problems encountered by participating farmers.

Farmer Field Schools on Fruit Fly IPM: Upon completion of basic preparations in each country, FFS for a systematic community-wide IPM on fruit fly for chosen crops commenced. Two areas, 2-3 km apart, with similar bio-physical and economic status were chosen for establishing FFS and population monitoring using Methyl Eugenol (Bador, BCRL, India) for *B. dorsalis* and *B. correcta* for fruit crops and Cue-lure (BaCue, BCRL, India for *B. cucurbitae*). A group of 25-30 women and men farmers participated in these FFS on weekly basis (in case of vegetable crops) and weekly to fortnightly basis during critical fruit fly stages for fruit crops. Every FFS meeting constituted of an agro-ecosystem analysis and calculation of the Flies per Trap/Day (FTD). The group of trainers and farmers also serviced (cleaning, changing lures and even changing bottles if get soiled) the bottle traps on regular intervals. Apart from FTDs, towards the end of the season economic analyses were carried out to assess the cost-benefits of the strategies that were introduced. Additional farmers from the communities were invited and results of the FFSs were shared with them during mid-season and end-season Field Days. Pre and post knowledge and skills tests were carried out to evaluate the increment in farmer knowledge and practices related to FF IPM.

RESULTS AND DISCUSSION

Farmers' participation: Farmers enthusiastically participated in these FFS and learned about the life cycle, ecology, biology and also practiced management strategies as part of the 1-2-3 management of FF (Fig.1 and 2).

Population monitoring: Excellent management of the FF was evident when FTDs were calculated and presented during weekly meetings. Initially IPM area recorded higher FTDs over the non-IPM area (Fig. 3). However, over time, fruit fly populations started declining in IPM areas resulting in higher production of safe fruits and vegetables for the market.

Economic returns: The reduced losses from FF damage in IPM areas resulted in higher yields leading to higher total and net-returns (Fig. 4).

The project within a short period of time since its inception in mid-2010 was able to establish a systematic and solid foundation for area-wide FF IPM adoption and adaption. This was possible by building the project interventions into existing strong IPM training programmes. These pilot initiatives and results obtained clearly demonstrate the prospects of successful community adaption of scientifically sound and robust technologies by using proven extension vehicles like FFS. Further, under the auspices of the project newer and better lures and traps are being developed to enhance the catches by lures and cue-lures, new dry traps to reduce servicing time and cost, and substitution of Malathion (which is widely used in small quantities to kill trapped flies) with less toxic biological substitutes like entomopathogens (*Beauveria bassiana*). Further, the project highlights the need for partnership between public and private organizations (BCRL, India and Pupuk Alam, Malaysia) for making available lures and protein baits respectively, to achieve sustainable fruit fly management in this region and beyond.

CONCLUSION

In conclusion, a strong complementary partnership of organizations working for farmers' empowerment and developing and the marriage of innovative scientific solutions are crucial for sustainable management of fruit flies for vegetables and fruits crops at smallholder production. Constant integration and adaptation of novel IPM strategies, participation of communities and strong support from government and markets would be required to reduce damage by fruit flies. As the project has just begun its activities, continued donor support for some time is needed before these efforts are internalized and become part of national IPM programmes and extension systems.

Acknowledgements

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References

Somsri, S., and S. Vichitrananda. 2007. Tropical Fruit Production and Marketing in Thailand. Horticulture Research Institute, Department of Agriculture, Chatuchak, Bangkok, Thailand 77p.

Clarke, Anthony R. and Armstrong, Karen F. and Carmichael, Amy E. and Milne, John R. and Roderick, George K. and Yeates, David K. 2005. Invasive Phytophagous Pests arising Through a Recent Tropical Evolutionary Raditation: The Bactrocera dorsalis complex of fruit flies. Annual Review of Entomology 50:pp. 293-319.

FIGURES

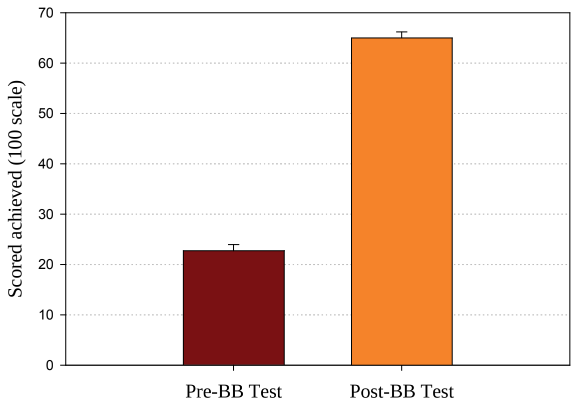

Figure 1. Knowledge and skill gains as expressed in pre and post ballot box scores achieved by FF-IPM trained farmers (Trang village, Ou Ta Ky commune, Thmor Koul district, Battambang province)

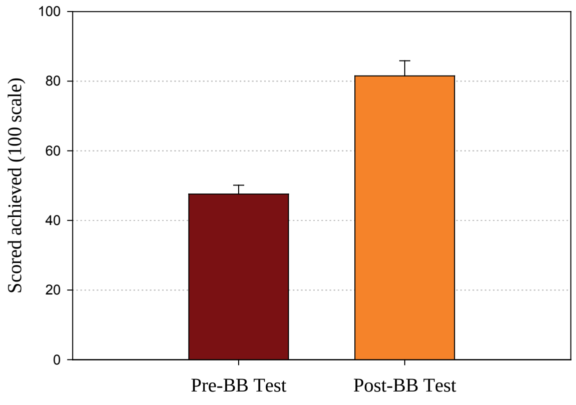

Figure 2. Knowledge and skill gains as expressed in pre and post Ballot Box score achieved by farmers (Sdao Kanlang village, Dey Ith commune, Kien Svay district, Kandal province)

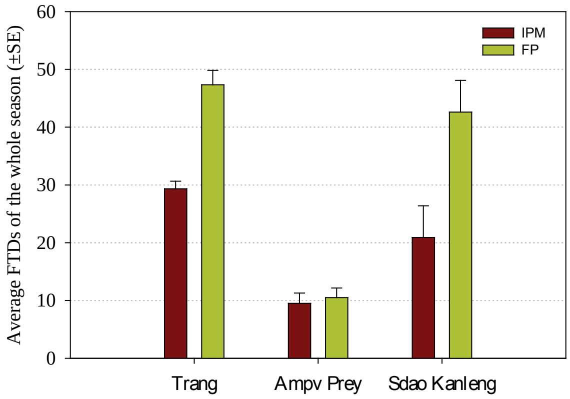

Figure 3. Average of FTDs (Flies per trap per day) from 3 FFS (season-long) conducted in Trang (6 sampling days, bitter gourd crop), Ampv Prey (7 Sampling days, Guava crop) and Sdao Kanleng (10 Sampling days. Guava crop) on bitter gourd and guava crops

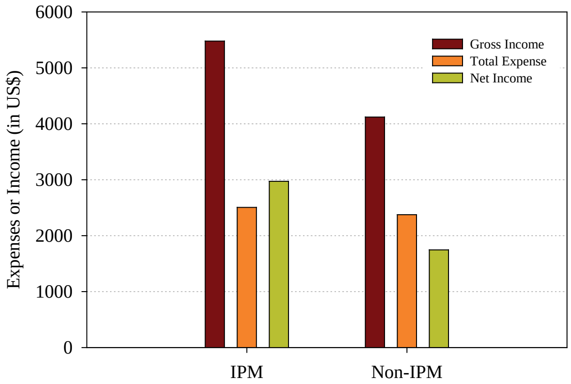

Figure 4. Gross income, total expense and net income achieved by bitter gourd IPM and non-IPM farmers (Trang village, Ou Ta Ky commune, Thmor Koul district, Battambang province). The IPM farmers harvested more healthy fruits with less cost (mainly on pesticides) leading to higher total and net-income (in US$).

Emergence of begomoviruses: a major threat to vegetable production in Southeast Asia

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ABSTRACT
Whitefly-transmitted begomoviruses have emerged as a major threat to vegetable production, particularly in the tropics and subtropics. The cucurbitaceous, malvaceous and solanaceous vegetables are most seriously affected. The most severely affected cucurbits include pumpkin (*Cucurbita pepo)*, muskmelon (*Cucumis melo*), cucumber (*Cucumis sativus*) and ridge gourd (*Luffa acutangula*). In northern India the diseases caused by begomoviruses have emerged as a major constraint in the production of cucurbits. Nearly 50% of the commercial crops of pumpkin, muskmelon, watermelon (*Citrullus vulgaris*) and bottlegourd (*Lagenaria siceraria*) are severely affected by WTGs in northern India. Similar spread of WTGs has also occurred in bottlegourd, cucumber and muskmelon in Thailand. Amongst the malvaceous vegetables, okra (*Abelmoschus esculentus*) is commonly grown across the world. Leaf curl disease (OLCuD) is a serious disease of okra in West and North-East Africa. Bhindi yellow vein mosaic disease (BYVMD), also known as yellow vein mosaic disease of Okra (OYVMD), is a serious constraint of okra production in Southeast Asia. The Indian Sub-continent was free of OLCuD until the late 1980s, but now it is a threat to okra cultivation. The most dramatic emergence of begomoviruses has been in tomato in Asia during the last two decades. The most important factors contributing to the emergence and spread of new begomoviruses are: evolution of new variants of the viruses; acquisition of satellite-like molecules; appearance of aggressive biotypes and increase in population of the vector; changes in the cropping systems; introduction of new crops and susceptible host genotypes; and movement of infected transplants. In addition, climate change and human activities have also played important role in the emergence of serious begomoviruses.

Keywords
Whitefly-transmitted viruses, begomoviruses, *Bemisia tabaci*, emerging viruses, climate change

INTRODUCTION
Whitefly (*Bemisia tabaci*) transmitted geminiviruses (WTGs), belonging to genus *Begomovirus,* Family *Geminiviridae,* have emerged as the most threatening group of plant viruses globally. The diseases caused by begomoviruses, have been known for a long time, but during the last three to four decades these diseases have assumed devastating proportions due to the emergence and spread of new begomoviruses and their variants, causing severe disease epidemics, particularly in the tropics and semi-tropics (Varma and Malathi 2003; Varma et al. 2011). The frequency with which new WTGs are appearing shows that these viruses are still evolving. During the last two decades severe disease epidemics, caused by newly emerged begomoviruses, have threatened the production of cucurbitaceous, malvaceous and solanaceous vegetables in various parts of the world.

Begomoviruses have unique twin particle morphology and their genome is either monopartite or bipartite ssDNA and infect dicotyledonous plants. A majority of the begomoviruses have bipartite genomes designated as DNA-A and DNA-B. Two virion-sense and four complementary- sense ORFs are located in DNA-A, whereas DNA-B has one virion-sense and one complementary-sense ORF. The two genomic components share a common region containing the origin of replication and regulatory regions for bi-directional transcription. So far, the ORF AV2 of DNA-A has been found only in the WTGs distributed in the Old World and not in the New World (Harrison and Robinson 1999). It is suggested that this ORF could have made DNA-B of some of the Old World begomoviruses redundant, resulting in the evolution of monopartite begomoviruses, which spread singly or in combination with satellite-like betasatellite and alphasatellite molecules (Briddon et al. 2004). The diseases caused by begomoviruses are easily recognized by their distinctive symptoms, like vein yellowing, yellow mosaic, and leaf curl. In this paper we briefly discuss the underlying factors leading to their emergence and spread of begomoviruses in selected vegetable crops.

Begomoviruses causing diseases in cucurbits

Cucurbits are popular vegetables in Asia. During the last decade cultivation of cucurbits in Southeast Asia has been affected by several begomoviruses (Table 1). In the Indian sub-continent, yellow vein mosaic of pumpkin (*Cucurbita pepo)*, caused by a begomovirus, has been known to occur in central-western India for over 60 years (Varma 1963). In 1990s, the Begomoviruses causing diseases in cucurbits spread in epidemic proportions in northern India, coinciding with sudden increase in whitefly populations early in the cucurbit growing season. In 2001 over 50% of the commercial crops of pumpkin, muskmelon, watermelon (*Citrullus vulgaris*) and bottlegourd (*Lagenaria siceraria*) were severely affected by begomoviruses in northern India (Varma and Malathi 2003). Sponge gourd (*Luffa aegytiaca*), widely grown in India, is affected by high incidence of *Tomato leaf curl New Delhi virus* (ToLCNDV) (Sohrab et al. 2003). ToLCNDV has also spread to a variety of other cucurbits (Table 1) causing serious diseases in India and Thailand (Ito et al. 2008; Mandal 2010; Varma et al. 2011).

A new ToLCNDV isolate has been found associated with a severe disease of oriental melon in Taiwan (Chang et al. 2010). Thus, ToLCNDV appears to emerge as a serious constraint to cucurbit production in Southeast Asia. Resistance to ToLCNDV in sponge gourd is shown to be controlled by a single dominant gene (Sabina et al. 2010). *Squash leaf curl China virus* (SLCCNV), which emerged in China in the 1990s (Hong et al. 1995), is another begomovirus, which is fast spreading in the Indian sub-continent and Southeast Asia in cucurbits (Table 1). The disease caused by SLCCNV in pumpkin results in up to 90% loss in yield (Singh et al. 2009).

Table 1: Emergence of diseases caused by begomoviruses in cucurbits in Southeast Asia and the adjoining regions (Varma et al. 2011)

S.N.	Acronym	Virus	Country	Host	Year
1	BGYVV	Bitter gourd yellow vein virus	Pakistan	Bitter gourd	2010
2	LYMV	Luffa yellow mosaic virus	Vietnam	Luffa	-
3	PepLCBDV	Pepper leaf curl Bangladesh virus	India	Bitter gourd	2010
4	PYMV	Pumpkin yellow mosaic virus	India		
5	SLCCNV	Squash leaf curl China virus	China	Squash	2002
			China	Squash	2005
			China	Squash	2005
			India	Pumpkin	-
			India	Pumpkin	2008
			India	Pumpkin	2009
			Pakistan	Squash	2004
					2010
			Vietnam:B	Squash	-
			Vietnam:K	Squash	-
6	SLCPHV	Squash leaf curl Philippines virus	Philippines	Squash	-
			Taiwan	Pumpkin	2005
7	SLCYNV	Squash leaf curl Yunnan virus	China	Squash	2000
8	ToLCNDV	Tomato leaf curl New Delhi virus	India	Bitter gourd	-
			Thailand	Luffa	-
				Bottle gourd	2008
				Cucumber	2008
				Muskmelon	2008

Begomoviruses spreading in leguminous vegetables

Yellow mosaic and golden mosaic diseases of grain legumes and leguminous vegetables are serious problems in the tropics and subtropics. The begomoviruses infecting legumes appear to have originated relatively recently (Varma and Malathi 2003). Nearly 30 distinct begomoviruses are reported to infect leguminous plants globally. Several of them have emerged in this decade. The most serious diseases include the bean golden mosaic (BGMD), cowpea golden mosaic (CPGMD) and yellow mosaic of mungbean (MYMD). BGMD is a major constraint in bean production in the Americas, CPGMD in West Africa, India and South America, and MYMD in the Indian subcontinent.

CPGMD was first detected in the Indian sub-continent in cowpea germplasm introduced from West Africa in 1978, and by 1984 it emerged as a major problem of cowpea cultivation in northern India. In the Indian sub-continent the disease is caused by a minor variant of Mungbean yellow mosaic India virus (MYMIV), showing the association of different begomoviruses with CPGMD in Africa and Asia (Varma et al. 2011). CPGMD has not been found to occur in Southeast Asia, but it can emerge if the genotypes susceptible to the endemic begomoviruses are introduced, as it emerged in the Indian sub-continent (Varma and Malathi, 2003).

Yellow mosaic disease (YMD) has emerged as a major threat to the production of a variety of leguminous vegetables, including Frenchbean (*Phaseolus vulgaris*), cluster bean (*Cyamopsis tetragonoloba*), hyacinth bean (*Lablab purpurea*), and mungbean (*Vigna radiate*), in Indian sub-continent (Varma et al. 2011). A serious outbreak of YMD in mungbean occurred in northern Thailand in 1977, resulting in a considerable reduction in crop area and a shift in the cropping pattern. Subsequently, the disease incidence became sporadic and did not recur between 1981-91, although mungbean continued to be grown in northern Thailand (Chiemsombat 1992). It is unusual for a disease caused by a WTG to completely disappear from an area in spite of the presence of susceptible plants and the vector. Factors leading to this situation could provide valuable clues for the management of begomoviruses.

Begomoviruses causing diseases in malvaceous vegetables

Bhindi yellow vein mosaic disease (BYVMD), also known as yellow vein mosaic disease of Okra (OYVMD) is a serious constraint of okra production in Southeast Asia. Two distinct begomoviruses, *Bhindi yellow vein mosaic disease* (BYVMV) and *Okra yellow vein mosaic virus* (OYVMV) have been found associated with these diseases. BYVMV is the most common WTG spreading in okra crops in the Indian sub-continent. Diversity in BYVMV has attracted limited attention, but frequent breakdown of resistance of okra varieties indicates occurrence of BYVMV variants in the Indian sub-continent. The Indian Sub-continent was free of OLCuD until the late 1980s, when the disease was first noticed in okra genotypes introduced from West Africa. The disease must have been caused by endemic begomoviruses in the susceptible genotypes. Soon the genes for susceptibility spread to the indigenous varieties (Varma and Malathi 2003). In Pakistan, OLCuD is shown to be caused by CLCuMV and in India by *Okra leaf curl India virus* (OKLCuIV) (Varma and Mandal 2003). Mixed infection with the begomoviruses causing OYVMD and OLCuD results in severe disease and complete loss in yield. In Thailand resistance to BYVMV in okra has been developed by mutation breeding (Phadvibulya et al. 2009). Durability of resistance in these lines remains to be seen.

Begomoviruses causing diseases in solanaceous vegetables

Solanaceous plants, particularly tomato, appear to be the most favoured host of begomoviruses (Varma et al. 2011). Many new begomoviruses affecting tomato have been detected in Southeast Asia and the adjoining regions during the last decade, and many more must be awaiting detection, considering the limited number of isolates characterized so far. The begomoviruses affecting tomato induce characteristic leaf curl symptoms, including severe reduction in leaf size, downward curling, crinkling of inter-veinal areas, inter-veinal and marginal chlorosis, occasional development of enations, purple discolouration of the abaxial surface of leaves, general yellowing of the leaves, shortening of internodes, development of small branches and reduced fruiting. The most devastating Begomoviruses affecting tomato are those with generic names 'tomato leaf curl virus' and 'tomato yellow leaf curl virus' (Varma and Malathi 2003). These Begomoviruses, commonly referred to as ToLCVs and TYLCVs, are widely distributed in Africa, the Americas, Asia, Australia and parts of Europe. *Tomato yellow leaf curl virus* (TYLCV) seems to have evolved in the Middle East between 1930 and 1950 (Lefeuvre et al. 2010), and has spread to almost all the tomato producing parts of the world.

In Southeast Asia and the adjoining regions, nearly 40 begomoviruses are reported to be associated with ToLCD and TYLCD. Many of these begomoviruses have emerged recently (Table 2). In the Indian Sub-continent, the occurrence of ToLCD, has been known for over 60 years (Vasudeva and Samraj 1948). It has also emerged in other parts of the sub-continent (Varma et al. 2011). *Tomato leaf curl New Delhi* (ToLCNDV) is the most widely distributed begomovirus infecting tomato crops in Bangladesh, India and Pakistan (Table 2). In northern India, ToLCNDV is the most serious constraint in tomato production. To minimize the losses caused by this virus, sources of resistance to ToLCNDV in tomato have been identified (Tripathi and Varma 2003) and transgenic lines resistant to ToLCNDV have been developed (Varma and Shelly 2006).

Table 2: Emergence of diseases caused by begomoviruses in solanaceous vegetables in Southeast Asia (shaded rows) and the adjoining regions (Varma et al. 2011)

S. No.	Acronym	Virus	Country	Vegetable Host	Year
1	ChiLCV	Chilli leaf curl virus	India	Chilli, tomato	2005
			Pakistan	Chilli, potato	2004
2	ChiLCMV	Chilli leaf curl Multan virus	Pakistan	Chilli	2009
3	PepLCBDV	Pepper leaf curl Bangladesh virus	Bangladesh	Pepper	1999
			Pakistan	Pepper	2004
4	PepLCLV	Pepper leaf curl Lahore virus	Pakistan	Pepper	2004
5	PepLCV	Pepper leaf curl virus	Malaysia	Pepper	1997
			Thailand	Pepper	-
6	PepYLCIV	Pepper yellow leaf curl Indonesia virus	Indonesia	Pepper, tomato	2005
7	TbCSV	Tobacco curly shoot virus	China	Pepper, tomato	2010, 2001
8	TbLCJV	Tobacco leaf curl Japan virus	Japan	Tomato	
9	ToLCBV	Tomato leaf curl Bangalore virus	India	Tmato	
10	ToLCBDV	Tomato leaf curl Bangladesh virus	Bangladesh	Tomato	
11	ToLCCNV	Tomato leaf curl China virus	China	Tomato	2002
14	ToLCGuV	Tomato leaf curl Guangdong virus	China	Tomato	2003
15	ToLCGxV	Tomato leaf curl Guangxi virus	China	Tomato	2003
16	ToLCGV	Tomato leaf curl Gujarat virus	India	Tomato	1999
			Nepal	Tomato	2000
17	ToLCHaV	Tomato leaf curl Hainan virus**	China		2010
18	ToLCHsV	Tomato leaf curl Hsinchu virus	China	Tomato	2005
			Taiwan	Tomato	2005
19	ToLCIV	Tomato leaf curl India virus*	India	Tomato	-
20	ToLCIDV	Tomato leaf curl Indonesia virus*	Indonesia	Tomato	-
21	ToLCJV	Tomato leaf curl Java virus	Indonesia	Tomato	-
22	ToLCJoV	Tomato leaf curl Joydebpur virus	Bangladesh	Tomato	-
			India	Chilli, tomato	2007
23	ToLCKV	Tomato leaf curl Karnataka virus	India	Tomato	1993
24	ToLCKeV	Tomato leaf curl Kerala virus	India	Tomato	2005
25	ToLCLV	Tomato leaf curl Laos virus	Laos	Tomato	-
26	ToLCMYV	Tomato leaf curl Malaysia virus	Malaysia	Tomato	1997
27	ToLCNDV	Tomato leaf curl New Delhi virus	India	Tomato, potato, chilli	1992, 2002, 2006
			Bangladesh	Tomato	2005
			Pakistan	Tomato, chilli	2001, 2004
28	ToLCPKV-	Tomato leaf curl Pakistan virus	Pakistan	Tomato	2004
29	ToLCPalV	Tomato leaf curl Palampur virus**	India	Tomato	2008
30	ToLCPaV	Tomato leaf curl Patna virus**	India		2009, 2010
24	ToLCPV	Tomato leaf curl Philippines virus	Philippines	Tomato	1995
25	ToLCPuV	Tomato leaf curl Pune virus	India	Tomato	2005
26	ToLCRaV	Tomato leaf curl Rajasthan virus	India	Tomato	2005
27	ToLCSLV	Tomato leaf curl Sri Lanka virus	Sri Lanka	Tomato	1997
28	ToLCSuV	Tomato leaf curl Sulawesi virus**	Indonesia	Tomato	2009
29	ToLCTWV	Tomato leaf curl Taiwan virus	Taiwan	Tomato	2005
30	ToLCVV	Tomato leaf curl Vietnam virus	Vietnam	Tomato	1998
31	TYLCCNV	Tomato yellow leaf curl China virus	China	Tomato	2004
32	TYLCGuV	Tomato yellow leaf curl Guangdong virus	China	Tomato	2003
33	TYLCIDV	Tomato yellow leaf curl Indonesia virus	Indonesia	Tomato	2005
34	TYLCKaV	Tomato yellow leaf curl Kanchanaburi virus	Thailand	Tomato, eggplant	2001
			Vietnam	Tomato, eggplant	2005
35	TYLCTHV	Tomato yellow leaf curl Thailand virus	Thailand	Tomato	2002
		TYLCTHV -B	China	Tomato	2002
		TYLCTHV -B	Myanmar	Tomato	1999
36	TYLCVNV	Tomato yellow leaf curl Vietnam virus	Vietnam	Tomato	2005
37	TYLCV	Tomato yellow leaf curl virus	Japan	Tomato	2005

Considerable variability has been found in the begomoviruses associated with ToLCD in India. For example *Chilli leaf curl virus* (ChiLCV), *Tomato leaf curl Gujarat virus* (ToLCGV) and ToLCNDV are bipartite begomoviruses, whereas *Tomato leaf curl Bangalore virus* (ToLCBV), *Tomato leaf curl Joydebpur virus* (ToLCJoV) and *Tomato leaf curl Karnataka virus* (ToLCKV) are monopartite Begomoviruses. *Tomato leaf curl Taiwan virus* (ToLCTWV) is also a monopartite begomovirus. The question of the origin of the begomoviruses associated with ToLCD is difficult to address, but the differences between the tomato isolates from different parts of the country suggest their diverse origin.

An epidemic of severe ToLCD in southern India in 1999 coincided with nearly 1000-fold increase in the whitefly populations and appearance of the B-biotype of *B. tabaci* (Banks et al. 2001). Tomato infecting Begomoviruses have also been detected in weeds like *Datura metel* and *Solanum miasum*, which may play an important role in the spread of these viruses (Sivalingam and Varma 2007).

ToLCD is also widespread in Southeast Asia (Table 2). In Indonesia, 100% infection of tomato by Tomato leaf curl Sulawesi virus (ToLCSuV) has been observed (Tsai et al. 2009). In China, TYLCV is reported to be spreading towards northern China from southern regions (Yu et al. 2009). *Tomato leaf curl Guangxi virus* (ToLCGxV), a recombinant monopartite WTG containing sequences from *Ageratum yellow vein virus, Euphorbia leaf curl virus* and *Tomato leaf curl China virus* (ToLCCNV), emerged in Guangxi province of China as a serious problem (Xu and Zhou 2007).

Malvastrum coromandelianum, an alternative host of *Tomato yellow leaf curl China virus* (TYLCCNV) may be playing an important role in the perpetuation and spread of TYLCCNV in China (Liu et al. 2009). The TYLCV infection in tomato in Japan seems to be spreading through domestic movement of transplants and transmission by B-biotype of *B. tabaci* (Kato et al. 2009)

Begomoviruses spreading in other solanaceous crops

Begomoviruses also cause serious diseases in potato and chilli and to a limited extent in eggplant. Foliar chlorosis, curling, smalling of leaves, fruit distortion and reduction in yield of chillies caused by *Pepper yellow leaf curl Indonesia virus* PepYLCIV was observed for the first time in 1999 in West Java, Indonesia. Since then, the disease incidence has increased 5.4-folds. Emergence of the disease in Indonesia has been assigned to 'invasion' of *B. tabaci* and the virus from central Thailand between 1994 and 1999 (De Barro et al. 2008). Begomovirus infection of chilli pepper (*Capsicum annuum*) is spreading fast in Taiwan. In 2007, less than 10% incidence of *Tomato yellow leaf curl Thailand virus* (TYLCThV) in Tainan county was observed, but by 2009, the incidence increased to 70% in some fields (Shih et al. 2010). *Tobacco curly shoot virus* (TbCSV) emerged in *Capsicum frutescens* in Sichuan Province in south-western China in 2009. This Province was apparently free from begomoviruses earlier (Qing et al. 2010).

In 2007 and 2008, high incidence of leaf curl disease (ChiLCD) of chillies resulted in enormous yield losses in the North-Western parts of the Indian sub-continent. The epidemic was caused by the spread of ToLCNDV and *Chilli leaf curl Multan virus* (ChiLCMV) in Pakistan (Akhter et al 2009) and ToLCNDV in India (Senanayake et al. 2007). In Indonesia also ChiLCD, caused by *Pepper yellow leaf curl Indonesia virus* has emerged in a serious epidemic form during the long and severe dry season (Hidayat et al. 2010). The Begomoviruses associated with ToLCD and TYLCD have a wide natural host range (Diaz-Pendon et al. 2010), which favours their perpetuation and also helps in the development of natural variants.

Potato is grown in regions and seasons, which do not favour active whitefly populations, but, in India, slight advancement in the date of planting of potato crops in northern plains resulted in the emergence of a serious apical leaf curl disease in the late 1990s, which is caused by an isolate of ToLCNDV (Usharani et al. 2004).

Underlying factors leading to the emergence and spread of Begomoviruses

In recent years, begomoviruses have emerged as threatening pathogens of vegetable crops. Begomoviruses and their variants are evolving at a very fast rate. At the beginning of the current century about 35 Begomoviruses (Varma and Malathi 2003) were known to occur in tomato, but within a few years, the number increased to >100, and the number is growing. Similar diversity is also observed in begomoviruses affecting other crops. Several factors seem to have driven the evolution of emerging begomoviruses (Varma and Malathi 2003; Fargette et al. 2006; Varma et al. 2011). These include evolution of new variants, evolution of satellite-like DNA molecules, appearance of whitefly biotypes, weather factors, changing cropping systems, movement of infected planting material and introduction of susceptible genotypes of cultivated plants.

Evolution of variants of begomoviruses

Evolution of variants is a major factor leading to the epidemics of the diseases caused by begomoviruses. Variants of begomoviruses evolve by mutation, pseudo recombination and/or genomic recombination. Variability is generally greater amongst the inter-regional isolates compared to the intra-regional isolates. Deployment of virus-resistant genotypes is a pracical approach to manage plant viral epidemics. However, it exerts selection pressure leading to the emergence of resistant breaking strains, 5-6 years of the deployment of resistant genotypes, like the breakdown of resistance to *Mungbean yellow mosaic India virus* in mungbean (Varma et al. 1992).

The ease with which genomic recombination occurs in begomoviruses not only between variants of the same virus but also between virus species, results in fast development of new variants or even new begomoviruses (Varma and Malathi 2003). Serious recombinants of begomoviruses causing diseases in vegetable crops have also appeared. *Tomato yellow leaf curl virus* (TYLCV) – Israel, the most widely distributed tomato infecting begomovirus, is a natural recombinant (Navas-Castillo et al. 2000). *Tomato leaf curl Guangxi virus* (ToLCGxV) and *Tomato leaf curl China virus* which have recently emerged as a serious pathogens in China are also recombinants, containing sequences of non-tomato and tomato-infecting begomoviruses (Xu et al. 2007; Yang et al. 2011). The begomoviruses associated with the leaf curl diseases of tomato have a wide natural host range, which helps in their perpetuation and provides opportunity for the development of natural variants.

Acquisition of betasatellites by begomoviruses

The Old World begomoviruses seem to have the ability to dispense with the DNA-B component of their genome, as the DNA A alone can cause systemic infection, as found for the Thailand isolate of TYLCV (TYLCV-Th) (Rochester et al. 1994). Some begomoviruses with similar genomic organization dispensed with DNA B to become monopartite viruses, and acquired betasatellite, to induce disease (see Varma et al 2011). Considerable molecular diversity occurs in the betasatellites associated with ToLCD in India (Sivalingam et al. 2010). Betasatellites are also found associated with the diseases caused by bipartite begomoviruses, like ToLCNDV. Co-infection of plants with bipartite ToLCNDV and the associated betasatellite increases symptom severity, viral replication and efficiency of transmission of the virus by *B. tabaci* (Sivalingam and Varma, 2012).

Viruses infecting new hosts and emergence of new virus disease problems

A large number of new begomoviruses have evolved rapidly in areas conducive to year round production of crops susceptible to these viruses, particularly after the ‘Green Revolution’ period. The most dramatic increase is in the number of begomoviruses infecting tomato globally (Varma et al. 2011). In India, potato cultivation in the northern plains was not affected by any begomoviruses, but in the late 1990s ToLCNDV emerged in potato a new host, due to advancement in the sowing of the crop coinciding with increase in B. tabaci populations (Varma and Malathi 2003).

Movement of infected planting material

Inadvertent movement of infected transplants plays an important role in the spread and emergence of begomoviruses. TYLCV emerged as a serious pathogen in the Americas after it was introduced, through infected transplants from Israel. The emergence and spread of TYLCV in Portugal, Spain, France, China, Japan and recently the Netherland, and several other countries/regions, may also have occurred similarly (Varma et al. 2011). In India, a TOLCNDV infection in potato has assumed serious proportions due to spread through the infected seed tubers.

Insect vector and the weather factors

In China, the dominant B-biotype of *B. tabaci* appeared in the late 1990s and by 2005-06 it was the only biotype of *B. tabaci* prevalent in many regions of the country (Wan et al. 2009). Emergence of B-biotype coincided with the WTG epidemics in many crops. The B-biotypes not only transmitted Begomoviruses efficiently, but also survived well on infected plants. In Indonesia, increase of begomovirus infections in chillies and tomato has been assigned to the 'invasion' of mainland Asian *B. tabaci* and Asian begomoviruses from Central Thailand. The studies have also shown integration of the genome of Asian *B. tabaci* with the Indonesia *B. tabaci* (De Barro et al. 2008).

Whitefly populations are greatly influenced by weather conditions. Their populations build up under conditions of high humidity and high temperatures. *B. tabaci* occurring in India are polyphagous with a very wide host range, resulting in the prevalence of a large number of begomoviruses in the region (Varma and Malathi 2003). During the last three decades, however, there has been a perceptible change in the biology of *B. tabaci* in northern India. Until the late 1970s, whitefly population build-up on plants coincided with the wet-season (June-October). The crops that suffered most during the wet-season were the grain legumes, particularly mungbean. By the 1990s, whiteflies population built up started in pre-wet-season and remained active throughout the year, resulting in the spread of begomoviruses to crops which were not affected earlier (Varma and Malathi, 2003; Varma et al., 2011). Emergence of Begomoviruses in cucurbits in 1990 in Northern India is attributed to unusual increase in whitefly populations early in the cucurbit growing season due to unexpected rise in day and night temperatures (Varma and Malathi 2003). Climate change resulting in warmer winters may have been an important factor leading to expansion in the period of activity and increase in populations of whiteflies, and emergence of WTG-induced diseases even in temperate crops under North Indian conditions.

Introduction of crops or genotypes susceptible to viruses endemic in a region

Cassava is a good example of indigenous begomoviruses infecting a new host. Cassava was introduced in Africa and Asia from Latin America between the 16 and 18th centuries. The cassava plantations in the Americas and South-East Asia are free from any disease caused by begomoviruses, but the crop is severely affected by cassava mosaic diseases in Africa, Southern India and Sri Lanka, where the disease is caused by the endemic viruses (Varma et al, 2011).

Introduction of exotic germplasm as a part of crop improvement programmes for introducing desirable genes from diverse sources, may also lead to the introduction of undesirable genes including the genes for susceptibility to biotic stresses (Varma and Malathi 2003). For example, MYMIV, endemic in the Indian subcontinent, did not infect cowpea (*V. unguiculata*), under field or experimental conditions until the late 1970s. In 1978, many exotic accessions of cowpea were introduced from West Africa, and for the first time CPGMD was observed in a few accessions; the disease soon became a serious problem as the gene for susceptibility moved to the popular cowpea cultivars. CPGMD in India was later shown to be caused by a variant of MYMIV that emerged after the introduction of susceptible cowpea germplasm (Varma et al. 1992; Roy and Malathi 2001). Similarly, leaf curl disease emerged in okra, starting with the accessions introduced from West Africa, where it is the most severe disease of the crop. Mixed infection by the Begomoviruses causing yellow vein mosaic and leaf curl diseases results in very severe disease rendering the plants non-productive (Varma and Malathi 2003).

Emergence of geminivirus problems with changes in the cropping systems

In India, introduction of summer crop of mungbean under irrigated conditions resulted in the unseasonal appearance of MYMIV (Varma et al. 1992), and advancement of potato planting time in the North Indian plains resulted in the emergence of a serious apical leaf curl disease (Varma and Malathi 2003). Changes in the farming systems have also resulted in the emergence and spread begomoviruses in other parts of the world.

CONCLUDING REMARKS

Begomoviruses are a serious concern in vegetable production. There is an urgent need to understand the factors leading to increase in begomovirus-induced diseases in diverse cropping systems. The changing scenario suggests greater increase in the occurrence of begomovirus associated epidemics. Use of resistant varieties is the most preferred approach to contain plant disease epidemics. However, the development of varieties resistant to begomoviruses requires ceaseless efforts, as the fast evolution of resistance breaking strains/isolates, necessitates quick varietal replacement. Resistance to begomoviruses has been mainly developed by traditional breeding. Recently, transgenic varieties have also shown promise. Notwithstanding the strength of using varietal resistance to contain begomoviruses, long term solutions require integrated approaches to manage begomovirus-associated disease problems.

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References

Akhter A, Qazi J, Saeed M, Mansoor S. A severe leaf curl disease on Chilies in Pakistan is associated with multiple begomovirus components. Plant Disease 2009; 93:962.

Banks GK, Colvin J, Reddy RVC, Maruthi MN, Muniyappa V, Venkatesh HM, Kumar KM, Padmaja AS, Beitia FJ, Seal SE. First report of the *Bemisia tabaci* B biotype in India and an associated *Tomato leaf curl virus* disease epidemic. Plant Disease 2001; 85:231.

Briddon RW, Bull SE, Imran A, Shahid M, Bedord ID, Narayan R, Siwatch SS, Yusuf Z, Abdel Salam AM, Markham PG. Divesity of DNA 1: a satellite-like molecule associated with nonopartite begomovirus-DNA beta complexes. Virology 2004; 324: 462-474.

Chang H, Ku H, Tsai W, Chien R, Jan F. Identification and characterization of a mechanical transmissible begomovirus causing leaf curl on oriental melon. European Journal of Plant Pathology 2010; 127: 9-228.

Chiemsombat P. Mungbean Yellow Mosiac Disease in Thailand: A Review. In: SK.Green & Deo-Hwan (Eds.), *Mungbean Yellow Mosaic Disease:* Proceedings of an International Workshop, Asian Vegetable Research and Development Center, Taipei, 1992; pp.54-58.

De Barro PJ, Hidayat SH, Frohlich D, Subandiyah S, Ueda SA. Virus and its vector, pepper yellow leaf curl virus and Bemisia tabaci, two new invaders of Indonesia. Biological Invasions. 2008; 10: 411-433.

Diaz-Pendon JA, Canizares MC, Moriones E, Bejarano ER, Czosnek H, Navas-Castillo J. Tomato yellow leaf curl viruses: menage a trois between the virus complex, the plant and the whitefly vector. *Mol Plant Pathololology* 2010; 11:441–450.

Fargette D, Konate G, Fauquet C, Muller E, Peterschmitt M, Thresh JM. Molecular ecology and emergence of tropical plant viruses. Annual Review of Phytopathology 2006; 44:235–260.

Harrison BD, Robinson DJ. Natural genomic and antigenic variation in whitefly-transmitted geminiviruses. Annual Review of Phytopathology 1999; 37: 369-398.

Hidayat SH, Sulandari S, Aidawati N. Emerging geminiviral diseases and their management. In: Sharma Pradeep, Gour Rajarshi k, Ikegami Masato, editors. The emergence of yellow leaf curl disease in chilli pepper in Indonesia. New York: Nova Science Publisher Inc; 2010. p. 147-165.

Hong Y, Wang X, Tian B, Cai J. Chinese squash leaf curl virus: a new whitefly- transmitted geminivirus. Scientia China. 1995; B38: 179-186.

Ito T, Sharma P, Kittipakorn K, Ikegami M. Complte nucleotide sequence of a new isolate of tomato leaf curl New Delhi virus infecting cucumber, bottle gourd and muskmelon in Thailand. Archives of Virology, 2008; 153: 611-613.

Kato S, Torisawa E, Yoshida K, Saito Y, Suganuma K, Iida F, Fuji S, Fukuta S, Fukaya M. Infection cycle of tomato yellow leaf curl virus (TYLCV) and preventing methods of TYLCV on nursery period. Research Bulletin of the Aichi Agricultural Research Center. 2009; 40: 69-76.

Lefeuvre P, Martin DP, Harkins G, Lemey P, Gray AJA. The Spread of Tomato Yellow Leaf Curl Virus from the Middle East to the World. PLoS Pathog 2010; 6(10): e1001164. doi:10.1371/journal.ppat.1001164

Liu P, Xie Y, Zhou XP. Malvastrum coromandelianum is an alternative host of Tomato yellow leaf curl China virus. Plant Pathology 2009; 58: 403.

Mandal B. Emerging geminiviral diseases and their management. In: Sharma Pradeep, Gour Rajarshi k, Ikegami Masato, editors. Emergence of begomoviruses diseases in cucurbits in India. New York: Nova Science publishers Inc; 2010. p.167-181.

Navas-Castillo J, Sanchez-Campos S, Noris E, Louro D, Accotto GP, Moriones E . Natural recombination between Tomato yellow leaf curl virus-Is and Tomato leaf curl virus. Journal of General Virology 2000; 81:2797–2801.

Phadvibulya V, Boonsirichai K, Adthalungrong A, Srithongchai W. Selection for resistance to yellow vein mosaic virus disease of okra by induced mutation. Induced plant mutations in the genomics era. Proceedings of an International Joint FAO/IAEA Symposium 2008 2009; 349-351.

Qing L, Xiong Y, Sun XC, Yang SY, Zhou CY. First report of Tobacco curly shoot virus infecting pepper in China. Plant Disease. 2010; 94: 637.

Rochester DE, de Paulo JJ, Fauquet CM, Beachy RN (1994) complete nucleotide sequence of the geminivirus tomato yellow leaf curl virus, Thailand isolate. Journal of Geneneral Virology 75:477–485.

Roy A, Malathi VG. Molecular cloning of cowpea golden mosaic geminivirus and its relationship with mungbean yellow mosaic geminivirus. Tropical Agricultural Research 2001; 13: 341–352.

Sabina Islam, Munshi AD, Bikash Mandal, Ravinder Kumar, Behera TK. Genetics of resistance in Luffa cylindrica Roem. against Tomato leaf curl New Delhi virus. Euphytica 2010; 174: 83-89.

Senanayake DMJB, Mandal B, Lodha S, Varma A. First report of *Chilli leaf curl virus* affecting chilli in India. Plant Patholology 2007; 56:343

Shih SL, Tsai WS, Lee LM., Wang JT, Green SK, Kenyon L. First report of Tomato yellow leaf curl Thailand virus associated with pepper leaf curl disease in Taiwan. Plant Disease 2010; 94: 637.

Singh AK, Mishra KK, Chattopadhyay B, Chakraborty S. Biological and molecular characterization of a begomovirus associated with yellow mosaic vein mosaic disease of pumpkin from Northern India. Virus Genes 2009; 39: 359-370.

Sivalingam PN, Varma A. Non-tomato natural hosts of tomato infecting begomoviruses in north-western India. Indian Journal of Virology. 2007; 18: 20-27.

Sivalingam PN, Malathi VG, Varma A (2010) Molecular diversity of the DNA-β satellites associated with tomato leaf curl disease in India Archives of Virology 155: 757–764.

Sivalingam PN, Varma A. Role of betasatellite in the pathogenesis of a bipartite begomovirus affecting tomato in India. Archives of virology 2012 DOI 10.1007/s00705-012-1261-7

Sohrab SS, Mandal B, Pant RP, Varma A. First reports of association of Tomto leaf curl New Delhi virus with yellow mosaic disease of *Luffa cylindrica* in India. Plant. Disease. 2003; 87-1148.

Tripathi S, Varma A. Identification of sources of resistance Lycopersicon to Tomato leaf curl geminivirus (ToLCV) by agroinoculation. Euphytica 2003; 129: 43-52.

Tsai WS., Shih SL, Green SK, Lee LM, Luther GC, Ratulangi M, Sembel DT, Jan FJ. Identification of a new begomovirus associated with yellow leaf curl diseases of tomato and pepper in Sulawesi, Indonesia. Plant Disease 2009; 93: 321.

Usharani KS, Surendranath B, Khurana SMP, Garg ID, Malathi VG. Potato leaf curl – a new disease of potato in northern India caused by a strain of *Tomato leaf curl New Delhi virus.* Plant Pathology 2004; 53: 235.

Varma A, Mandal B (2003) Other vegetables: amaranthus, chayote, colocasia and xanthosoma, egg plant, lablab, okra, onion, pea and sweet pepper. In: Loebenstine G, Thottappilly G (eds.) Virus and virus-like diseases of major crops in developing countries. Kluwer, Dordrecht

Varma A, Dhar AK, Mandal B. 1992. MYMV transmission and conrol in India. Mungbean Yellow Mosaic Disease: *Proceedings of an International Workshop,* Asian Vegeable Research and Development Center, Taipei pp. 8-27.

Varma A. Malathi V G. Emerging geminivirus problems: a serious threat to crop production Annals of Applied Biology 2003; 142: 145-164.

Varma A, Shelly P. GE tomato resistant to leaf curl disease. ISB News Report. 2006.

Varma, PM. Transmission of plant viruses by whiteflies. Bulletin NISI, National Institute of Science in India, 1963; pp.11-33.

Varma A, Mandal B, Singh MK. Global emergence and spread of whitefly (Bemisia tabaci) transmitted geminiviruses. In: Thompson WMO, editor. The whitefly, Bemisia tabaci (Ho- moptera: Aleyrodidae) interaction with geminivirus-infected host plants. Netherlands: Springer; 2011. p. 205–92.

Vasudeva RS, Samraj J. A leaf curl disease of tomato. Phytopathology 1948; 38: 364-369.

Wan F, Zhang G, Liu S, Luo C, Chu D, Zhang Y, Zhang L, Jiu M, Lu Z, Cui X et al. Invasive mechanism and management strategy of Bemisia tabaci (Gennadius) biotype B: progress report of Program on invasive alien species in China. Science China of Life Science 2009; 52:88–95.

Xu Y, Zhou XP. A new begomovirus associated with leaf curl disease of Euphorbia pulcherrima. Journal of Plant Pathology 2007; 89: Suppl.3, S69. 2

Yang X, Guo W, Ma X, An Q, Zhou X. Molecular characterization of *Tomato leaf curl China virus,* infecting tomato plants in China, and functional analyses of its associated betasatellite. Appl. Envirnmental Microbiology 2011; 77: 3092-3101

Yu WenGui Zhao, TongMin Yang, MaLi Zhao, LiPing Ji, YingHua Zhou YiJun. PCR detection and sequence analysis of whitefly-transmitted geminivirus in tomato from Anhui and Shandong provinces. Jiangsu Journal of Agricultural Sciences 2009; 25: 747-751.

Toxicity of insecticides on diamondback moth from three areas in Thailand

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ABSTRACT
Diamondback moth, *Plutella xylostella* (L.) is a key pest of crucifer crops in Thailand. Many insecticides repeatedly used for a period have shown reduced toxicity to this pest due to resistance. This work evaluated the toxicity status of various insecticides to field populations of diamondback moth in Thailand by using a standard leaf dip bioassay. The lethal concentration toxicity (LC_{50}) of each insecticide was estimated by probit analysis. The toxicity ratio was determined by dividing the field recommended dose by the LC_{50} value. The insecticides showing toxicity ratio more than 20 in the Tha Muang population from Kanchanaburi province in 2008 were flubendiamide, *Bt. aizawai*, *Bt. kurstaki*, and spinosad; in the Tub Berg population from Petchabun province in 2009 were flubendiamide, chlorantraniliprole, spinosad, *Bt. aizawai*, *Bt. kurstaki*, and fipronil; and in the Sai Noi population from Nonthaburi province in 2010 were spinosad, fipronil, and *Bt. aizawai*. At that time, the spraying of indoxacarb should be avoided in three areas because of resistance risk. Data from Sai Noi population in year 2011 pointed that more insecticides should be cautioned for spraying, which were indoxacarb, chlorfenapyr, fipronil, tolfenpyrad, flubendiamide and chlorantraniliprole. The results suggested the importance of accuracy and revision of field recommended dose due to reduced toxicity of insecticides recommended for good agricultural practice in crucifer crops. The management of resistance problem in this pest by using insecticides showing high toxicity in rotation with others which also show high toxicity and have different modes of action may be useful tactic.

Keywords
Diamondback moth, *Plutella xylostella*, insecticide toxicity, insecticide resistance

INTRODUCTION
Diamondback moth, *Plutella xylostella* (L.), is serious insect pest of cruciferous vegetables in many countries around the world including Thailand. The control cost for it in the early 1990s was average US$1 billion annually (Talekar and Shelton 1993). In Thailand, farmers depend absolutely on the use of various synthetic insecticides to control this pest. This pest has become one of the most difficult pests to control in Thailand and worldwide (Attique et al. 2006; Sarita et al. 2010). Due to the injudicious use of various insecticides by most of Thai farmers, reduced efficacy in regard to insecticide resistance has been frequently claimed.

Insecticide resistance in the diamondback moth has been a great concern for all farmers who grow vegetables in Thailand. For many years, the unsuccessful control of diamondback moth has been extended primarily because of resistance evolution in some parts of the world to every class of insecticide used extensively against it (Shelton et al. 2000; Liu et al. 2003; Sarfraz and Keddie 2005). To date, *P. xylostella* has developed resistance to 81 insecticides (APRD 2009). Insecticide resistance management (IRM) strategy was demonstrated to solve this problem successfully (Mau and Gusukuma-Minuto 2001).

Introducing IRM strategy to farmers in order to mitigate insecticide resistance in the diamondback moth in Thailand was extremely necessary. Resistance monitoring is a part of planning IRM. The resistance status known is important for forecasting the failure of insecticide control and can be applied in combination to integrated pest management (IPM) in the future. However, the information of insecticide resistance status of diamondback moth in Thailand is few. This study therefore investigates the toxicity of commonly used insecticides in diamondback moth populations from three important vegetable growing areas in Central Thailand from 2008 to 2011. The information obtained will be used for planning IRM strategy to prevent severe damage caused by the resistant diamondback moth in the future.

MATERIALS AND METHODS

Insect cultures

Diamondback moth larvae and pupae were collected from the important vegetable growing areas in Thailand - Tha Muang district, Kanchanaburi province; Tub Berg district, Phetchabun province and Sai Noi district, Nonthaburi province from 2008 to 2011. More than 300 insects were collected from each district and reared to establish F1 population from each district in laboratory at the Pest Management Group, Office of Plant Protection Research and Development, Department of Agriculture, Thailand. Adults that emerged from the field populations were provided with 10% honey solution in cotton wool and mass-mated at random in cages. Adults were allowed to lay eggs on crinkled sheets of aluminum foil. The emerged larvae were fed with young cabbage leaves. Third instar of F1 larvae from each population were used for bioassays. All populations were maintained at 26 $\pm$ 1^{o}C.

Insecticides used

Commercial formulations of all insecticides, spinosad (Success 12%SC; Dow Agroscience (Thailand) Company Ltd., Bangkok, Thailand) , indoxacarb (Ammate 15% SC; DuPont (Thailand) Company Ltd., Bangkok, Thailand), emamectin benzoate (Proclaim 1.92% EC; Syngenta Crop Protection Company Ltd., Bangkok, Thailand), chlorfenapyr (Rampage 10% SC; BASF (Thailand) Company Ltd., Bangkok, Thailand), fipronil (Ascend 5% SC; BASF (Thailand) Company Ltd., Bangkok, Thailand), tolfenpyrad (Hachi Hachi 16% EC; TJC Chemical Company Ltd., Bangkok, Thailand), flubendiamide (Takumi 20%WDG; TJC Chemical Company Ltd., Bangkok, Thailand), chlorantraniliprole (Prevathon 5% SC; DuPont (Thailand) Company Ltd, Bangkok, Thailand), *Bt. aizawai* (Xentari 35,000 DBMU/mg or 10.3% AI; Sotus International Company, Ltd., Nonthaburi, Thailand) and *Bt. kurstaki* (Bactospeine10,600 IU/mg FC or 2.12% AI; Thep Wattana Company Ltd., Bangkok, Thailand) were used in this study. The insecticide concentrations were prepared with reversed osmosis water containing 0.025% spreading agent (Tension T-7, Sotus International Company, Ltd., Nonthaburi, Thailand).

Leaf dip bioassay

All insecticide formulations were diluted to generate serial dilutions with reversed osmosis water containing 0.025% Tension T-7. The leaf-dip method was used for bioassays (Ninsin et al. 2000). Cabbage, *Brassica oleracea* L., leaves measuring 5 cm x 5 cm were cut and dipped in different concentrations of insecticides for 10 s and then allowed to air dry at room temperature. Control leaves were dipped in water containing 0.025 % Tension T-7 only. Each leaf was then placed in individual 100-cm^{3} plastic cup containing a single filter paper. Ten third instar larvae were released into each cup. An average of five concentrations of each insecticide was used. Each concentration and control was replicated four times. Larvae were then kept at 26 $\pm$ 1^{o}C and allowed to feed on the treated leaf. The mortality was assessed after 48 h. except for flubendiamide, chlorantraniliprole, *Bt. aizawai* and *Bt. kurstaki* at 72 hr. Larvae that did not respond to pencil-tip prodding were considered to be dead.

Statistical analysis

The mortality data were analyzed by probit analysis to estimate the median lethal concentrations (LC50) and the 95% fiducial limits (FL) (Finney 1971). Mortality was corrected using Abbott's formula (Abbott 1925). Differences in insecticide susceptibility or LC50 between populations were considered to be significant when the 95% FL of LC50 values did not overlap. Toxicity ratio (TR) was calculated by dividing the field recommended dose of each insecticide by the LC50 value of that insecticide in each population (McLeod et al. 2002). Resistance factor (RF) was calculated by dividing the LC50 of each insecticide in each year by the lowest LC50 of each insecticide in previous data shown in Table 1, because of unavailability of susceptible strain.

RESULTS

Toxicity of insecticides on three populations of DBM in year 2008-2010

The diamondback moth (DBM) from Tha Muang, Tub Berg and Sai Noi populations showed obvious variation in susceptibility and resistance factor to most insecticides commonly used by farmers. The study presented here also revealed the progressive increase in resistance of the diamondback moth to most insecticides, especially in flubendiamide and chlorantraniliprole from 2008 to 2011.

Large variation in susceptibility to various insecticides was observed in DBM population from three areas in year 2008-2010. All populations showed high susceptibility to spinosad, emamectin benzoate, fipronil and *Bt. kurstaki* (LC50s were between 1.15-8.70 mg/liter, Table 1). DBM from two populations, Tha Muang and Tub Berg, also showed high susceptibility to flubendiamide, *Bt. aizawai*, and *Bt. kurstaki* (LC50s were between 0.160-3.45 mg/liter, Table 1). In contrast, low susceptibility to indoxacarb, chlorfenapyr, tolfenpyrad, was observed in all populations (LC50s were between 18.5-79.2 mg/liter, Table 1).

Accordingly, toxicity ratio (TR) reflected level of susceptibility of DBM to most insecticides (Table 2). Flubendiamide and chlorantraniliprole showed very high toxicity ratio (TRs of flubendiamide in Tha Muang and Tub Berg population were 243.9 and 375.0, TR of chlorantraniliprole in Tub Berg population was 333.3, Table 2)

Susceptibility of Sai Noi population to insecticides in year 2011

Clear variation in either susceptibility or resistance factor to most insecticides were also revealed in diamondback moth from Sai Noi population in year 2011. Variation in susceptibility to various insecticides varied across different year also. In this year, high susceptibility to spinosad, emamectin benzoate and *Bt. kurstaki* has been found in this population (LC50 were between 3.79-6.26 mg/liter, Table 3). However, low susceptibility to tolfenpyrad (LC50 was 792 mg/liter, Table 3) and chlorantraniliprole (LC50 was 557 mg/liter, Table 3) were obvious. It should be noted that this population showed very low susceptibility to flubendiamide (LC50 was 55,779 mg/liter, Table 3). Generally, there was a progressive increase in resistance to most insecticides over time.

Susceptibility of Sai Noi population to most insecticides was decreasing. This can be seen from either increasing of LC50 values in spinosad, emamectin benzoate, chlorfenapyr or decreasing of TR (Table 1, 3 and 4). Specifically, higher increasing of LC50 values of fipronil, tolfenpyrad, flubendiamide and chlorantraniliprole in this population were obviously found (LC50 increased from between 1.15-57.4 to 88.5-5,779 mg/liter, Table 1 and 3)

Resistance and toxicity of insecticides in Sai Noi population in year 2011

Change in toxicity ratio of various insecticides and resistance factor of F1 generation *P. xylostella* collected from Sai Noi district in 2010-2011 was also observed. Toxicity ratios of most insecticides were decreasing except those of indoxacarb and *Bt. kurstaki*. Toxicity ratio of spinosad, emamectin benzoate, chlorfenapyr and *Bt. aizawai* decreased 0.5 time in average, whereas that of tolfenpyrad decreased more than 0.5 time (TR changed from 1.7 to 0.3, Table 4). However, TR of fipronil decreased more than 10 times (TR changed from 130.4 to 1.7, Table 4). More importantly, toxicity ratio of chlorantraniliprole decreased 100 times in average

(TR changed from 9.4 to 0.1, Table 4), whereas that of flubendiamide decreased more than 100 times (TR changed from 5.7 to 0.01, Table 4).

Resistance factors (RF) of most insecticides have increased in Sai Noi population from year 2010 to 2011 except for those of indoxacarb and *Bt. kurstaki*. Due to our lacking of susceptible strain, the lowest LC50 of each insecticide in our previous data shown in Table 1 was used for calculating RF. Resistance factor of spinosad, emamectin benzoate, chlorfenapyr and *Bt. aizawai* increased 2 times in average, whereas those of fipronil and tolfenpyrad significantly increased more than 10 times (RF of fipronil changed from 1.0 to 77.0 and RF of tolfenpyrad changed from 2.7 to 37.4, Table 4) since the 95% fiducial limits of LC50s did not overlap (Table1 and 3). More importantly, resistance factor of DBM from this population in year 2010 to 2011 significantly increased more than 50 times in chlorantraniliprole (RF changed from 35.4 to 2,479.4, Table 4), however that of flubendiamide increased more than 500 times (RF changed from 66.3 to 36,116.9, Table 4) according to the 95% fiducial limits of LC50s did not overlap (Table1 and 3).

DISCUSSION

Insecticide resistance caused unsuccessful control as well as reduction in number of effective insecticides to be used. This problem has been a major concern of farmers who grow vegetable in Thailand. In recent year, insecticide resistance problem has continually extended. Resistance profile in the diamondback moth from many locations varied. The insecticides causing resistance should be avoided for spraying. Insecticide resistance management (IRM) strategy is the critical tactic to alleviate insecticide resistance problem (Mau and Gusukuma-Minuto 2001). Various scientific data should be obtained to establish practical IRM for resistant diamondback moth in each area.

Our data indicated that insecticide resistance in the diamondback moth from important vegetable growing areas in Thailand has increased. For instance, Sai Noi population showed reduced susceptibility as well as increasing in resistance factor to many insecticides. Reduced susceptibility and increasing in resistance factor were more intense in both fipronil and tolfenpyrad causing resistance factor increased from 1.0 to 77.0 in fipronil and from 2.7 to 37.4 in tolfenpyrad (Table 4). The worst case can be seen in diamide insecticide, flubendiamide and chlorantraniliprole, in Sai Noi population. The resistance factor in this population sharply increased from 66.3 to 36,116.9 in flubendiamide and from 35.4 to 2,479.4 in chlorantraniliprole (Table 4). The development of resistance in the diamondback moth to many insecticides has been reported from many countries (Li et al. 2006; Zhao et al. 2006; Huang et al. 2008; Wang et al. 2010; Zhou et al. 2010), resulting in ineffectiveness of recommended insecticides for the diamondback moth within a short period. Reduction of susceptibility and increment of resistance factor were general signs of insecticide resistance. However, due to our unavailability of true resistance strain of diamondback moth to compare, the resistance factors observed in this study may be lower than reality. Thus, our resistance factors could probably show trend. Our results therefore indicated future trend of resistance problem in the areas studied and suggested that the implementation of IRM to reduce this concern should rapidly be developed and utilized.

To establish IRM strategy, the insecticides causing resistance should be avoided as well as the appropriate insecticides in each area should be recommended in order to alleviate control failure. In each area in year 2008-2010, the intensification of resistance in each insecticide varied due to the difference in selection pressure. At that time, insecticide that should be avoided for spraying in Tha Muang population was indoxacarb because of high LC50 (LC50=79.2 mg/liter, Table 1) and low TR (TR=1.4, Table 2). In both Tub Berg and Sai Noi population the insecticides that should be avoided were indoxacarb and tolfenpyrad because of low TR and high LC50 (LC50=27.5 and 66.8 mg/liter in indoxacarb, LC50=46.2 and 57.4 mg/liter in tolfenpyrad, Table 1). High LC50 value normally indicated reduced susceptibility to insecticides. The insecticides showing high LC50 should be avoided for spraying.

Data from Sai Noi population in year 2011 pointed that more insecticides should be cautioned or avoided for spraying, which were indoxacarb, chlorfenapyr, fipronil, tolfenpyrad, flubendiamide and chlorantraniliprole (LC50=64.1, 46.8, 88.5, 793, 5,779 and 557 mg/liter respectively, Table 3). Fipronil, tolfenpyrad, flubendiamide and chlorantraniliprole should be no longer be used in Sai Noi area for a period of time due to significant increasing in RF (RF changed from 1.0 to 77.0 in fipronil, from 2.7 to 37.4 in tolfenpyrad, from 66.3 to 36,116.9 in flubendiamide and from 35.4 to 2,479.4 in chlorantraniliprole). The data suggested that these insecticides should be switched to other insecticides which are in different group or mode of action and also show no cross resistance, for example *Bt. aizawai* and *Bt. kurstaki*. The insecticides causing resistance in the diamondback moth should be paused for a period of time until the declination of severity of resistance would be obvious. Judicious use of insecticides including appropriate doses, correct application techniques, the limiting of spray times and windows and thoughtful and cooperative rotation of products on an area-wide basis should be considered also (Wang et al. 2010; Zhao et al. 2006). Therefore, updated data from resistance monitoring was so crucial for selecting proper insecticides, discarding unfavorable insecticides and designing IRM strategy.

Regular resistance monitoring in the diamondback moth from the important vegetable growing areas in Thailand is crucial for the sustainable use of insecticides for control. The information obtained can help growers switch insecticides before a major economic loss of the crop. The management of spraying by using window strategy and effective insecticide partners for rotation should be extensively utilized. IPM practices including crop rotation or crop-free period should be maximized to decrease selection pressure of insecticides used by farmers.

CONCLUSION

The toxicity of various insecticides on diamondback moth from three areas in Thailand varied. The resistance problem in diamondback moth to many insecticides has progressively increased. More importantly, sharp increment of resistance was prominent in diamide insecticide, flubendiamide and chlorantraniliprole. A number of insecticides should be cautioned or avoided for spraying. In Tha Muang population (year 2008) was indoxacarb. In Tub Berg population (year 2009) was indoxacarb and tolfenpyrad. In Sai Noi population (year 2010-2011) was indoxacarb, chlorfenapyr, fipronil, tolfenpyrad, flubendiamide and chlorantraniliprole. Data from this toxicity monitoring was vital for selecting suitable insecticides, discarding adverse insecticides and designing IRM strategy in Thailand.

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References

Abbott WS. 1925. A method of computing the effectiveness of an insecticide. *J. Econ. Entomol.* 18: 256-267.

[APRD] Arthropod Pesticide Resistance Database. 2009. Arthropod pesticide resistance database. (http://www.pesticideresistance.org/).

Attique MNR, Khaliq A, Sayyed AH, 2006. Could resistance to insecticides in Plutella xylostella (Lep., Plutellidae) be overcome by insecticide mixtures? *J. Appl. Entomol.* 130: 122-127.

Finney DJ. 1971. Probit Analysis, third ed. Cambridge University Press, London.

Huang XY, Zhou XM, Bai LY. 2008. Monitoring the resistance of diamond back moth to 13 insecticides in Changsha. *Plant Prot.* 34: 146-148.

Li AG, Yang YH, Wu SW, Li C, Wu YD. 2006. Investigation of resistance mechanisms to fipronil in diamondback moth (Lepidoptera: Plutellidae). *J. Econ. Entomol.* 99: 914-919.

Liu T-X, Sparks AN, Chen W. 2003. Toxicity, persistence and efficacy of indoxacarb and two other insecticides on *Plutella xylostella* (Lepidoptera: Plutellidae) immatures in cabbage. *Int. J. Pest Manag.* 49: 235-241.

Mau, RFL, Gusukuma-Minuto L. 2001. Diamondback moth resistance to spinosad in Hawaii: confirmation,review of causal factors and establishment of a mitigation plan, pp. 75-80. In: Proceedings of 5th International Seminar on Technology of Cole Crops Production, 17-18 May 2001. University de Celaya, Celaya, Guanajuato, Mexico.

Ninsin KD, Mo J, Miyata T. 2000. Decreased susceptibilities of four field populations of the diamondback moth, Plutella xylostella (L.) (Lepidoptera: Yponomeutidae), to acetamiprid. *Appl. Entomol. Zool.* 35: 591–595.

McLeod P, Diaz FJ, Johnson DT. Toxicity, Persistence, and Efficacy of Spinosad, Chlorfenapyr, and Thiamethoxam on Eggplant When Applied Against the Eggplant Flea Beetle (Coleoptera: Chrysomelidae). 2002. *J. Econ. Entomol.* 95(2): 331-335.

Sarfraz M, Keddie BA. 2005. Conserving the efficacy of insecticides against *Plutella xylostella* (L.) (Lep., Plutellidae). *J. Appl. Entomol.* 129: 49-157.
Sarita N, Basweshwar S, Ghodki G, Lande K, Vrushali P, Atul ST, 2010. Inheritance of resistance and cross resistance pattern in indoxacarb-resistant diamondback moth Plutella xylostella L. *Entomol. Res.* 40: 18-25.
Shelton A M, Sances FV. Hawley J, Tang JD, Boune M, Jungers D, Collins H L, Farias J. 2000. Assessment of insecticide resistance after the outbreak of diamondback moth (Lepidoptera: Plutellidae) in California in 1997. *J. Econ. Entomol.* 93: 931-936.
Talekar, NS, Shelton AM. 1993. Biology, ecology and management of the diamondback moth. *Annu. Rev. Entomol.* 38: 275-302.
Wang X, Li X, Shen A, Wu Y. 2010. Baseline Susceptibility of the Diamondback Moth (Lepidoptera: Plutellidae) to Chlorantraniliprole in China. *J. Econ. Entomol.* 103(3): 843-848.
Zhao JZ, Collins HL, Li YX, Mau RF, Thompson GD, Hertlein M, Andaloro JT, Boykin R, Shelton AM. 2006. Monitoring of diamondback moth (Lepidoptera: Plutellidae) resistance to spinosad, indoxacarb and emamectin benzoate. *J. Econ. Entomol.* 99: 176-181.
Zhou L, Huang J, Xu H. 2010. Monitoring resistance of field populations of diamondback moth *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) to five insecticides in South China: A ten-year case study, *Crop Protection*, doi:10.1016/j.cropro.2010.10.006

TABLES

Table 1. Susceptibility to various insecticides of F1 generation *P. xylostella* collected from crucifer fields of Tha Muang district, Kanchana Buri in 2008; Tub Berg district, Petchabun in 2009 and Sai Noi district, Nonthaburi in 2010; Thailand

Insecticide	LC_{50} (95% FL) [1] [mg/liter]		
	Tha Muang	Tub Berg	Sai Noi
spinosad	8.70 (4.17-21.7)	1.70 (0.725-4.44)	1.79 (0.960-2.72)
indoxacarb	79.2 (27.5-377)	27.5 (7.76-141)	66.8 (39.1-103)
emamectin benzoate	5.63 (1.86-28.6)	1.16 (0.512-2.07)	1.51 (0.542-2.95)
chlorfenapyr	33.0 (10.3-198)	19.9 (6.14-59.5)	18.5 (3.71-37.4)
fipronil	8.40 (4.38-17.3)	3.46 (1.76-8.00)	1.15 (0.005-4.49)
tolfenpyrad	21.2 (7.85-85.1)	46.2 (23.8-93.9)	57.4 (31.7-109)
flubendiamide	0.246 (0.113-0.593)	0.160 (0.0366-0.811)	10.6 (3.84-22.8)
chlorantraniliprole	-	0.225 (0.0535-0.587)	7.97 (4.09-13.7)
Bt. aizawai	3.45 (1.83-6.41)	3.11 (1.62-6.36)	14.1 (7.09-26.8)
Bt. kurstaki	2.79 (1.28-6.68)	1.27 (0.337-5.17)	8.61 (4.27-19.0)

[1] at 48 hr. except for flubendiamide, chlorantraniliprole, *Bt. aizawai* and *Bt. kurstaki* at 72 hr.

Table 2. Toxicity ratio of various insecticide in F1 generation *P. xylostella* from Tha Muang district, Kanchana Buri; Tub Berg district, Petchabun and Sai Noi district, Nonthaburi; Thailand

Insecticide	The field recommended dose [mg/liter]	Toxicity ratio (TR) [1] of LC_{50} [mg/liter] as compared to the field recommended dose in each population		
		Tha Muang [2]	Tub Berg [3]	Sai Noi [4]
spinosad	240.0	27.6	141.2	134.1
indoxacarb	112.5	1.4	4.1	1.7
emamectin benzoate	19.2	3.4	16.6	12.7
chlorfenapyr	200.0	6.1	10.1	10.8
fipronil	150.0	17.9	43.4	130.4
tolfenpyrad	240.0	11.3	5.2	1.7
flubendiamide	60.0	243.9	375.0	5.7
chlorantraniliprole	75.0	-	333.3	9.4
Bt. aizawai	412.0	119.4	132.5	29.2
Bt. kurstaki	127.2	45.6	100.2	14.8

[1] Toxicity ratio = the field recommended dose / LC50 of each insecticide in each population
[2] Toxicity ratio of LC_{50} in 2008
[3] Toxicity ratio of LC_{50} in 2009
[4] Toxicity ratio of LC_{50} in 2010

Table 3. Susceptibility to various insecticides of F1 generation *P. xylostella* collected from crucifer fields of Sai Noi district, Nonthaburi, Thailand in June-August 2011

Insecticide	n [1]	Slope $\pm$ SE	LC_{50} (95%FL) [2] [mg/liter]	χ^2	df
spinosad	280	2.478$\pm$0.311	5.00 (2.03 - 8.75)	12.016	4
indoxacarb	280	1.600$\pm$0.213	64.1 (24.9 - 128)	10.036	4
emamectin benzoate	240	1.701$\pm$0.272	3.79 (2.14 - 7.73)	3.640	3
chlorfenapyr	280	1.373$\pm$0.146	46.8 (33.7 - 65.5)	1.252	4
fipronil	240	2.330$\pm$0.284	88.5 (51.4 - 169)	6.480	3
tolfenpyrad	320	1.850$\pm$0.183	792 (628 - 992)	4.116	5
flubendiamide	240	0.853$\pm$0.186	5,779 (2,878 – 24,946)	1.029	3
chlorantraniliprole	240	2.021$\pm$0.224	557 (304 - 926)	4.389	3
Bt. aizawai	280	1.267$\pm$0.207	35.8 (22.8 - 52.7)	0.896	4
Bt. kurstaki	200	1.621$\pm$0.283	6.26 (3.67 - 9.04)	1.140	2

[1] Number of larvae used in bioassay, including control

[2] at 48 hr. except for flubendiamide, chlorantraniliprole, *Bt. aizawai* and *Bt. kurstaki* at 72 hr.

Table 4. Change in toxicity ratio of various insecticides and resistance factor of F1 generation *P. xylostella* collected from crucifer fields of Sai Noi district, Nonthaburi, Thailand in 2010-2011

Insecticide	Toxicity ratio (TR) [1]		Resistance factor (RF) [2]	
	Year 2010	Year 2011	Year 2010	Year 2011
spinosad	134.1	48.0	1.1	2.9
indoxacarb	1.7	1.8	2.4	2.3
emamectin benzoate	12.7	5.1	1.3	3.3
chlorfenapyr	10.8	4.3	1.0	2.5
fipronil	130.4	1.7	1.0	77.0*
tolfenpyrad	1.7	0.3	2.7	37.4*
flubendiamide	5.7	0.01	66.3	36,116.9*
chlorantraniliprole	9.4	0.1	35.4	2,479.4*
Bt. aizawai	29.2	11.5	4.5	11.5
Bt. kurstaki	14.8	20.3	6.8	4.9

[1] Toxicity ratio = the field recommended dose / LC50 of each insecticide in each year

[2] Resistance factor = LC50 of each insecticide in each year / the lowest LC50 of each insecticide shown in Table 1

* asterisk indicates 95% fiducial limits of LC50 in year 2011 not overlapping with that in year 2010

Control of root gall disease in chili caused by root-knot nematodes

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ABSTRACT

Root gall disease in chili is caused by root-knot nematodes (*Meloidogyne incognita*). The disease can reduce chili yield and quality by 50-100%. Farm trials and technology transfer events were conducted in 2008-2010, in Ubon Ratchathani and Yasothorn provinces, in the lower northeast of Thailand. A participatory technology development research was carried out in order to test the root-knot nematodes control technology which had been approved from glasshouse experiment. The root-knot nematode control techniques were; burning the seedling bed with rice husk for 8 hours before seeding, plowing and sun dried the soil in planting area, planting sunnhemp (*Crotalaria juncea*) in the planting area and at 45-50 days after emergence (DAE), plowing sunnhemp and left them to be composed for 2 weeks before planting chili. The results showed that tested technology could effectively control the root-knot nematodes. At 120 days after planting (DAP), it was found that the average number of 2nd stage larvae in tested plots was increased only 22%, whereas that of control plots was increased up to 280%. The root gall index was observed at 0-2.4 in tested plots compared to 3.7-4.4 in control plots. This root-knot nematode control technology could significantly increase chili yields by 47-59 %, and the farmers obtained about 75-88% more profits. Apart of conducting the farm trials, this technology will be introduced to other chili plantations around Thailand.

Keywords

chili, root gall disease, root-knot nematodes

INTRODUCTION

In 2007, about 3,000 rais of chili grown in Ubon Ratchathani province were severely damaged by root gall disease which caused by root-knot nematodes (*Meloidogyne incognita*). The disease reduced chili yield by 50-100 %, and it was resulted in a reduction of farmers' incomes about 50-80 million baht per year. The nematodes grow well in sandy loam soil and can be spread out rapidly by irrigation, contaminating with machines and equipments, and infesting in seedlings. The infested plants were stunt as the root systems were destroyed, then will be dried and died. At seedling stage was reported as a critical stage (Shooprapawan et al. 2007). Maneekao et al. (2008) reported that in glasshouse condition, the effective control methods for this disease were; burning the seedling beds, or application of abamectin, or intercropping with sunnhemp (*Crotalaria juncea*). However, the last method could reduce the root gall disease up to 100 %. In order to solve the problem sustainably, participatory technology development (PTD) research was conducted in 2008-2010 in farmers' fields of Ubon Ratchathani and Yasothorn provinces, in the lower northeast of Thailand. In addition, technology transfer was subsequently carried out to the target groups.

MATERIALS AND METHODS

Farm trial

The farm trials were carried out based on participatory technology development (PTD) research program.

In 2008-2009, 6 farm trials were conducted in Nonglaow sub-district, Muangsamsib district, Ubon Ratchathani province. In 2010, 10 farm trials were conducted in Phothiyan sub-district, Patiew district, Yasothorn province. In 2008-2009, there were 2 replications in each farm trial, but in 2010 no replication was applied. Each farm trial, there were 2 treatments comparison i.e. control and tested technologies. The chili production practices of both technologies were as follows.

Control technology

Seed treatment: Chili seeds were soaked in warm water (50-55 °C) for 15-20 minutes. Then they were subsequently soaked in fresh Trichoderma solution for 1 night**.**

Seed bed preparation: Seed beds were burned with rice husk for 8 hours. The beds were applied with 50-100 kg/rai of lime and 1-2 kg/m^2 of *Trichoderma* mixed compost.

Seedling treatment: Seedlings (35-40 days after emergence) were soaked with fresh *Trichoderma* solution for 30 minutes before planting.

Planting method: Planting holes were prepared with 100 g of *Trichoderma* mixed compost per hole. Seedlings were grown at 50 x 50 cm in spacing.

Fertilizer application: Chicken manure was applied at 100 kg/rai, once a month. Chemical fertilizer grade 15-15-15 was applied 20 kg/rai at 15 and 30 DAP, then it was increased to 30 kg/rai, at 60 and 90 DAP. Fertilizer grade 13-13-21 was applied 30 kg/rai at 120 DAP, and then every month throughout the crop cycle. In addition, calcium nitrate was sprayed at 30 DAP, calcium boron was sprayed at 45 DAP and every month, later. Some farmers sprayed plant hormones and fish bio-extracts.

Pest control: Weed control was carried out by hand pulling. Integrated pest management; i.e. spraying pesticides, *Bacillus thuringiensis*, *Bacills subtilis*, and herbal bio-extracts were introduced to control the insects and diseases.

Harvesting: The crops were harvested in weekly interval from about 90 DAP up to 3-4 months after first harvest.

Tested technology

Chili production technologies in tested plot were the same as in control plot, except the root-knot nematode control techniques. The root-knot nematode control techniques were; plowing and sun dried the soil in planting area, broadcasting 5 kg/rai of sunnhemp seeds in the planting area. At 45-50 days after emergence, plowing sunnhemp and left them to be composed for 2 weeks before planting chili.

Two replications were imposed in each farm, in 2008-2009, in order to be compared statistically by t-test.

Numbers of 2nd stage larvae were randomly collected from a sample of 100 g soil, 5 spots from each plot. These were done 5 times at; before planting sunnhemp, before planting chili, 45 days after planting chili, 120 days after planting chili, and after harvesting chili.

Root gall index was observed and recorded according to Hussey and Jansen (2001) which was divided into 5 levels as shown in Figure 1.

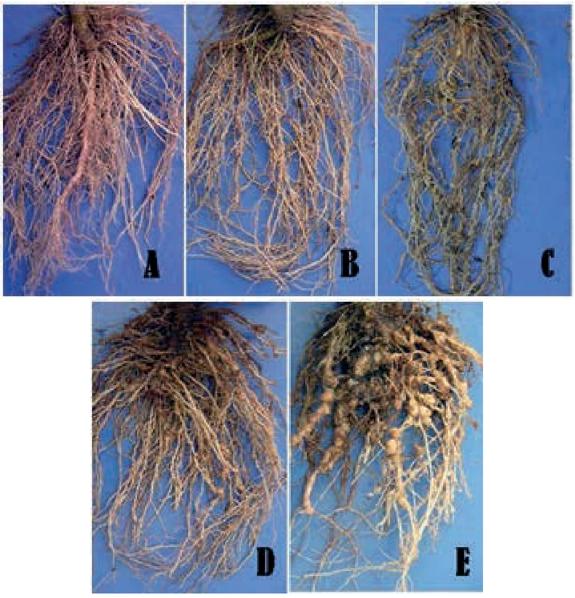

Figure 1. Root gall index (Hussey and Jansen 2001)

Level 1 (A) = no gall in root system
Level 2 (B) = gall < 25 % of root system
Level 3 (C) = gall 25-50 % of root system
Level 4 (D) = gall 51-75 % of root system
Level 5 (E) = gall > 75 % of root system

Means of harvesting times and fresh yields of chili were recorded. Cost, incomes, benefits and benefit cost ratio (BCR) were calculated. The data derived from 2-replicated farms were computerized and statistically compared by t-test. Other data were compared by mean.

Technology transfer

Technology transfer was carried out by training courses, farm visiting and field day event in the target areas.

RESULTS AND DISCUSSION

Farm trial

Number of Nematodes: In 2008-2009, it was found that average number of 2nd stage larvae in tested plot was raised from 18 at starting experiment, to 24 after harvest chili, whereas in control plot, it was significantly increased from 14 to 41 (Table 1). This was clearly observed in 2010, the number of 2nd stage larvae in tested plot was increased only from 14 at starting experiment, to 17 after harvest. On the other hands, it was remarkably increased from 10 to 38 in control plot (Table 3).

Root Gall Index: In 2008-2009, root gall index in tested plot was observed at 2.4 compared to 3.7 in control plot (Table 1). In 2010, the result was clearly demonstrated, root gall index in tested plot was not observed, whereas in control plot was found at 4.4 (Table 2).

Table 1. Number of 2nd stage larvae of *Meloidogyne incognita* (larvae/500 g soil) and root gall index in farmers' fields of Ubon Ratchathani province, 2008-2009 (means of 6 fields)

Periods	With Sunnhemp	Without Sunnhemp	t-test
Before planting sunnhemp	18	14	**
Before planting chili	13	20	**
45 DAP chili	17	27	**
120 DAP chili	22	27	**
After harvesting chili	24	41	**
Root gall index	2.4	3.7	**

These findings suggested that sunnhemp residues could subsidize growth of free-living nematodes which could compete or even kill root-knot nematodes (Wang and McSorle 2001). There was a research reported that in the soil with sunnhemp residues, there were the antagonist fungi; i.e. *Monocosporium ellipsospora* and *Arthrobotrys dactyloides*. These fungi produced momocrotaline substance which was toxic to root-knot nematodes when it reacted with mirosinase enzyme (Brown et al. 1991).

Yields: In 2008-2009, although, numbers of harvesting times of both technologies were equally (11 times), the average fresh yield in tested plot was 1,410 kg/rai, whereas, control plot was derived only 962 kg/rai (Table 3). In 2010, tested plot could be harvested for 20 times whereas control plot be harvested only 13 times. The average fresh yield in tested plot was 2,421 kg/rai, whereas, control plot was derived only 1,521 kg/rai (Table 4). The increase of crop yields in tested plot was due to the less number of nematodes and root gall index, and the effects of nutrients from sunnhemp residues (Phompanjai 2007).

Table 2. Number of 2nd stage larvae of *Meloidogyne incognita* (larvae/500 g soil) and root gall index in farmers' fields of Yasothorn province, 2010 (means of 10 fields)

Periods	With Sunnhemp	Without Sunnhemp
Before planting sunnhemp	14	10
Before planting chili	14	15
45 DAP chili	10	28
120 DAP chili	17	38
Root gall index	0	4.4

Table 3. Harvesting times, chili yields, cost, incomes, benefits and benefit cost ratio of farmers in Ubon Ratchathani province, 2008-2009 (means of 6 fields)

Characteristics	With Sunnhemp	Without Sunnhemp	t-test
Harvesting times	11	11	ns
Yields (kg/rai)	1,410	962	**
Cost (baht/rai)	18,714	18,394	ns
Incomes (baht/rai)	56,106	38,265	**
Benefits (baht/rai)	37,392	19,871	**
Benefit Cost Ratio	3.2	2.4	**

Economic Returns: In 2008-2009, production cost of both technologies were similarly (18,714 and 18,394 baht/rai), but the net profit of tested plot was about double of control plot (37,392 and 19,871 baht/rai) (Table 3). The same results were clearly found in 2010 (Table 4).

Table 4. Harvesting times, chili yields, cost, incomes, benefits and benefit cost ratio of farmers in Yasothorn province, 2010 (means of 10 fields)

Characteristics	With Sunnhemp	Without Sunnhemp
Harvesting times	20	13
Yields (kg/rai)	2,421	1,521
Quality yields (%)	92	85
Cost (baht/rai)	24,455	19,729
Incomes (baht/rai)	56,683	34,983
Benefits (baht/rai)	31,228	17,850
Benefit Cost Ratio	2.3	1.8

Technology transfer

Technology transfer was carried out by training courses, plot visiting and field day events in the target areas.

The training courses were conducted 4 times in Ubon Ratchathani and Sri Saket provinces with the total of 169 attendant farmers. The project was ended up with a deriving of 3 model farms in Muangsamsib district, Ubon Ratchathani province. There were farmers from the nearby areas and JIRCAS officers visited the model farms. In addition, a field day was conducted in Yasothorn province in 2009.

CONCLUSION

The root gall disease in chili which caused by root-knot nematodes (*Meloidogyne incognita*), could be effectively controlled by burning the seedling bed with rice husk for 8 hours before seeding, and planting sunnhemp (*Crotalaria juncea*) as green manure, then plow and left them to be decomposed for 2 weeks before planting chili. This method could reduce the number of nematodes up to 55%. The chili yields were increased 47-59%, and the farmers obtained 75-88% more profits. Therefore, this technology will be introduced to other chili plantations around Thailand.

References

Brown PD, Morra MJ, McCaffrey JP, Auld DL, Williams III L. 1991. Allelochemicals produced during glucosinolate degradation in soil. *Journal of Chemical Ecology* 17: 2021-2034.

Chompunit S. 2003. Plant Hormones and Nutrients in Bio-extracts. Published Paper No. 3/1993. Chemical Agricultural Research Group, Agricultural Production Sciences Research and Development Office, Department of Agriculture, Bangkok, Thailand.

Hussey RS, Jansen GJW. 2001. Root-knot nematodes: *Meloidogyne* species. pp. 43-70. In: Starr JL, Cook R Bridge J (ed.). Plant Resistance to Parasitic Nematodes. CABI Publishing, New York, USA.

Maneekao S, Tungjitsomkid N, Phompanjai P, Srisombat N, Srithongchai W, Worasatit N, Jansong N, Saithanu B, Nimkingrat T, Ketsakul S, Khamsha U. 2008. Test of cropping system for root-knot nematodes control in the lower northeast. In: The Progressing Report of Agricultural Research Project. Department of Agriculture, Bangkok, Thailand.

Phompanjai P. 2007. Chili production on market situation. *Plibai Newsletter* 10 (2): 11-12.

Shooprapawan Y, Saksirirat W, Hiransali A, Sanaumuang N. 2007. Survey, collection and evaluation the efficiency of soil borne fungus in the lower northeast for nematode control. *Kaen Kaset* 35 (1): 104-114.

Ubon Ratchathani Field Crops Research Center. 1998. Green Manure Cropping. 20 pp.

Wang KH. McSorley R. 2001. Multiple cropping systems for nematode management. *Phytopathology* 91: 145.

The control of tomato root knot nematode by *Jeevatu* based organic liquid manure

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ABSTRACT

Among a wide variety of crops, tomato has been one of the main off season vegetable crops of Nepal, but the root-knot nematode which infects plant roots, drains nutrients, leads to poor root and shoot growth, and causes a decline in the fruit quality and yield of crops is a major constraint to successful production. Worldwide, several practices have been designed to control nematodes effectively, yet no such practice is yet economically successful in controlling the pest. There has also been a challenge to find the best alternative to control root knot nematode in a sustainable, eco-friendly and cost effective way. In today's literature, analysis of published data, experiments and observations have shown that firstly, it is reported as almost impossible to control root knot nematode properly by any means in developing countries. Secondly, it is not possible to manage once the root knot nematode is firmly established in the field. Thirdly, none of the commercially available bio-control agents have been found to be highly effective against root knot nematodes.

However the present study revealed that *Jeevatu* based organic liquid manure is an eco-friendly, cost effective technology to control root-knot nematode problems in tomato. The use of *Jeevatu* based organic liquid manure has managed to control root-knot nematodes and other pest problems along with bringing vigorous plant growth and development. Several experiments have reported that a wide range of pest problems have been successful managed by using *Jeevatu* in several crops like club root in cole crops, late & early blight of tomato & potato, soft rot of ginger, insect pests, etc. *Jeevatu* based organic liquid manure has been found to be eco-friendly, increases soil organic matter thus sequesters carbon dioxide, mitigating the adverse effect of global warming. Yet, further investigations are now needed to develop and disseminate sustainable eco-friendly technologies to achieve crop productivity and dependable agro-ecosytem services in other parts of the world.

Keywords: *Jeevatu*, root-knot nematode, tomato

INTRODUCTION

Plant parasitic root-knot nematodes belong to *Meloidogyne spp.* It is estimated that, the infection of root knot nematode causes about 5% yield loss in various crops worldwide (Wikipedia 2011). Root-knot nematode larvae infect plant roots, drain nutrients, causing poor root and shoot growth, and ultimately reduce quality and yield of crops (Noling 2009; Perry 2010; Wikipedia 2011). It also accelerates the onset of *Fusarium* wilt disease significantly in certain circumstances (Noling 2009).

Recently, tomato has become one of the main off season vegetable crops of Nepal. Many local farmers, particularly living in the vicinity to Kathmandu valley are cultivating one of the first off season tomato hybrid from Nepal called *Srijana* inside plastic houses. *Srijana* is cultivated during the rainy season April/May and lasts for 7 to 8 months. *Srijana* is one of the popular varieties of tomato because it is tolerant to bacterial wilt, to the high temperature of the mid hills, has long fruiting duration and is suitable for growth in plastic houses. Due to the long crop growth duration, under the plastic, the infection of root knot nematode starts in the first year. Further this problem becomes more exaggerated due to cultivation of the tomato during the summer/rainy season inside the same plastic house for many years without proper rotation.

Worldwide, several attempts have been made to control root knot nematodes effectively. However not a single chemical based technology has been found effective to control it without severely toxic environmental measures being taken. Ultimately, it has forced the scientists to find the best technology to control root knot nematode in environmentally friendly ways.

Jeevatu™ is a trade name of a mixed culture of naturally occurring beneficial microorganisms in the form of concentrated liquid suspension. *Jeevatu* has been developed by the Nepalese Farming Institute (NFI) over the course of more than 30 years of research and development. It contains useful microbes such as lactic acid bacteria, *Azotobacter* spp., *Trichoderma* spp., phosphorus solubilizing bacteria, potash solubilizing bacteria, photosynthetic bacteria, yeast, etc. *Jeevatu* is being commercially produced by Nepalese Natural Bio-products and used in SAARC countries for pesticide residue free agro-products and vegetables. Several experiments have been conducted to control a wide range of pest problems by using *Jeevatu* in several crops like club root of cole crops, late and early blight of tomato, damping off of seedlings, rhizome rot of ginger, various insect pests, etc. (Paudel and Poudel 2010; Poudyal 2011).

The present study was conducted at the Central Vegetable Seed Production Centre, Khumaltar, Lalitpur, Nepal to control root-knot Nematode on female parent line (HRD 17) of hybrid tomato *Srijana* by using *Jeevatu* based organic liquid manure.

MATERIALS AND METHOD

Preparation of Jeevatu based organic liquid manure

Jeevatu based organic liquid manure was prepared during the third week of April 2010. A white 500 gauge thick plastic bag (1.25 x 1 square meters) was placed inside a circular pit having 61 cm diameter and 30 cm depth. The circular pits were made in a sunny and well protected place. Ordinary compost 25 kg, non-chlorinated water 50 liter and 1 liter of *Jeevatu* was kept in the plastic bag and mixed thoroughly to make a *Jeevatu*-based organic liquid manure. The decoction was stirred thoroughly twice a week for two weeks and the *Jeevatu* based organic liquid manure was maintained for six months. Altogether 10 bags of *Jeevatu* based organic liquid manure were prepared and for use in this experiment and other superimposed studies.

Soil fumigation

Soil fumigation was done 15 days before transplanting of seedlings by drenching the mixture (50 liters of solution in 16.2 square meters) containing 1 liter of formaldehyde and 9 liter water on well pulverized soil. The mixture of formaldehyde was drenched onto the soil bed thoroughly using a watering can. Immediately after drenching, the soil bed was covered by polythene sheeting to make the bed airtight for proper fumigation for 72 hours. The soil was uncovered after 72 hours and left as such for another 3 days to remove the gas and the toxic effects of the formaldehyde. Before the transplanting of tomato seedlings, the soil was again tilled properly to ensure proper aeration for another 7 days.

Planting material

Initially 225 gm ash, 1 kg DAP, 0.5 kg MOP, 200 gm Biozyme, 100 gm Zinc Power (a mixture of micro nutrients) were thoroughly mixed. Twenty five grams of that mixture (fertilizers and micro-nutrients) and 1 kg of well decomposed compost were applied in each pit 3 days before transplanting the female parent line (HRD-17) of *Sirjana* hybrid tomato. Compost and fertilizers were applied in all treatments uniformly and seedlings were planted on May 28, 2010.

Application of liquid manure

Drenching of the diluted decoction of *Jeevatu* based organic liquid manure was started 10 days after transplanting of seedlings. Application of diluted decoction of *Jeevatu* based organic liquid manure was done twice a week and continued for 4 months (total 32 drenchings).

Treatments and replications

Treatment 1 (T-1): Drenching of solution containing one part of formaldehyde with 9 parts of water (before transplanting).

Treatment 2 (T-2): Drenching of the decoction twice a week containing one part *Jeevatu* based organic liquid manure with 3 parts water.

Treatment 3 (T-3): For control drenching only normal water twice a week.

T-1, T-2 and T-3 were tested and compared to elucidate the role of *Jeevatu* based organic liquid manure in the management of root-knot nematode of tomato.

Nine replications of each treatment were made with 9 plants in each replication. With 3 plants (spaced 6 x 1.2 meter apart) in each treatment, altogether 81 tomato seedlings were planted in this experiment. All the treatments and replications were arranged in rows.

Statistical analysis

The results were very apparent and did not require statistical tools to determine the outcomes. The results of different treatments were compared with each other.

RESULT AND DISCUSSION

Plant growth

Normal plant growth was observed during the initial stage in all treatments and there were no visible symptoms of nematode infection up to two months after planting.

Nematode infection

Two months later in July, after the transplanting of the seedlings, infection of root-knot nematode was found in the control plot (T-3) and 3 months later in the formaldehyde treated plot (T-1). Initially small knots were observed in the roots just below the ground level and their size increased with time (Fig. 1).

Effect of Jeevatu on root-knot nematode control

As in other crops, the use of *Jeevatu* based organic liquid manure played a vital role in root-knot nematode control in tomatoes. All 27 plants of the control treatment (T-3) were found to be infected by nematodes with big knots in the root as in figure 1. Likewise, all 27 plants cultivated on the chemically treated soil (1 part formaldehyde with 9 part water, i.e. T-1) were also found to be infected by nematodes, however the knots were observed 3 months after transplanting in this treatment. Knots were also found to be smaller as compared with the control plot by visual observation as in figure 2 below. On the other hand, in T-2 (3 parts water with 1 part *Jeevatu* based organic liquid manure) treatment, no plant was found infected by root-knot nematode. In this treatment, all 27 plants were completely free from root-knot nematode infection. After continuous soil drenching by *Jeevatu* based organic liquid manure for 4 months (32 times of drenching 2 times a week), no further infections were observed even after stopping the drenching treatment.

Figure 1. Infestation of root-knot nematode.


Figure 2. Smaller size root-knot in treatment 1.


Figure 3. Control of root-knot nematode by *Jeevatu* based organic liquid manure.


Figure 4. Plastic shed where experiment was conducted.

Pre-planting protection measures like crop rotation, cultivation of resistant varieties, cultural tillage practices, cultivation of clean seedlings; fallowing of land, use of chemical nematicide, etc were suggested by many workers to control nematode infection in several crops (Noling 2009; Perry 2010; Richard, et al. [date unknown]; Vann et al. [date unknown]; Wikipedia 2011). But in practice, it is almost impossible to control nematodes properly by using chemicals alone or by other methods particularly in developing countries like Nepal. No one has provided a single measure solution to control root-knot nematode effectively, till now. Moreover, use of toxic chemicals to control the nematode is not only unfriendly to the environment but also unsustainable in many developing-country contexts.

According to Noling (2009), post-plant curative measures were not available to rectify nematode problems and it is not possible to control the pest completely once the nematode becomes established in the field. Clean fallowing of land for many years was also suggested by many scientists but it is also impossible in our conditions, particularly for off season tomato production in plastic houses. Generally ordinary plastic houses made of local materials can be used for cultivation of rainy season tomato for 4 years with simple maintenance each year. In Nepal high value crops like hybrid tomato are cultivated in such plastic houses during the rainy season to protect the crop from heavy rain damage. Several tomato hybrids including *Srijana* and N-162 can be harvested for about 7 to 8 months continuously in the mid hills of Nepal. Due to farming in plastic houses for many years continuously and the long period of production of the above mentioned cultivars, the infection of root knot nematodes is being accelerated.

Several biological control agents or organic compounds are made available in the market but according to Vann et al. (date unknown) very little reliable research data is available. Similarly, according to Widmer et al. (date unknown); none of the commercially available formulations of biological agents have been found to be highly effective against root knot nematodes.

In contrary to these statements, *Jeevatu* based organic liquid manure has been found to be very effective in controlling root-knot nematode in tomato. Further investigation and research in this regard is recommended to develop eco-friendly technologies in various crops, in the coming years worldwide.

Field trials carried out by NFI and *Purbanchal* University, Nepal in the past has shown encouraging results. *Jeevatu* based technology is capable of significantly improving soil fertility & controlling pest problems. Studies done by the Soil Science Division and the Horticulture Research Division, Nepal Agriculture Research Council on tomato crops at *Sharda Batase*-1of *Kavre* (hill) district suggest the average increase in soil fertility in terms of organic matter percentage, nitrogen percentage, available phosphorous kg/ha and available potash kg/ha were 1.25, .062, 150.83 and 602.5 respectively after the harvest of tomato 143 t/ha (Annual Report 2008/2009). During the growth of the fruit of tomato, calcium deficiency was observed in all experimental plots which was successfully managed by the drenching of *Jeevatu* based organic liquid manure, two times a week, in 1:4 ratios (one part *Jeevatu* based organic liquid manure and four parts of water). The result reveals that organic liquid manure can also supply the micronutrients needed by the crops. Further, it has been noted that the tomato produced by the use of such eco-friendly technologies, can be kept at room temperature for 3-4 weeks in Kathmandu. Similarly the club root of cabbage was successfully managed by the use of Jeevatu at Sanothimi of Bhaktapur district (Poudel 2008). According to a leaflet provided by the NFI *Jeevatu* based technology has managed *Fusarium* spp., *Pythium* spp., *Septoria* spp., *Rhizoctonia species*, *Sclerotium rolfsii*, *Phytophthora infestans*, *Alterneria solani*, *Plasmodiophora brassicae*, *Colletotrichum lindemuthianum*, *Verticillium* spp., *Erysiphe cichoracearum*; root knot nematode, Tomato Yellow Leaf Curl Virus, Cucumis Mosaic Virus and insect pest in the tomato, beans, cole crops cucurbitaceous crops on experimental plots.

Saffron (*Crocus sativus*) corm rot is a great threat to the saffron industry particularly in India (Jammu & Kashmir). Fungal pathogens such as *Fusarium* spp., *Penicillium* spp., *Rhizoctonia* spp. and *Athelia rolfsii* (previously *Sclerotium rolfsii*) have been reported from corm rot affected saffron crops. Longer planting cycles and replanting of unsorted corms are considered the main reason for increased corm rot incidence. Disease management includes cultural measures and corm treatment with fungicides (Anonymous 2008). Saffron corms in large amounts were introduced in Nepal during 1972 from Jammu & Kashmir. The saffron corms were planted at *Ghuguti* of *Jumla* district of Nepal of which not a single corm gave flower and the whole plot was destroyed by corm rot. Later during the mid-1990's the NFI had used *Jeevatu* to control the corm rot of saffron and successfully developed and disseminated an organic package of practices for saffron cultivation (NFI 2009). The package of practices on Himalayan medicinal plants viz. Jatamansi (Spikenard, *Nardostachys grandiflora DC, syn. Nardostaschys Jatamansi DC*), Kutki (Gentain, *Picrorrhiza Kurrooa* Royle ex Benth) and Panch Aunle (Salep, *Dactylorhiza hatagirea*) was developed by managing powdery mildew, white grubs and other pest problems with the use of *Jeevatu* (NFI 2011).

Many devastating pathogens of various crops fall within the same families of the above cited pathogens and a technology which can control problems in one member (Genus) of a particular family can often control them in the other members (Genus) of the same family. It therefore suggests sufficient evidence that *Jeevatu* based technology could control all the pest problems of cereals, pulses, vegetable crops, fruit crops and medicinal plants.

Global warming poses a big threat to the world. The extensive use of chemical fertilizers and pesticides, the expansion of the meat industry and the destruction of the forests to grow agricultural commodities are responsible for almost one third of the greenhouse gases that are causing global climate change. Similarly given the amount of fossil-fuel energy used to transport commodities around the world, to process them, to freeze them and then finally to package and to distribute the final products to super markets; the food industry's role in creating the crisis increases significantly. Further, the consequences of having used hazardous chemicals in farming for quite a long time has reduced agricultural yields, decreased the shelf life of fruits and vegetables, lessened the natural taste of our agricultural products and exaggerated many human diseases. The use of chemicals in farming is therefore also responsible for imbalance in the whole natural ecosystem. (http://database.healthandenvironment.org)

Thus chemical use has undermined soil fertility, exaggerated pest problems as well as immensely increased the cost of cultivation while productivity has remained stagnant. Agriculture is thus increasingly becoming unaffordable with rising input costs and diminishing outputs. Besides these, the overuse chemicals in agriculture practices has had a detrimental effect in overall eco-system services, bio-diversity and human health. Farming with the use of chemical based inputs has thus become unsustainable in the SAARC region.

The use of chemicals in farming prevents the activities of beneficial microbes in the soil. In natural conditions, the soil contains microorganisms; the beneficial ones aid plant growth and protect plants while the harmful ones destroy the crop. Once the function of beneficial microbes ceases, plants become fully dependent on chemicals for nutrition and protection while also making them prone to pest problems resulting in unsustainable farming system.

On the other hand, use of commercial bio-agents (in eco-friendly or organic farming) having limited functions, have raised the cost of cultivation resulting in high prices for organic products which have become out of the price reach of the majority of people in the SAARC region. Similarly the use of botanical pesticides is not dependable due to a number of factors, *viz.* 1) limited types botanical pesticides are available in concentrate form; 2) knowledge of botanical pesticides has yet to be explored for the control of many pest problems; 3) collection, preparation and use of botanical pesticides in commercial farming is difficult. This clearly indicates that there is an urgent need to develop/disseminate sustainable technology to reduce the cost of cultivation of such eco-friendly or organic farming, at least to be not more than the cost of chemical based farming.

Successful field level experiments have shown that the microbial based technologies are capable of increasing soil organic matter to one percent, sequestering carbon dioxide, which results in a significant improvement of soil fertility, control of the pest problems and increases crop productivity.

NFI has used *Jeevatu* to control the pest problems in many crops and helped reduce input costs of agriculture significantly. The plant protection cost in one hectare of land with the use of chemicals on an average is in Indian currency Rs. 100,000 to 150,000. This tends to increase every year. However, with *Jeevatu* based interventions, the plant protection cost comes down to Indian currency Rs. 38,025/hectare/year that is almost one-fourth to one-third of the above cost (Paudel and Poudel 2010).

Following the fourteenth (2007), fifteenth (2008) and sixteenth (2010) declarations a multi-stakeholder dialogue of SAARC was held in Dhaka (10 October 2010) with an extensive discussion on the theme 'Management of Soil/Land towards Sustainable Agriculture in South Asia'. The multi-stakeholder dialogue noted the sustainable eco-friendly and cost-effective concept based on *Jeevatu* introduced by Nepal. Pursuant to the multi-stake holder dialogue and sixth meeting of the technical committee on agriculture and rural development (*Dhaka, 10-12 October 2010*), the Government of Nepal convened a regional workshop with an expert group on "Up-scaling of sustainable eco-friendly farming technology focused on beneficial microbes (*Jeevatu*) in the SAARC region" in Nepal, *Dhulikhel* 5-6 July 2011 to discuss and develop the project further. The regional workshop was attended by delegates from SAARC countries. The delegates from member states made a field trip to *Sharda Batase* village of *Kavre* district (30 km from Kathmandu). One hundred and twenty four (124) households have adopted the *Jeevatu* based farming technology for plant protection and plant nutrition in the village alone. In the recent past the village had extensively used chemical fertilizers, pesticides and was facing their negative effects.

The expert group has fully agreed and approved the core strength of *Jeevatu*-based technologies that makes agriculture sustainable, eco-friendly and self-reliant. At the expert group meeting several papers were presented on the use and rationale of using *Jeevatu* based technologies Gautam (2011) and other scientists highlighted the scientific rationale behind *Jeevatu's* efficacy.

Higa (1991) notes there is a greater likelihood of controlling soil microflora by introducing mixed, compatible cultures rather than single pure cultures. This provides us a very strong scientific rationale to explain why *Jeevatu* is so successful. Since *Jeevatu* is not a pure culture and it contains a mixed culture of beneficial microorganisms *Jeevatu* is more efficacious than other similar commercial products available in the market.

It is known that certain fungal species provide protection against plant pathogens through the induction of jasmonic acid, salicylic acid, etc. For example, the fungus *Trichoderma* spp. helps maize against the fungal pathogen *Colletotrichum graminicola. Trichoderma* secretes a highly effective hydrophobin-like elicitor that induces systemic disease resistance in maize (Gautam 2011). Gautam (2011) further explain that, during the fermentative production of the mixed culture suspension of *Jeevatu*, microorganisms secrete different metabolites that act as elicitors and later induce defense mechanisms once applied in the field. Likewise, *Jeevatu* may produce compounds antagonistic to other soil microbes and microbes of *Jeevatu* may compete in space and nutrition, etc. However, the biochemical mechanisms and pathways by which it protects plants are not fully understood.

The main precautionary factor in effectively getting results through this microbial based intervention is to ensure that contamination with chemical pesticides doesn't happen. One should not mix or contaminate (by any means) *Jeevatu* with any types of chemical pesticide. With such contamination, the beneficial microbes of *Jeevat*u will die, and then *Jeevatu* cannot work so every care should be taken to avoid such contamination. It is therefore appropriate that sprayers used to spray chemical pesticides should not be used to spray *Jeevatu or Jeevatu* based organic liquid manure.

CONCLUSION

Extensive use of chemical pesticides and fertilizers in agriculture are not only polluting the environment but also accelerating climate change and global warming to some extent. Yet, it is still very difficult to manage pests of crops in eco-friendly ways. To solve this problem, Nepalese scientists have developed a package of beneficial microbes—*Jeevatu*. It is one of the best bio-agents to control root knot nematode of tomato and to control several diseases and insect pests in various crops. *Jeevatu* is also very useful being low cost, sustainable and appropriate for eco-friendly farming and hence such technology needs to be replicated in many crops worldwide.

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References

Anonymous 2008. Corm Rot, Saffron - India: (Jammu and Kashmir), Update Source: The Daily Rising Kashmir [edited]. Archive Number 20081114.3584. Published Date 14-11-2008.

Gautam R. 2011. Modes of Action of Jeevatu for Plant Protection and Nutrition. Up-scaling of Sustainable Eco-friendly Farming Technology Focused on Beneficial Microbes (Jeevatu) in SAARC Region.

Higa T. 1991. Effective microorganisms: A biotechnology for mankind. p.8-14. In J.F. Parr, S.B. Hornick, and C.E. Whitman (ed.) Proceedings of the First International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C., USA.

NFI (2009): Organic Package of Practices in "Seminar on High Value Low Volume Cash Crops on Saffron. A paper presented for Income Generation in Karnali Zone" held on November 30, 2009 at Hotel Himalaya, Lalitpur.

NFI 2011. Organic Package of Practices in "Seminar on Medicinal plants. A paper presented for Income Generation in Karnali Zone, held on January, 2011 at Hotel Himalaya, Lalitpur, Nepal.

Noling JW. 2009. Nematode Management in Tomatoes, Peppers and Eggplant. University of Florida, IFAS Extension. http://edis.ifas.ufl.edu/ng032.

Paudel K.B and Poudel A (2010): Pesticide Residue Free Commercial Vegetable Production Technology (pp 58-73). In: Improved Agriculture Technology Packaging in Nepali (2066/67) Published by, Agriculture Extension Directorate Department of Agriculture, Harihar Bhawan, Lalitpur, Nepal.

Perry EJ. 2010. How to manage pests, pests in gardens and landscapes. University of California, Davis, CA 95616. http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7489.html

Poudel A 2008. "Club Root Management on Bhaktapur District." A Mini-Thesis Submitted to Purbanchal University Faculty of Science and Technology, Himalayan College of Agricultural Sciences and Technology (HICAST) Kathmandu, Nepal. In Partial Fulfillment of the Requirements for the degree of Bachelor of Science (Honours) in Agriculture (Plant Pathology), 2008.

Poudyal BK. 2011. The control of Soft Rot of Ginger by Jeevatu Based Organic Liquid Manure. Up-scaling of Sustainable Eco-friendly Farming Technology Focused on Beneficial Microbes (*Jeevatu*) in SAARC Region.

Richard MR. Sally AM. Randall CR. (date unknown). The Ohio State University, Extension. HYG-3115-96 . http://ohioline.osu.edu/hyg-fact/3000 /3115.html

SAARC. 2007. Fourteenth SAARC summit declaration, New Delhi, 2007.

SAARC. 2008. Fifteenth SAARC summit declaration. Colombo, 2008: Colombo Statement on Food Security.

SAARC. 2010. Sixteenth SAARC Summit Declaration (Thimphu, 2010): World Bank: "India Country Overview 2010.

Soil Science Division. Nepal Agriculture Research Council Annual report 2008/2009.

Vann S, Kirkpatrick TL, Cartwright R. (date unknown). Control root-knot nematodes in your garden. University of Arkansas. http://www.uaex.edu/Other_Areas/publications/PDF/FSA-7529.pdf

Widmer TL. Ludwig JW. and Abawi GS. (date unknown). The Northern Root-Knot Nematode on Carrot, Lettuce, and Onion in New York. http://vegetablemdonline.ppath.cornell.edu/ factsheets/ RootKnotNematode.htm

Wikipedia.2011.http://en.wikipedia.org/wiki/Root-knot_nematode

http://database.healthandenvironment.org

http://www.healthy.net/library/newsletters/Update/swisspesticides.htm

ANNEX

Treatments and Replications

- Total number of treatment (3)
- Total number of replication (9)
- Number of plants in each treatment (3)
- Number of plants in each replication (9)
- Total number of plants in all replications and treatments (81)

T-1 = 1 part Jeevatu based liquid manure with 3 parts water
T-2 = 1 part formaldehyde with 9 parts water
T-3 = control, ordinary water

		Treatments		
		1	2	3
Replications	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			

Comparison of cultivation systems for Asian leafy vegetables and herbs in greenhouse

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ABSTRACT
Most of the Asian leafy vegetables and herbs have culinary, nutritional and medicinal importance but intensive cultivation systems are rarely investigated. There are different possibilities to cultivate leafy vegetables and herbs in greenhouses using hydroponics as substrate-culture and aeroponics, but there are discussions regarding the influence on the quality of the plants. In different experiments, clones of water spinach (*Ipomoea aquatica*) and Asian herbs of the family Lamiaceae were cultivated: Thai Basil (*Ocimum basilicum*), Holy Basil (*Ocimum sanctum*), Perilla or Beefsteak Plant (*Perilla frutescens*) and Vietnamese Balm (*Elsholtzia ciliata*). The aim of these experiments was to find the most suitable cultivation system for these special vegetable and herbs regarding harvestable biomass production and nutritional value. Leaf area and number of shoots as well as the biomass production were investigated over three to four harvest periods. The nitrate, vitamin C, carotin and essential oil content were determined to evaluate the nutritional value. Water spinach and the herbs could be harvested after two to four weeks. In total between 3 and 4 harvests were possible in substrate-culture and aeroponics as well but with higher yield in substrate-culture. In aeroponics, the biomass production was dependent on the plant densities investigated. Visually, the quality of all plants was better in case of 20 x 20 cm plant density in cultivation than at 10 x 10 cm plant density. The highest yield was obtained for the highest density with 100 plants per m². It was proved that length of the stems and the leaf area were influenced by plant's density. The vitamin C content was highest in all herbs cultivated in aeroponics whereas the essential content oil was highest in Holy Basil and Perilla cultivated in substrate. Also the carotin content in water spinach was the highest in substrate-culture.

Keywords
Cultivation systems, medicinal and aromatic herbs, quality assessment, essential oil

INTRODUCTION
The quantity of fresh consumed herbs is increasing in Germany. In this respect a rising interest exists to use also exotic especially Asian vegetables and herbs in restaurants and at home too. Many of Asian leafy vegetables and herbs have culinary and medicinal importance as well. Leafy vegetables and herb are also from high importance as source of vitamins, minerals and bioactive compounds in the daily diet in the Asian regions (Böhme and Pinker 2007). For market supply production of high quality crops the year round is required. There are different possibilities to cultivate leafy vegetables and herbs in greenhouses using hydroponics as substrate-culture and aeroponics (Böhme and Pinker 2007). The cultivation system may influence the product quality (Guadagnin et al. 2005, Rouphael and Colla 2005, Lenhard and Leonhard 2006) and the yield as well. Substrate-culture, nutrient-film-technique and aeroponics are available. For all cultivation systems plant density, frequency of harvesting, composition of the nutrient solution and their EC and pH value influence the yield and the content of minerals, vitamins and essential oil (Takano and Yamamoto 1996; Smith et al. 1997; Teixeira et al. 2002; Miceli et al. 2003). The cultivation of herbs aeroponic system guarantees a high cleanness enables fast reaction by nutrient solution changing and comfortable handling of the crops; however, because of its low buffering capacity problems in water supply and fertilization act

much stronger than in substrate-culture. Therefore, these studies aimed to compare cultivation systems for leafy vegetable and herbs regarding harvestable biomass production and nutritional value of the plants. Own experiments indicated that aeroponics and substrate-culture can be used for cultivation of water spinach (Hoang and Böhme 2001; Pinker et al. 2004; Pinker et al. 2007; Cofalka 2011).

For these studies water spinach (*Ipomoea aquatica Forssk*) and four Asian herbs as Thai Basil (*Ocimum basilicum L.*), Holy Basil (*Ocimum sanctum* L.), Perilla or Beefsteak Plant (*Perilla frutescens* (L.) Britton) and Vietnamese Balm (*Elsholtzia ciliata* (Thunb.) Hyl) were selected because of their high market potential.

RESEARCH METHODS

Plant material

Three clones of *Ipomoea aquatica* were used in these experiments. These clones with the numbers 209, 214, and 216 had shown the highest yield and stability in the former experiments (Pinker et al. 2004; Pinker et al. 2007). For rooting of the cuttings perlite was used. After the first three weeks 10 plants per clone of the *Ipomoea aquatica* were harvested in two-week-intervals and evaluated separately.

The herbs - Thai Basil (*Ocimum basilicum*), Holy Basil (*Ocimum sanctum*), Perilla (*Perilla frutescens*) and Vietnamese Balm (*Elsholtzia ciliata*) - were propagated by seeds. Mainly seeds from the Vietnamese state seed company were used. Holy Basil was provided by the German seed company Rühlemanns. The herbs were harvested between three to four times.

Substrate culture

For the experiment in substrate culture peat mix was used in pots with 14cm diameter. The pots were placed on tables with a density off 33 plants per m². The pots were watered by dam up of the tables or by trickle irrigation. The basic composition of the nutrient solution was N (130 ppm), P (50), K (225), Ca (120), Mg (60), Fe (3), HCO_3 (90). The EC-value was adjusted with 1.7 mS cm^{-1} and the pH-value was about 6.5.

Aeroponics

In aeroponics the plants in the rockwool cubes were placed in styradur sheets with holes of 4cm diameter. The nutrient solution was sprayed every 300 seconds for 60 seconds. In aeroponics the density of the plants was different: in case of water spinach 33 plants per m², Thai Basil 50 and 200 plants m², Holy Basil density 100 plants m², Perilla 25 and 100 plants m² and Vietnamese Balm 100 plants m². The same nutrient solution as for substrate-culture was used. The EC-value was adjusted with about 2.0 mS cm^{-1} and the pH-value 5.7.

Evaluation

The yield was recorded as fresh and dry matter production after each harvest for both cultivation systems. The internal quality was evaluated regarding the content of the minerals as potassium, calcium, magnesium, phosphor and the nitrate content in mixed samples of three harvests. Chlorophyll and carotene content was estimated spectrophotometrically in 80% acetone from six leaf samples collected randomized distributed from each clone. Vitamin C content was analysed by titration method from three repetitions. The content of essential oil of herbs was analysed by distillation.

Statistics

Results were analysed using ANOVA (SPSS) with variance analysis and mean comparison with Tukey-test or Kruskall-Wallis test. Frequencies were compared with Chi-square-test. Significant differences are indicated by different letters in the figures.

RESULTS AND DISCUSSION

Ipomoea aquatica

The *Ipomoea aquatica* plants were harvested in the two cultivation systems at the same time. In this experiment, the fresh matter of water spinach in aeroponics was significantly lower in comparison to substrate-culture for clone 216—the most productive clone of all clones in all harvests (Fig. 1), although there were significant differences between the harvests. The less productive clones 209 and 214 had also differences between aeroponics and substrate-culture, however significant higher yield in substrate-culture could be only proved in the first harvest.

The differences in fresh matter yield of the three clones were in line with former results using Nutrient-Film-Technique (Pinker et al. 2004). Maybe in substrate-culture the yield potential can be better realized than in aeroponics.

For the quality of leafy vegetables the nitrate content is very important. New EU regulations indicate maximum thresholds for the amount of nitrate in one kg fresh vegetables. For example, these values are in the range of 4000 to 5000 mg nitrate per one kg fresh lettuce cultivated in greenhouse (Food Standard Agency 2011). The nitrate content in water spinach measured in the fresh matter in all variants was lower than this accepted threshold and it was not significantly different between the treatments. Although nitrate contents in the clones 209 and 214 cultivated in aeroponics were higher than in substrate culture, whereas for clone 216 the nitrate content in aeroponics (3920 mg per kg FM) was similar to substrate-culture (3457 mg per kg FM) (Fig. 2).

Regarding the mineral content, in all three clones the content of K, Mg and P was higher in aeroponics than in substrate-culture. The highest difference was detected for the Mg content. The differences in the content of calcium and phosphorus were not significant between the treatments (Table 1).

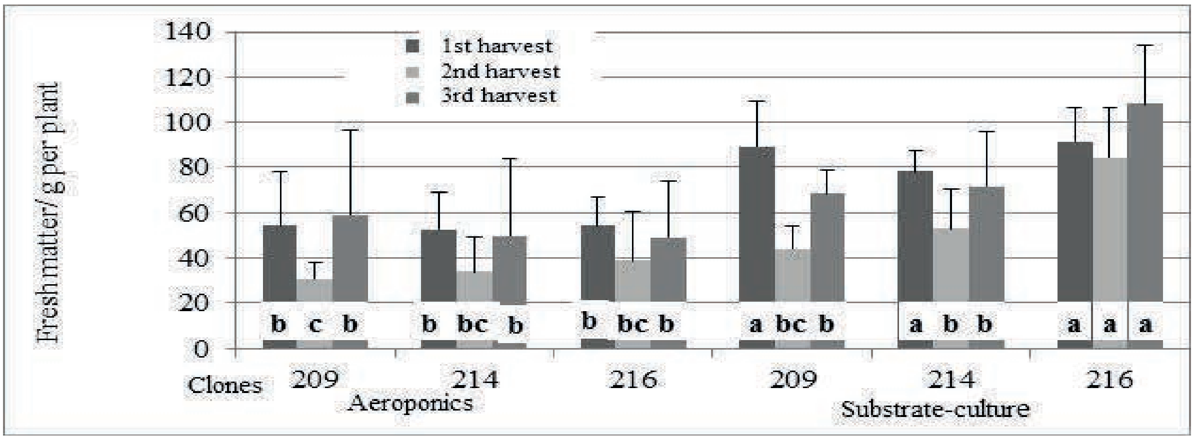

Figure 1. Fresh matter yield of three clones of *Ipomoea aquatica* of three subsequent harvests in aeroponics and in substrate-culture. Different letters indicate significant differences (Tukey-test, P<0.05).

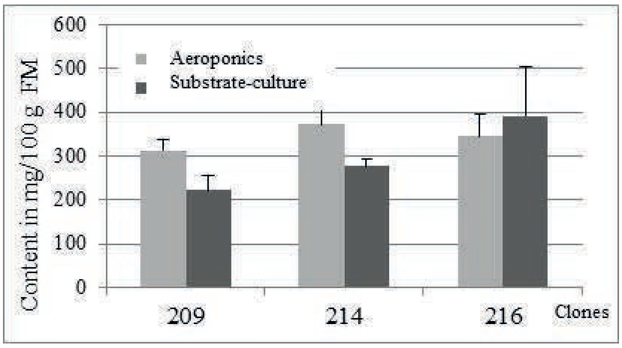

Figure 2. Nitrate content of three clones of *Ipomoea aquatica*, cultivated in aeroponics and in substrate-culture (Kruskall-Wallis test α ≤ 5 %)

The potassium content in all treatments was higher than described in the literature (Howard et al. 1962; Cornelius et al. 1985). It seems the water spinach is in the group of vegetables with highest content of potassium. determined for the less fast growing clones 209 and 214 in substrate-culture (Fig. 3).

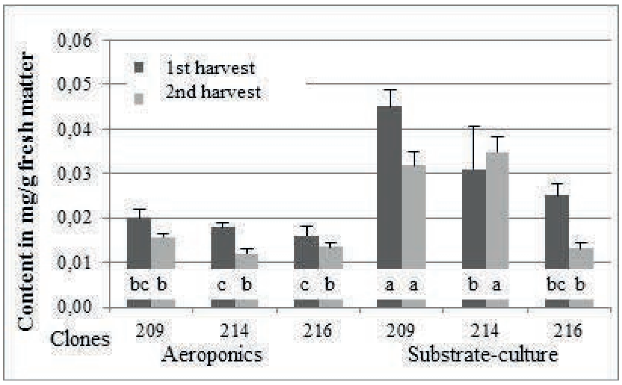

Figure 3. Carotene content of three clones of *Ipomoea aquatica*, cultivated in aeroponics and in substrate-culture at two harvesting times. Different letters indicate significant differences (Tukey-test, P<0.05).

Table 1. Mineral nutrients K, Ca, Mg and P in the different clones of *Ipomoea aquatica* cultivated in aeroponics and substrate-culture (in mg per 100g edible fresh matter). Different letters indicate significant differences (Tukey-test, P<0.05; ns = non-significant).

Cultivation system	Clone	Potassium	Calcium	Magnesium	Phosphate
Aeroponics	209	683,63 **b**	113,07 **ns**	48,86 **a**	78,61 **ns**
Aeroponics	214	710,21 **a**	103,71 **ns**	36,58 **b**	75,23 **ns**
Aeroponics	216	683,52 **ab**	99,61 **ns**	36,89 **b**	75,39 **ns**
Average Aeroponics		692,45	105,46	40,78	76,41
Substrate-culture	209	643,95 **b**	80,53 **ns**	26,54 **d**	76,16 **ns**
Substrate-culture	214	528,12 **c**	85,38 **ns**	25,49 **d**	70,39 **ns**
Substrate-culture	216	544,93 **c**	91,01 **ns**	30,43 **c**	70,26 **ns**
Average Substrate-culture		572,33	85,64	27,49	72,27

The content of Ca in water spinach is also very high in comparison to other vegetables, even comparable to chard (Souci et al. 1994). The highest amount of Ca could be analysed in plants of the first harvest, the content decreased later on. The content of Mg in water spinach cultivated in aeroponics was significantly higher than in the substrate-culture. The amount was in average of all clones two times higher in comparison to the substrate-culture. The values are similar to the average Mg content in parsley with 40 mg per 100 g edible fresh matter (Souci et al. 1994). Also the content of P in water spinach in all treatments of the experiment was much higher than in vegetables as European spinach *(Spinacea oleracea* L.) and chard (Souci et al. 1994).

For substrate-culture, the content of ascorbic acid in all three clones was not significantly different (data not shown). The chlorophyll and carotene content was remarkable higher in substrate-culture (Fig. 3). Interestingly, significant higher carotene content was determined for the less fast growing clones 209 and 214 in substrate-culture (Fig. 3).

Asian herbs

In substrate-culture the yield was considerably higher than in aeroponics for all herbs investigated (Table 2). As already mentioned, the cultivation system influences not only on the fresh matter production, but also on the compounds of the plants. For the two parameters investigated, vitamin C and essential oil content, different effects of the cultivation system was recorded. The vitamin C content in aeroponics was higher than in substrate-culture in all herbs. The vitamin C contents ranging between 17 and 35 mg per 100g fresh matter are comparable with those in basil, lettuce and tomatoes (USDA 2010). The essential oil content, however, was higher in Holy Basil and Perilla cultivated in substrate-culture. Whereas, the essential oil in Vietnamese Balm, was a little higher in plants cultivated in aeroponic system.

These results are in line with results of Smith et al. (1997). They found an influence of the cultivation system on the fresh matter productivity and amount of essential oil as well. It seems in further experiments the composition of the nutrient solution has to be taking into consideration.

Table 2. Fresh matter yield, vitamin C and essential oil in Holy Basil (*Ocimum sanctum*), Perilla (*Perilla frutescens*) and Vietnamese Balm (*Elsholtzia ciliata*) cultivated in substrate-culture and aeroponics. Significant differences in the cultivation groups, not significant between the species (Tukey-test, P<0.05).

Herb species and cultivation method	Fresh matter (g/m²)	Vitamin C (mg/100g)	Essential Oil (ml/plant)
O. sanctum (Substrate)	656,9	18,5	0,0127
O. sanctum (Aeroponics)	447,2	20	0,0088
P. frutescens (Substrate)	783,9	35	0,0350
P. frutescens (Aeroponics)	634,4	51	0,0250
E. ciliata (Substrate)	601,9	17,5	0,0192
E. ciliata (Aeroponics)	520,9	18	0,0213

To optimize the cultivation in aeroponics the effect of the density of plants on the biomass production was investigated (Table 3). In all species the yield was higher in variants with higher number of plants per square meter. However, calculating the ratio between input (number of plant per m²) and output (yield) the efficiency of low plant density is higher. In further experiments further plant densities should be investigated.

Table 3. Yield (g/m²) in two plant densities and three to four harvests of Thai Basil, Perilla and Vietnamese Balm cultivated aeroponically.

	Thai Basil		Vietnamese Balm		Perilla
No of plants/m²	**100**	**25**	**100**	**25**	**100**
1st harvest	1244	551	1170	730	1104
2nd harvest	1207	676	500	590	292
3rd harvest	786	280	2070	1490	794
4th harvest	689	275	0	0	420

The lower density of plants had also their advantages regarding plant quality measured as the stem length and leaf area (Fig. 4). During the whole plant development both parameters were higher than in the treatments with higher plant density. With other words, if the consumers prefer larger leaves for cooking, lower density of plants can be recommended.

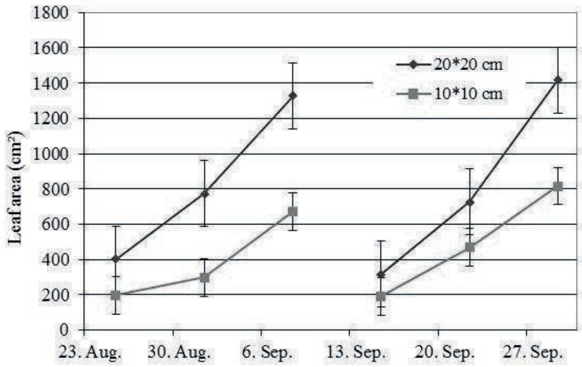

Figure 4. Leaf area of Thai Basil (*O. basilicum*) cultivated in aeroponics with plant density of 25 and 100 plants per m ²

CONCLUSION

- Water spinach can be cultivated in substrate-culture and aeroponics as well with higher yield and higher carotene and chlorophyll content in substrate-culture but in both systems a high quality can be guaranteed.
- The cultivation of the four Asian herbs was successful in substrate and in aeroponic system as well, but currently in substrate-culture the growth was better than in aeroponics.
- It seems further investigations are necessary, in particular to develop the appropriate nutrient solution and growing conditions in aeroponics.
- Herbs could be harvested after two to four weeks and in total between 3 and 4 harvests were possible in greenhouses during summer time that means more harvests than in open fields.
- In aeroponics, the biomass production was dependent on the plant densities and can be further optimized.
- The nitrate content of all three herbs and water spinach was below the thresholds for vegetables in Germany.
- In comparison of substrate-culture and aeroponics no significant differences were found for Vitamin C and Essential Oil in Holy Basil and Vietnamese Balm.
- In Perilla the vitamin C content was higher in aeroponic system, whereas the Essential Oil content was higher in substrate cultivation.

References

Böhme M. and I. Pinker: Investigation Regarding the Potential for Cultivation of Indigenous Vegetables in Southeast Asia, Acta Hort. 752, 179-185, 2007

Cofalka L. 2011. Influence of the cultivation system on the content of nutritious substances in water spinach (Ipomoea aquatica Forsskal). Master thesis, Humboldt-Universitaet zu Berlin, Faculty of Agriculture and Horticulture

Cornelius, J., Nugteren, J. A. Und Westphal, E. 1985. Kangkong (Ipomoea aquatica Forsk.): an important leaf vegetable in Southest Asia. Abstracts on Tropical Agriculture. Bd. 10, 4. S. 9-21.

Food Standard Agency 2011. Draft Eu Legislation As Regards Nitrate In Green Leafy Vegetables.18th February Reference: IPA 0036

Guadagnin S. G., Rath S., Reyesi F. G. R. 2005. Evaluation of the nitrate content in leaf vegetables produced through different agricultural systems. Food additives and contaminants December 2005; 22(12): 1201-1208

Herrmann, K. 1987. Exotic food, Nutritive substances and use. Für Biologen, Chemiker und Ernährungswissenschaftler. Heidelberg, New York, London, Paris, Tokyo: Springer Verlag. Berlin. S. 89, 106. ISBN 3-540-16830-3.

Hoang T. L. 2003 Investigations on the effect of humic acid on the growth and nutrient uptake of tomato (Lycopersicon esculentum MILL) and water spinach (Ipomoea aquatica FORRK). Doctoral thesis at Humboldt-Universität zu Berlin, Germany. Publishing in Internet GmbH.

Hoang, T.L. and Böhme, M. 2001. Influence of humic acid on the growth of water spinach (Ipomoea aquatica Forssk.) in hydroponic system. Wissenschaftliche Arbeitstagung, BDGL-Schriftenreihe, Band 19:57.

Howard, F. D., Macgillivray, J. H. Und Yamaguchi, M. 1962. Nutrient composition of fresh California-grown vegetables.California Agricultural Experiment Sation, University of California, Bulltin 788. S. 16-17; 36-37.

Lenhard W. A., Leonhard W. V. 2006. A comparison of three different hydroponic sub-systems (gravel bed, floating and nutrient film technique) in an Aquaponic test system. Aquacult. Int (2006) 14:539–550

Miceli, A., Moncada, A., Vetrano, F. and D'Anna, F. 2003. First Results On Yield And Quality Response Of Basil (Ocimum Basilicum L.) Grown In A Floating System. Acta Hort. (ISHS) 609:377-381

Pinker. I., U. Bubner and M. Böhme 2004. Selection of water spinach genotypes (Ipomoea aquatica Forssk.) for cultivation in greenhouses. Acta Hort. 659: 439-445

Pinker I., U. Bubner and M. Böhme: Selection of Water Spinach (Ipomoea aquatica Forssk.) - Genotypes for Protected Cultivation in Temperate Regions Acta Hort. 752, 441- 445, 2007

Rouphael Y., Colla G. 2005. Growth, yield, fruit quality and nutrient uptake of hydroponically cultivated zucchini squash as affected by irrigation systems and growing seasons. Scientia Horticulturae 105, Issue 2, 10 June, Pages 177-195

Smith Chr. A., Svoboda K. P., Noon M. M. 1997. Controlling The Growth And Quality Of Hydroponically grown Basil (Ocimum basilicum L.), Acta Hort. (ISHS) 450:479-486

Souci, Fachmann and Kraut 1994. Die Zusammensetzung der Lebensmittel. Nährwert-Tabellen. Stuttgart:Medpharm.

Takano, T., Yamamoto, A. 1996. Effect Of Anion Variations In A Nutrient Solution On Basil Growth, Essential Oil Content, And Composition. Acta Hort. (ISHS) 426:389-396

Teixeira J.P., Marques M.M, Facanali R., Furlani P.R. 2002, Essential Oil Contents in Two Cultivars of Basil Cultivated on NFT Hydroponics, Acta Hort. (ISHS), 569: 203-208

USDA 2010. National Nutrient data base. http://www.nutrition-and-you.com/basil-herb.html

Westphal, E. 1994. Ipomoea aquatica, p. 181-184. In: J. S. Siemonsma and K. Piluek (eds.), Plant resources of South-East Asia, No 8 Vegetables, Bongor, Indonesia.

Onion production: Challenges and ways to meet out the demand of the country

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ABSTRACT
Onion is an important vegetable and spice crop grown in almost all the parts of India since thousands of years. The onions are regarded as highly export oriented crop amongst vegetables and earning valuable foreign exchange for the country. India is producing sufficient quantity of onion, but the availability of produced quantity is not regular and some times not sufficient to meet the demands of both domestic and export markets. Total annual requirement of the country based on population and onion consumption, state-wise production and availability during different periods are worked out to study the challenges to meet out the demand of the country. There has been significant increase in research infrastructure and development programmes of onion in the recent past, which has helped in increasing the production, productivity and availability in the country. In view of increased awareness about advantages of onion consumption, increasing population and increased urbanization, the demand is increasing. The export requirement is also increasing. The constraints in increasing the onion production were also studied in depth. For increasing production and thereby sustaining the availability, round the year, for meeting domestic and export requirements, there is need to increase productivity and improve quality through crop management in field and post harvest management. To achieve the target of quality production and supply round the year for consumption, export, planting material for seeds and also for dehydration, the strategies in the form of medium and long term measures suggested in the study are to be implemented.

Keywords
onion, shallot, seed, bulbs.

INTRODUCTION
India being endowed with varying agro-climatic conditions provides opportunity for growing large number of horticulture crops including vegetables. Onion is an important vegetable and spice crop grown in almost all the parts of India since, thousands of years. It originates from the region comprising North West India, Afghanistan, Tazik and Uzbek. Western Asia and the area around the Mediterranean seas are the secondary centers of development. It is used as salad and cooked in various ways in curries, fried, boiled, baked, used in soup making and pickles. The medicinal properties of onion as anti-microbial and antibiotic are well recognized. Though common onion is not rich in food value, these have got considerable quantity of cellulose and sugar. Common onion ranks medium in the supply of proteins, calorie value and vitamin B & C. Small onions are, however more nutritive than big onions. The onions are regarded as highly export oriented crop amongst vegetables and earning valuable foreign exchange for the country. Though the country is producing sufficient quantity of onions, but the availability of produced quantity is not regular and sufficient to meet the demands for both domestic requirement and exports. Thus a perspective is presented to regulate the production of onions round the year in the country.

Global perspective of onion
A global review of area and production of major vegetables shows that onion ranks fourth in area and production of vegetables in the world among nine major vegetables namely onion, potato, cauliflower, green peas, cabbage, tomatoes, okra, green beans, cucumber and gherkins.

In India among these nine vegetables, onion ranks second in area and third in production. About 732.32 lakh tones of onions produced from about 36.46 lakh hectares area in the world. India ranks second in area and production, the first being China amongst the onion producing countries in the world. The highest productivity of onion in world is of Korea Rep (66.67 MT/ha) followed by USA (56.56 MT/ha), Spain (53.53 MT/ha) and Netherland (48.81 MT/ha). India being a second major onion producing country in the world has a productivity of 16.41 MT/ha only. (FAO 2009).

Maharashtra is the leading state in India producing 49.05 lakh MT onions from 4.15 lakh hectare area. The other major states producing onions are Karnataka, Gujarat, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh and Uttar Pradesh and In India per hectare yield is highest in Gujarat (24.4 MT/ha) followed by Punjab (22.22 MT/ha), Jharkhand (20.9 MT/ha), Haryana (20.5 MT/ha), (Bihar (20.3 MT/ha), Madhya Pradesh (17.5 MT/ha) and Andhra Pradesh (17.0 MT/ha). Productivity of onion shows variable trend as crop is susceptible to various weather variations. Yield obtained in India with those obtained in developed countries show that there is a wide gap between the optimum yield of the onion crop. The details of area, production and productivity of onion in different countries of the world during the year 2009 are given in Table 1 and state-wise area, production and productivity of onion in India during the year 2010-11 are given in Table 2.

State-wise annual requirement of onion in India

The total annual requirement of the country based on population and onion consumption is given in Table 3. The data indicates that out of total estimated requirement of 141.49 lakh MT, the country is producing 151.2 lakh MT of onion annually. The consumption data is collected during the year 2008-09 from different parts of the country on sample survey basis by personal visit of officials of NHRDF from its centers spread all over the country in urban and rural areas. 5000 Nos. of families were randomly selected in different states for recording the data on consumption of onion and it is concluded from the study that on an average, the onion consumption is @ 35g/person/day and 65% population of India consumes onion. Thus surplus of 9.68 lakh MT exists, even though some times prices increases due to disturbance in harvesting schedule and more losses in storages, the gap if any needs to be bridged based on defining strategies in from of medium and long terms to make sure availability of onion round the year in the country.

State-wise status of onion production in India

Two to three crops of onions are now taken in various parts of the country. Fresh onion starts coming from July onwards in the markets from Kurnool in the State of Andhra Pradesh and Tirpur in Tamilnadu State and continues till April-May from other parts of these states. In Karnataka State, also there are two crops as that of Andhra Pradesh. In Maharashtra State, fresh onion starts coming in market in September and continues till April-May in Satara, Nasik, Ahmednagar and some parts of Pune district. Gujarat State produces three crops i.e. rainy season (November-January) in Bhavnagar district, winter (February-March) and summer (April) in Rajkot, Junagarh and Jamnagar districts. Rainy season onion production, which was not common in northern states is, however, now being taken up in some pockets of Rajasthan (Alwar, Dausa, Bharatpur and Ajmer), Haryana (Rewari, Mewat and Gurgaon districts) and Punjab (Patiala) states thereby making Maharashtra onion surplus for export. In Northern, Eastern and Central parts of India, summer season onion is commonly cultivated which is available in April-May (Table 3). Multiplier onion (shallot) is grown in Tamilnadu and Odisha states. The quality of multiplier (shallot) onion produced in Odisha is better. Small pickling onion is produced near Mydukur in Cuddapah district in Andhra Pradesh during rainy season and in Karnataka, near Chickballapur and Bangalore in all the three seasons exclusively for export. The quality of Karnataka small onion is better in view of mild climate which prevails almost round the year.

Round the year availability of onion is depicted in Table 3. The data clearly indicate that early rainy season onion is cultivated only in southern and western states i.e. Tamilnadu, Karnataka, Andhra Pradesh and Maharashtra and harvesting takes place from July to

September. Later on fresh onion harvesting started almost in all the subsequent months in one or other states of the country. As per the availability and requirement (Table 4), the state Tamilnadu is facing annual deficit of 2.60 lakh MT onion. Karnataka is having annual surplus of 20.85 lakh MT to cater the need of adjoining states and others. The requirement of these states some times met from the onions produced and stored in Maharashtra, when Karnataka is not having too much surplus. Similar is the situation for other states also where deficit in lean periods are met out either from Maharashtra, Gujarat or other adjoining states, but due to climatic vagaries and other abnormal situations, round the year availability is hampered resulting into rise in prices, quantity restrictions and ban on export, and sometimes import of onions are also done to fulfill the requirements.

India has sufficient R&D backup in terms of development of improved varieties, standardization of pre and post harvest technology and seed production technology. The technologies developed by National Horticultural Research and Development Foundation (NHRDF), Horticultural Institutes of Indian Council of Agricultural Research (ICAR) and various State Agricultural Universities are being disseminated to the farmers by NHRDF and State Dept. of Horticulture / Agriculture, but to achieve the goal of self sufficiency, several genuine constraints have been identified and the gap is required to be bridged for ensuring onion availability round the year.

Constraints

No doubt production and productivity have increased substantially over the past 20 years; it is still has quite low productivity when compared to the countries like Netherlands, United States of America, China & Korea Republic. The constraints which have been identified for low production and productivity are enumerated as under:

- Nonavailability of high yielding storable varieties for all the three seasons.
- Lack of strategy for expansion of area in rainy, winter and summer seasons in non-traditional pockets.
- Non-availability of quality seed of improved varieties in adequate quantities.
- Onion varieties developed are not uniform in colour, shape & size. Bolting and doubles are observed in almost all varieties. The marketable recovery thus is low.
- Non-availability of high yielding & storable F1 hybrids.
- All varieties are susceptible to diseases and insect pests.
- Sub-optimal standards of cultivation adopted by farmers.
- Lack of high TSS white onion varieties suitable for dehydration and high TSS bigger bulb sized yellow varieties for export.
- Inadequate storage facilities, transportation and marketing support.
- No regular Government policy on export.

Strategies to ensure availability of onion round the year

In order to make onions available round the year for consumption, export, planting material for seeds and also for dehydration, the following medium term and long term strategies are to be adopted:

Medium-term measures

Augmenting quality seed production programme

Onion seed production is normally being taken up in Gujarat, Maharashtra, Karnataka, Madhya Pradesh and to some extent in Odisha, Rajasthan, Tamilnadu and West Bengal. Though no authentic data on demand of seeds are available, the total requirement of onion seed based on area under onion comes to about 8200 tonnes. Out of this only 8-10% seed is produced by organized sectors like National Horticultural Research and Development Foundation, National Seeds Corpn., Maharashtra State Seeds Corpn., Indian Council of Agricultural Research and State Agricultural Universities. Rest 90% seed is produced either by private seed companies (35%) or by the farmers themselves (55%). Thus there is need to strengthen the production of quality seed. The quality seed production of improved varieties will replace the local seed material thereby production and productivity will also increase.

The Government of India has taken up good initiatives through its National Horticulture Mission (NHM) programmes where assistance is being provided to the state Government and also National Horticultural Research and Development Foundation for encouragement to the farmers for quality seed production. The assistance is also being provided for creating infrastructural facilities and seed storage to seed producing agencies including NHRDF to maintain the quality of seed. Now it is necessary to state Governments to ask / involve state seed corporations to come forward and produce quality seed of onion at least to meet the requirement of their states.

Rainy season onion production through bulblets

Rainy season onion since cultivated during monsoon, it has been observed that nursery is damaged during heavy rainfall or due to unfavorable climatic conditions. The technology of production of rainy season onion through sets (bulblets) has already been standardized and developed by NHRDF. The NHRDF distributing seeds of rainy season onion varieties Agrifound Dark Red for production of sets in states of Gujarat, Rajasthan, Haryana and Punjab and onion growers engaged in bulblet production The productions of bulblets are needs to be strengthened in above states as well as in other potential states like Bihar and Uttar Pradesh also so as to increase early production of onion during rainy season.

Area expansion under rainy season onion

The area under Rainy season onion crop in the country is about 20% of the total area cultivated. This needs to be increased in non traditional rainy season onion producing states so as to ensure the availability and reduce the pressure of supply from major rainy season onion producing states like Maharashtra and Gujarat. The NHRDF at their own and with financial assistance from National Horticulture Board and also under its National Horticulture Mission programmes of Government of India has taken up the programme on area expansion of rainy season onion by protected growing of seedlings in Northern and Eastern India covering states of Haryana, Rajasthan and Bihar and good coverage under rainy season onion noted. The project was also taken for production of bulblets in northern and eastern India where demonstration and trainings were arranged. The involvement of more agencies required so that significant impact noted.

Adoption of plant protection measures during epidemics

Quite often due to unfavourable weather conditions, diseases like purple blotch, stemphylium blight, colletotrichum blight and thrips, insect pest are attacking the standing onion crop and a major damage in production and quality is experienced. These diseases and insect pests are to be controlled by a campaign on mass plant protection, so as to restrict the pathogens/pests for entering into the unsprayed field. The education and training on diseases and insect pests management are to be imparted to the farmers and Agriculture Department Officers for tackling such situations on large scale.

Long-term measures

Development of high yielding variety of F1 hybrids

The varieties presently developed and popular amongst farmers are though giving optimum yield but the productivity level is certainly low as compared with the high yielding varieties popular in other countries. Thus there is need to develop such varieties which are high yielding and either tolerant or resistant to diseases and pests. Onion being cross pollinated crop, it always have wide scope for selection as natural variability is created constantly. Besides, to increase the yield, F1 hybrids are needed. The thrust area of development of F1 hybrids in short day types has remained still an important area of research. Despite identification of CMS lines alongwith maintainer by the Institutes of Indian Council of Agricultural Research, no commercial hybrids have reached to the farmers successfully. The efforts are being made by

NHRDF also for screening of the germplasm having tolerance to purple blotch and stemphylium blight. Several new collections are due to release. The more efforts required to be made by public sector Institutes for development of F1 hybrids in short day conditions.

Establishment of monitoring cell for reviewing production, availability and prices of onion

The monitoring groups at State level and District level are required to be formed to review the crop condition, area expansion as well as storage. Based on the recommendations of this group, State Govt. will formulate the programme for increasing onion production and storage capacity in most of the onion growing areas. The financial assistance for creating storage facilities is also required. Present storage capacity is estimated to be around 25.00 lakh MT in India compared to 12.0 lakh MT in 1999-2000. Further the programmes are required to be continued in order to increase storage capacity every year with target of 30 lakh MT by the year 2013-2014, when total onion production is expected to the tune of 180 Lakh MT. The National Horticultural Research and Development Foundation (NHRDF) has also provided technical guidance for creation of storage facilities and maintaining buffer stocks to regulate the supplies to the states of Karnataka, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, Odisha etc. For creation of more onion storage facilities the subsidies should be provided by major onion producing states to the growers so that the buffer stock be maintained.

Quality seed production and distribution in adequate quantities

As discussed earlier, the total requirement of quality seed of onion is over 8200 tonnes. Out of this National Horticultural Research and Development Foundation, National Seeds Corp., Maharashtra State Seeds Corp. and such other agencies are meeting requirement about 8-10% only. Rest quantity of seed is supplied by private seed companies and is being produced and distributed by the farmers themselves where there is no quality control about isolation and rouging off types and so on. Further seeds of newly developed identified varieties having better yield and quality are not being produced. There is, therefore, urgent need for National Horticultural Research and Development Foundation, National Seeds Corp. and Maharashtra State Seeds Corp. to discuss and arrange quality seed production of improved varieties in large quantity for meeting the demand of the farmers. Although it is neither possible to produce the entire quantity of seed by different agencies nor it is possible to replace the old varieties at one stroke, slowly and slowly the programmes are to be planned for replacement of old varieties in phased manner.

Development of biotic and abiotic stress tolerant varieties

As mentioned under the constraints, presently, there is no variety which has been bred by the Universities or Institutes as resistant to different field or storage diseases and insect pests so also heat tolerant or moisture stress. Since purple blotch, stemphylium blight diseases and thrips insect in the field, basal rot, black mold and bacterial brown rot in storages are the diseases many times causing severe damage to the crop, there is need to develop resistant / tolerant varieties quickly so as to solve the problem of the farmers and make available quality onions in adequate quantities. This work can be taken up by ICAR Institutes, NHRDF and State Agricultural Universities.

Adaptation of biological control measures against pests and diseases

Presently farmers are being advocated to use pesticides for control of diseases and pests where there is problem of pesticide residues beyond the permissible limits. Since it is health hazardous, if there are residues beyond the permissible limit, there is need to develop biological control measures against diseases and pests. It is therefore essential that necessary facilities for developing the biocontrol techniques, may be strengthened and training to farmers be imparted. It may be mentioned here that European and other such markets are very particular about pesticides residues, as such efforts in development of biological control measures against diseases and pests are to be undertaken. The promotion of organic farming will also be one of the important tools to combat the problem.

Development of yellow colour hybrids and OPs for export especially to European and Japanese markets

India is presently exporting onions to mostly Gulf countries, South East Asian countries, Bangladesh and Sri Lanka, where there is not much scope to increase the further export. There is, however, good scope to increase the export by diversifying the market to Europe and Japan. These countries do not prefer our strong pungent onions. Presently very little quantity of yellow onions is being produced in Jaipur district of Rajasthan state of India but that too for local consumption. There is possibility of producing yellow onions at economical rates which could be harvested from February onwards. It may be produced in Odisha, Maharashtra, Gujarat, Madhya Pradesh and other parts. Europe and Japan require mild pungent yellow onions from February onwards till May. India, therefore, can very well arrange production of yellow onions for supplying to Europe and Japan. Custom farming of yellow onions could be organized exclusively for export by the exporters with the help of NHRDF or other such agencies.

Development of bigger bulblet varieties in multiplier / shallot types

Thailand is the major supplier of multiplier / shallot onion at present. There was a time when India was the major supplier of multiplier / shallot onion to Sri Lanka and other countries. In view of multiplier / shallot onions being vegetatively propagated crop, Sri Lanka and other countries selected their own material and started multiplying themselves instead of depending on India. Thailand being at higher latitude the size of bulblets is bigger. In India so far major attention for development of multiplier / shallot onion has been given in Tamilnadu. Since Odisha also grows multiplier / shallot onion and has better material in view of being at higher latitude, bigger bulblet variety should be developed so as to regain the export of multiplier / shallot onion already lost.

Training of trainers, farmers, traders and exporters

Trainers, farmers, traders and exporters should be trained regularly with the latest innovations in the production and post harvest management so that farmers are able to get good crop and traders and exporters are able to handle the crop with minimum post harvest losses in various post harvest handling operations at their level.

Establishment of adequate curing and storage facilities by farmers, traders and exporters

Presently there are only few traders and onion growers who have got storage facilities and curing sheds that too of conventional types. The losses thus are on very high side after the produce is brought to the market. It is necessary for the onion growers to have at least a small 10 tonne capacity temporary curing shed for curing of the bulbs after harvesting in shade and then store in ventilated storage godowns so that whenever prices are low, they are able to withhold the stock and release slowly and slowly without post-harvest losses. Traders and exporters should also have their own curing shed and also storage godowns of improved types having ventilation from bottom to avoid the post harvest losses. This will help in safe handling of the produce and avoid damage from heat and rains. Farmers and other concerned may get help for creation of such facilities from Cooperative banks or NABARD / NHB/ NHRDF.

Designs and salient features of improved storage structure developed by NHRDF:

- Construction of structure on raised platform to prevent moisture contact and dampness.
- Use of Mangalore tiled roof or other suitable material to prevent built up of high temperature inside.

- Increased centre height and more slope for better air circulation and preventing humid microclimate inside godown.

- Providing bottom ventilation for free and faster air circulation to avoid formation of hot and humid pockets between he onion layers.

- Avoid direct sunlight on onion bulbs to reduce sunscald, fading of colour and quality deterioration.

- Restriction on width of each stack to 60-75 cm for hot and humid weather, 75-90 cm for mild and humid weather and 90-120 cm for mild and dry weather conditions.

- Maintenance of stacking height to 100 cm for small and multiplier onion and hot weather and 120 cm for mild weather and for big onion to avoid pressure bruising.

- Providing cubicles instead of continuous stack and sufficient space for ventilation from all sides.

- One cubic meter area of store accommodates about 750 kg onions. Accordingly, construction of godown for required capacity and construction of more units instead of single big structure and in zigzag manner when constructed in more rows.

- Providing two tier if space available is insufficient.

- Periodical disinfection of structures and premises to check rottage. The cost efficiency of structures is based on locally available material and labour.

Designs of onion storage structures for different capacities i.e. 5, 10, 15, 20, 25 and 50 MT have already been developed by NHRDF and the design along with estimates for 50 MT capacity is given in Table 1.

Improvement in packing

Plastic woven bags which are not only attractive but uniformity of onions could also be easily seen inside the bags should be used in place of hessian bags.

Creation of proper and adequate facilities for handling onion at ports

Ventilated storage godowns should be provided at the ports. If new storage godowns / sheds are not possible to be constructed immediately, exhaust fans or ceiling fans should at least be provided for the time being and stacking of onion bags on pallets in the existing shed. Use of hooks should be totally banned at the ports. Electrically ventilated containers should be introduced for transport of onions to different destinations.

CONCLUSION

Onion has been very important crop in India both for domestic and export markets. The onion also pays more economic returns to the farmers and foreign exchange to the country through export and there are more rural employment opportunities. There has been significant increase in research infrastructure and development programmes of onion in the recent past, which has helped in increasing the production, productivity and availability in the country. In view of increased awareness about advantages of onion consumption, increasing population and increased urbanization, the demand is increasing. The export requirement also is increasing. For increasing production and thereby sustaining the availability round the year, to meet domestic and export requirements, there is need to increase productivity and improve quality through adaptation of improved varieties along with crop management in field and post harvest management. To achieve the target of quality production and supply, round the year, the strategies in the form of medium and long term measures suggested are to be implemented.

TABLES AND FIGURES

Table 1. Estimate for onion storage of capacity 50 M.T.

Sr. No.	Total Qty.	Description	Rate (Rs.)	Unit	A (Rs.)
1	10.2	Excavation for foundation	110	Cu.m.	1122
2	2.55	P.C.C. 1:4:8 in foundation	2500	Cu.m.	6375
3	6.21	R.C.C. 1:2:4 for columns	3200	Cu.m.	19872
4	440 kg.	Nominal Reinforcement to columns	52	Kg-	22880
5	3300kg.	Structural Steel Works	60	Kg.	198000
6	160	A/C Sheet Roofing	200	Sq.M.	32000
7	25	A/C Sheet Ridge	120	Rmt	3000
8	2798.4	2"Dia 1/2 Bamboo Strips @2"C/C.	25	Rmt	69960
				Total:	**353209**
			Contingencies@ 5%		17660
			Total		**370869**
			VAT @ 4%		14835
		Service tax 12.24% on 33% of total (11)			14980
			Grand total		**400684**

Table 2. Area, production and productivity of onion in major onion producing countries during 2009

Countries	Area (ha)	Production (MT)	Yield (MT/ha)
China	947611	21046969	22.21
India	846909	13900000	16.41
United States of America	60120	3400560	56.56
Turkey	65000	1849580	28.46
Egypt	54000	1800000	33.33
Pakistan	129600	1704100	13.15
Russian Federation	85700	1601550	18.69
Iran (Islamic Republic of)	47450	1512150	31.87
Brazil	66013	1511850	22.90
Netherlands	26000	1269000	48.81
Spain	23600	1263400	53.53
Republic of Korea	18000	1200000	66.67
Mexico	41726	1195820	28.66
Japan	24000	1154000	48.08
Myanmar	75000	1050000	14.00
Algeria	42662	980160	22.98
Indonesia	93000	952638	10.24
Ukraine	58500	875600	14.97
Uzbekistan	28000	795000	28.39
Bangladesh	107748	735140	6.82
Poland	31419	707792	22.53
Nigeria	33788	687149	20.34
Argentina	23288	650000	27.91
Morocco	28000	650000	23.21
Peru	17775	601956	33.87
South Africa	20500	461926	22.53
Germany	8632	433036	50.17
WORLD	**3646117**	**73231830**	**20.08**

Source: FAO Yearbook 2009.

Table 3. State-wise area, production and productivity of onion in India during 2010-11

Sr. No.	State	Area (000 ha)	Area Share (%)	Production (000 MT)	Production Share (%)	Productivity (tones/ha)
1	ANDHRA PRADESH	47.8	4.49	812.6	5.38	17.00
2	BIHAR	53.3	5.01	1082.0	7.16	20.32
3	GUJARAT	62.0	5.83	1514.1	10.02	24.42
4	HARYANA	22.2	2.08	453.9	3.00	20.48
5	JHARKHAND	14.6	1.37	305.0	2.02	20.86
7	KARNATAKA	190.5	17.90	2592.2	17.15	13.61
8	MADHYA PRADESH	58.3	5.48	1021.5	6.76	17.52
9	MAHARASHTRA	415.0	39.01	4905.0	32.45	11.82
10	ODISHA	34.8	3.27	385.9	2.55	11.11
11	PUNJAB	8.2	0.77	182.3	1.21	22.16
12	RAJASTHAN	49.0	4.61	494.2	3.27	10.08
13	TAMIL NADU	33.8	3.18	338.9	2.24	10.03
14	UTTAR PRADESH	23.2	2.18	368.6	2.44	15.87
15	WEST BENGAL	21.3	2.00	298.0	1.97	14.02
16	OTHERS	29.9	2.81	363.6	2.41	12.15
	TOTAL	**1063.8**	**100.00**	**15117.7**	**100.00**	**14.21**

Source: Horticulture Division, Government of India, New Delhi.

Table 4. Round the year availability of onion in India

Month	Places where Onions are harvested &available	Season
January	Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Odisha.	Winter
February	Maharashtra, Gujarat, West Bengal, Madhya Pradesh.	Winter
March	Maharashtra, Madhya Pradesh Gujarat, Tamilnadu, Karnataka, Andhra Pradesh, West Bengal, Odisha.	Winter
April	Maharashtra, Madhya Pradesh, Gujarat, Tamilnadu, Karnataka, Andhra Pradesh, Rajasthan, West Bengal, Odisha.	Summer
May	Maharashtra, Gujarat, Rajasthan, Haryana, Punjab, Uttar Pradesh, Bihar.	Summer
June	Haryana, Punjab, Uttar Pradesh, Bihar, Himachal, Uttarakhand.	Summer
July	Tamilnadu, Karnataka, Andhra Pradesh.	Early Rainy
August	Tamilnadu, Karnataka, Andhra Pradesh.	Early Rainy
September	Karnataka, Andhra Pradesh, Tamilnadu, Maharashtra.	Early Rainy
October	Maharashtra, Gujarat, Tamilnadu, Karnataka, Andhra Pradesh, Rajasthan, Madhya Pradesh.	Rainy
November	Maharashtra, Gujarat, Tamilnadu, Karnataka, Andhra Pradesh, Rajasthan, Haryana, Punjab, Uttar Pradesh, Bihar, Madhya Pradesh.	Rainy
December	Maharashtra, Gujarat, Rajasthan, Madhya Pradesh, Haryana, Uttar Pradesh, Punjab, Bihar.	Rainy

Table 5. Annual requirement of onion in different states and position of production/availability

State	Requirement (MT)	Availability (MT)	Surplus/ Deficit (MT)
Andhra Pradesh	703041.42	812584	109542.58
Bihar	861967.75	1082027	220059.25
Gujarat	501410.55	1514090	1012679.45
Haryana	210525.65	453862	243336.35
Karnataka	507614.08	2592240	2084625.92
Madhya Pradesh	602832.03	1021521	418688.97
Maharashtra	933117.07	4905000	3971882.93
Odisha	348320.37	385910	37589.63
Rajasthan	569811.73	494207	-75604.73
Tamilnadu	599023.87	338900	-260123.87
Uttar Pradesh	1657274.69	368573	-1288701.69
Rest Other States	2554204.41	1148834	-1405370.41
Total	**10049143.63**	**15117748.00**	**5068604.37**
Requirement for export, seed bulbs and for dehydration	1900000	0	-1900000
Loss during handling, transportation & storage	2200000	0	-2200000
Total	**14149143.63**	**15117748.00**	**968604.37**

Note: 65% population consumes onion @ 35 g / person / day.

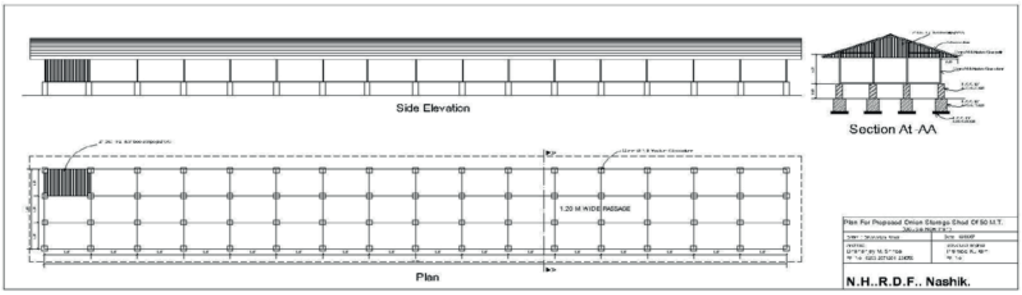

Figure 1: A view of improved onion storage structure.

Low pressure drip irrigation for commercial vegetables in Myanmar

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ABSTRACT
Drip irrigation is used extensively by both large and small commercial vegetable growers in the United States, Europe, Australia, and the Middle East where significant benefits include not only higher water use efficiency, but higher yields, improved product quality, earlier maturity, and reduced disease susceptibility. Imported drip systems are still relatively expensive in Southeast Asia, however, and it is primarily wealthier farmers who currently enjoy these benefits. There are also perceptual barriers to adoption as many farmers are accustomed to applying copious amounts of water to vegetable crops and are unfamiliar with drip or their crops' actual water requirements. As an NGO whose mission is to help boost small farm incomes, IDE-Myanmar began experimenting with low-pressure gravity-fed drip systems in 2006. While the basic design is similar to the microtube systems of the 1960s, local improvements include filters designed for low pressures, easy-to-use fittings, and inexpensive collapsible header tanks. After hundreds of controlled tests and farmers' field trials, our locally manufactured drip sets were offered for sale by private dealers throughout Myanmar in 2009. We continue to develop system improvements and support an on-farm demonstration and farmer education program to promote this "new" technology. Supporting materials include illustrated installation guides, system design software, videos, testing/filtering of dissolved iron, and an easy-to-use water requirement calculator. Approximately 5000 small farm drip systems have been installed in Myanmar since 2008 and the number of users is increasing at an accelerating pace.

Keywords
Drip, microirrigation, low pressure, gravity

INTRODUCTION
Commercial vegetable growers in the United States, Australia, Europe, and the Middle East have long enjoyed the benefits of drip (or trickle) irrigation which have been described in numerous research and extension publications over the past 40 years. These benefits include higher yields, improved product quality, earlier maturity, and reduced risk of foliar (and some soil borne) diseases. Other advantages over conventional irrigation include higher water use efficiency and application uniformity that is unaffected by wind and causes less soil crusting. In some cases weed pressures are reduced and farmers can perform weeding and other field operations while irrigating. Less energy and labor are generally required for drip irrigation. Application of plant nutrients through drip systems (fertigation) enables precise fertilizer placement and timing, resulting in better nutrient use efficiency. Drip has also been used successfully on saline soils and with saline water where other irrigation methods failed. Lastly, drip irrigation has synergistic interactions with plastic mulches which further boost yields and product quality.

Drip irrigation also has significant barriers to adoption by small farmers in developing countries. These include high initial system costs (especially if most components are imported), the need for relatively clean water, and the tendency for emitters to clog with contaminants such as dissolved iron. Even more important are *perceptual* barriers which include the seeming complexity of drip systems and the almost instinctual first reaction from farmers that drip will not supply sufficient water to their crops. Some drip components such as LLDPE[1] lateral tubing are also occasionally damaged by rodents or other animals. Seasonal removal and disposal of used drip laterals and plastic mulch is also a problem for commercial vegetable growers in the United States. Overcoming these barriers require not only the appropriate design of hardware, but also an equal or greater emphasis on farmer education and on-farm demonstration.

Having worked with drip irrigation for a dozen years in the United States before beginning work with International Development Enterprises[2] (IDE) in Myanmar, the senior author understood first-hand drip's benefits after numerous demonstrations and trials with small commercial vegetable farmers in the state of Kentucky (Rowell, 1999). Given this background, we did not spend a lot of time doing replicated field trials comparing drip with conventional irrigation methods as such trials have been conducted by many researchers in many countries. Our goal from the beginning was to develop and promote a drip irrigation system which was both easy-to-use and *affordable* to small--but commercial scale--fruit and vegetable growers.

Such a system must function well for a reasonable commercial plot size with very low system pressures, usually obtained from an elevated water tank. Another objective was to help establish private local manufacturing of all system components. While the task of developing a low pressure system--without benefit of motorized pumps--was daunting, knowing the high potential benefits was motivation enough to make the considerable investment in time and money.

Myanmar, while largely cut off from its potential export markets, produces large quantities of vegetables to supply its population of 58 million people. The country is blessed with diverse agroclimatic zones ranging from tropical to temperate and grows an enormous variety of vegetable crops including a large number that are considered indigenous. The major commercial crops are chili (12,900 ha), tomato (10,600 ha), onion (71,000 ha), and potato (37,000 ha); these together with a wide variety of other vegetable crops comprise a production area of about 75,000 hectares (Maung Maung Yi, 2009).

Given the fact that motorized pumps are at present unaffordable to most small vegetable farmers and that the electricity grid does not extend to the vast majority of villages in Myanmar, it is not surprising that in most cases commercial vegetable crops are irrigated by hand watering with large sprinkler cans (Figure 1) or by furrow/flood in areas where water is more abundant. Irrigation with sprinkler cans requires backbreaking and time-consuming labor: our own surveys revealed that it is not uncommon for small vegetable growers to carry 4-6 t of water daily on their backs to irrigate vegetable crops.

Figure 1. Sprinkler cans used on vegetable crops.

[1]Low linear density polyethylene is the primary ingredient in drip lateral tubing.
[2]IDE is an international NGO that promotes affordable microirrigation technologies for smallholders as its primary tool for raising incomes and reducing poverty using design thinking and a business development approach. IDE-Myanmar was renamed *Proximity Designs* in 2011 after becoming independent from IDE International in 2009.

Proximity Designs is a non-governmental organization providing humanitarian assistance to the people of Myanmar since 2004; our mission is to increase incomes and improve the food security of vulnerable rural households. True to its roots in IDE International, Proximity's social enterprise activities focus on creating and marketing affordable products and services for rural households that enable them to dramatically improve their livelihoods through increases in productivity and income. Products are made in Myanmar and sold at production cost while research and design, marketing, and HR costs are donor funded. With operations in 115 townships across 9 states and divisions, our work reaches an estimated 75 percent of Myanmar's rural population. We currently employ over 140 promotion staff nationwide and have built up distribution channels using 154 private agro-dealer shops and over 600 private independent village "agents" who offer our irrigation products including drip systems. Dealers are motivated to carry our products because we let them charge a profit margin on every sale, while independent village agents install pump and drip systems for small fees.

The following is a description of the evolution and development of our low cost, low-pressure drip system and how this system has been demonstrated and promoted from 2006 to the present. Much of the descriptive text will be found under *Materials and Methods* below. The on-farm demonstration and applied research approaches described are different from those in which the endpoint is publication in a refereed journal article. Our goals from the beginning were to develop a practical and affordable low pressure drip system in as short a time as possible using a combination of rapid prototypes and quick field tests or screenings, leaving the customer or end user to help make final determinations regarding its suitability for its task. This is similar to an approach employed by the Department of Horticulture at the University of Kentucky when well managed but unreplicated trials were used to screen large numbers of commercial vegetable varieties (Rowell, 2006). This paper is a first attempt at describing the process of developing a low cost, low pressure drip system for commercial vegetable growers and other horticultural crop farmers in Myanmar.

MATERIALS AND METHODS

Modern commercial drip systems from Netafim[3] were first introduced by representatives of the company and the Myanmar Agriculture Service (MAS) in one township in Mandalay Division in 1994 and later by an Israeli-local joint venture in 2006 within a government-organized vegetable production zone in Yangon Division. These efforts were soon discontinued or abandoned, however, due to their high management requirements and expense in the first case and as a result of iron precipitate clogging and other problems in the second. The systems were also considered too complex and costly for widespread adoption by local vegetable growers (Dr. U Win Htin and U Kyaw Win, personal communication). Our efforts to introduce this technology also began in 2006 through IDE Myanmar (now *Proximity Designs*) with support from the Bill and Melinda Gates Foundation.

When the senior author arrived in the country with the task of introducing drip in 2006 it was assumed--even by IDE--that this would be as simple as demonstration and sales of pre-packaged "drip kits" imported from IDE-India. But as we began to work with these kits it soon became apparent that they were not suited to vegetable production in the country. The prepackaged kit sizes were often too small or too large, but a more serious problem was that main or submain-to-lateral connectors were at fixed spacings which did not match the most common row-to-row spacings for vegetable crops in Myanmar. There were also no connectors available for flexible pipe which is ubiquitous in Myanmar. In addition, importation of the kits was slow, difficult, and expensive. For these reasons the Indian lateral tubing, microtube emitters, and screen filters were removed from kits on hand and used in our own custom on-farm installations and test plots from 2006 to 2008, with incremental substitution of locally-made components as they were developed.

[3]Drip systems were produced and installed by Netafim, a major global drip irrigation company based in Israel.

The basic design of IDE India's drip kit is an adaptation of an older microtube emitter system first introduced in Israel and the US in the 1960s. While this type of emitter has long since been abandoned for field use in developed countries in favor of more convenient (built-in) and clog resistant labyrinth or turbulent flow path emitters, microtubes are still used in many greenhouses in the United States and elsewhere. Significant improvements to the microtube system have been made based on research by Jack Keller[4] and J.N. Ray in India where use of these systems became widespread through marketing and promotion efforts of IDE-India.

Drip system research and development

Lateral/emitter screening

Somewhat skeptical of the microtube system, we began a series of "quick and dirty" screenings of various emitter types/laterals in a commercial vegetable grower's field at Bauk Htaw, an area of mostly leafy greens production within the Yangon city limits (Figure 2). With these tests we intended to eliminate the worst performers using very low pressures from elevated gravity tanks (height to the bottom of the tanks was 1.1 m or 3½ ft, = 1.5 psi) and dirty surface water together with simple 25 mm (1-inch), 100-mesh screen filters. Leaf lettuce was grown (Dec 2006-Jan 2007) followed by leaf mustard (Feb-March 2007). Both crops were grown in raised beds 15 m (50 ft) long and 1 m wide as is normal farm practice for leafy vegetables in Myanmar. Crop management (other than irrigation) and marketing was the responsibility of the local farmer.

Figure 2. Screening of drip laterals in Yangon, Dec 2006.

Two 15 m lengths of each lateral/emitter type were used on each bed. Six lateral/emitter systems were screened including three with moderate to high flow rates (IDE-India's microtube system, IDE-Nepal's 'baffle' emitter system, Adrilite[5], Table 1) and three low to moderate flow rate lateral/emitter systems including T-Tape[6], Chapin Watermatics drip tape, and a new Indian drip lateral product from Das Agroplastics. These were also compared to a control plot which was watered with sprinkling cans according to the farmer's usual practice. All plots were watered daily using equal amounts of water. Yield and product quality were measured by harvesting all plants in the bed within a 3 m subplot. Emitter flow rates from the different systems were measured indirectly by recording the amount of water discharged hourly from each of six 208-liter (55-gallon) plastic drums providing water to the six drip systems.

[4] Dr. Keller, CEO of Keller-Bliesner Engineering, Logan, Utah and Professor Emeritus, Utah State University, is a global authority in drip and sprinkler irrigation engineering. He is also the Senior Irrigation Advisor and long-time board member of IDE International. Dr. Keller has spent a large part of his professional career helping develop affordable microirrigation systems for low income farmers in India and throughout the developing world. Most low-pressure drip systems for developing countries, including ours, are based on his pioneering work.

[5] A product from Jordon that is very similar to Netafim products with hard plastic turbulent flow path emitters embedded inside the lateral tubing.

[6] T-tape is a drip lateral product with turbulent flow path emitters formed in the tubing during the extrusion process. Now sold by John Deere and commonly used on vegetable crops in the USA and elsewhere.

Table 1. Drip lateral and emitter systems tested at Bauk Htaw, Yangon, Myanmar, 2007.

Lateral/emitter type	Source	Emitter spacing	Flow rate
External, "baffle"	IDE Nepal	60 cm	high
External, microtube	KB brand, IDE India	--	high
Internal labyrinth flow path, *Adrilite*	Adritec Group Int., Jordon	30 cm	moderate-high
Internal labyrinth flow path, Das	Das Agroplastics, Pune, India	30 cm	low-moderate
Internal labyrinth flow path, *T-Tape*	T-Systems, now John Deere (USA)	30 cm	low
Internal labyrinth flow path, Chapin	Chapin Watermatics (USA), now Jain, India	30 cm	low

Open-pollinated leaf lettuce and leaf mustard were grown at equidistant spacings in 7 rows/bed. Emitter uniformity, while not measured directly, was observed by rating plant uniformity and vigor within the beds under the different drip systems. Any problems with flow or emitter clogging were also noted. Although emitters were soon hidden from view under dense plant canopies, it was easy to know when there were clogging problems by the lack of flow over time from the gravity tanks and resultant poor plant growth.

System performance testing

2009. While some information on low pressure, gravity-fed drip system performance was available from IDE-India, most of it was not applicable to the pipe sizes and drip components used in Myanmar after 2008. We also did not know the best possible arrangement of main, submains, and laterals to achieve maximum application uniformity at very low operating pressures. To answer these and other questions we conducted a series of 118 field tests on a more or less level one-acre (0.4ha) vacant plot in front of the Myanmar Agriculture Service's Plant Protection Division office in Yangon from March to June, 2009.

In nearly all of these tests the "bottom line" dependent variable was the coefficient of uniformity (*CU*) proposed by Keller (2002) as the standard measure of application uniformity for smallholder drip irrigation systems. The *CU* is derived from the coefficient of variation (*cv*) of catch can observations. The catch can *cv* is a measure of the variability of the amounts of water collected in catch cans from drip emitters at different locations within a test field and is easily calculated using a hand calculator or spreadsheet as follows:

$$cv = sd/q \times 100$$

where *sd* = standard deviation of the catch can amounts of the population, and *q* = overall average of all catch can observations. The *CU* is simply *100 – cv* and therefore a measure of water application uniformity. We used a *CU* of 80% as the minimum acceptable value in our tests as proposed for smallholder drip and sprinkler irrigation systems in developing countries (Keller, 2002).

Three groups of 6 catch cans each (18 total) were buried so that water from individual microtubes flowed easily into the containers. The first group of 6 cans was placed near the end of the first lateral closest to the main line, the second in the center of a lateral at the center of the plot, while the third was near the end of the last lateral (Figure 3). Water was collected in the cans for 3 minutes, after which the *CU* was calculated and the test repeated.

Figure 3. Manometers and catch cans used in drip system performance testing, 2009-10.

Independent variables examined in this first series of tests included water tank height, main line diameter, splitting of lateral lines with a center submain, placement of the main line (side or field center), use of a “T” connector to join the main line to submains, etc. In all cases we determined the maximum number of emitters (and length of laterals) that could be used and still maintain a *CU* of at least 80%. To do this we first selected what we considered a reasonable number of emitters/laterals and then increased or decreased this number after each test until the minimum *CU* was reached.

2010. A second series of tests was designed to pinpoint the source of large pressure losses occurring between the water tank and the first lateral and identify possible solutions. All tests were conducted in early 2010 at the same location as the previous year’s tests, but with a different experimental setup. Unlike previous tests, we did not set up a full drip system but used only a 1.8 m (6 ft) high water tank and its fittings together with a 30.5 m (100 ft) length of 32 mm (1¼-inch) locally made soft flexible pipe with a ball valve on the end. We used the ball valve to simulate total system flow. A single 14 m (45 ft) lateral with 6 microtubes at its far end was connected to the main at a distance of 2.7 m (9 ft) from the water tank. Two microtubes were also inserted in the main line between the tank and the first lateral about 30 cm (1 ft) from the lateral-to-main connection.

System pressures were measured using the microtubes described above connected to simple manometers made from transparent tubing sold for medical use (IV tubing). The tubing was mounted on vertical stands made from steel angle iron with cloth measuring tape attached behind the tubing (Figure 3). Pressure was measured as the height of the water column in the tubing and measurements were taken from two microtubes adjacent each area with catch cans (2009) and at the end of the single lateral used in 2010. All 2010 tests were conducted using two system flow rates corresponding to small (average 1890 lph or equivalent to approximately 1000 microtube emitters @ 2 lph/emitter[7]) and medium-sized (average 3667 lph or approximately 1940 microtubes) drip systems. Flow rates were determined before each test by direct measurement at the far end of the main line. High flow was simulated with an open valve while the lower flow rate was simulated by partially closing the valve.

Existing and alternative components and fittings of the water tank and drip set were tested for their effects on application uniformity and system pressure. The following components were evaluated and compared in a series of 80 tests conducted from March-May 2010:

1. PVC elbows vs. current water tank outlet nipple
2. 90° vs. 120° elbow at water tank outlet
3. Long vs. short elbow at water tank outlet
4. Flexible pipe vs. PVC pipe (25 and 32 mm or 1 and 1.25 inch) from water tank to filter
5. Flexible pipe from filter to ground vs. all PVC
6. Ball valve vs. no ball valve
7. 25 vs. 32 mm (1 vs. 1.25-inch) PVC pipe from water tank to ground
8. Ordinary screen filter vs. no filter
9. Myanmar-made vs. Indian screen filter (25 mm or1-inch)
10. External screen filter vs. 3 types of in-tank stainer/filters
11. Ordinary screen filter vs. 4 prototype in-line filters and two screen mesh sizes

Low pressure drip system design software

Low pressure drip system efficiency is highly sensitive to pressure variation. Given the large number of components and fittings affecting performance, and having gone through the laborious process of field testing many of these parts to optimize our system’s performance, we believed a computer software design tool would be extremely useful for improving current and developing new system configurations and designs. The program would also enable us to determine the best system configurations for fields larger than the size of two of our current drip sets. While a good MS Excel© program had been developed earlier by Andrew Keller, it was limited to only a few variables.

[7]1890 lph = 500 gph @ 0.53 gph/emitter and 3667 lph = 970 gph.

Our goal was to develop an easy-to-use program for both specialists making component design changes, and for drip technicians and field staff designing custom systems for farmers. To this end we hired irrigation engineer Ryan Weber in early 2011 to develop a low pressure hydraulic model based on field tests in Myanmar. An experimental drip system was installed within a two-acre (0.8ha) plot of turfgrass at the FMI Estates properties just across the Yangon River on the west side of Yangon. In addition to the usual IV-tube manometers, in-line pressure sensors with dataloggers were used to monitor small changes in system pressure. Measurements also included tests of water application uniformity of microtube emitters. In addition to recording observations for software development, Weber and Tun Tun Khine also tested samples of large diameter 63 mm (2.5-inch) LLDPE layflat pipe from IDE-India for its suitability for use as main and submain lines in our drip system.

Farmers' field testing and demonstration

The first two seasons, 2007-2008

Ten small preliminary drip system tests were established in Jan-March 2007 at Kungyangon Township about 100 km south of Yangon and in Hllegu and Hmawbi Townships 25-30 km north of Yangon. Kungyangon was selected because IDE Myanmar's foot-powered treadle pumps were popular there and because of a local tradition of elevating old oil drums to use for watering vegetables and other crops with hoses. Hmawbi and Hllegu also had a high concentration of vegetable growers using our treadle pumps.

In most cases the plots consisted of 100-200 m of drip laterals applied to a few rows within a farmer's existing commercial planting which was watered by sprinkler cans, furrow, or elevated tank and hose prior to drip installation. Old 208 l (55-gal) oil drums on 1.2-1.5 m (4-5 ft) high stands were used as header tanks to pressurize the systems. Ordinary 25 mm (1-inch), 100 mesh screen filters from IDE-India were used together with *Tape-loc* (T-Systems, USA)[8] main-to-lateral connectors. The main line was 25 mm (1-inch) diameter flexible pipe (recycled PVC) available throughout Myanmar. In some cases treadle pumps were mounted on stands above the oil drums for easy filling. This required the user to operate the pump from above the tank (Figure 4) or use treadles on the ground linked to the pump by ropes or cables. This practice of filling elevated tanks with treadle pumps existed in some parts of Myanmar even before we began introducing drip. In a few cases farmers filled tanks by hand from nearby wells. Either the microtube emitter system (IDE-India) or Das (turbulent flow emitter) laterals were used in these tests. Das laterals were used only at sites where a tube well was the water source.

Figure 4. Elevated ordinary treadle pump (left) and new *Sin Pauq* pump with Proximity drip system (right).

After completion of the drip lateral screenings and preliminary farmers' field tests described above, we established another 60 demonstrations/trials on small farms within almost every agro-climatic zone in the country in late 2007-early 2008. Locations were chosen according to the interest of our promotion staff and the perceived interest of farmers in those

[8] Inside diameters were only 4 mm which limited overall system performance in larger farmers' field trials.

areas. Indian microtube systems were installed at most sites while laterals with extruded turbulent flow path emitters from Das Agroplastics were installed at about a third of the sites.

Unlike the previous year, elevated water tanks used for many of the 2007-08 on-farm demonstrations were prototypes of what came to be known as the "Water Basket". The Water Basket consisted of inexpensive plastic tarp material folded and riveted to form a cubical 200-gallon water container[9]. These tanks were elevated on sturdy 1.8-2.4 m (6-8 ft) tall bamboo or wooden stands and had to be enclosed with bamboo or wooden sidewalls (Figure 4, left).

All of these tests/demonstrations were custom installations (no kits) done directly by the authors together with local field staff as the technology was still unknown to both field staff and farmers. Drip was installed on a wide variety of crops including 9 different vegetables, 6 different fruit crops, 4 different flower crops and betel vine (*Piper betle* L.).

2008-09

On-farm demonstration has been the cornerstone of our drip irrigation promotion program from the beginning, and over 300 demonstrations and installations were conducted across the country during the 2008-09 dry season. While drip system components were provided free of charge to farmers in some areas who had never heard of drip, two-thirds of the total systems installed were sold to farmers already convinced of its value. These farmers and our staff also benefited from the draft publication of *Easy Watering in Six Steps--Drip Irrigation Installation Guide*, an illustrated booklet with simple start-to-finish instructions on how to install a small gravity-fed drip system.

Given the expense and difficulty of importing drip kits and components at the time, we concluded that *drip irrigation would never become economical and accessible to the majority of Myanmar's small farmers without access to inexpensive locally made products*. All of our installations now included components which we had designed and manufactured in-country including a simple punch and connector system for joining drip laterals to flexible pipe and an ordinary 25 mm (1-inch) plastic screen filter. The main or submain-to-lateral connectors were designed both to accommodate variable lateral tubing diameter and for easy installation and good fit in locally available recycled flexible plastic pipe. The connectors were also designed with very large (10 mm) inside diameters to reduce friction losses and increase flow in low pressure systems.

2009-10

After implementing significant system improvements based on our early 2009 system performance tests described above, the 2009-10 growing season marked the launch of the first drip set made entirely in Myanmar. Components of the new packaged sets are shown in Figure 5. The set was designed for typical installations of about 365 m^2 (3936 ft^2) of vegetables and other crops with typical row-to-row spacing of 1.2 m (4 ft). This was a size we considered large enough for local commercial plantings but still small enough to be affordable to smallholder farmers. In addition, a 20% introductory discount was offered that year as an extra incentive to new customers.

[9] The concept and initial design of the Water Basket came from Stanford University's "Design for Extreme Affordability" classes in 2006 and 2007 in collaboration with IDE-Myanmar. We manufactured over 4000 in May and June of 2008 to use for emergency water supplies in the aftermath of cyclone *Nargis*. The Water Basket remains a vital component of Proximity's low pressure drip systems. New self-supporting designs continue to undergo testing and improvement.

Figure 5. Main components of Proximity's packaged drip set, 2011.

Treadle pumps, Water Baskets, and main line pipe were sold separately but available through the same field staff and dealer shops. It was decided not to package and sell flexible pipe for main or submains as this material was bulky, expensive to transport, and generally available in small hardware and plumbing shops throughout the country.

Over 500 drip sets were installed by our field staff and agents during the 2009-10 dry season. In this first year of formal sales it was decided to target former customers who already owned treadle pumps. We assumed that many pump users would have earned extra cash and would be more interested in new products based on their experience with the pump and their relationship with us and our field staff. These farmers, while not the poorest or the most risk averse, were much more likely to try this radically new and unfamiliar technology than those with absolutely no spare cash (or in debt) and who were unfamiliar with our products. This launch year also coincided with the first season in which we began offering product loans, and more than half of drip sales were as a result of these loans. The loan program turned out to be a two-edged sword, however, requiring a lot of time to administer by field staff who might otherwise have done more drip installations and on-farm demonstrations.

It has been our policy to provide an interested farmer a drip set or partial set free-of-charge in a new area in exchange for their willingness to take ownership of all other aspects of crop production and marketing while providing us with a minimal amount of feedback. Free demonstrations continued only in areas which had not seen a drip system and for the first time the majority of sets were *sold* by our field staff and dealer shops. These first drip sets were installed by our field staff with the full participation of the farmer, or in many cases, the whole family.

2010-11

Important changes in system components were implemented for the 2010-11 dry season as a result of the performance tests conducted in the spring of 2010. The new drip set included a newly-designed screen filter which greatly reduced pressure losses and all new fittings/pipes connecting the Water Basket to the main line. Even more importantly, Proximity's design team launched the entirely new and inexpensive plastic *Sin Pauq* (Baby Elephant) treadle pump, the first such pump designed for easy mounting above an elevated tank (Figure 4, right). This combination of Water Basket, *Sin Pauq*, and drip set--now with nearly all components optimized for low pressure operation--set the stage for rapid expansion of drip irrigation during the 2010-11 dry season and beyond.

RESULTS AND DISCUSSION

Drip system research and development

Lateral/emitter screening

Only a few examples of the results will be presented here. Figure 6 shows total marketable yields of mustard and leaf lettuce per 15 m (50 ft) bed. These data should be considered as only rough indicators of drip system performance and no firm conclusions are possible without further replication. It was obvious from these simple tests, however, that low to moderate flow rates from turbulent flow path emitter products (T-tape, Das, Adrilite) resulted in higher yields and better uniformity of densely planted leafy greens than from IDE-India (KB) microtube or Nepali 'baffle' systems with their very high flow rates (Figure 6). Some of the drip systems also resulted in yields equal to or slightly higher than sprinkler can watering for leaf lettuce, but not for mustard. Direct comparisons with sprinkler can watering, however, were beyond the scope of this study and no firm conclusions are possible.

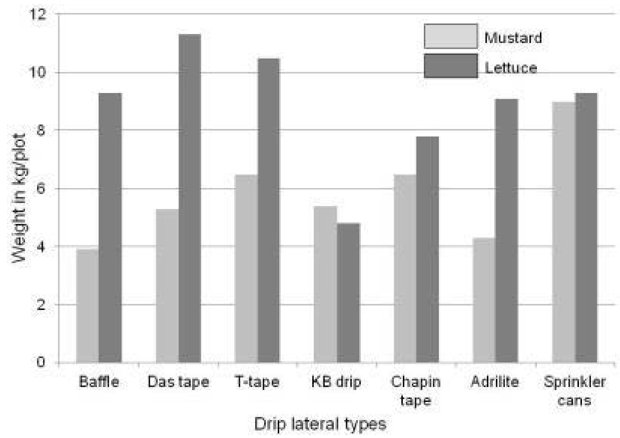

Figure 6. Relative marketable yields of mustard and leaf lettuce from 6 different drip laterals and sprinkler cans, Yangon, 2007.

The reasons why low flow rate drip laterals performed better became obvious as the season progressed. Both lettuce and mustard formed solid canopies of plants which completely covered the bed surface, and within these canopies it was easy to see that plants in rows farthest from the KB (microtube) and 'baffle' emitters were not receiving sufficient water. We believe this to have occurred because of the wide beds and high flow rates. Water behaves differently in soil at high and low flow rates; at high rates the soil matrix becomes saturated and gravity is the dominant force causing more downward movement of the water column. At low flow rates (Chapin, T-tape, Das) water moves more by capillary action through small pore spaces in the soil, resulting in water which is pulled in all directions and the formation of a larger wetted area. This would naturally result in more uniform plant growth across wide beds.

While we do not consider dense plantings of leafy greens in wide beds particularly suitable for drip irrigation because of the cost of multiple laterals, they were quick and easy indicators of emitter/drip system performance. If we had used only these preliminary findings, however, we might have selected a turbulent flow path emitter system as the best choice for Myanmar farmers. As it turned out there were other more important selection criteria including resistance to clogging and ease of manufacturing.

Figures 7 and 8 show water discharge rates for the 6 drip lateral/emitter systems with the leaf lettuce crop on 21 and 27 Dec. The *x* axis indicates the number of gallons (1l = 0.264 gallons) remaining in the tanks while the y axis is the number of hours after beginning irrigation that day. Steeper lines indicate faster discharge and higher flow rates. The data shown in Figure 7 indicate more or less normal flow rates at low pressures from all systems. If we examine the lines on 27 Dec, however, it becomes clear that some clogging has occurred in three of the turbulent flow path emitter laterals including T-tape, Chapin, and to a lesser degree, Das (Figure 8). T-tape appears to have been partially blocked when the irrigation began and completely blocked 4½ hours later. Although a thorough flushing the following day resulted in better flow from these laterals, the problem persisted.

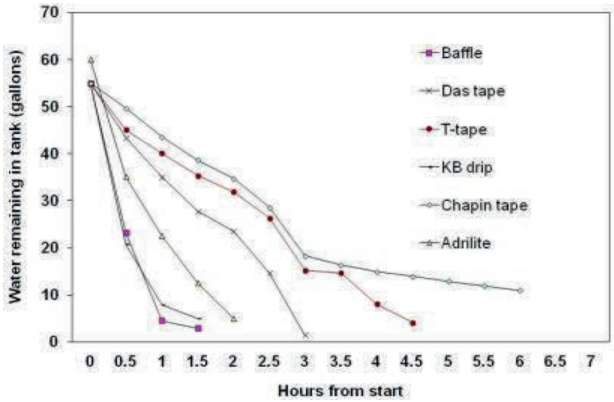

Figure 7. Water remaining in tanks 1½-6 hours after start of drip irrigation on leaf lettuce from 6 lateral types, Yangon, 21

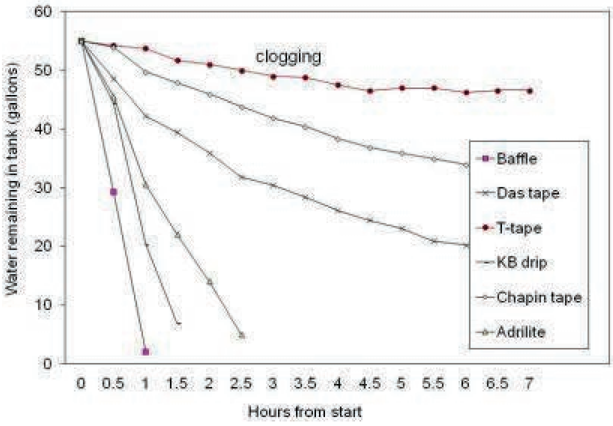

Figure 8. Water remaining in tanks 1-7 hours after start of drip irrigation on leaf lettuce from 6 lateral types, Yangon, 27 Dec 2006.

We continued to measure hourly flow from all treatments for a week after harvesting mustard on 10 March. By 15 March, 90% of the T-tape emitters were clogged, and by 16 March 60% of the Chapin emitters were partially or completely clogged together with 90% of Das emitters. Attempts to clean and re-use these laterals on a third crop were unsuccessful. It should be understood that we purposefully tested these systems under difficult conditions for drip. Water at the site was dirty surface water from a nearby city drainage canal; knowing that most local farmers could not afford expensive sand or disc filters, we used only simple 100-mesh screen filters in these tests. Under these conditions of inadequate filtration, all turbulent flow emitters (with the possible exception of Adrilite) became clogged after only two short-season crops or a period of about 70 days.

While Adrilite laterals appeared to be more clog resistant than other labyrinth flow path emitter products in our tests, this product has complex injection molded emitters that are installed during the extrusion process—a manufacturing process impossible to duplicate at this time in Myanmar. While IDE-Nepal's baffle emitter system was also resistant to clogging, we did not like its fixed emitter spacing nor the very small lateral pipe diameters which could limit its use in larger plantings. For these reasons we selected the microtube emitter system for further testing as it appeared to be the most robust in terms of clogging, was flexible in terms of emitter spacing, and would perhaps be the easiest to manufacture. We also decided to do further farmers' field testing of Das laterals the following dry season in situations with relatively clean well water.

System performance testing

2009. Significant limitations of our custom drip installations became apparent after extensive country-wide farmers' field testing during the 2007-08 and 2008-09 dry seasons. Customer satisfaction was reasonably good but somewhat less than expected with frequent user complaints of “not enough water” from emitters farthest away from the water tanks. In addition, nearly nothing was known regarding the size limits or water application uniformity of the system for given tank heights/operating pressures, main line diameters, and arrangements of laterals.

Only a summary of the most relevant conclusions from the early 2009 uniformity tests are included here. After comparing 1.2, 1.8, and 3 m (4, 6, and 10 ft) heights we chose to use a water tank height of 1.8 m (6 ft, height to bottom of the tank) used in conjunction with 32 mm (1¼-inch) flexible pipe for main and/or submains. Twenty-five mm (1-inch) pipe reduced flow and system performance considerably while the more expensive 38 mm (1½-inch) pipe did not offer sufficient advantages to justify its cost for a small drip system.[10] Several field arrangements of main, submains, and laterals were compared for best performance under low pressures.

These results were simplified as four ‘good’, ‘better’ and ‘best’ configurations shown in Figure 9 and Table 2[11] which were published in our installation guide. These results also led to the design and manufacture of new components for 2009 including two sizes of plastic ‘T’-fittings used to join mains to submains (Fig. 5). The tests also revealed significant gains in pressure and flow from removing the ordinary one-inch screen filter as was reported by some of our customers. We considered the advantages of having this basic filtration outweighed potential gains in pressure and system size, however, and all results published in our installation guide were from tests which included a screen filter. Filter problems were studied more in depth in the 2010 tests.

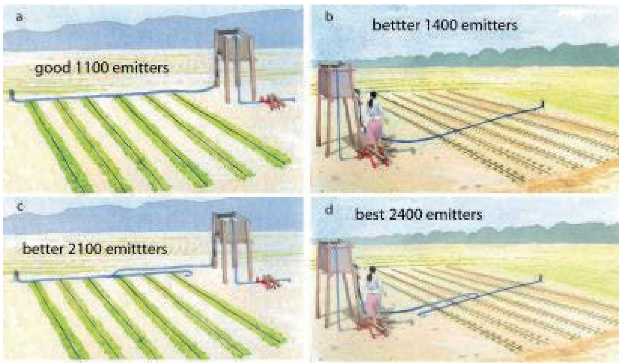

Figure 9. Illustrations used in the installation guide showing results of tests of drip field layouts.

Table 2. Maximum number of 15 m (50 ft) laterals and microtubes (MTs) possible with current drip system and 1.8 m (6 ft) height to water tank outlet using 32 mm (1.25-inch) main and/or submains with 30 cm (12-inch) spacings between microtubes.

Field layout	No. 15 m laterals	Max. no. MTs
side main, no “T”	22	1100
center main, no “T”	28	1400
side submain, with “T”	42	2100
center submain, with “T”	48	2400

2010. While the above tests resulted in a better functioning system that could be optimized in terms of field design, further studies were required after the 2009-10 dry season. The 2009 results were shared with Jack Keller in the interim who observed that we were losing most of our system pressure at some point or points between the elevated tank and the junction of the

[10] These tests used locally available recycled PVC flexible pipe. Larger pipe diameters of this material is expensive and did not improve system performance in 2009 in part because of a small diameter Water Basket outlet used in those tests. Later tests revealed significant advantages if larger diameter LLDPE tubing could be used for main and submains.

[11] Results shown in Table 2 are those from the current (2011) edition of the installation guide.

main or submain to the first laterals. A series of tests was subsequently conducted in early 2010 to try and pinpoint sources of these losses and to redesign the system to minimize them.

While eleven separate components were tested at moderate and low system flow rates for their effects on system pressures and water application uniformity, only the most important results are summarized here. It was found that rigid, nominal 25 mm/1-inch PVC (inside diameter is actually 32 mm or 1¼ in.) pipe functioned better than 30 mm/1¼-inch (30 mm actual i.d.) flexible pipe, at least for the first 60 cm (2 ft) below the water tank where the pipe joined the filter. To simplify installations we chose to use this rigid 1-inch PVC for the entire length of pipe required between the water tank and ground level, at which point 1¼-inch flexible pipe could be used as the main line without significant additional pressure losses. The old outlet used on the Water Basket was also found to restrict flow and was enlarged to 34 mm.

Filter testing and design. Many of these tests concerned high losses of pressure from our standard 25 mm (1-inch) screen filter which is of the same design used in most IDE and other small drip systems around the world. Losses were the same with this type of filter regardless of whether it was manufactured in India or Myanmar and amounted to nearly half (46%) of the total system pressure at low flow rates (Figure 10). This should not be surprising as these filters were originally designed for use with higher system pressures than are obtained from gravity systems using only 1.2-1.8 m (4-6 ft or 1.7-2.6 psi) header tanks. To resolve this problem we tested three filter designs mounted at the outlet *inside* the Water Basket and four prototype screen filters mounted in the usual position between the Water Basket outlet and the ground.

A summary of results comparing pressure losses from several of the filters and prototypes is shown in Figure 10. While all filters mounted inside the Water Basket performed well without significant losses, we decided not to use this type as they were difficult to remove for cleaning. The straight in-line external filter prototype shown in Figure 11a looked very promising with relatively low pressure losses (23% of total head) at low flow rates more typical of our drip set size (Fig. 10).

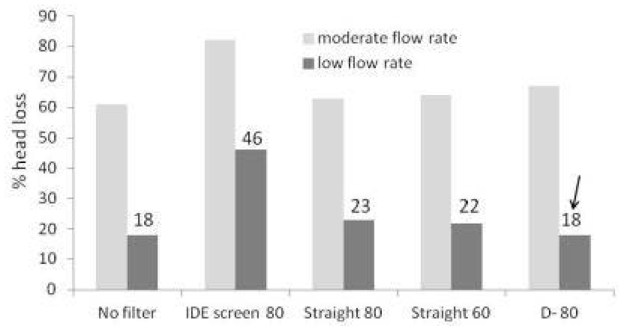

Figure 10. Relative pressure losses (%) from no filter, ordinary screen filter (IDE screen 80), straight pipe filter prototype, and new Proximity filter prototype (D-80).

A filter of this design, however, required that the entire filter body be removed from the line in order to clean the screen element. The prototype in Figure 11b was made to overcome this problem and performed just as well, reducing total head losses from 46% with the ordinary filter to only 18% (equivalent of no filter) while allowing easy access to the filter element for cleaning.

Based on these findings, Proximity's design team developed the final form of the injection molded filter body shown in Figure 11c which has been used in all our drip sets since late 2010. While designed for tight friction fits with ordinary rigid PVC pipe and small drip systems, local farmers are also using it with flexible pipe submains at higher pressures for larger systems using motorized pumps. Since changing to this filter we have received no further complaints of pressure losses and almost never see drip systems in the field with the filter removed. The net result from these changes in the filter and other components was that with the same low system pressure we could now effectively irrigate over twice the area as the system used prior to the 2010-11 dry season.[12]

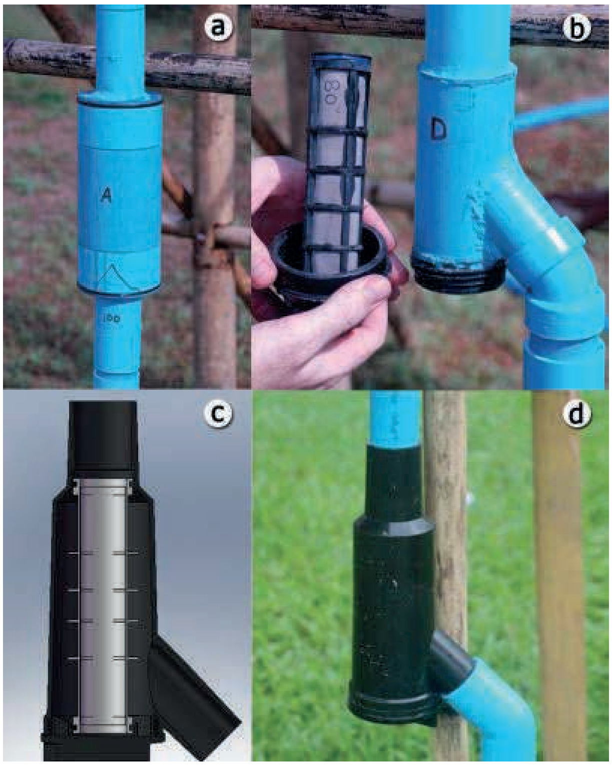

Figure 11. Screen filter prototypes straight (a), D-80 (b) and final product (c-d).

Low pressure drip system design software

While the 2010 tests resulted in significant improvements in low pressure drip system performance, we did not have time to determine exactly what these improvements meant in terms of system size, numbers of emitters possible, and field configurations like those shown in Figure 9. But instead of beginning another time-consuming series of field trials, we invested in software development to answer these and other questions. Weber and Tun Tun Khine conducted a series of field trials in early 2011 which resulted in a computer model for low pressure drip systems. The model is now being used to develop a user-friendly program (for PCs and possibly other portable electronic devices). Weber's model uses basic hydraulic principles along with measured characteristics of individual drip system components to show the effects of component design changes, main, sub-main and lateral diameters, various field layouts, and effects of inlet pressure on overall system performance. The new software is still being tested but will soon be released as a Proximity Designs irrigation product. It was used to determine the maximum number of emitters/laterals for different system configurations using new drip components and fittings first sold in the 2010-11 season. The results were published in the latest (2011) edition of our *Installation Guide* (Figure 9 and Table 2).

Large diameter main/submain system

In addition to drip system modeling, Weber and Khine tested larger diameter (64 mm or 2.5-inch) LLDPE layflat tubing from an IDE-India sprinkler set for use as drip main/submains with some of our existing system components. They obtained further reductions in pressure losses using this pipe which was not only considerably larger, but also has a much smoother inner surface than local flexible pipe. Both factors reduce losses from friction within the pipe, especially at higher flow rates in larger systems.

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[12]The new system can easily irrigate two full drip sets (1200 emitters) or about 730 m^2 of vegetable crops with a CU of at least 80% and a height to the Water Basket outlet of 6 ft (1.8 m).

Further modeling using the software showed that a 51 mm (2-inch) diameter layflat size would be ideal in terms of pressure gains and maximum system size. Using a 51 mm/2-inch layflat main line, a tank height of only 0.6 m (2 ft) was enough for uniform application of water through a system the size of our current drip set. A height of only 1.2 m (4 ft) could uniformly irrigate a plot twice the size of our current set or 732 m^2 (7870 ft^2) of a commercial vegetable crop using 1.2 m (4 ft) row-to-row spacings.

Although using larger pipe requires redesign of several components including the main system valve and filter, the potential gains are significant. Not only will the new pipe be easier to store and transport, it should also be half the price of smaller diameter local flexible recycled PVC pipe while lasting just as long or longer. Our immediate goal is find or help establish another local LLDPE pipe manufacturer while making the required system design changes over the next two years.

Farmers' field testing, demonstration, and sales

The first season, 2006-07

Results of the early 2007 farmers' field trials were mixed and limitations of the systems tested quickly became apparent. Only about half the farmers were satisfied with system performance and some were quick to stop using it and return to watering with sprinkler cans. Those who had to fill elevated tanks by hand using sprinkler cans or other containers could not see any obvious advantages over watering with the cans directly. We concluded early on that *few farmers would adopt drip if required to fill an elevated tank (of any type) by hand*. Other farmers observed that water application was not uniform, especially when long laterals over 21 m (70 ft) were used; still others described the common fear that drip could not possibly supply enough water to their plants.

Other serious challenges observed during this first year included the old oil drum water tanks which were expensive, relatively small, difficult to transport, and difficult to fit with a proper outlet. So it was understood early on that two of *the most critical elements of simple and inexpensive low pressure drip systems would be a cheap and easily elevated water tank in combination with a treadle pump or other simple means of filling these tanks*.

Iron problems

A more serious problem was observed at a tube well site in Hmawbi Township where Das drip laterals had been installed on a plot of chilis. Emitters in these laterals became completely blocked with iron precipitate within a month of installation; the same problem was observed at another site in Kungyangon. We have since learned that dissolved iron is a fairly common problem in well water in parts of Myanmar and now routinely test for it. We feared that without some simple solution to the problem, there might be large areas of the country where drip irrigation would not be possible.

Fortunately one of our field staff showed us a simple solution to this problem used by villagers in an area where iron-contaminated drinking water was commonplace. It is well known in that area that drinking water from local wells could be 'cleaned' by letting it pass through a simple container holding burned rice husks obtained from a local rice mill.[13] Using a commercial iron test kit,[14] we found that a 20-gallon container of burnt husks could remove high levels of iron almost instantaneously as the water passed through it. In our tests, water with 5 ppm iron was reduced to 0-1 ppm after passing rapidly through the filter. Taking advantage of this local technique, we manufactured simple 20-gallon containers made of tarp material with porous bottoms; these were filled with burnt rice husks and suspended between an elevated treadle pump and Water Basket. Drip is now used extensively with these filters in areas where the problem is severe and where we thought drip would never be possible[15].

[13] Most rice mills in Myanmar are powered by stationary steam engines; rice husks from the milling process are burned as fuel for a boiler which supplies steam to the engine. The burnt residues from this process must be removed and discarded, and it is this material which is used for filtering iron. It is suspected that this material may contain activated carbon.

[14] Hach test kit model IR-18 (for 0-5 mg/l Fe), Hach Co., Loveland, Colorado, USA.

[15] Dissolved iron levels above 1.5 ppm are considered "severe" in terms of clogging hazard for drip irrigation.

2007-08

The second series of 60 on-farm tests with various crops during the 2007-08 dry season was more successful than the first with over half of the farmer-cooperators showing genuine interest in drip irrigation. An in-depth survey of drip users conducted in early 2008 indicated that 61% liked the system and planned to continue to use it next dry season. While we considered this an acceptable continuation rate for first time users (Commodity Growers Assn., 1998)[16], there were still perceptual and performance problems with the new system. Our survey indicated that the primary concern of 40% of the new drip users was insecurity about the amounts of water applied, i.e., they did not think drip could provide as much water as copious amounts from traditional sprinkler cans. Our installation team also spent a lot of time discussing crop water requirements with farmers who were trying drip, often explaining how equal amounts of water could be applied with drip as with traditional watering methods.

There were also cases of lack of application uniformity, usually resulting from less flow from emitters farthest from the elevated water tank. In addition, we recognized the urgent need for more drip irrigation training for field staff and for the development of drip-related educational tools and materials (Table 3) to use in conjunction with a strong and ongoing on-farm demonstration program.

An unexpected and frustrating hardware problem was the variable inside diameter of the LLDPE lateral tubing purchased from IDE-India. While nominally 16 mm, individual 100 m rolls of tubing varied widely, so much so that laterals would often not fit IDE-India's own or other commercial lateral-to-main connectors designed for 16 mm tubing. The tubing was often either too large, requiring further securing with wire and resulting in very leaky connections, or in fewer cases was too small, not fitting onto the connectors at all.

During the course of the season we also observed more cases of emitter clogging of Das, "D-tape"[17], and even microtube emitters from iron in well water. While in most cases Das and D-tape did not clog when used for a single season with iron-free tube well water, *we decided not to continue to test or promote labyrinth flow path emitter laterals*. The decision was made in part because of the risk of clogging, but also because of the near term impossibility of setting up local manufacturing for these or similar products.

2008-2011 dry seasons

Over 300 custom drip systems were installed in the 2008-09 dry season followed by over 500 installations of pre-packaged small farm drip sets in their 2009-10 launch year. Over half of the '08-09 installations were paid for with our product loans first offered in that year. The majority (over 70%) of systems installed after the 3rd season were also purchased with product loans administered by the same field staff who were promoting and installing drip systems. About this time, self-employed independent village "agents" began doing a few drip installations for small fees in some areas.

Our drip user survey conducted just after the third or 2008-09 season clearly indicated a growing satisfaction with the product and its performance with 79% now reporting their intention to continue to use drip compared with 61% the previous year. The perceptions of drip also appeared to be changing as now only 10% of users surveyed reported that drip was 'not supplying enough water' compared with 40% after the 2007-08 season.

Questions about satisfaction with drip and Water Baskets were included in a new *Customer Care Survey* of 200 drip users conducted just after the 2009-10 dry season. Respondents were given four choices of "unsatisfied", "neutral", "satisfied", or "very satisfied" in answer to the questions and 88% were either "satisfied" (37%) or "very satisfied" (51%)

[16] This study evaluated the impact of a long term on-farm demonstration program for drip irrigation with small commercial vegetable growers in Kentucky in the southeastern US. The authors reported 50-60% continuation rates for first time users.

[17] D-tape is the brand name for an extruded labyrinth or turbulent flow path emitter drip lateral available in Thailand. Its appearance is very similar to the Das product and may be manufactured using the same or similar machinery. We installed several systems using D-tape during the 2007-08 dry season.

with the ease of use of the product. More significantly, 91% reported that they had recommended drip to a friend or neighbor.

When asked about using hired labor for crop production before and after drip adoption, 59% reported that they had used hired labor prior to using drip while only 5% reported having hired labor after drip adoption. These farmers also reported that, prior to drip adoption, the made an average of 119 trips to the field daily using sprinkler cans. This amounts to a daily burden of carrying 4 t of water to the field on their backs. We know from this and countless interviews with farmers that the *elimination of this heavy labor and the resultant time and energy savings are the primary motivations for adopting drip.*

Sales of drip systems jumped more than fourfold to over 2100 units during the 2010-11 dry season[18]. This can be attributed to a number of factors, not least of which was a new emphasis on drip promotion communicated to field staff by Proximity Design's leadership during the launch meeting at the beginning of the season. It was now clear that drip was a product that was here to stay and that all field staff were expected to actively promote it and conduct at least five on-farm demonstrations in areas where no drip systems had been used before.

Drip sales were also given a boost as a result of our first serious efforts to train self-employed village "agents" who in the past did local treadle pump installations for small fees. Many of these agents installed drip on their own plots after learning how to set up and operate a small system during their training program in Yangon. Given proper 'hands-on' training, these agents often became the first adopters in their communities where they are known and trusted. Nearly all these agents are farmers themselves and help begin the process of farmer-to-farmer observation and discussion which can result in further adoption without the same level of promotional efforts required of our full-time staff. They no doubt multiply the capacity of full-time field staff and will remain key players in the scaling up and further expansion of drip in Myanmar.

Other factors helping boost sales were the availability of credit through product loans and the launch of the easily elevated *Sin Pauq* treadle pump, sales of which increased rapidly in 2010-11, the year of its introduction. Last but not least, the drip system itself had undergone several major changes including a newly-designed screen filter and other components which significantly reduced pressure losses compared with ordinary filters and drip components designed for higher pressures. This year also saw the expansion of sales of individual drip components for larger drip systems using motorized pumps.

Table 3. Drip irrigation publications and training materials developed for Myanmar*

Guidebooks and bulletins	Date	Length	Language(s)
Easy Watering in 6 Steps—Drip Irrigation Installation Guide. 3rd edition	2011	32 p.	Burmese and English
Drip Irrigation for Fruit Crops and Betel Vine	2010	20 p.	Burmese and English
Filtering Iron for Drip Irrigation in Myanmar	2010	2 p.	Burmese and English
Simple Fertigation for Drip Irrigation in Myanmar	2011	5 p.	Burmese and English
ET-based Water requirement calculators			
Water Wheel Calculator for Myanmar Vegetable Crops	2009	--	Burmese
Water Wheel Calculator for Myanmar Fruit and Tree Crops	2010	--	Burmese
Videos and clips			
Goodbye Sprinkler Cans	2010	4 min	Burmese, English subtitles
How Drip Irrigation Works	2010	5 min	Burmese, English subtitles
What Farmers are Saying about Drip Irrigation	2009	19 min	Burmese, English subtitles
Time lapse of water spread in soil from microtubes (loop)	2011	30 sec	(no soundtrack)

******some of these will be available from our website: www.proximitydesigns.org*

[18] This figure does not include a large amount of lateral pipe and fittings sold to customers who were expanding an existing drip set for larger plots or making their own systems using our components.

CONCLUSION

Based on hundreds of controlled tests and on-farm demonstrations conducted over the past five years, we have developed a robust, locally manufactured low pressure drip irrigation system which is becoming increasingly popular with both small and large commercial horticultural crop farmers in Myanmar (see *Appendix*). Over 5000 sets have been installed to date with 85% of these having been sold last season and during the first three months of the current (2011-12) dry season. These have been used on a very wide range of crops including 16 different vegetable crops, 14 fruit crops, 5 ornamental crops and 7 crops grown for other uses such as perfume, betel leaves and coffee.

We have created a market for not only a new product, but an entirely new system of irrigation for which none previously existed. While developing each component of the drip set to function well using very low system pressures was essential, this alone did not ensure success. We could not have developed a drip system in the Myanmar context in isolation and without substantive and concurrent efforts to develop affordable water containers and inexpensive pumps to fill those containers.

In has been our experience that the concept of drip irrigation is more difficult to sell than the hardware. We devoted a considerable amount of time and resources to develop training aids and tools which help change perceptions and which simplify and explain the technology to both staff and farmers unfamiliar with it. In the beginning stages at least, the scaling up of drip requires an extensive network of well-trained, field-based promotion staff and/or private agents who can comfortably explain, install, and demonstrate the technology in areas where it was previously unknown. Strong perceptual barriers must be overcome with effective practical staff training and on-farm demonstration ("seeing is believing"). It is especially important that these staff ensure success of the first adopters so that farmer-to-farmer diffusion can occur. Often overlooked is also the level of technical support/expertise required to ensure their success. This includes the ability to train key staff and counterparts, to solve problems as they inevitably arise, to experiment with system changes, and to produce appropriate educational tools and materials (Table 3) in support of the on-farm demonstration and training programs.

The importance of product loans or other credit cannot be underestimated, especially in countries like Myanmar where farmers currently have little or no access to low-interest agricultural loans. Although time consuming and difficult to manage in the beginning, the product loans made available to our customers since 2009 have accelerated adoption of drip and helped ensure more equitable access to the technology.

Our history of introducing drip in Myanmar has been one of slow growth--testing, improving, and demonstrating custom systems built with imported pieces and parts while gradually substituting locally made components as they were developed[19]. Only in the final stages were drip sets or 'kits' assembled and marketed with all locally made components (Figure 5). We are still at the 'early adopter' stage in many parts of the country and a generation may be required before the technology is well known and widespread. This poses a challenge to donors supporting social enterprise efforts and organizations implementing those efforts who may expect quick results and impact. It is hoped that the lessons learned and described in this paper will help others shorten the time and effort required to introduce drip in similar socio-economic settings.

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[19]IDE-Vietnam is taking a similar approach in its efforts to introduce low cost drip in one of the poorest and driest provinces in the country.

References

Commodity Growers Association. 1998. Pumpkin patches on tobacco road—improving horticultural and other farm product opportunities in tobacco communities. Commodity Growers Cooperative Association, Lexington, Kentucky, USA. 72p.

Keller, J. 2002. Evolution of drip/micro irrigation: traditional and non-traditional uses. Keynote address, International Meeting on Advances in Drip/Micro Irrigation, 2-5 December, 2002, Tenerife, Spain.

Maung Maung Yi. 2009. Importance, production, consumption, and development of vegetables in Myanmar. p. 19-30 in Proceedings, Workshop on Vegetables for Sustainable Food and Nutritional Security. FAO Myanmar. 181p.

Rowell, B. (ed.), 1999. 1999 Fruit and Vegetable Crops Research Report. Dept. of Horticulture, University of Kentucky Publ. PR-423. see this and following (1998-present) annual research reports for details of ongoing on-farm demonstration program with drip irrigation on commercial vegetables in Kentucky. http://www.uky.edu/Ag/Horticulture/comveggie.html

Rowell, B. 2006. Rapid action cultivar evaluation (RACE) trials. p. 8 in Snyder, J.C. and Smigell, C. (eds.). 2006 Fruit and Vegetable Crops Research Report. Dept. of Horticulture Publication PR 538. University of Kentucky, Lexington.

APPENDIX
Components of Proximity Design's low pressure drip system

While we plan to implement further improvements over the next two years, the components of our current system are as follows:

1. 16 mm LLDPE lateral tubing (200 micron wall thickness) with 1-1.1 mm (inside diameter) microtube emitters

2. Low cost, large capacity (567-945 liter or 150-250 gallon) collapsible Water Basket header tanks with appropriate large diameter outlets and fittings for connections with drip system.

3. Low cost treadle pumps for filling header tanks. Treadle *pressure pumps* can be used at ground level to fill elevated tanks while ordinary suction treadle pumps must be mounted above the tank. The inexpensive plastic *Sin Pauq* pump is now the most popular pump used with our drip systems. All treadle pumps, however, are limited to suction heads of no more than 7.6 m (25 ft) or areas with surface water or relatively shallow groundwater.

4. Simple one-piece 'high flow' lateral-to-submain connectors with punch for easy installation and removal in flexible pipe. Connectors have large 10 mm inside diameters and variable (stepped) outside diameters to accommodate variations in lateral tubing diameter.

5. Lateral-to-lateral couplers to join ends of lateral tubing and for lateral repairs; inside and outside diameters are the same as the lateral-to-submain connectors above.

6. T-fittings for joining main to submains (designed for local 32 mm (1¼-inch) flexible pipe.

7. Large diameter main and submain pipes, main valve, and fittings. We consider nominal 32 mm pipe (1¼-inch with an inside diameter of approximately 30 mm) to be a *minimum* size for main and submain lines for small drip systems of up 0.1 ha (¼ acre). Larger systems are possible with valves and zoning and/or larger pipe diameters. All fittings between the Water Basket and main line have inside diameters of at least 28 mm and are included with either drip sets or Water Baskets.[20]

8. Low cost plastic 'flow through' screen filter. The configuration of this filter was designed to minimize pressure losses in low pressure systems while using a standard screen element which can be cleaned without removal of the filter body from the system. The filter body is designed for friction fits with 32 mm (1¼-inch) PVC pipe with large inlet and outlet diameters (34 mm and 30 mm, respectively).

9. An effective means of filtering dissolved iron from well water when necessary. This has been accomplished with dramatic results by passing water through burned rice husks before entering the primary water tank.

10. A highly illustrated and easy-to-read installation guide with which farmers can install a simple drip set without additional training (included with every Proximity drip set).

11. Easy to use *Water Wheel* water requirement calculators based on local ET and simplified crop coefficients (vegetables) or canopy shading (fruits). Not included in drip sets but used by field staff to help farmers estimate amounts of water to apply with drip.

[20]We plan to replace flexible recycled PVC main/submain pipes with cheaper 2-inch (51 mm) diameter LLDPE layflat pipe for use in both large and small drip systems.

Assessing technology and socioeconomic constraints and prospects of low-cost drip irrigation for vegetable farming in Southeast Asia

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ABSTRACT
Farmers' enthusiasm in using low-cost drip irrigation as seen at many on-farm research and demonstration sites across Southeast Asia clearly indicates a high potential of the technology to smallholding vegetable growers. Despite supports from several development agencies (NGOs and government agencies), a wide-scale farmer-to-farmer dissemination of this technology has not yet been occurred in the region. Farmers have not invested their own resources in low-cost drip irrigation kits that cost less than USD100 for irrigating a 200-300-m^2 cropland, with potential profits of more than USD200 within a crop season. Recently, questions have been raised on the effectiveness and sustainability of this technology. We have analyzed the constraints and prospects of the drip kits by reviewing and evaluating results from several on-farm research trials across the four countries in Southeast Asia (Cambodia, Indonesia, Philippines, and Vietnam). This was supplemented by information compiled from farmers' group level survey. Majority of the farmers surveyed reported saving on labor, water resources, and convenience in irrigating crops as main benefits under the drip systems. Nevertheless, farmers' adoption behavior towards the technology varies greatly across the study sites/countries. Some of the reasons for farmers' reluctant to invest on the technology are high initial investment costs, lack of local suppliers, inadequate input markets of the drip kits (inadequate local level business services to support the maintenances and services), farmers lack of understanding and basic know-how on using the drip kits, absence of rural credit systems, and poor targeting of clients/locations by the projects disseminating the technology. In fact, in many places, presence of a 'high subsidy-syndrome', that is, free kit distribution system adopted by many development projects, also has provided disincentives to farmers for investing on the technology using their sources of fund. Suggestions and recommendations are provided to encourage wider adoption of the drip technology for improving livelihoods of the smallholding farmers in Southeast Asia.

Keywords
Low-cost drip irrigation technology, vegetables, water productivity, rural livelihoods, technology adoption, impacts, farmers' perceptions, Southeast Asia.

INTRODUCTION
Flooding during the monsoon, and water shortage during the dry season are main characteristics of farming in monsoonal Asia. The majority of smallholding farmers in the Southeast Asia grow vegetables during the dry season, after harvesting rice. Therefore, agricultural water management issue in the region is closely linked with agricultural productivity, and in turn, with objectives of rural poverty alleviation. Some innovations have been made in providing water to smallholding farmers during the dry season to increase their productivity and farm income. "Simple and affordable micro-irrigation" scheme is one of them (Polak and Yoder, 2006). Other water management technologies developed for smallholding

farmers in tropical Asia include: treadle pumps, low cost water storage tank, drip kits, small electric-pump, hand pump, rain water harvesting pond, etc.

Recent effects of global warming and climate change have furthermore exacerbated the water scarcity problems in the Southeast Asia, and the way farmers grow crops (vegetables), manage the water resources, and reduce risk of crop losses. Flood related damage to farmlands and production in many parts of Southeast Asia in mid 2011 is just an example of a growing climate related risk and uncertainty in he region. Intensive vegetable production in tropical Asia takes place as peri-urban systems or cool highland systems in the hinterlands (Midmore and Jensen 2003). During the dry season, water scarcity is the major concerns for cultivation of vegetables in both the production systems. There is an urgent need for improved technology options for efficient water management to improve crop productivity, farm income, and the rural livelihoods.

With growing water scarcity, several rural development agencies have worked to develop irrigation technologies that are suitable for smallholding systems. For example, the International Development Enterprises (IDE), a non-governmental organization, has developed a low-pressure based low-cost drip irrigation technology, targeting requirements of small-plot size farmers in the tropics. This costs less than USD100 for irrigating 200-300 m^2 crop land. The focus of this paper is on the simple design and low-pressure based low-cost drip technology. Hence, hereafter the word “drip” is synonymous with a low-cost drip irrigation technology.

Wherever good access to water and market is available, farmers grow vegetables and other high value crops (Midmore and Jensen 2003; Mariyono and Bhattarai 2009). In the same way, whenever smallholding farmers adopt low-cost drip, by and large, they start growing vegetables, or other high value crops (for review, see Polak and Yoder 2006; Palanasami et al. 2011). Research and development agencies (and NGOs) are promoting this kind of low-cost drip irrigation technology also as a vehicle for growing vegetables, and to provide more income and employment to the smallholding farmers. Adoption of drip technology not only helps for diversification of crops and income sources but also makes the farming more resilient from the volatile agricultural markets, and the erratic climate change related stresses. In some clusters of Asia, adoption of the microirrigation technologies, and/or, low-cost microirrigation, has led to dramatic expansion of intensive vegetable production activities, and improved rural livelihoods (Namara et al. 2007; Bhattarai 2008; IDE 2009; Palada et al. 2010).

In South Asia (India, Nepal, Sri Lanka), the low-cost drip technology was first introduced by IDE in the mid 1990s. Several other local NGOs and governmental extension services there have also taken up the technology for out-scaling and up-scaling. In addition, recently, little more durable drip irrigation sets are provided by several private agencies in India; but with high governmental subsidy supports, which ranging from 50-90% of cost across the Indian states (Palanasami et al. 2011). Compared to South Asia, the extent of adoption and dissemination of the low-cost drip technology is at slower pace in Southeast Asia. Large part of distribution of the drip kits is done through project supports and project based distribution, with partly or complete subsidy on its cost.

Most of the studies on yield performance of simple and affordable drip irrigation kits are done largely on-station or on-farm trials, using small-size trial plots ranging from 50 to 200 m^2. The results from such on-farm research and trials have demonstrated large benefits of low-cost drip compared to the farmers’ conventional irrigation practices (Palada et al. 2010, IDE 2009; Roberts and Long 2006). However, limited numbers of socioeconomics assessments are done analyzing farmers’ constraints, their adoption behaviors and perceptions, and their investment decision-making process on the drip technologies.

Past studies have reported huge benefits of low cost drip irrigation system for smallholding farmers, and/or small-plot size farmers (Polak and Yoder 2006). However, farmer-to-farmer dissemination and wide-scale adoption of the technology have not yet been realized fully. For example, in Cambodia, most of the farmers using drip received the drip kits from project support; only very few of them have purchased, from their own source of fund[1]. The low-cost drip kits with cost less than USD100 can irrigate 200-300 m^2 cropland, which can give a potential profit of more than USD200 within a first crop season (in case of Cambodia). Nevertheless, recently, a little larger size of drip (for 1500 m^2 crop land) is getting popular among market-garden vegetables growers in northern Cambodia (Siem Reap areas). These large-size kits are distributed through input dealers in Cambodia, by an irrigation equipment supplier located in southern Vietnam.

Adoption behavior and impacts of the low-cost drip technologies have not yet been analyzed extensively, and as per the authors' knowledge, certainly not done comparing the results across wider countries (regions). Likewise, very limited information is available on farmers' experiences in its uses, and farmers evaluating the technology by themselves. In the context of South East Asia, we do not know yet what factors lead to more adoption, and/or, what factors lead to farmers' failure in sustainably maintaining and using the drip technologies. Recently, questions have been raised on the effectiveness and sustainability of this technology.

In the past, results on impacts of low-cost drip irrigation technology vary by study, by location, and crop season when the research was carried out. In one study in Sri Lanka, net income of farmers who used microirrigation systems (MIS) in the dry zone area increased substantially during 2000-2003, while there was hardly any such impact realized in the another zone (intermediate zone) of the country with moderate rainfall (Ekanayake et al. 2007). The same study reported a 19% technical efficiency improvement was recorded by high intensity MIS using farmers; land productivity measured by chili yield was highest with high intensity MIS users in the dry zone. Farmer satisfaction and land holding size were found to be important factors for better adoption of the microirrigation system (Ekanayake et al. 2007).

Outside of Asia, a recent review and synthesis study on performance and acceptability of microirrigation including drip irrigation kits has reported importance, profitability and farmers' preferences of low-cost drip for high value crops in the West Africa region (Abric et al, 2011). It also emphasizes on increasing productivity of smallholding farmers in the region by increasing their access to water through low-cost irrigation technologies. Likewise, a study in Kenya revealed that the majority of farmers who discontinued using micro-irrigation was largely due to lack of maintenance facilities nearby, irrelevant background of farming cultural where the technology was introduced, and unreliable supply of water (Kulecho and Weatherhead 2005).

Similarly, Stillhardt (2005) emphasized the importance of several factors to be considered while introducing microirrigation technologies in a place; some of them are: affordability of the drip kits, initial assistance to limited resource and subsistence farmers, training on farming knowledge, agronomic and technical support, and better access to infrastructure and markets. Local availability of system components and spare parts, and more local knowledge in customizing the kits according to farmers' needs, are also essential factors for wider adoption of the technology.

The rapid dissemination of the drip technology to smallholding farmers in eastern India was almost entirely done through subsidies provided by local NGOs, and in collaboration with IDE-India programme (DFID 2003). Whereas, the successful adoption of the affordable drip technology, particularly the customized drip kits in western India (Maharasthra and Gujarat states), was due to availability of better business support services and better output markets, and informed farmers. Market chains for fruits and vegetables in the states of Maharasthra and Gujarat,are better developed than other parts of India, thus low-cost drip kits were largely disseminated in those two states of through market-force, with least project subsidy. Relatively better education and agribusiness know-how of farmers in western India also supported this process (DFID 2003).

Both technical and economic factors are important to influence farmers' decision to adopt the low-cost microirrigation and other technologies. Namara et al. 2007 reported the following factors as important determinants for adoption of low-cost microirrigation in India: 1) level of

[1] In Cambodia, the IDE has distributed more than 1200 drip kits to farmers in the last 6-7 years. However, less than 5% of the farmers have purchased drip kits using their own funds.

education of the household head; 2) access to groundwater; 3) type of cropping pattern (cereals, vegetables and fruits, or other high value crops); 4) income source types; and 5) social and poverty status of households (communities).

With this background, the objectives of this study are to: 1) review and assess the extent of use of low-cost microirrigation technologies for small-scale vegetable farming in selected countries in Southeast Asia; 2) evaluate constraints and opportunities faced by farmers in using the drip technology, and 3) assess its impacts on farmers' resource use-, their perceptions, and their adoption behavior.

METHODOLOGY

Project study sites and locations

The study summarizes information from previous studies and on-farm research carried out in four countries in Southeast Asia (Cambodia, Indonesia, Philippines and Vietnam). One to two farming communities in each of the countries were selected as project sites for studying farmers' field level performances of low-cost drip irrigation technology. The low-cost drip kits were introduced in these sites as a component of AVRDC's research and development projects in the last 5-6 years. The project sites (farm communities) were in Prey Veng and Svay Reing provinces in Cambodia, located about 150 km south of the capital ─Phnom Penh. These communities were the pilot sites for the AVRDC-IDE Cambodia joint project on water productivity funded from CGIAR Challenge Program on Water and Food (CG CPWF) in 2005-2006. IDE has on-going drip irrigation project activities in these provinces. In Indonesia, the low-cost drip irrigation technology was introduced to farmer collaborators under the two projects: Sustainable Agriculture and Natural Resource Management (SANREM) Collaborative Research Support Program (CRSP) Vegetable Agroforestry under U.S. Agency for International Development (USAID) in Bogor, West Java and Integrated Disease Management for Chili funded by Australian Centre for International Agricultural Research (ACIAR) in Rembang, East Java. The sites in the Philippines were located in Lantapan and Bukidnon provinces, the on-farm research were implemented under the SANREM CRSP. The project site in Vietnam was located in Binh Phouc Province, in Southern Vietnam under the SANREM CRSP Project.

Number of sites and vegetable crops

During 2005-2008, 59 on-farm trials (managed by farmers and project partners) were established to assess performances of low-cost drip irrigation technology in those four countries. The most number of trials were in Cambodia (49 sites), followed by Philippines (6 sites), Indonesia (2 sites) and Vietnam (2 sites). These on-farm trials were carried out under different research projects. The scopes and methodology of these studies, and crops selected for on-farm trails, varied across the sites countries[2].

The active involvement of IDE/Cambodia office on the research made it possible to encourage more farmers to join the on-farm trials; besides IDE/Cambodia was then also using the low-cost drip irrigation as its flagship technology for livelihood improvement activities in the nearby areas of the study sites. A large number of on-farm research trials were in Cambodia; thereby more issues related to Cambodia are discussed than that of other countries.

At these on-farm research sites, with the drip systems, a range of vegetables were grown, including: cucumber (*Cucumis sativus*), eggplant (*Solanum melongena*), sponge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia*), yard-long bean (*Vigna unguiculata* var. sesquipedalis), chili pepper (*Capsicum annuum*), amaranth (*Amarathus spp*.), kangkong (*Ipomoea aquatica*), green bean (*Phaseolus vulgaris*), katuk (*Sauropus spp*), sweet pepper

[2]). Ideally, for comparison of the performances of drip technology across the sites (countries), one needs to control effects of crops, crop growing seasons, and other farm practices. In practice, it is not feasible to control all of these factors in cross – countries comparisons with diverse set of agro-climatic conditions, and with different crop growing seasons. Comparison and interpretation of these results have been done taking into consideration of these limitations of the synthesis and review study at a regional scale.

(*Capsicum annuum*), cabbage (*Brassica campestris*), mustard (*Brassica juncea*) and pak-choi (*Brassica chinensis*).

Treatments and on-farm research

In each site, a simple research trial consisting of two treatments were laid out in plots of varying sizes (100 to 200 m^2). The two treatments were: low-cost drip irrigation (improved technology), and hand-watering (farmer's practice as control). In drip system, for water storage purpose, farmers used bucket kit for small plots (20-50 m^2), and drum kit for larger plots (100-200 m^2). Most of the trial plots were one-farmer-one replication type, where the two treatments are laid out side by side with no replication. Plant spacing, crop cultural practices including fertilizer application, weeding and pest management practices were all based on farmers' own methods, they were same for the two trial plots of a farmer, and varied with vegetable crops. For the trial plots, the project provided the low cost drip kits to farmers (farmer cooperators) at no cost. The farmers provided their land areas to grow vegetables, labor and material inputs for setting up the trial plots; and they kept the critical farm data of the trial plots, as instructed by the researchers (trial supervisors).

Table 1. Number of sites and vegetable crops grown by farmers under low-cost drip kits.

Country	No. of trial sites	Vegetable crops grown
Cambodia	49	Cucumber, eggplant, yard-long bean, sponge gourd, bitter gourd
Indonesia	2	Chili pepper, amaranth, kangkong, yard-long bean, green bean, katuk (*Sauropus*)
Philippines	6	Sweet pepper, tomato, cabbage, Chinese cabbage
Vietnam	2	Amaranth, kangkong, mustard
Total	59	

Note: These trials were conducted at different periods (and different seasons) during 2005-2008.

Observations and data collection

The drip kits were evaluated based on: 1) technical performances in terms of differences on yield level, labor uses and water uses across the treatments (drip and locally followed practices); 2) suitability of the drip technology at local context of farming; and 3) marketability and profitability of the drip technology (farmers perceive additional benefits across the two treatments; drip versus local irrigation practices).

In each site, data on water use, time and labor use in irrigating crop on on-farm trials plots, and harvested yield (vegetable quantity) were collected and recorded by the farmer cooperators, with assistance of the research team (research assistants/field supervisors). To assess the sustainability of the technology, follow-up evaluation were conducted at selected sites one to two years after completion of the trials. At selected sites, farm group surveys were conducted by the project team focusing on farmers' perceptions on the technical and socioeconomic performances of the drip kits, including discussions on its limitations, further modifications and refinements needed. The results are summarized by comparing and contrasting the drip irrigation technologies related findings across the sites (and countries). Results from large numbers of on-farm trial are included from the project work in Cambodia, for convenience in comparison; the information is compared across the four countries. Our discussion, conclusions and implications are provided at the end.

RESULTS AND DISCUSSION

Data collected were at high quality and reliability, despite involvement of large numbers of farmers and huge variation on on-farm trial setting across the locations (countries). The nature and scope of the trials varied by countries, depending upon nature of project-funding available for the drip irrigation trials in each country. The results on performances of drip uses are summarized by countries.

Results from on-farm trials

Cambodia

Evaluation of the results of the on-farm trials in Cambodia in 2006 showed that, compared to traditional farmers practice (hand watering), the increased on crop yield as well as labor productivity (return per hour) and water productivity (yield per unit of water applied) all were higher in drip system (Table 2). The increase in yield (15%) coupled with the decrease in water and labor usage led to an improvement in labor productivity. The return on labor use on farming under drip irrigation was about $3.75 per eight-hour of work day, which is three times the average farm labor wage ($1.25 per day) in Cambodia in 2005-2006 (Palada et al. 2008 and 2010; Roberts and Long 2006).

Table 2. Effect of drip irrigation on selected farm performances in Cambodia (Adapted from Roberts and Long 2006; and Palada et al. 2008).

Parameters	Farmer Practice	Drip	Difference
Total crop yield (kg/m²)	0.52	0.60	+15%
Total labor use (hr/m2)	0.27	0.17	- 37%
Irrigation per unit labor use (hr/m^2)	0.15	0.04	-0.73%
Net income per unit labor use (US$/hr)	0.28	0.47	+68%
Total water usage (mm/m2)	189	108	-43%

Note: Derived from average of 49 on-farm trial data.

The most important advantages of the drip system reported by the framers were labor time saving, less drudgery of irrigating the crops, and water saving (Table 3). Other benefits of the drip, as reported by farmers, include better soil moisture, better soil aeration around plant roots, less need for weeding (labor saving), easier to irrigate, and less incidence of diseases and pests on crops (Table 3). Large-share of the additional vegetables produced were consumed within the household, majority of the drip users were subsistence farmers, and they were learning to grow vegetables and other high value crops.

Table 3. Advantages of drip irrigation as identified by drip users (farmers) in Cambodia (2006), under different project regimes (Source: Roberts and Long 2006).

Advantage/Feature of drip	CIDA-CPWF funded project (n=19)	CARE- funded project (n=30)	Sample Avg.
Labor saving (%)	82	71	75
Water saving (%)	64	76	72
Soil with good moisture (%)	36	62	53
Less weeds (%)	18	62	47
Easy to irrigate (%)	36	48	44
Healthy crops (%)	18	38	31

CIDA – Canadian International Development Agency
CPWF – Challenge Program for Water and Food
CARE- Cooperative for Assistance and Relief Everywhere

Notes: Table values indicate the percentage of respondents that selected the specified advantage. Column totals sum to more than 100% because farmers were able to identify more than one advantage.

Indonesia

In Indonesia, except for green bean, the use of drip irrigation in Bogor, West Java, did not increase vegetables yield significantly compared to similar vegetables under rainfed[3] conditions (Table 4). The relatively ineffectiveness of drip irrigation there was attributed to high rainfall since the trial was conducted during the wet season. The yields of amaranth and kangkong under rainfed conditions were slightly higher than that of the crops under drip irrigation. But in the other parts of Indonesia with less rainfall, and/or, area with inadequate access to water such as in Rembang, East Java, the benefit of drip irrigation on chili production was substantially high than that of crops in farmers' practices (Palada et al. 2011).

Table 4. Yield of vegetables (t/ha) under drip irrigation, Bogor, Indonesia, 2008 (Source: Susila et al. 2009)

Treatment	Ama	Kan	LoB	GrB	Kat
Drip	4.21	3.73	5.37	6.42	7.30
Rainfed	4.23	4.00	5.18	6.36	7.12
T-test	NS	NS	NS	*	NS

NS = not significant; *=P≤0.05
Ama-Amaranth; Kan-Kangkong; LoB-Long Bean; GrB-Green Bean; Kat-Katuk

In a focus group discussion in Rembang, Central Java, in December 2008, farmers using the low-cost drip for chili mentioned that they were even ready to pay up to USD150 per set of the drip kit, if the kits were available at the local market. Chili farmers in Rembang pointed out several benefits of using drip such as convenience (less drudgery) of irrigation, saving in electricity cost on pumping water, saving of labor time, and increased crop yield. The low-cost drip kits used on trial in Rembang in 2008 were imported from India, with cost of about 50 USD per kits (price in India). IDE has no project activities in Indonesia and as per the authors' knowledge; no other NGOs or private agency is supplying such low-cost drip technologies in Indonesia. Ready availability of the low-cost drip kits is a major also observed in several other countries in Asia. .

Philippines

Selected results from on-farm trials with low-cost drip irrigation are summarized in Table 5. Yield of Chinese cabbage was increased by over 47% under drip irrigation compared to locally followed rainfed farming. Yield of common cabbage, tomato and pepper under low-cost drip irrigation system increased by 32%, 23% and 38%, respectively, despite of frequent rainfall during the crop growing season in that particular year (2007). Frequent rains narrowed down the yield difference between drip and rainfed plots. A benefit-cost analysis cross these alternate means of irrigation also showed that drip irrigation was more profitable for these crops than alternate practices (Palada et al. 2011).

Table 5. Yield of common and Chinese cabbage under drip irrigation, Lantapan, Bukidon, Philippines. Dry season, 2008 (Source: Ella et al. 2008).

Crop	Drip (t/ha)	Rainfed (t/ha)	T-test (5%)	Yield increase on drip (%)
Common cabbage	45	34	NS	32
Chinese cabbage	50	34	*	47
Tomato	48	39	NS	23
Pepper	11	8	NS	38
Mean	39	29		34

*Significant; NS= Not significant

On the other hand, in a research managed vegetable agroforestry system trial in the Philippines, drip irrigation on bell pepper did not provide advantage over the control treatment (rainfed) (Table 6). Installing root barrier between pepper and tree hedgerows improved growth parameters and pepper yield; they were almost similar with that of drip-irrigated plots without

[3] Unlike other places, the tropical Indonesia receives frequent rainfall; hence, rainfed vegetable is cultivated profitably at several places in Indonesia.

root barrier (Table 6). The difference in fruit yield and total biomass between the control and drip-irrigated plots was about 1.0 $t.ha^{-1}$ (Table 6). This insignificant effect of drip irrigation treatment was due to the even distribution of rainfall during the field experiment period; the rainfed crop did not have any moisture stress during the crop growth period. Compared to farmers practice (rainfed), the installation of root barrier slightly increased yield of bell pepper, but the difference was statistically not significant at 5 % level.

Table 6. Effect of drip irrigation on growth parameters and yield of bell pepper, Bukidnon, Philippines, Dry season, 2008 (Source: Mercado et al. 2008).

Treatment	Biomass[1] (t/ha)	Fruit yield DW[2] (t/ha)
Rainfed	3.77	2.12
Drip	4.80	3.23
Root bar.	5.58	3.00
Mean	4.72	2.78
SED	0.40ns	0.33ns

[1] Determined at harvest. [2]Dry weight. ns=not significant.

Vietnam

Of the three leafy vegetable crops included in trials in Vietnam study sites, yields of amaranth and mustard green were significantly higher in drip irrigated plots than in plots under furrow surface irrigation, or plot with hand watering (Table 7). Drip irrigation did not increase yield of kangkong, instead was slightly lower than that of the crop under farmer's practice (hand watering). There was also no major economic advantage (cost saving) from vegetables cultivation in under the low-cost drip irrigation kits developed by IDE with compared to farmer's irrigation practices.

Table 7. Yield of selected vegetables under drip irrigation and alternate technologies, Vietnam, 2008 (Source: Phouc et al. 2011).

Treatment	Amaranth (t/ha)	Mustard (t/ha)	Kangkong (t/ha)
Drip	10.3	9.5	11.6
Hand watering	9.3	8.8	11.4
T-test	*	**	ns

* = P<0.05; ** = P<0.01; ns = Not significant

Farmers' evaluation and experience

This section presents farmers' responses compiled from interviews with farmers' group using the drip irrigation, and farmer cooperators involved in on-farm research. The information is summarized in terms of technical performance, suitability, and marketability of the drip technology. The specific results and farmers' responses varied by the sites, nevertheless, in all these sites, the most common benefits of low-cost drip irrigation reported by the farmers are savings in labor time and quantity of water use under drip system compared to farmers' practice of irrigation (control).

Technical performance

This section presents variation on selected technical performance of the drip technology across the sites (countries). Farmers in Vietnam and Cambodia reported about 42-43% water savings[4] under the low cost drip irrigation versus alternate hand watering irrigation method (Table 8). Labor saving in drip systems ranged from 27% in Vietnam to 65% in Indonesia, and it was 38% in Cambodia (Table 8). Crop yield under drip irrigation increased by 10% in Vietnam to 64% for the Philippines (Table 8), however, the use of drip irrigation did not result in higher net

[4] No data on quantity of water uses by irrigation regimes were available (collected) from on-farm trials conducted in Indonesia and the Philippines.

income to the farmers in the very first year of cultivation. Farmers in Cambodia reported a net income increase by only of 3%, whereas farmers in Vietnam reported a 7% increase in net income (Table 8) in the first year of drip use. This is due to high initial cost of the drip kits, an added expense in farming in the first year. However, in the second and succeeding cropping season, the net income could increase as the drip kits will last for 3- 4 cropping season.

Table 8. Technical performance of low-cost drip irrigation technology based on farmers' response and experience across the study sites (Source: Palada et al. 2011)[1].

Criteria	Cambodia (%)	Indonesia (%)	Philippines (%)	Vietnam (%)
Water savings	43	NA	NA	42
Labor savings	38	65	NA	27
Yield increase	15	15	64	10
Net farm Income	3	NA	NA	7

NA = data not available
[1]The data are compiled from on-farm research trials as reported earlier; out of results from each country level studies, as also noted earlier.

Suitability

In this section we present results on: 1) problems or constraints farmers experienced in using the drip irrigation system; and 2) farmers' suggestions for improving the drip irrigation system. The major issues on use of the drip, as mentioned by the drip users (farmers), are grouped into two major categories: technical and socioeconomic constraints. The results are summarized in Table 9. The most important constraints on using the drip system, as faced by the farmers, was clogging of drip lines. In Cambodia, farmers mentioned difficulty in filling the water jar (water container) since it was raised up to 2 meters high and hauling water from water source took considerable amount of their time and also it was drudgeries task. In Indonesia, farmers reported that the main line (tube) was not working properly─with several leakages, and additional labor days required to set up the drip system. Uniformity in water distribution, especially on uneven slope of field, was the other major problem encountered by farmers in the Philippines and Vietnam. Farmers also faced leaking of water from the fittings (joints) that connect the main and sub-main lines to the main valve. The O-rings and gaskets of the low-cost drip were made of low-quality materials and so were broken easily. The farmers there also pointed out that frequent rainfall led drip irrigation to be less effective. This was particularly the problem in Indonesia and Philippines, with high tropical rainfall frequency.

In terms of gender aspect of technology adoption, farmers in Cambodia pointed out some extent of different roles of men and women in using the drip and in growing vegetable under drip systems. Men prepared the row/beds, carried or pumped water into the jar and managed the use of fertilizers and pesticides. In most cases, women planted the crop, involved in weeding and taking care of the crop, and were responsible for selling the crops.

In Cambodia, most farmers were able to solve locally the drip use related problems such as cleaning blocked micro tubes by blowing and shaking, placing a ladder near water jars that were too high, and pumping water to small jars and needed to be filled regularly. Farmers also suggested using high quality fittings, O-rings and gaskets to reduce water leaks. In the case of non-uniformity of water distribution, farmers also suggested to have a control valve on the drip system to improve irrigation uniformity for uneven types of land.

Table 9. Technical and socio-economic constraints experienced by farmers using the low-cost drip technology.

Country\ Constraints	Technical	Socioeconomics
Cambodia	Difficulty filling jar, water leakage from fittings, poor quality components, clogged lines, kits not assembled, kits do not include drums	More labor needed in filling water tank, if water lifted manually
Philippines	Reduced water distribution and uniformity, drip technology is not suitable in sloping land, or, area with frequent rainfalls	No local fabricators of drip kits, so thee kits are not available locally
Indonesia	Main line not working properly, frequent rainfall drip less effective	Extra labor to set up drip, no local supply of drip, no local fabricators, or spare parts
Vietnam	Drip is not suitable for broadcasted and direct seeded vegetables	Low-cost drip sets are not readily available at the local market.

Source: Information compiled from several group discussions at the project sites with farmers using the drip irrigation, conducted at different periods during 2006-09.

Marketability

Farmers' responses on marketability of the drip irrigation system is evaluated in this section based on perceived benefits, willingness to purchase the drip kit, technology design characteristics, and source of technical information. These factors largely also varied by the sites/countries. Almost all drip users reported saving in use of factor inputs such as labor, time, and water. Other benefits mentioned by farmers were uniform water distribution on the field (Indonesia), higher and better quality of crop yields (Philippines and Vietnam).

In the early stage of technology dissemination in Cambodia**,** 22-25% of the Cambodian farmers were willing to pay between US$5.00 and $20.00 per kit (Roberts and Long 2006). Farmers in the Indonesia, Philippines, and Vietnam were also willing to buy the drip kits if the kits were locally available, and the price is affordable, or at least the same price on which it is provided by the IDE. Unlike the case in Cambodia, the low-cost drip kits are not readily available at local markets in the Philippines and Indonesia, but need to be imported from outside. Since 2009, in Vietnam, a private sector started supplying drip kits for commercial uses for larger crop acreage, and with three times higher cost than that of the drip kit supplied by IDE. This same commercial size drip kit is retailed by private dealers in some parts of Cambodia (in Siem Reap market center), with technical support from IDE. Through the help of private retailing agencies, IDE/Cambodia is importing components of drip kits, from Southern Vietnam (Ho Chi-Minh City) and retailing the drip kits in southern provinces of Cambodia.

In the context of Indonesia and the Philippines, unavailability of local fabricators to make such simple drip kits and non-existence of regular business support systems─disseminating NGOs or business support agencies─ are the critical bottle necks. In the case of the Philippines, in 2009-2010, the local government of the study site, attempted to import the drip kits from India, and to disseminate it to farmers nearby. However, due to several administrative hurdles in processing the import-permit from the government in India, the local government had to cancel the import order. In the case of the Philippines, had there been a local fabricator, the low-cost drip kits would have been disseminated to a large number of farmers.

In relation to technology design and system configuration, 60% of the farmers surveyed in Cambodia mentioned that the drip kits should be sold as pre-assembled and it should also include a water container (bucket, tank or drum) for easy and convenience in its installation even by an inexperienced farmer. A pre-assembled kit should include tank, spigot, filter, and sub-main pipe so that the farmers themselves could assemble the rest of the system (IDE 2009; Palada et al. 2008). They also reported that smaller systems of 100 m^2 to 200 m^2 would be better for them, especially for those using the drip for the first time. Only some (less than 25%)

of the surveyed farmers─ those experienced in using the drip kits─ in Cambodia preferred for a larger plot-size drip kit such as for 1,000 m^2 to 2,000 m^2 .

In Indonesia, drip users, who were also commercial vegetable farmers, suggested that the main line of the drip should be of larger-size than what is being supplied by IDE. Farmers in the Philippines felt that the drip system should be modified to increase water distribution uniformity by installing control valves to regulate water pressure. In Vietnam, farmers mentioned that the low-cost drip irrigation is not suitable for vegetables broadcasted and/or direct seeded with no fixed width between rows.

Determinants to adoption of low-cost drip kits

Based on the survey, suggestions of farmers using the drip kits, and review of literature on the topic, the major factors affecting adoption of the drip kits by smallholding farmers can be divided into four major categories[5] , as mentioned below.

1. *Location-specific factors*: agroecology, local climate, wind, rainfall pattern, crop growing season, and local farming systems;
2. *Technology-specific characteristics*: simple or complex technology, support services to farmers, and type of crops cultivated (high valued or low-valued);
3. *Farmers' specific determinants*: level of entrepreneurship, vegetable growing experience, farm training, education level, risk taking ability, etc., and;
4. *Institutions and policy factors*: agricultural policies, markets, local government supports, access to credit, training and other support, technology subsidy (or import tax).

In areas with a distinct wet and dry season, drip irrigation is more effective in the dry season. However, drip irrigation is not an effective technology for increasing farm productivity in areas with high rainfall or with frequent rainfall even in the dry season, with no distinct wet and dry season. In those areas, farmers would be reluctant to invest on the drip or other water saving devices (technologies), as was the case in some of our surveyed sites in Indonesia (Bogor) and the Philippines (Lantapan and Bukidon provinces).

Farmers' adoption decision of the drip technology is also influenced by its design (simplicity of complexity) of the drip-technology, configuration system, and how it is convenient to use. In addition, the material quality of drip kit components, its durability as perceived by the farmers, is equally important factors. Poor quality of the drip components can result in reduced efficiency and shorter life span. Farmers in Indonesia found ways to replace some of the components with other locally available materials (water supply pipe), when they encountered problems of water leaks, uneven irrigation due to low-pressure. In concurring with the facts reported by drip farmers in Cambodia, we also think that smallholding vegetable farmers will most likely adopt drip irrigation kits, even purchase in the local markets, if the system (kit) comes in a complete package, which includes tank (water container) and pre-assembled components of major parts rather than separate components. In some parts of South Asia, the low-cost drip kits are also sold in a preset package for smaller size plot area such as for home garden uses.

Under farmers' specific determinant: socioeconomic factors associated with individual farmers' characteristics, including his entrepreneurship, risk bearing ability, farming experiences, and gender dimensions of individual farmers are impact factors determining level of adoption of the drip technology. Other factors include relative cost of drip kits, availability of disposable income to the farm households, nature of crops grown by farmers. These factors greatly vary across the farmers in a community, and among farmers groups across the communities, thus, affecting level of adoption of the drip in the site.

Under institutions and policy factors: availability and access to market for the crops produced, farmers access to credit market for purchasing the drips and other farm inputs,

[5] Detailed discussions on factors affecting adoption of an agricultural technology can be found in (CIMMYT 1993; Doss 2006):

technical supports from the local extension agencies (or NGOs), access to infrastructure and road, as well as level of training and capacity building elements attached to the dissemination activities. Namara et al. (2007) have also pointed out importance of these issues in determining adoption of low-cost drip in India.

Farmers are willing to pay for the cost of the drip kits where farmers are growing high value vegetables and for market-sale (e.g. chili in Indonesia). Dissemination of this technology in areas with functional market and good infrastructure, and to farmers already familiar in growing market garden type of vegetable farming will lead to higher adoption. In areas where commercial vegetables farming is a new technology, training the farmers on how to use the drip technology, as well as how to grow vegetables for the markets would likely to increase its acceptability and adoption level. Aside from relatively high initial investment cost in setting up the drip system, the establishment of an effective distribution chain for drip irrigation kits has still a difficult task. In many places in Southeast Asia, the network of drip-kit suppliers is not well developed, and the technology largely depends on project funds that provide partial or full subsidy to acquire the kits (Abric et al. 2011).

CONCLUSIONS AND IMPLICATIONS

In our review and survey assessments, vegetables grown under the drip irrigation system generally resulted in higher crop yield and labor saving compared to the case in farmers local practices (hand watering or rainfed systems). Farmers also got more marketed yield and net farm income from drip irrigated vegetables than the alternate production system. Hence, the low-cost drip kits are effective tools for improving their access to water, and in turn, for improving productivity of smallholding farmers, especially for small plot-size farmers.

In water scarce environments, access to drip (or irrigation) alone is necessary but not sufficient for enhancing crop yield and farming productivity. Farmers' feedback on use of the drip, and its impacts on farm performances, varied by the study sites (countries) selected. This is consistent with diverse sets of study sites (countries) included in the survey. The most important benefits of using the drip, as reported by large numbers of the farmers surveyed, are savings on labor use (time) for irrigation and in other farm operation, in convenience in irrigating crops, and saving of water quantity. Yield increase under drip irrigation was not reported by large-number of farmers (sites), which also varied by crop types and by sites. The drip technology can not be effective in areas with high rainfall, and/or, areas with frequent rainfall in the dry season. Crop failures due to pest infestation, flooding and rain damage can also easily negate the benefits of drip irrigation technology, as reported by many of the farmers (sites) that we surveyed. The crop production issues also need to address along with dissemination of the low-cost drip kits.

In our study sites, clogging of drip emitters and pipe-lines was some of the common technical constraints experienced by farmers in using the drip; then, water leaking in fittings and reduced uniformity of water distribution were also reported by many farmers. At many of these surveyed sites, lack of local supply of drip kits was another critical obstacle for effective dissemination of this technology. As noted earlier, farmer level of adoption of drip irrigation technology is determined by: location specific agro-climate (growing season, rainfall pattern); technology specific factor (design and configuration, its cost); farmers specific factors (level of risk taking ability, entrepreneurship, farming experience, education, etc); and socioeconomic and policy factors (including local supply chain of drip kits, building up knowledge base, farm sector training). Thus, for successful adoption and dissemination of the low-cost drip technology, one needs to address several of these factors together.

Although benefits of increased labor and water use efficiency (productivity) were demonstrated with the use of low-cost drip irrigation, there exist several areas of further improvement to achieve its full potential. Many of the farmers surveyed (drip users) lacked farming knowledge on when and how much water to apply for their crops. Many farmers had the tendency to over irrigate the crops, which resulted in to reduce water use efficiency even in the drip irrigation systems. Along with the use of drip, training farmers in growing vegetables and other high-value crops is also critical step for sustaining adoption of the new technologies.

The crop production training should include use of new production technologies, mulching, agronomy package, IPM to decrease crop failure risk, and to improve crop yield.

Finally, improved local supply chains of the low-cost drip kits within a country (region) would facilitate effective technology dissemination, and in turn, its easy availability and affordability to farmers. In many places that we surveyed, the absence of local supply of drip kit, and local fabricators, was a major obstacle in adoption and dissemination of the technology. This is a simple technology, once farmers know how to use it, they would demand it, but at many places, private input suppliers (manufacturers) are not directly involved on its fabrication. This needs to be studied and explored in subsequent studies on the topic.

To encourage farmers to adopt the low-cost drip kits and continuation of its use in the future, external intervention on several fronts are required, as noted earlier. It is not only just distribution of the drip kits by an external agency (development NGO, or R&D agency), but continuous farm technical support from extension services locally (government, NGOs or private sectors), business development services, repair and maintenance services, and providing better access to farmers to the local markets for sale of increased produces and enhanced profitability. Assurance on sale of increased produces (vegetables) is also a good incentive to the smallholding farmers for prospectus of better farm income and profitability, which would then encourage for adoption of the improved technology such as the low-cost drip or even the large-size drip.

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Literature cited

Abric S, Sonou M, Augeard B, Onimus F, Darlin D, Soumaila A, Gadelle F. 2011. Lessons learned in the development of smallholder private irrigation for high-value crops in West Africa. Joint Organizational Discussion Paper – Issue 4. The World Bank, Washington, D.C. USA.

Bhattarai M. 2008. Socioeconomic Impacts of Low cost Tank with Drip irrigation for Vegetable production: a community scale case study in Nepal. A poster presented at World Water Congress, Montpellier, France, 1-4 Sept., 2008.

CIMMYT. 1993. The adoption of agricultural technology: A guide for survey design. International Maize and Wheat Improvement Center (CIMMYT), Mexico, D.F..

Doss CR. 2006. Analyzing technology adoption using micro studies: limitations, challenges, and opportunities for improvements. *Agricultural Economics*, 34(3): 207-219.

DFID. 2003. Low cost microirrigation technologies for the poor. Final Report. DFID Knowledge and Research Program (KAR) R392. Department for International Development, UK.

Ella VB, Reyes MR, Yoder R, Olila N, Palada MC, Midmore DJ, Dillaha T. 2008. Low-cost drip irrigation technology for sustainable agroforestry systems in Vegetable Agroforestry Systems in the Philippines (unpublished).

Ekanayake EMT, Gunaratne LHP, Gunawaayake ERN. 2007. Technical and Socioeconomic Assessment of Microirrigation Systems in the Small Scale Farming Sector of Sri Lanka. 18th An. Cong of the PGIA.

International Development Enterprises (IDE). 2009. Introduction and promotion of low-cost drip irrigation. Final Report. International Development Enterprises, IDE-Cambodia. 13 p.

Kulecho K, Weatherhead EK. 2005. Reasons for smallholder farmers discontinuing with low-cost microirrigation: A case study from Kenya. *Irrigation and Drainage Systems* 19:179-188.

Mariyono J, Bhattarai, M., 2009. Chili production practices in Central Java, Indonesia: a baseline report. AVRDC- The World Vegetable Center, Taiwan.

Mercado, AR, Arcinal G, Duque C, Palada MC, Reyes MR. 2008. Vegetable agroforestry (VAF) system: Understanding vegetable-tree interaction is a key to successful farming enterprise. SANREM CRSP Annual Report Year 3. World Agroforestry Center, Claveria, Misamis Oriental, Philippines.

Midmore DJ, Jansen. HGP. 2003. Supplying Vegetables to Asian Cities: is there a case for peri-urban production? *Food Policy*, 28:13-37.

Namara RE, Nagar RK, Upadhyay B. 2007. Economics, adoption determinants, and impacts of microirrigation technologies: empirical results from India. *Irrigation Science* 25:283-297.

Palada MC, Bhattarai M, Roberts M, Baxter N, Kimsan R, Kan S, Wu DL. 2008. Increasing on-farm water productivity through affordable microirrigation vegetable-based technology in Cambodia. Proc.2nd International Forum on Water and Food, CG Challenge Program on Water and Food (CPWF). 11-13 November 2008, Addis Ababa, Ethiopia.

Palada MC, Bhattarai SP, Roberts M, Baxter N, Bhattarai M, Kimsan R, Kan S, Wu DL. 2010. Increasing on-farm water productivity through farmer-participatory evaluation of affordable microirrigation vegetable-based technology in Cambodia. J. Applied Irrigation Science 45(2):133-143.

Palada,MC, Mercado AC, Roberts M, EllaVB Reyes MR,. Susila AB, Ha DH, Wu DL, Bhattarai M. 2011. Farmers' experiences on low- pressure drip irrigation for vegetable production in Southeast Asia and the Pacific. In *Acta Hort*. Conference Proceeding Kahane, et al., (eds),"Horticulture for Development" (in press).

Palanisami K, Mohan K, Kakumanu KR, Raman S. 2011. Spread and Economics of Microirrigation in India: Evidence from Nine states. Economic and Political Weekly. Vol. XLVI Nos 26&27 (25 June 2011), p 81-86 pages.

Phouc PHD, Du LV, Tuan DH, Ha DH. 2011. An assessment of drip irrigation systems for home garden vegetables in Binh Phuoc Province. pp. 43-48 In: DH Ha, LV Du, LT Loan, NK Loi, ND Thanh, PHD Phuoc, DJ. Midmore, D. Catacutan, MC Palada, MR Reyes, R Cajilig, K Kunta and S Sombatpanit (editors). Vegetable Agroforestry and Cashew-Cacao Systems in Vietnam. World Association of Soil and Water Conservation (WASWAC) Special Publication No. 6a.

Polak P, Yoder R. 2006. Creating wealth from groundwater for dollar-a-day farmers: Where the silent revolution and the four revolutions to end rural poverty meet. *Hydrogeology Journal* 14: 424−432.

Roberts MS, Long A. 2006. Drip irrigation trials in Prey Veng and Svay Rieng, 2005- 2006. Final Report, IDE-Cambodia.

Stillhardt B. 2005. Socioeconomic and institutional aspects influencing adoption of microirrigation technology in Eritrea. Irrigation Development in Eritrea: Potentials and Constraints. Proc. Workshop of the Association of Eritreans in Agricultural Sciences (AEAS) and the Sustainable Land Management Program (SLM), Eritrea. 14-16 August 2003, Asmara, Eritrea.

Susila AD, Prasety T, Palada MC. 2009. Drip irrigation: Will it increase yield in traditional vegetable production system? pp. 89-95 In: Susila AD, Purwoko BS, Reyes MR, Palada MC (eds.). Agroforestry and Vegetable Production in Southeast Asian Watersheds. SANREM Research Report. Dept. of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Bogor, Indonesia.

Effect of organic matter application and conservative tillage on vegetable yield and soil organic carbon content on a volcanic ash soil in West Java, Indonesia

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ABSTRACT
To examine the possibility of substituting chemical fertilizer with organic matter for cabbage (*Brassica oleracea L.* var. *capitata*) and lettuce (*Lactuca sativa*) cultivation, and to elucidate the effect of organic matter application and conservative tillage on the soil organic carbon, a field experiment was carried out during 2009 to 2011 on a volcanic ash soil in Lembang, West Java, Indonesia. 12 treatments which are the combinations of two factors, namely, fertilizer application (HM0: 113.0kg N/ha, 96.0kg P_2O_5/ha, 120.0kg K_2O/ha + horse dung manure 0ton/ha; HM20: 56.5 kg N/ha, 48.0 kg P_2O_5 kg/ha, 60.0 kg K_2O/ha + horse dung manure 20ton/ha; HM40: 28.3kg N/ha, 24.0kg P_2O_5 kg/ha, 30.0kg K_2O/ha + horse dung manure 40ton/ha) and crop management (CC: cabbage-cabbage-fallow, CLF: cabbage-lettuce-fallow, CLB: cabbage-lettuce-black oat, CLM: cabbage-lettuce-black oat + minimum tillage) were applied. Plants were harvested and the yield was determined. Soil organic carbon content was determined before the experiment and after each harvest. Cabbage yield in all the treatments except CC treatments was not significantly different both in the first and fourth cropping season, suggesting chemical fertilizer application for cabbage cultivation can be substituted by organic matter without yield loss. Lettuce yield in HM40 treatments was significantly higher than that of the HM0 treatments both in the second and fifth cropping season, indicating the advantage of manure application for lettuce cultivation. Soil organic carbon content in HM20 (6.39%), and HM40 treatments (6.52%) were higher than HM0 treatments (6.22%) after the third cropping season under the minimum tillage condition, suggesting soil organic carbon can be increased by the organic matter application under conservative tillage practice. Due to the fluctuation of soil organic carbon content, longer term observation will be necessary to propose a practical farm management to increase soil organic carbon while maintaining the crop yield and farmers' income.

Keywords
Cabbage, lettuce, organic matter, conservative tillage, soil organic carbon

INTRODUCTION
Organic matter application and conservative tillage is effective way to increase soil fertility so that farmers can get better crop yield in a sustainable way. Due to the growing concern about global warming, these practices are also being recognized as practical methods to sequestrate carbon by increasing soil organic carbon (SOC). However, agriculture has been largely

excluded from carbon markets, because of the high level of uncertainty and the transaction costs associated with smallholder agriculture, which manages most of the agricultural carbon (Alessandro et al. 2010). The uncertainty of SOC in farm land partly results from the diversities in the characteristics of organic matters applied to soil. The nature of soil and land managements such as tillage intensity, crops and fallows significantly affect the accumulation rate of SOC in farm land. Also, it takes longer period to observe significant changes in SOC. Tristram and Wilfred (2002) reported that carbon sequestration rates can peak in 5 to 10 years with a change from conventional tillage to no-tillage and reach a new equilibrium in 15 to 20 year by analyzing a global database of 67 long-term agricultural experiments mainly in North and South America, and Europe. There are few studies which elucidated the impacts of land management especially in Southeast Asia over the long term. Therefore, it is beneficial to observe the impacts of long term organic matter application and conservative tillage in the region to identify the effect of these practices to increase SOC. Andosol is developed from volcanic origin material such as volcanic ash and it is a typical soil in the highland area in West Java in Indonesia. It has a very large specific surface with aluminium hydroxide groups, which has a strong affinity for phosphate ions and consequently it is generally P-deficient (FAO 1993). It is also known that the decomposition rate of organic matter in Andosol is lower than that in the other types of soil (Rural Culture Association 1999), which can favorably affect an accumulation rate of SOC. In the present study, effect of organic matter application and conservative tillage on vegetable yield and SOC was examined to determine the possibility of decreasing chemical fertilizer application and increasing SOC in farm land of Andosol so that it can work as a carbon sink.

MATERIALS AND METHODS

A field experiment was carried out in an experimental field in Indonesian Vegetable Research Institute, located in Lembang, Bandung, West Java (latitude: 6°48'S, longitude: 107°39'E, 1250 m above sea level) with a mean annual temperature and precipitation of approximately 20 °C and 1900 mm, respectively (Fauzi and Agus 2008). Lembang locates in highland areas of West Java which is one of the vegetable production centers in Indonesia. A moderate climate in this area is suitable for temperate zone vegetables. The field examined (50 m * 10 m) had been used as an experimental field where cabbage and lettuce had been grown during September 2006 to July 2009 to observe land management and crop rotations on the yield of cabbage (Sumarni et al. 2011). General properties of the original soil, as shown in Table 1, suggested that this soil was characterized by a high organic matter content (T-C content of the surface soil: 6.18%), high capacity to store nutrients (CEC: 23.77 cmol(+)*kg^{-1}), and very low bulk density (0.39 g/cc).

Table 1. General properties of the soil (Fauzi and Agus 2008)

Horizon	Depth (cm)	pH (H_2O)	T-C (%)	T-N (%)	C/N	CEC cmol(+)*kg^{-1}	Bulk density (g/cc) *1
Ap	0-28	4.5	6.18	0.37	17	23.77	0.39
Ah	28-45	5.2	8.03	0.38	21	42.29	0.39
Bth1	45-63	5.3	7.60	0.31	25	44.84	0.39
Bth2	63-87	5.3	6.50	0.21	31	32.65	N.A.
Bw1	87-112	5.3	2.26	0.17	13	23.63	N.A.
Bw2	112-140	5.4	2.50	0.19	13	33.74	N.A.
Bw3	140-230	5.5	2.47	0.21	12	26.51	N.A.
2Ah	> 230	5.0	5.97	0.17	35	34.70	N.A.

*1 20-60cm

Cabbage (*Brassica oleracea L.* var. *capitata*) and lettuce (*Lactuca sativa*) was grown as main crops during September 2009 to July 2011 (Table 2). Black oat (*Avena strigosa*) was grown as a cover crop in dry season in some treatments, then after harvest, incorporated into the soil in conventional tillage and left on the soil surface in minimum tillage. The crops were planted three times a year. The first cropping season (rainy season) starts in September, followed by the second (transitional season, starts in January) and the third cropping season (dry season, starts in April).

Table 2. Cropping pattern in the experiment field

Year	2009		2010						2011			
Month	Sep.	Dec.	Jan.	Apr.	Apr.	Jul.	Sep.	Dec.	Jan.	Apr.	Apr.	Jul.
Season	1st		2nd		3rd		4th		5th		6th	
Crop	Cabbage		Cabbage / lettuce		Black oat / fallow		Cabbage		Cabbage / lettuce		Black oat / fallow	

In the experiment to investigate the possibility of substituting chemical fertilizer with organic matter, and to elucidate the effect of organic matter application and conservative tillage on the SOC, 12 treatments were set up with three replications and randomized block design. The treatments are the combinations of two factors, namely, fertilizer application (HM0: 113.0kg N/ha, 96.0kg P_2O_5/ha, 120.0kg K_2O/ha + horse dung manure 0 ton/ha; HM20: 56.5 kg N/ha, 48.0 kg P_2O_5 kg/ha, 60.0 kg K_2O /ha + horse dung manure 20 ton/ha; HM40: 28.3kg N/ha, 24.0kg P_2O_5 kg/ha, 30.0kg K_2O /ha + horse dung manure 40 ton/ha) and crop management (CC: cabbage-cabbage-fallow, CLF: cabbage-lettuce-fallow, CLB: cabbage-lettuce-black oat, CLM: cabbage-lettuce-black oat + minimum tillage) (Table 3). N, P_2O_5 and K_2O were applied as urea, superphosphate and potassium chloride, respectively. The amount of chemical fertilizer application in HM0 is the standard dosage recommended by Indonesian Vegetable Research Institute. Chemical fertilizer application of HM20 and HM40 is the half and quarter of the standard dosage respectively. Horse dung manure was selected as a typical organic fertilizer available in the study area. Fertilizer was applied manually. All the manure and superphosphate was applied as base fertilizer. A half of urea and potassium chloride was applied as base fertilizer and top dressing respectively. Base fertilizer was applied in the planting hole and top dressing was applied on the soil surface.

Table 3. Treatments in the field experiment

Treatment	I. Nutrient management	II. Crop management
LT1	HM0 (HM0ton/ha +NPK1)	CC (C-C-F, CT)
LT2	ditto	CLF (C-L-F, CT)
LT3	ditto	CLB (C-L-B, CT)
LT4	ditto	CLM (C-L-B, MT)
LT5	HM20 (HM20ton/ha +NPK1/2)	CC (C-C-F, CT)
LT6	ditto	CLF (C-L-F, CT)
LT7	ditto	CLB (C-L-B, CT)
LT8	ditto	CLM (C-L-B, MT)
LT9	HM40 (HM40ton/ha +NPK1/4)	CC (C-C-F, CT)
LT10	ditto	CLF (C-L-F, CT)
LT11	ditto	CLB (C-L-B, CT)
LT12	ditto	CLM (C-L-B, MT)

Note:
HM = Horse dung manure
NPK1 = 113.0kg N/ha, 96.0kg P_2O_5/ha, 120.0kg K_2O/ha (standard dosage)
NPK1/2 = 56.5 kg N/ha, 48.0 kg P_2O_5 kg/ha, 60.0 kg K_2O /ha (half dosage)
NPK1/4 = 28.3kg N/ha, 24.0kg P_2O_5 kg/ha, 30.0kg K_2O /ha (quarter dosage)
C = Cabbage, L = Lettuce, F = Fallow, B = Black oat , CT = Conventional Tillage, MT = Minimum Tillage

Of the temperate zone vegetables which are produced in the study area, cabbage, cauliflower, Chinese cabbage and some others in the cruciferous family can be relatively lucrative. The production of these crops in Lembang has faced losses attributable to clubroot disease, which is caused by *Plasmodiophora Brassicae*. Crop rotation excluding Cruciferae for two or three cropping seasons (eight to twelve months) can prevent outbreaks of the disease (Yamada et al.

2005). In the present experiment, cabbage was grown in the first season and lettuce was grown in the second season except CC treatments. In the third season, a half of the treatments were fallowed and black oat was planted in another half. The same cropping pattern was implemented in the second year. In CLM treatment, minimum tillage was introduced. The soil was undisturbed except making planting holes for cabbage and lettuce seedlings. Since the growing period of lettuce (approximately 50 days) is shorter than that of cabbage (approximately 90 days), lettuce was planted and harvested twice in a cropping season. In the second planting of lettuce, no fertilizer was applied. The crops were planted during September 2009 to July 2011 (6 cropping seasons). The area of each plot was $10.8m^2$ (3m * 3.6m) at an interval of 0.7m. In each plot, 6 rows were prepared at an interval of 60.0 cm and 8 plants were grown at an interval of 37.5 cm. During the experiment, irrigation was carried out when plants were subjected to water stress and pesticides were applied as conventional method.

Plant samples (above ground) were collected from each of the 12 treatments at the end of each cropping season. The cabbage and lettuce samples in outer edge of the plot were abandoned and 24 plant samples were collected from each plot. After removing the outer part of the cabbage and lettuce head, the weight of plant samples were measured to calculate the crop yield. Soil samples were collected from each of the 12 treatments before the experiment and at the end of each cropping season. The organic carbon contents were determined by dry combustion method.

Analysis of variance (ANOVA) was carried out for the dataset of plants from the 12 treatments to investigate the effects of fertilizer application and crop management.

RESULTS AND DISCUSSION

Cabbage and lettuce yield under 12 treatments are shown in Table 4. Cabbage yield in all the treatments except CC treatments (LT1, 5, and 9) was not significantly different both in the first and fourth cropping season. The yield of CC treatments was always lower than the other treatments due to the outbreak of clubroot disease. The results suggested chemical fertilizer application for cabbage cultivation can be substituted by organic matter without yield loss. Table 5 shows the estimated N, P_2O_5 and K_2O input provided by chemical fertilizer and horse dung manure application in the respective treatments. It indicated that the N, P_2O_5 and K_2O input of HM20 and HM40 treatments is higher than HM0 treatment. Since the rate of nutrient component release from organic matters is much lower than chemical fertilizers, it cannot be assumed that all the nutrient components provided by the manure were absorbed by crops in a season. However, based on the experiment results it can be safely said that the chemical fertilizer application for cabbage can be halved and quartered without any yield loss by 20ton/ha and 40ton/ha horse dung manure application respectively. In the first cropping season, yield difference between CC treatments, and CLB treatments (LT3, 7 and 11) and CLM treatments (LT4, 8 and 12) was not significant. This is because of the outbreak of clubroot disease though CLB/CLM treatments applied crop rotation. In the previous experiments, Velvet bean (*Mucuna* sp.) was planted as a cover crop in the dry seasons (April 2007 – July 2007 and April 2008 – July 2008) in CLB/CLM treatment plots, while CLF treatment plots were left fallow. Yamada (2008) reported that though all kinds of non-host plants cultivation were effective in reducing clubroot damage, the affect of legumes like peanut and red kidney bean cultivation was lower than just fallow periods. It is supposed that the velvet bean cultivation in the previous experiments reduced the effect of crop rotation to prevent clubroot disease. In the fourth cropping season, after black oats were planted in the plots, the cabbage yield in CLB/CLM treatments was significantly higher than CC treatments.

Table 4. Cabbage and lettuce yield

Treatment	Cabbage				Lettuce			
	1st season		4th season		2nd season		5th season	
	Yield (kg/m^2)	*1	Yield (kg/m^2)	*1	Yield (kg/m^2) *2	*1	Yield (kg/m^2) *2	*1
LT1	1.559	a	0.000	a	N.A.		N.A.	
LT2	4.902	b	2.158	b	1.610	a	2.190	a
LT3	3.330	ab	1.082	b	1.778	a	2.705	a
LT4	2.957	ab	1.778	b	1.610	a	2.435	a
LT5	0.644	a	0.232	a	N.A.		N.A.	
LT6	4.522	b	1.430	b	1.778	ab	3.800	b
LT7	3.452	ab	1.855	b	1.997	ab	4.470	b
LT8	4.586	ab	2.248	b	2.126	ab	4.432	b
LT9	1.314	a	0.193	a	N.A.		N.A.	
LT10	4.773	b	2.776	b	2.177	b	4.831	c
LT11	4.316	ab	2.583	b	1.932	b	4.947	c
LT12	3.556	ab	2.081	b	2.538	b	4.973	c

*1: The data with the same letter in the same column are not significantly different (Tukey, $p<0.05$)
*2: The total amount of two harvests in a cropping season

Table 5. Estimated NPK input in the experiment (per cropping season)

Treatment	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
HM0	113	96	120
HM20	191	202	208
HM40	296	292	298

Note: N, P_2O_5 and K_2O content of Horse dung manure was cited from Table 7

Lettuce yield in HM40 treatments (LT10-12) was significantly higher than HM0 (LT2-4) in the second season. The same difference was observed in the fifth cropping season. In the fifth cropping season, lettuce yield in HM20 treatments (LT6-8) was significantly higher than HM0 treatments, too. As mentioned in the cabbage yield, due to the sufficient amount of nutrient component supplied by horse dung manure, the results indicated the advantage of manure application for the lettuce yield.

In the first year of the experiment, SOC in HM20 (6.39%, LT8) and HM40 treatments (6.52%, LT12) were higher than HM0 treatments (6.22%, LT4) after the third cropping season under the minimum tillage condition, suggesting SOC can be increased by the organic matter application under conservative tillage practice (Table 6). However, as for the change of SOC from the beginning of the present experiment to the third cropping season, HM20 (LT8) showed the largest increase (+0.30%) while that of HM0 (LT4) and HM40 (LT12) was almost same (+0.08% and +0.04% respectively). In the second year, the SOC of all the treatments decreased and overall change of SOC during the whole experiment period was negative in the range from -0.75% to -1.35%. It is not clear why SOC decreased in the second year of the experiment. The previous experiment results in the same field suggested that the SOC in the field fluctuated very frequently (Sumarni et al. 2011). A further observation is necessary to conclude the effect of organic matter application to SOC. Horse dung is one of the popular organic materials in the study area. Horses are used as common means of transportation in Lembang and it is easy for the farmers to get necessary amount of horse dung for their farms from the horse owners. Table 7 shows the chemical components of horse dung manures used in the experiment. It also shows the chemical contents of the other typical organic matters including black oat and velvet bean planted in the experiment field. It indicated that though organic carbon content of the horse dung manure is almost same as the cow dung and dent corn, its C/N ratio is much lower than the other organic matters. This means that the horse dung manure can be decomposed more rapidly in soil and its effect to increase SOC is lower than the other organic materials. Table 8 shows that the estimated organic carbon inputs by the field managements in the experiment. Comparing to the amount of SOC in the soil surface of experiment field, the amount of organic carbon provided by horse dung manure is relatively small. It can be concluded that the horse dung manure is useful as an alternative of chemical fertilizer as was shown in the field experiments. On the other hand, it is difficult to expect to increase SOC only by the horse dung manure applications within short period. Katamine et al. (2000) reported that the 20 years continuous organic matter application (1,340 kg/ha organic carbon per cropping season, two cropping season a year) in Andosol upland field in Tochigi Prefecture in Japan (annual temperature and precipitation is 13.4 °C and 1,418mm respectively) increased SOC content by 1%. The amount of organic carbon application is slightly higher than the HM20 treatment and much lower than the HM40 treatment.

Considering the higher annual temperature and precipitation in the present experiment field, the possible increase of SOC by organic matter application would be lower in the present experiment field. It is supposed to be difficult to observe significant increase of SOC within the two years experiment.

The amount of organic carbon provided by the black oat is much larger than that of horse dung manure and it is anticipated that the black oat cultivation can increase SOC content. In the first cropping year (First to third cropping season), the increase of SOC of CLB treatments (LT3, 7 and 11) was higher than CLF (LT2, 6 and 10) treatments (or the decrease of SOC was lower) (Table 8). However, in the second year (Forth to sixth cropping season), this tendency was not obvious. During the overall experiment period, any significant difference between the CLF and CLB treatments was not observed. It may suggest that the decomposition of organic carbon is too high to observe significant impact from black oat cultivation to increase SOC content. It is necessary to conduct further experiments to determine the impacts of black oat cultivation to SOC.

Table 6. Soil organic carbon (SOC) in the experiment fields

Treatment	SOC before experiment (%) (1)	SOC 3rd season (%) (2)	SOC 6th season(%) (3)	SOC change 1st year (%) (2) - (1)	SOC change 2nd year (%) (3) -(2)	SOC change whole period (%) (3) - (1)
LT1	6.52	6.34	5.17	-0.18	-1.17	-1.35
LT2	6.48	5.93	5.34	-0.56	-0.58	-1.14
LT3	6.56	6.36	5.54	-0.20	-0.82	-1.02
LT4	6.14	6.22	5.32	0.08	-0.90	-0.82
LT5	6.23	6.24	5.23	0.01	-1.01	-1.00
LT6	6.00	6.38	5.16	0.38	-1.22	-0.84
LT7	6.03	6.45	5.12	0.42	-1.33	-0.91
LT8	6.09	6.39	5.22	0.30	-1.18	-0.87
LT9	6.29	6.30	5.38	0.01	-0.92	-0.91
LT10	6.52	6.55	5.42	0.03	-1.13	-1.10
LT11	5.95	6.33	5.20	0.38	-1.13	-0.75
LT12	6.48	6.52	5.64	0.04	-0.88	-0.84

Table 7. Chemical components of organic matters

Organic material	Water (%)	Org-C (%)	N (%)	C/N	P (%) *4	K (%) *5
Horse dung manure *1	77.6	5.93	0.67	8.9	0.77	0.74
Black oat *2	11.3	28.90	0.95	30.4	0.20	0.46
Velvet bean *2	73.2	12.71	0.84	15.1	0.05	0.28
Rice straw cow dung manure *3	66.3	8.93	0.65	13.7	0.18	0.81
Cow dung *3	78.9	5.29	0.36	14.7	0.09	0.30
Dent corn *3	86.3	5.17	0.25	20.7	0.03	0.48
Barley straw *3	11.5	35.04	0.86	40.7	0.06	0.21

*1: Horse dung manure used for the first cropping season
*2: By authors in the previous experiment in 2007
*3 Katamine et al. (2000)
*4: P_2O_5 for horse dung manure
*5 K_2O for horse dung manure

Table 8. Estimated organic carbon input in the experiment

Practices	Org-C (kg/ha)	Remarks
Horse dung manure (20 t/ha) application	1,186	Org-C in horse dung manure = 5.93% *1
Horse dung manure (40 t/ha) application	2,372	Org-C in horse dung manure = 5.93% *1
Black oat cultivation	9,248	Org-C in black oat = 28.90% *1, Yield = 32 ton/ha *2
Soil organic carbon content	48,204	0-20cm depth, SOC=6.18% *3, Bulk density=0.39g/cc *3

*1: See Table 7
*2 Average yield of the third cropping season
*3: See Table 1

Conservative tillage is an effective way to increase SOC (IPCC 2006). In the present experiment, positive impact of minimum tillage to SOC was not observed. This is firstly because the amount of organic carbon applied by manure was not enough to show the significant difference between minimum tillage and conventional tillage within short term. Secondly, though significant amount of organic material was supplied by the black oat cultivation, the above ground biomass of black oat was not incorporated into soil in the minimum tillage application but left on the soil surface. It is supposed that most of the organic carbon contained in the black oat in the minimum tillage treatments was run off by the rain or decomposed on the soil surface without accumulating in the soil while the incorporated black oat biomass in the conventional tillage treatment was retained more in soil.

CONCLUSION

Chemical fertilizer application for cabbage can be halved and quartered without any yield loss by 20 ton/ha and 40 ton/ha horse dung manure application respectively. Horse dung manure application in the same amount showed the advantage for the lettuce yield. In the first year of the experiment, SOC in the fields with horse dung manure application was higher than that without manure application under the minimum tillage condition. However, as for the change of SOC content from the beginning of the present experiment, there were no clear tendencies in SOC changes. The horse dung manure is useful as an alternative of chemical fertilizer. On the other hand, it is difficult to expect to increase SOC by the horse dung manure applications within short period due to the lower C/N ratio of horse dung manure and higher SOC in the experiment fields. Black oat cultivation in dry seasons has potential to increase SOC due to the higher carbon content. Further observation is necessary to determine the effect of these practices on SOC and to propose a practical farm management to increase soil organic carbon while maintaining the crop yield and farmers' income.

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References

Alessandro De Pinto, Marilia Magalhaes, Claudia Ringler. 2010. Potential of Carbon Markets for Small Farmers: A Literature Review. IFPRI Discussion Paper 01004.

FAO, 1993, World Soil Resources, An explanatory note on the FAO World Soil Resources Map at 1:25 000 000 scale, World Soil Resources Report 66 Rev. 1, Rome: FAO.

Fauzi, Agus. 2008. Soil profile description for JIRCAS experiment site in Lembang.

IPCC. 2006. IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use

Katamine M, Kamewada K, Suzuki Y, Ito Y, Nakayama K, Uchida F. 2000. Effect of twenty year-continuous applications of organic materials on the growth of crops and physicochemical properties of soil on Andsol upland fields, Bulletin of Tochigi Agricultural Experiment Station. 49: 25-32.

Rural Culture Association. 1999, *Nougyou gijutsu taikei dojou hiryou hen.* 3: 13-16 (in Japanese).

Sumarni N, Rosliani R, Suwandi, Sugino T, Miyata S. 2011. Long-term cropping pattern management in relation to cabbage yield in the highland of Lembang, West Java. Book of abstracts of International society for horticultural science (ISHS) Symposium "Sustainable Vegetable Production in SE Asia" 16-16.

Tristram O West, Wilfred M Post. 2002. Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis. Soil Sci. Soc. Am. J. 66:1930–1946

Yamada M, et al. 2005. Control of cabbage clubroot disease by employing one-year crop rotations with three vegetable combinations in West Java highlands of Indonesia. In: Koyama O (ed.), Evaluation of Vegetable-based Farming Systems and Improvement of Vegetable and Fruit Cultivation in Highland Regions in West Java, Indonesia. JIRCAS Working Report No. 43, Tsukuba, Japan: Japan International Research Center for Agricultural Sciences.

Yamada M. 2008. Vegetable Crop-Rotation Technologies to Prevent Clubroot Damage: Crop Rotation and Several Cultural Practices. In: Sugino T(ed.), Sustainable and Diversified Vegetable-based Farming Systems in Highland Regions of West Java. CAPSA Working Paper No. 100. 18-26. UNESCAP CAPSA

Demonstration of the scope and feasibility of organic farming in vegetable crops – an experience

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ABSTRACT
Organic farming has been an age-old practice in human civilization. The green revolution technologies adopted during the last century undoubtedly, increased agricultural production several fold, but at the same time it brought about several environmental problems and health hazards. Due to recent growing consciousness towards human health and environmental safety, organic farming, especially of vegetables and other horticultural crops has gained momentum worldwide in recent years. A long term demonstration plot of organic vegetable cultivation on a permanent basis was initiated at UAS, GKVK, Bangalore during 2008-09. The demonstration was laid out using locally-important vegetables. The vegetables were grown in a cropping plan staggered over different months of the year. The organic practices of growing of Sunhemp and its incorporation to soil, use of organic manures, Neem cake, vermicompost, bio-inoculants like *Azetobacter, Azospirillium, Rhizobium* and *phospho bacteria*, and crop rotation treatments were imposed on the plot. Organic plant protection practices were also adopted in the demonstration plot of vegetables such as thegrowing of trap crops like Marigold and Mustard, eco-friendly pesticide formulations like the application of *Trichoderma*, use of botanicals like Neem oil, NSKE, bio-dynamic preparations like foliar spray of cow urine, cow dung slurry, *Jeevaamrutha*, and use of pheromone traps were adopted in the plot. The results of organic vegetable trials conducted have indicated that yield levels are still 60-70 percent of conventional farming practices in the first year and have improved the soil physical quality and also improved soil health by enhancing its resistance capacity against soil-borne diseases including nematodes. Soil physical quality, nutrients and microbial flora of soil samples examined after one year of the imposition of treatments indicated substantial changes in the parameters. Association of bio-fertilizers along with different organic manures used in the organic cultivation of vegetables resulted in better yield and better quality of vegetable crops is discussed in this paper.

Keywords
Organic, vegetables, quality, soil health

INTRODUCTION
Organic farming works in harmony with nature rather than against it. This involves using techniques designed to achieve good crop yields without harming the natural environment or the people who live and work in it. Organic farming does not mean going ‘back’ to traditional methods. Many of the farming methods used in the past are still useful today. Organic farming takes the best of these and combines them with modern scientific knowledge.

Organic farming methods combine scientific knowledge of ecology and modern technology with traditional farming practices based on naturally occurring biological processes. While conventional agriculture uses synthetic pesticides and water-soluble synthetically purified fertilizers, organic farmers are restricted by regulations to using natural pesticides and fertilizers. The principal methods of organic farming include crop rotation, green manures and composts, biological pest control, and mechanical cultivation. These measures use the natural environment to enhance agricultural productivity: legumes are planted to fix nitrogen in the soil, natural insect predators are encouraged, crops are rotated to reduce pest infestation and renew soil, and natural materials such as potassium bicarbonate and mulches are used to control diseases and weeds. Organic farmers are careful in their selection of plant breeds, and organic researchers produce hardy plants through plant breeding.

Crop diversity is a distinctive characteristic of organic farming. Conventional farming focuses on mass production of one crop in one location, a practice called monoculture. This makes apparent economic sense: the larger the growing area, the lower the per-unit cost of fertilizer, pesticides and specialized machinery for a single plant species. Yet, the science of agroecology has revealed the benefits of polyculture (multiple crops in the same space), which is often employed in organic farming. Planting a variety of vegetable crops supports a wider range of beneficial insects, soil microorganisms, and other factors that add up to overall farm health, but managing the balance requires expertise and close attention.

Organic farming practices are assuming importance all over the world nowadays in order to make the harvested produce free of pesticide residues and other harmful chemicals, to minimize soil, water and environmental pollution and sustain soil productivity. Organic food has evolved from being a fashion cult to being considered a necessity for healthy living and the global food markets present a bright situation for organic food suppliers, as the demand far outstrips the supply. Organic vegetable farming is becoming important in the agriculture sector in India and it includes all agricultural systems that promote environmentally, socially and economically sound production of vegetables. These systems take local soil fertility as a key to successful production. By respecting the natural capacity of plants, animals and landscape, it aims to optimize quality in all aspects of agriculture and the environment.

Organic vegetable agriculture reduces external inputs by refraining from the use of chemo-synthetic fertilizers, pesticides and pharmaceuticals. Instead it allows the powerful forces of nature to increase both agricultural yields and disease resistance. We have recently exploited our natural resources to significant limits in order to realize high productivity and greater overall production. During the recent past, the use of chemicals for the management of pest and diseases and for improvement of soil fertility has increased. Some of these chemicals do not degrade easily and enter into human body leading to health hazards. Therefore in several countries around the world including India, demand for organically produced vegetables is increasing amongst consumers. In this direction it is the endeavor of all people concerned with organic or safe vegetable production to develop feasible and economically viable packages of practice based on the information available and technology developed for farmers interested in organic vegetable farming. The principal objectives of organic vegetable farming are to develop a sustainable farming system for guaranteed adequate vegetable production in the foreseeable future, to develop a self-sufficient agriculture system which would rely as much as possible upon its own resources and to develop an alternative strategy to chemical farming which would be a guideline for the working of biological processes in natural eco-systems.

MATERIAL AND METHODS

A long term permanent demonstration plot of organic vegetable cultivation was initiated at the vegetable block of land of the Department of Horticulture, University of Agricultural Sciences, GKVK, Bangalore during 2008-09 which was supported by the National Horticulture Mission, Government of Karnataka. The demonstration was laid out with important vegetables: mainly Solanaceous species, Leguminous species, root vegetables, leafy vegetables, cucurbits and perennial vegetables like Drum stick, Curry leaf and *Coccinea* and other under exploited vegetables.

The soil of the selected plot was a well-drained sandy loam with a pH of 5.91 and was devoid of salinity problems (EC 0.27 ds m^{-1}). The initial organic carbon content was 0.51 to 0.72 per cent and the available N, P and K were 450.9, 28.3 and 98.6 kg/ha respectively. The micronutrients such as sodium, calcium, magnesium were 0.137, 3.29 and 1.67 meq/100gm respectively. The sulphur content was 6.14 ppm.

The peak monthly evaporation (184–234 mm) was during April-May. The total rainfall received during the year 2008, 2009 and 2010 was 730.7, 912.7 and 1181.1mm, respectively. Initial soil samples were drawn from the plot before the start of the experiment (2008) and after three years (2010). These were analysed for soil quality, nutrient composition and also for initial microbial load. All the experiments were carried out in a fixed plot layout in the pattern of permanent manurial experiments. In these plots no chemicals had been used since 2005. The vegetables were grown as per a cropping plan and thus staggered over different months in a year. The organic practices of growing of sunhemp and its incorporation into soil, use of organic manures, Neem cake, vermicompost, bio-inoculants like *Rhizobium*, *Azatobacter, Azospirillium,* and phosphrous solubilising bacteria, crop rotation treatments were imposed on the plot. Organic plant protection practices were adopted in the demonstration plot of vegetables such as the growing of trap crops like Marigold and Mustard, eco-friendly formulations such as the application of *Trichoderma*, use of botanicals like Neem oil, NSKE, bio-dynamic preparations like foliar spray of cow urine, cow dung slurry, *Jeevamrutha*, and use of pheromone traps were adopted in the plot. For weed management hand weeding was adopted and when a drip system with raised bed planting was followed, comparatively less weed infestation was observed.

Solanaceous vegetables (tomato, brinjal, chilli, sweet pepper), leguminous vegetables (french bean, cluster bean and *Dolichos* beans), okra, radish, leafy vegetables (palak, amaranthus), cucurbits (bottle gourd and ridge gourd) were sown during June to November months of the year 2008, 2009 and 2010 respectively and perennial vegetables (drum stick, curry leaf, *Coccinea* and chow-chow) were sown during June 2008.

RESULTS AND DISCUSSION

The nutrient composition of the different organic manures used in the organic farming demonstration are presented in Table 1. It can be seen that the influence of organic cultivation systems on soil pH, EC, OC and nutrient status was substantive., Organic farming improved these parameters indirectly enhancing soil physical and chemical properties (Table 2). Improvement in soil pH, EC, OC and nutrient status is attributed to extensive use of organic manures, bio inoculants like, *Rhizobium*, *Azatobacter, Azospirillium,* and phosphrous solubilising bacteria and crop rotation practices. Unlike conventional and chemical farming systems, organic farming brings the soil pH towards the neutral range, and at such a neutral pH most of the soil nutrients will be available to plants. Further results clearly indicated that organic cultivation had significantly improved the soil OC content and also resulted in a higher content of all the minor nutrients in addition to enhancing the most important macro elements (phosphorus and potash) from the crop quality parameters point of view (Prabhakar and Hebbar 2008).

Table 1. Nutrient composition of organic manures used in the organic farming demonstration

Nutrients	FYM	Vermicompost	Sun- hemp	Neem cake
Nitrogen – N (%)	0.75	0.60	0.75	5.2 – 5.3
Phosphorous – P (%)	0.17	5.04	0.12	1.0 – 1.1
Potassium – K (%)	0.55	0.80	0.51	1.4 – 1.5
Calcium – Ca (%)	0.91	0.44	---	---
Magnesium – Mg (%)	0.19	0.16	---	---
Iron – Fe (ppm)	146.5	175.20	---	---
Zinc – Zn (ppm)	14.5	24.45	---	---
Copper – Cu (ppm)	2.8	4.89	---	---

Table 2. Soil pH, EC, OC and nutrient status as influenced by organic cultivation system

Parameters	Before initiation of the experiment (2008)	After three years (2010)
pH	5.91	6.13
EC (mmhos/cm)	0.278	0.307
OC (%)	0.50	0.65
N (Kg/ha.)	450.9	521.1
$P_2 o_5$(Kg/ha.)	22.30	28.30
K_2o (Kg/ha.)	91.60	126.4
Na (Meq/100 gm)	0.12	0.14
Ca (Meq/100 gm)	3.25	3.29
Mg (Meq/100 gm)	1.67	1.78
S (ppm)	6.44	7.99

Comparison of the microbial population in organic cultivation system before and after three years of cropping is presented in Table 3. Increased microbial population in the soil was observed in the year 2010 as compared to year 2008 (before the initiation of the experiment). This is due to a favorable niche that has been provided by organic practices like, green manuring, application of a higher amount of vermicompost and bio-dynamic preparations which includes cow urine, cow dung slurry and *jeevaamrutha* (Prabhakar and Hebbar 2008).

Table 3. Microbial population (cfu/g) in organic cultivation system before and after three years of cropping

Microbial population	Before initiation of the expt. (2008)	After three years (2010)
Bacteria (10^8)	91.2	129.8
Fungi (10^4)	3.4	8.4
Actinomycetes (10^5)	2.8	6.9
Total Diazotrophs (10^4)	8.1	13.0
Azospirillum (10^4)	4.2	8.3
Azotob-acter (10^4)	3.6	9.1
Phospho-bacteria (10^4)	6.1	10.9
P.fluorescens (10^4)	4.9	8.6

The yield of different vegetables in the initial period is about 60-70 percent of conventional farming practices, but over the years it has showed an increasing trend (Table 4). A percentage increase in yield from 7.44 to 28.51 was observed in different vegetables over the year 2008 to year 2010. Compared to chemical fertilizers, organic practices won't supply large amounts of nutrients at a specific time, which are required by plants. This may lead to reduced yield in initial years but later on, as organic practices are continued, increased micro flora in the soil along with improved soil physical and chemical properties are able to enhance the yield compared to the initial years.

Table 4. Performance of vegetable crops in organic farming (2008-2010)

No.	**Vegetable**	**Variety**	**Yield (t/ha)**			**Percentage increase of yield**
			2008	**2009**	**2010**	
1.	Tomato	Pusa Ruby	16.66	17.98	20.10	20.04
2.	Brinjal	Arka Shirish	15.03	16.18	17.23	14.63
3.	French bean	Arka Komal	7.01	8.45	9.01	28.51
4.	Cluster bean	Local	5.00	5.70	6.30	26.00
5.	Chilli (Green)	G-3	8.00	8.70	9.20	15.00
6.	Sweet pepper	Sun Set	8.00	8.71	9.03	12.80
7.	Hebbal Avare	HA-3	3.12	3.36	3.79	21.47
8.	Bhendi	Arka Anamika	5.67	6.23	6.43	13.40
9.	Radish	Arka Nishanth	8.57	9.23	10.59	23.57
10.	Palak	Local	7.50	7.96	8.56	14.13
11.	Amaranthus	Local	10.60	11.37	12.25	15.56
12.	Bottle gourd	Local	15.00	16.78	17.95	19.66
13.	Ridge gourd	Local	6.50	7.38	8.37	28.76
14.	Drumstick	GKVK-1	15.31*	16.45*	---	7.44
15.	Curry leaf	Local	---	1.8*	2.31*	28.33
16.	*Coccinia*	Local	16.49*	17.68*	18.06*	9.52

* Yield in kg/tree

CONCLUSION

In total it can be concluded that organic cultivation gives a reasonably comparable yield with good quality of produce and at the same time can sustain soil productivity by enhancing its health as well as its nutrient status compared to conventional systems. Due to its low cost inputs and sustainable nature this organic farming system best suits small and medium farmers where they can less afford high cost external inputs.

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References

Prabhakar M, Hebbar SS. 2008. Current status and prospects of organic farming in vegetable crops. National conference on organic farming in horticultural crops, CPCRI, Kasargod held on 15-18 October. pp 38-47.

Figure 1. Demonstration of the organic way of vegetable cultivation

Performance of vegetable soybean cultivars under organic crop management system

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ABSTRACT
The objective of this study was to evaluate growth and yield performance of vegetable soybean (*Glycine max)* cultivars under organic crop management practices. Four cultivars: Kaohsiung No. 6 (KS 6), Kaohsiung No. 9 (KS 9), Tainan ASVEG No. 2 (TNAV 2), and Japan aromatic flavor variety Cha-mame were grown in spring and fall seasons in organic experimental farm at AVRDC – The World Vegetable Center in 2006-2007. Organic crop management practices consisted of *rhizobium* seed inoculation, application of balanced solid and liquid organic fertilizer, integrated pest management involving sex pheromone, yellow and blue sticky paper traps, and bio-pesticide sprays (Neem and Bt); and bio-agents (*Trichoderma* spp., *Bacillus subtilis* and. *Streptomyces* spp. for fungal disease management. Yield performance showed that TNAV 2 produced the highest total pod yield, followed by KS 9 and Cha-mame. However, differences were not significant. TNAV 2 matured late whereas Cha-mame matured early. Over three growing seasons, Cha-mame produced the highest graded pod yield, followed by TNAV 2 and KS 9. This study indicates that both vegetable soybean cultivars Cha-mame and TNAV 2 have greater yield potential than other cultivars when produced under organic farming system.

Keywords
Vegetable soybean, organic farming, integrated pest management, high-value vegetables.

INTRODUCTION
Vegetable soybean (*Glycine max* L. Merrill) is an important crop and source of dietary protein in Southeast Asia (Lumpkin et al. 1992; Konovsky et al. 1994; Mentreddy et al. 2002). The potential biomass yield of vegetable soybean can reach as high as 40 t/ha, consisting of 10 tons of marketable green pods and 30 tons of plant residue that can enrich the soil or feed animals (Shanmugasundaram and Yan 2004). Vegetable soybean is the number one processed frozen food in Taiwan for export market. It has become one of the most important cash crops in Taiwan (Lin and Cheng 2001; Ma et al. 2008). Frozen vegetable soybean imports into US increased from about 300 to 500 t per year in 1980s to about 10,000 t in 2000 (Lin 2001). Taiwan and China are major suppliers of frozen vegetable soybean to the United States. The increasing popularity of soybean as a nutraceutical is currently driving the demand for this vegetable (Lin 2001; Mentreddy et al. 2002). Green pods and products made out of fresh seed are in great demand in most Asian countries, particularly Japan (Lumpkin and Konovsky 1991; Shanmugasundaram 2001).

Lack of suitable cultivars is one of the factors limiting vegetable soybean production in Southeast Asia. Most cultivars of Japanese origin appeared to be suitable for production in Southeast Asia. The Japanese classify soybeans as summer or fall types (Kono 1986). Most cultivars are temperature-sensitive, summer types; only a few are day-length sensitive, fall types. Summer types are planted in the spring and harvested immature after 75-100 days, while fall types are planted in early summer and take 105 days or more. Lingxiao and Kyei-Boahen (2007) evaluated 27 vegetable soybean cultivars and found that cultivars varied from maturity group III to VII. The late-maturing varieties were generally taller, had more nodes/plant, pods/plant, and fresh green pod yield at R6 stage (full seed) than the early-maturing varieties. Konovsky et al (1994) described differences in horticultural traits of some cultivars from Japan and China. Carter and Shanmugasundaram (1993) have compiled a list of vegetable soybean cultivars grown in Japan and Taiwan. AGS 292 a pure line selection was found to be relatively less sensitive to photoperiod and temperature.

Cultivars that produce high pod yields and also high amount of biomass have been developed through breeding at AVRDC – The World Vegetable Center and Taiwan District Agricultural Improvement Stations in Kaohsiung and Tainan. For example, cultivar "Kaohsiung 7" was selected at Kaoshiung District Agricultural Research and Extension Station (KDARES), Taiwan with excellent characteristics including higher yields and better adaptability, larger fresh pod, higher pod set for mechanical harvest, and larger black seed (Chou and Cheng 2002). These cultivars serve dual purposes of pod production and as a green manure crop to replenish soil nutrient levels including nitrogen, soil organic matter and improve soil structure and sustainability (Shanmugasundaram 2001). Due to their short duration (99 to 120 days), vegetable soybeans fit well into existing crop rotation patterns. Dual purpose varieties serve as main summer crop and enable farmers to turn in green crop residue as green manure before planting crops next spring (Shanmugasundaram and Yan 2004). AVRDC in cooperation with KDARES also succeeded in developing and releasing three vegetable soybean varieties for export to Japan, namely Kaohsiung #1, 2, and 3 (Shanmugasundaran et al 1991).

Most of the high yielding vegetable soybean cultivars have been produced under conventional method of cultivation using chemical fertilizers and pesticides. Pesticide residue may hinder the export potential of vegetable soybean especially in countries where strict quality standards are imposed (Srinivasan et al 2009) Studies on the performance of vegetable soybean cultivars under organic crop management system are limited. Ideal and suitable cultivars for organic vegetable soybean production in Southeast Asia should be high yielding (total and graded pods), resistant to insect pests and diseases, early maturing, less sensitive to photoperiod, adapted for growing all year round (spring, summer and autumn seasons), high biomass for green manure, large pod and seed size, high nutritional quality and good storability. For export market requirements, Lai et al (2004) suggested that vegetable soybean should have 100-dry seed rate of 30 g or more, two or more seeds per pod, gray pubescence on pod, short cooking time, easy-to-squeeze pod texture after cooking, and slightly sweet taste.

Increasing concern about environmental quality, human health, and safer agricultural products has led to the development of organic vegetable soybean production in Taiwan and Southeast Asia (Ma et al. 2008). Development of cultivation technologies and expansion of export markets for organic vegetable soybean will be a challenge for sustainable development of vegetable soybean enterprise. The objectives of this study were to: 1) determine growth and yield performance of vegetable soybean cultivars under organic management practices; and 2) identify vegetable soybean cultivars that are suitable for organic production system.

MATERIALS AND METHODS

The field trials were established at AVRDC Organic Field during the dry season of 2006 and 2007. The surface soil structure is silty loam with a pH range of 7.2 and 7.8. The field trials were laid out using a randomized complete block design with three replications. The experimental treatments were the four vegetable soybean cultivars (Cha-name, KS 6, KS 9 and TNAV 2). Figures 1 to 4 show the features of each cultivar. Cha-mame is a Japanese fragrant (aromatic) cultivar with taro flavor and high in sugar content (sweetness). It has brown seed and white flower and matures early. KS 6 is a cultivar developed at KDARES, Taiwan. It matures in 73 days with high graded pod yield. KS 9 is also developed from KDARES. It is high yielding in graded pods with potential yields of 9-10 t/ha). It has good flavor and taste, but seeds are harder than other cultivars. TNAV 2 is developed from Tainan District Agricultural Improvement Station, Taiwan. It matures in 85 days during spring planting and 72 days during fall planting. Pods are large and green with good flavor and taste. It is also resistant to downy and powdery mildew disease.

The cultivars were grown in plots consisting of four beds measuring 1 m wide by 3 m long. The beds were spaced by 50-cm furrows. Three seeds were sown per hill and then thinned down to two seedlings per hill. Seeds were sown in double rows 12 cm apart. Row spacing between double rows was 35 cm with a plant population equivalent to 33,333 plants per hectare.

Organic crop management practices consisted of rhizobium seed inoculation, application of balanced solid and liquid organic fertilizer. Plastic mulching combined with solarization was used to control soil-borne diseases as well as weeds. Bio-agents *Trichoderma harzianum* T2 strain (100 X) and *Bacillus subtilis* strains Y1336 (500X) and WG6-14 (100X) were tested to control soil-borne diseases at seedling stage and other diseases at later growing stages. Other integrated pest management strategies involved sex pheromone, yellow and blue sticky paper traps, and bio-pesticide sprays (Neem and Bt). Plots were frequently furrow-irrigated to maintain soil moisture at field capacity. Data were collected on total and graded pod yield, days from planting to harvest and observations on incidence of pests and diseases.

Standards for graded pods

Vegetable soybean is actually grain soybean harvested at R6 stage when the pods are still green but fully developed. The seeds of vegetable soybeans are commonly larger, sweeter and much tender than grain soybean. Export standard for graded pods are green pods without disease and pest damage and contain two or more seeds per pod. Pod size is 1.3 cm in width and 4.5 cm in length. A 500-g fresh sample contains about 150-170 pods. Other quality standards include gray pubescence, short cooking time, easy to squeeze after cooking and sweet taste.

RESULTS AND DISCUSSION

Total pod yield

Differences in total pod yield were significant ($P \leq 0.05$) among cultivars in all cropping seasons (spring and autumn 2006 and spring 2007 (Table 1). In spring 2006, cultivar TNAV 2 produced the highest total pod yield followed by KS 9. Cultivar Kaohsiung No. 6 produced the lowest total pod yield. In autumn 2006 growing season, TNAV 2 maintained the highest yield, but was not significantly ($P \geq 0.05$) different from cultivars Cha-mame, KS 6 and KS 9 (Table 1). In the spring of 2007, cultivars Cha-mame, TNAV 2 and KS 9 significantly ($P \leq 0.05$) outyielded cultivar KS 6. Small yield differences were obtained between Cha-mame, TNAV 2 and KS 9 in spring 2007, but TNAV 2 maintained as the highest yielder.

Over three growing seasons mean total pod yield was similar between cultivars Cha-mame and KS 9. In general, mean total pod yield was higher in spring than in autumn planting. Low temperature during the later part of the autumn season can reduce pod size and filling that may have contributed to lower yield compared to summer planting. This result is consistent with previous reports where yield is higher in spring than autumn planting (Sundar et al. 2004). The higher yield of TNAV 2 can be attributed to its longer growing period than other cultivars. Cultivar Cha-mame was the shortest in terms of growing period. Cha-mame a fragrant variety matured the earliest in both spring and autumn trials.

Cha-mame

Kaohsiung No. 6

Kaohsiung No. 9

Tainan ASVEG-2

Table 1. Total pod yield of vegetable soybean cultivars grown under organic management system. AVRDC, Taiwan.

Cultivar	Total pod yield (t/ha)			
	SP-2006	AU-2006	SP-2007	Mean
Cha-mame	12.5 ab	9.7 a	10.8 a	11.0
Kaohsiung No. 6	11.8 b	7.1 b	8.5 b	9.1
Kaohsiung No. 9	13 .6 a	9.2 a	10.3 a	11.0
Tainan ASVEG 2	14.0 a	10.4 a	11.2 a	11.9
Mean	12.9	9.1	10.2	

Mean separation in columns by Tukey's Test, P<0.05
SP = spring, AU = autumn

Graded pod yield

Graded pod yields of cultivars were almost similar in spring 2006 (Table 2) and differences were not significant (*P≥0.05*). Significant differences in graded pod yield were observed among cultivars in autumn 2006 and summer 2007 planting. Cultivar Cha-mame produced the highest graded pod yield in both seasons (autumn 2006 and spring 2007). However, its yield was not significantly (*P≥0.05*) different with KS 9 and TNAV 2 in autumn 2006 (Table 2). In spring 2007 both cultivars Cha-mame and TNAV 2 significantly outyielded KS 6 and KS 9 As with total pod yield, similar results were obtained with graded pod yield where average yield was higher in spring than in autumn planting (Table 2).

Table 2. Graded pod yield of vegetable soybean grown under organic management system. AVRDC, Taiwan

Cultivar	Graded pod yield (t/ha)			
	SP-2006	AU-2006	SP-2007	Mean
Cha-mame	8.3 a	5.9 a	6.3 a	6.3
Kaohsiung No. 6	7.6 a	4.5 b	4.8 b	5.6
Kaohsiung No. 9	7.6 a	5.2 ab	5.2 b	6.0
Tainan ASVEG 2	8.3 a	5.9 a	6.3 a	6.8
Mean	7.9	5.4	5.7	

Mean separation in columns by Tukey's Test, P<0.05
SP = spring, AU = autumn

Among cultivars, Cha-name and KS 6 have higher percent graded pod yield than KS 9 and TNAV 2 (Table 3). Graded pod yield of Cha-name and KS 6 reached more than 60% in spring and autumn plantings of 2006.

Table 3. Percent graded pod of vegetable soybean grown under organic management system. AVRDC, Taiwan.

Cultivar	Graded pod (%)			
	SP-2006	AU-2006	SP-2007	Mean
Cha-mame	66.4	60.8	58.3	61.8
Kaohsiung No. 6	64.4	63.3	56.5	61.4
Kaohsiung No. 9	55.9	56.5	50.5	54.3
Tainan ASVEG 2	59.3	56.7	56.3	57.4
Mean	61.5	59.3	55.4	

This result suggests that for organic vegetable soybean production, cultivar Cha-mame has great potential for growing in Southeast Asia. Since this is a cultivar from Japan, there is high opportunity for Southeast Asian countries to expand production for export market to Japan and other countries.

Incidence of insect pests and diseases

Vegetable soybean is attacked by various insect pests at different plant growth stages. In this trial leaves were slightly defoliated by tomato fruitworm (*H. armigera*), common armyworm (*S. litura*) and beet armyworm (*S. exigua*). Soybean webworm (*Omiodes indicata*) and Taiwan tussock moth (*Porthesia taiwana*) were promising defoliators. Whitefly (*Bemisia tabaci*), thrips (*Megalurothrips usitatus*) and small green leafhopper were the major sucking insects.

Limabean pod borer (*Eteiella zinckenella*) and legume pod borer (LPB), *Maruca vitrata* were the major pests on the pods. Insect pest incidence in general was low and there was no variation among cultivars in terms of insect damage. The integrated pest management consisting of sex pheromones and sticky paper traps, bio-pesticides such as *Bacillus thuringiensis* (Bt), neem and *nucleopolyhedrovirus* (NPV) was effective in managing insect pests to minimum level.

The major diseases observed were root rot (*Rhizoctonia solani*) and anthracnose (*Colletotrichum truncatum*). Other diseases were downey mildew (*Peronospora manshurica*), rust (*Phakopsora pachyrhizi*), purple blotch (*Cercospora kikuchi*) and bacterial pustule (*Xanthomonas axoropodis* pv. Glycine). Disease infection level and occurrence were low in this trial and no difference among cultivars were observed in terms of disease infection. Bio-agents *Trichoderma harzianum* T2 strain (100 X) and *Bacillus subtilis* strains Y1336 (500X) and WG6-14 (100X) were quite effective in controlling disease infection.

CONCLUSION

This study has shown that growth and yield performance varied among vegetable soybean cultivars when grown under organic management systems. In terms of total pod yield promising cultivars are Cha-mame, TNAV 2 and KS 9 with potential yields of 11-12 t/ha. In terms of graded pod yield the three cultivars maintained higher yield (above 6.0 t/ha) compared to KS 6. Both Cha-mame and KS 6 have higher percent graded pod than KS 9 and TNAV 2. Over three growing seasons average yield is greater in spring planting than autumn planting for all cultivars. The incidence of insect pests and diseases was not serious in reducing yield levels in all cultivars. Integrated/organic pest management was effective in bringing down insect population and disease infection. Based on the results of the study, cultivars Cha-mame and TNAV 2 have great potential for organic vegetable soybean production in Southeast Asia for export market. Cha-mame matures early and has ideal qualities suitable for organic export market.

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References

Carter TE, Shanmugasundaram S. 1993. Vegetable soybean (Glycine). Pages 219-239 In: JT Williams (ed.) Underutlized Crops – Pulses and Vegetables. Chapman, London.

Kono S. 1986. Edamame. pages 195-243 In, Sakukei o Ikasu Mamerui no Tsukurikata. Nosangyoson Bunka Kyokai, Japan.

Konovsky J, Lumpkin TA, McClary D. 1994. Edamame: the vegetable soybean. Pages 173-81 In A.D. O'Rourke (ed), Understanding the Japanese Food and Agrimarket: a multifaceted opportunity. Haworth Press, Binghamton, New York.

Lal G, Lai SH, Shanmugasundaram S. 2004. Suggested cultural practices for vegetable soybean. AVRDC Training Guide. AVRDC, Tainan. 4 p.

Lin FH, Cheng ST. 2001. Vegetable soybean development for export to Japan: A historical perspective. Pages 87-91 In: TA Lumpkin and S Shanmugasundaram (eds.). Proc. 2nd International Vegetable Soybean Conference. Washington State University, Pullman, Washington, USA.

Lin CC. 2001. Frozen edamame: Global market conditions. Pages 93–96. In: T.A. Lumpkin and S. Shanmugasundaram (Compilers), 2nd Int. Vegetable Soybean Conf., Washington State Univ., Pullman, Washington, USA.

Lingxiao Z, Kyei-Boahen S. 2007. Growth and yield of vegetable soybean (Edamame) in Mississippi. HortTech 17(1):27-31.

Lumpkin TA, Konovsky J. 1991. A critical analysis of vegetable soybean production, demand, and research in Japan. Pages 120–140. In: S. Shanmugasundaram (ed.), Vegetable soybean: Research needs for production and quality improvement. Asian Vegetable Res. Dev. Center, Taiwan.

Lumpkin TA, Konovsky JC, Larson KJ, McClary DC. 1992. Potential new specialty crops from Asia: Azuki bean, edamame soybean, and *Astralagus*. p. 45–51. In: J. Janick and J.E. Simon (eds.), New Crops. Wiley, New York.

Ma CH, Juroszek P, Palada MC, Srinivasan R, Wang TC, Yang RY. 2008. Integration of production technologies for organic vegetable soybean in Taiwan. HortScience 43(4):1106.

Shanmugasundaram, S., Yan, M.R. 2004. Global expansion of high value vegetable soybean. In: World Soybean Research Conference, 7th. Londrina: Brazilian Agricultural Research Corporation, National Soybean Research Center. Pages. 915-920.

Shanmugasundaram S, Chang ST, Huang MT, Yan MR. 1991. Varietal improve-ment of vegetable soybean in Taiwan.*In:*Vegetable Soybean: Research Needs forProduction and Quality Improvement: proceedings of a workshop held at Kenting,Taiwan, April 29 — May 2, 1991. Asian Vegetable Research and Development Center,Publication No. 91-346, pp. 30-42.

Mentreddy SR, Mohamed AI, Joshee N, Yadav AK. 2002. Edamame: A nutritious vegetable crop. P. 432-438 In: J Janick and A Whipkey (eds.). Trends in New Crops and New Uses. ASHS Press, Alexandria, Virginia, USA.

Shanmugasundaram, S. 2001. Global extension and diversification of fresh and frozen vegetable soybean. Pages. 161–165. In: T.A. Lumpkin and S. Shanmugasundaram (Compilers), 2nd Int. Vegetable Soybean Conf., Washington State Univ., Pullman.

Shanmugasundaram S, Cheng ST, Huang MT, Yan MR. 1991. Varietal improvement of vegetable soybean in Taiwan. p. 30–42. In: S. Shanmugasundaram (ed.), Vegetable soybean: Research needs for production and quality improvement. Asian Vegetable Res. Dev. Center, Taiwan.

Srinivasan R, Su FC, Huang CC, Lin MY, Hsu YC. 2009. Integrated pest management in organic vegetable soybean production. Paper presented at the Conference on International Research on Food Security, Natural Resource Management and Rural Development. University of Hamburg, Germany.

Studies on evaluation for adoption of high value cole crops in the plains of West Bengal

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ABSTRACT
A wide change in attitude is noticed over the last 5-10 years among the policy makers, growers, and consumers with regard to the quality of life as related to the quality of food as well as diverse sources of food. Quality and quantity, both factors are for instance being searched in crops and plant species with greater emphasis than in past in recognition of their role in combating diet imbalances and to feed the 'hidden hunger' of developing countries. However, considerable attention is being given on the production technology of vegetables which are rich in nutrient content and greater yield potential. But yet, No systematic work has been done on evaluation and commercialization of high value nutrient rich cole crops. Therefore, the present study were carried out at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia in West Bengal during rabi season of 2008-09 with objectives to evaluate the production technology and popularization of high value cole vegetable crops. The cole vegetables taken under this investigation are Chinese cabbage, Red cabbage, Sprouting broccoli and Brussels sprouts. Cultivation of these value added vegetables can boost the income of farmers due to very high market price and export demand. The investigations were followed in Randomized Block Design with different replications for each crop. Three varieties of Chinese cabbage namely (Tropical Delight, Optiko and Tropic Prince), four varieties of Red cabbage (Ruby mart, Red queen, Primero and Red cabbage), twelve varieties of Broccoli (Fiesta, Princess, Sultan, Nokghuk, Early You, KE-180, Priya, Puspa, Grandsino, Rapido, Prema and Packman) and three varieties of Brussels sprouts (Rubine, Hilds ideal and Sanda) were evaluated. Observations recorded under the physical parameters of different varieties of each genotype. In general, the performances of these crops with different hybrid varieties proved that there is ample scope to grow these vegetables due to prevailing suitable agroclimatic condition as well as the gaining importance of these high value cole vegetables as potential vegetable for export. Among all the varieties of Broccoli Nokguk was found superior, which gave higher yield in combination with best head formation. In case of Chinese cabbage, variety Optiko had shown the overall best performances. Red Queen variety of Red cabbage and Sanda variety of Brussels sprouts had shown better performances in compare to other varieties. Among these four high value cole crops, the growth, development and yield of Brussels sprouts was not found effective. The prevailing environmental conditions of this zone may not be suitable for growing this crop. So, proper management practices are highly required for the cultivation of this crop.

Keywords
Evaluation, high value, exotic cole vegetables.

INTRODUCTION
India is endowed with a wide range of tropical, sub-tropical and temperate vegetable crops. But still there are some vegetables which are lesser known or rare to most of our growers and consumers. Our farmers can earn a lot of profit by growing this rare or unusual high value cole vegetables nearby big cities (peri-urban areas) and towns as they attract very high prices in cosmopolitan markets, star hotels and places of tourists' interest. They can also be exported to foreign especially European countries where their cultivation is not possible throughout the year in open field conditions. But due to lack of information about their cultural practices for our conditions the production or availability of these vegetables is still meager. Chinese cabbage, Sprouting broccoli, Red cabbage and Brussels sprouts, etc. have opened up new opportunities for vegetable growers of West Bengal for diversification and

off-season production for high market in metropolis. But due to lack of preference in food among Indians some of the introduced vegetables could not get popularity though they are rich in protein, carbohydrates, minerals, vitamins and fibre etc. However, with the growing tourist industry and nutritional awareness among people, these vegetables are gaining popular. Among the cole crops broccoli is more nutritious than other cole crops, such as cabbage, cauliflower and kohlrabi It is fairly rich in carotene and ascorbic acid and contains appreciate quantities of thiamin, riboflavin, niacin and iron . Realizing the tremendous potential of sprouting broccoli in domestic and foreign market, the cauliflowers growers of terai zone of West Bengal are gradually adopting the broccoli cultivation (Saha *et.al.* 2006). To popularize this high value cole crops and its variety among the marginal and small farmers, proper demonstration should be adopted through personal contact approach, monitoring, motivation and awareness creation about benefits. Efforts are being made on long way in making farmers and consumers of West Bengal in adopting new exotic vegetables and varieties, which created an impact on ground level and helped the state in a big way in addressing/lessening the problems of hunger, under nutrition and malnutrition not only in West Bengal but elsewhere in the country as well. But no systematic work has been done on evaluation of these vegetables in West Bengal. However, State is facilitated with good and congenial agro - climatic condition for cultivation of these crops. Therefore, present studies were aimed at promotion of high value cole vegetables by identifying new promising varieties with high productivity under wide range of environmental conditions, better horticultural characteristics and market opportunities.

MATERIALS AND METHODS

The present studies were carried out at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia in West Bengal during rabi season of 2008-09 with the principle objective to evaluate the production technology and popularization of exotic high value cole crops. The cole crops taken under this investigation with details are as follows:

Chinese cabbage (Brassica campestris var. *pekinensis)*

Chinese cabbage taken under investigation was sown on experimental plot in Randomized Block Design with seven replications. Varieties considered are Tropical delight, Optiko and Tropic prince. The transplanting of seedling was accomplished on first week of November with the spacing of 45 cm x 45 cm having plot size (2 m x 2 m). Fertilizer doses were applied in NPK ratio (80:50:30) kg per hectare. Regular irrigation earthling up and crop protection measures were adopted as per recommended practices. Observations recorded were based on physical parameters of crop including yield factor. Mean value of randomized data were used for statistical analysis.

Red cabbage (Brassica oleracea var. *rubra)*

The design of the experimental site for Red Cabbage was Randomized Block Design, replicated five times. The four varieties used in this investigation were Ruby mart, Red Queen, Primero and Red cabbage. The transplanting of seedlings was done on first week of November with the spacing 45 cm x 45 cm. Adopted fertilizer doses are in NPK ratio of (75:60:40) kg per hectare. All the cultural and biological practices were adopted as recommended practices. Observations recorded and mean value obtained were used for statistical analysis.

Broccoli (Brassica oleracea var. *italica)*

The design of experimental site was Randomized Block Design replicated thrice utilizing twelve genotypes showing diverse features. Genotypes taken under observations were Fiesta, Princess, Sultan, Nokguk, Early you, Priya, Puspa, Grandsino, Rapido, Prema, and Packmen. The transplanting of seedlings were accomplished on first week of November with the spacing of 60 cm x 45 cm. Applied fertilizer doses are in NPK ratio of (100:80:100) kg per hectare. Regular cultural practices, crop protection measures were adopted as per the requirements of crop. Observations were taken under physical and yield attributing parameters. Mean value of randomized data were used for standard statistical analysis.

Brussels sprouts (Brassica oleracea var. *gemmifera)*

The design adopted in Brussels sprouts experimental site was Randomized Block Design, replicated seven times by utilizing three genotypes possessing diverse morphological characters. They were Rubine, Hild's ideal and Sanda. The transplanting of seedling were done on first week of November with the spacing of 60 cm x 45 cm. Fertilizer doses were applied in NPK ratio of (120:60:100) kg per hectare. Recommended cultural and agronomical practices were adopted. Observations were recorded on five randomly selected plants in each replication for each cultivar. Mean value of data were used for standard statistical analysis.

RESULTS AND DISCUSSION

The twelve different varieties of Broccoli were varied significantly. The height of the plants varied from 30.78 to 41.69 cm. From the data it revealed that the variety, Nok Guk recorded significantly maximum plant height (41.69 cm) while Early You variety recorded the minimum (30.78 cm). The lowest plant height observed in some other varieties might be due to its inherent genotypic characteristics or for the variations in agro-climatic condition. The number of leaves per plant is an important character that might influence the yield. The cultivars included in the study produced an average variation of 11.33 to 20.20 leaves per plant. The maximum number of leaves per plant was recorded as 20.20 in variety Fiesta, followed by Nok Guk (19.00), Grand Sino (18.077), and Priya (15.30). The lowest number of leaves was noticed in the variety Puspa (11.33) Sultan (11.93), Early You (12.06) and Princess (13.07). Lower number of leaves in some cultivars was probably due to slow rate in leaf initiation which would be an inherent character of the cultivars. This is in agreement with previous investigation in which some of the cultivars were included (Vanparys 1998; Rooster et al. 1998; McCall et al. 1996). In determining the photosynthetic efficiency of the leaves, the surface area of the leaves is an important factor. In this investigation, plant spread (cm^2) in each cultivar were recorded and found significant differences. The range of plant spread was 4515.87 to 6641.81cm^2. It has been found from the experiment results, the maximum plant spread (6641.81cm^2) was obtained with variety Princes. The minimum plant spread of 4515.87 cm^2, with variety Puspa was recorded.

It has been found from the experimental results that the highest stem diameter was measured in variety Prema (3.77 cm) followed by Grandsino (3.70 cm). Similarly the higher site in diameter of stem was observed with variety Princes (3.67 cm), Nokguk (3.67 cm), and Early You (3.66 cm). From the Table no.1 it is clear that among the above mentioned varieties there were significant differences among themselves. Rest of the other varieties different significantly from the above mentioned one. However, the lowest diameter of stem was obtained with variety Fiesta (3.32 cm). This similarity and dissimilarity among the varieties in stem diameter may be attributed to the variability in their genetic configuration. In respect of the stem length, statistically parity was observed. Among the twelve varieties the minimum stem length (20.42 cm) was observed in variety Early You. This showed that the cultivars represent a good range of genetic diversity in response of stem length.

Yield and yield attributing characters due to different varieties showed a significant differences effect. In respect of earliness of head initiation and days required to harvesting, the cultivars under study were found significant. The average number of days to head initiation varied from 59.00 to 70.00. The cultivar Early You, Sultan, Puspa, Rapido, Prema and Packman found earlier and Grandsino found very late in respect of head initiation. The average period required days to harvesting varied from 72.00 to 85.67. The highest head diameter was recorded in Nokguk (23.63 cm) followed by Early You (21.70 cm).

Significant increase in head weight was observed in response to different varieties. The maximum head weight of 375.00 gm was found with Nok Guk, variety. The varieties which produced comparatively more head weight are namely Early You, Prema, Fiesta, Princes, Packman and Puspa. The highest head weight might be due to resulted from the highest head diameter of the respective varieties. The minimum head weight of 233.83.gm was obtained with Grandsino variety. There was a significant and positive effect of different varieties on head yield (q/ha) Nok Guk performed the highest results in head yield (149.74 q/ha) and the other two varieties showed statistically similar results (120.86 q/ha, 119.72 q/ha). It indicates that next to Nok Guk, there two varieties, Early You and Princes have ability to produced good head yield. The other remaining varieties has produced similar head yield. The tabulated data (Table 1) showed clearly that the best quality of more number of sprout (spears) was recorded from the variety Priya followed by Early You. The lowest numbers of sprout were observed from Nok Guk variety. The differences in number of sprout among these varieties may be due to their own genetic characters. Results given in Table 1 reflected significant differences in the sprout weight of the different varieties. The highest sprout weight was obtained from Grand Sino followed by Nok Guk.

The present experiment revealed that the yield and yield attributing characters significantly differed within the different varieties. On the basis of performance of varieties related to head yield and concerning yield attributing characters, Nok Guk performed the highest head yield and other two varieties Early You, and Princes are also considered suitable for positive response for boosting higher yield.

It was observed from the experiment that out of three varieties of Chinese cabbage the maximum plant height (29 cm), head diameter (48.6 cm), head length (31.0 cm) and head width (16 cm) were observed in variety Optiko.Tropical delight showed maximum plant spread (2927 cm^2) and leaf area (909.7 cm^2) followed by variety Optiko, which have a plant spread of (2901.1cm^2) and leaf area of (903.3 cm^2).Among the three varieties the minimum days of 23.43 was required for head initiation in Tropic Prince. Tropical delight required maximum days of 29.14 for head initiation followed by Optiko. Tropic Prince required 50days for harvesting after transplanting where as Tropical delight and Optiko required 59.57 and 59.28 days for harvesting after transplanting. The highest yield was obtained in Optiko (439.14 q/ha) followed by Tropic Prince (413.43 q/ha) and Tropical Delight (389.42 q/ha).

Among the four varieties of Red cabbage head initiation was found early in variety Primero (50 days) followed by Ruby mart (52 days). All the varieties took approximately 89 to 95 days to harvest. It has been revealed that out of four varieties, maximum plant spread (4132.4 cm^2), number of outer leaves (11.5), leaf area (966 cm^2), head diameter (45.5 cm), head length (16.8 cm) and head width (14.8 cm) were found in variety Red Queen. Plant height was found maximum in variety Red Cabbage (69.5 cm) followed by Primero (32.8 cm). Head compactness was found more or less same in all the four varieties. Regarding yield, highest head yield was obtained in Red queen (312 q/ha), followed by Primero (262.4 q/ha) and Ruby mart (271 q/ha). The lowest head yield of 217.4 q/ha was obtained from Red cabbage variety.

It revealed from the table no.4 that among the four varieties of Brussels sprouts Hild's ideal required minimum days (105.33 days) for sprout initiation followed by variety Rubine (107.67 days). Maximum number of sprouts were developed in variety Hild's ideal (45.63) compared to other varieties. Variety Hild's ideal has a minimum plant height of 100.69 cm whereas variety Sanda has maximum plant height of 104.13 cm. The weight of sprout per plant was found maximum in variety Sanda (603.87 gm) followed by variety Rubine (552.12 gm). The yield was found maximum in variety Sanda (151.0 q/ha) followed by variety Rubine (137.92 q/ha).

CONCLUSION

The experiment performed on the evaluation and commercialization of exotic cole vegetable crops for sustainable agriculture production in West Bengal was found to be satisfactory.

The performances of these crops with different hybrid varieties proved that there is ample scope to grow these crops due to prevailing suitable agro climatic condition of the state as well as the gaining importance of these high value cole crops as potential vegetable for export. Among all the varieties of Broccoli, Nokguk was found superior, which gave higher yield in combination with best head formation.

In case of Chinese cabbage, variety Optiko had shown the overall best performances. Red queen variety of Red cabbage and Sanda variety of Brussel sprouts had shown better performances in compare to other varieties.

References

McCall, D.; Sorensen, L. and Jensen, B.D. (1996). Broccoli varieties. *S.P. Rapport Statens Planteavlsforsog*, **8**: 32.

Rooster, L.de.; Callens-D; de-Rooster-L(1998). Early cultivation of broccoli. Milady is only suitable for the earliest cultivation. *Proeftuinnieuws*, **8** (22):31-32.

Saha, P.; Chatterjee, R. and Mukhopadhyay, D. (2006) Effect of boron and molybdenum on yield and quality of sprouting broccoli under terai agroecological region of West Bengal. *Crop Research Hisar*. 32(3): 396-400.
Vanparys, L. (1998). Summer cultivation of broccoli. Fiesta and Marathon are the best. *Proeftuinnieuws*, **8**(14): 29-31.

TABLES

Table 1. Varietal evaluation of different varieties of Broccoli

Variety	Days to Head initiation (Days)	Days to harvest (Days)	Plant height (cm)	Plant spread (cm^2)	Number of leaves	Leaf area (cm^2)	Head diameter (cm)	Stem diameter (cm)	Stem length (cm)	Number of sprout	Sprout weight (gm)	Sprout yield / plot (kg)	Head weight (gm)	Yield (q/ha)
Fiesta	67.67	80.67	40.74	5009.58	20.20	4961.14	21.64	3.32	30.29	3.67	25.72	1.50	233.83	93.53
Princies	61.33	72.00	34.53	6641.81	13.07	1041.11	20.27	3.67	22.00	4.76	45.30	3.40	320.28	119.89
Sultan	59.00	72.00	32.47	4987.08	11.93	812.32	19.99	3.39	21.31	3.92	64.68	4.00	259.56	103.83
Nokguk	63.67	78.33	41.69	5543.19	19.00	464.39	23.63	3.67	28.92	1.35	57.00	1.24	375.00	145.47
Early you	59.00	72.00	30.78	5775.74	12.06	887.18	21.70	3.66	20.42	5.16	35.79	2.94	333.67	128.11
KE-180	63.67	76.00	38.47	5607.93	13.47	852.52	20.67	3.70	25.07	4.46	54.79	3.84	251.67	100.67
Priya	63.67	73.00	36.61	5913.78	15.30	1022.68	20.14	3.63	26.67	6.10	33.43	3.26	255.83	102.33
Puspa	59.00	73.00	33.07	4515.87	11.33	896.48	20.17	3.49	21.67	4.77	31.00	2.36	289.00	115.6
Grandsino	70.00	78.33	34.70	5708.6	18.07	720.55	21.10	3.72	26.4	2.4	76.55	2.95	281.67	112.67
Rapido	59.00	72.00	40.00	5731.59	15.20	945.95	20.65	3.55	28.53	3.81	30.25	1.84	253.33	114.83
Prema	59.00	74.4	35.20	5367.55	13.30	1112.09	21.57	3.77	23.60	4.06	27.67	1.80	263.89	108.00
Packmer	59.00	77.33	36.20	4785.67	13.40	1108.49	19.37	3.65	24.30	4.69	40.93	3.05	279.60	111.60
SEm (±)	3.0965	2.6328	1.4030	520.038	1.0502	1045.85	0.9925	0.1782	1.8655	0.4477	4.493	0.345	34.081	13.004
CD at 5%	6.3651	5.4118	2.8840	1068.96	2.1587	2149.79	2.0402	0.3662	3.8846	0.9203	9.236	0.7104	70.055	26.731

Table 2. Varietal evaluation of different varieties of Chinese cabbage

Variety	Days to head initiation (Days)	Days to harvest (Days)	Plant height (cm)	Plant spread (cm^2)	Number of outer leaves	Leaf area (cm^2)	Head diameter (cm)	Head length (cm)	Head width (cm)	Total yield / plot (kg)	Net yield per plot (kg)	Yield (q/ha)
Tropical delight	29.14	59.57	27.5	2927	5.4	909.7	44.7	28.3	14.5	15.81	9.42	389.42
Optiko	28.57	59.28	29	2678.3	5.6	877.6	48.6	31.0	16.0	18.628	14.47	439.14
Tropic prince	23.43	50.0	28.3	2901.1	6.3	903.3	42.6	28.6	13.4	17.428	11.90	413.43
SEm (±)	0.6042	0.6335	0.5334	138.33	0.497	36.25	0.7893	0.637	0.603	0.380	0.5874	7.9456
CD at 5%	1.3165	1.3804	1.1622	301.43	N.S	78.99	1.7198	1.388	1.315	0.828	1.2801	17.3136

Table 3. Varietal evaluation of different varieties of red cabbage

Variety	Days to head initiation (Days)	Days to harvest (Days)	Plant height (cm)	Plant spread (cm^2)	Number of outer leaves	Leaf area (cm^2)	Head diameter (cm)	Head length (cm)	Head width (cm)	Total yield / plot (kg)	Net yield / plot (kg)	Yield (q/ha)
Ruby mart	52	91	32	2878.2	7	915	45.3	16.2	14	10.04	6.89	271
Red queen	56.8	89	31.2	4132.4	11.5	966	45.5	16.8	14.8	11.98	8.32	312
Primero	50	89.6	32.8	2685.5	7.6	992.2	39.7	14.8	12.4	10.57	7.5	262.4
Red cabbage	57.8	94	69.5	3131.6	11	952.8	36.3	12.6	10.5	9.18	5.92	217.4
SEm (±)	0.6	0.4967	1.70	440.68	0.65	67.69	2.321	1.015	0.728	0.2852	0.1908	6.6563
CD at 5%	1.3074	1.082	3.704	960.24	1.43	N.S.	5.057	2.212	1.587	0.6214	0.4159	14.5041

Table 4. Varietal evaluation of different varieties of Brussels sprouts

Variety	Plant height (cm)	Plant spread (cm)	Days required for sprout initiation	No of sprout	Weight of sprout /plant (gm)	Yield (q /ha)
Rubine	101.42	4536.42	107.67	42.57	552.12	137.92
Hilds ideal	100.69	4920.95	105.33	45.63	492.00	123.00
Sanda	104.13	5248.14	113.33	43.85	603.87	151.00
SEm	2.9614	91.2352	3.8586	1.4949	20.3688	5.0999
CD 5 %	7.2466	223.2545	9.4421	4.8815	49.8428	12.475

Production of high value vegetables in the flower-based cropping system in Nadia District of West Bengal province, India

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ABSTRACT
Production of high value vegetables is widely practiced in the flower-based cropping system in Nadia District of West Bengal province of India. Since the agro-climatic factors of this district permits farmers to follow this cropping system, they fetch high net returns around the year by growing high value vegetables in this cropping system. The present study seeks to determine the cost of cultivation and relative profitability of the production of high value vegetable crops in the flower-based cropping system in Nadia District of West Bengal Province of India. Fifty farmers were selected for studying the cost of cultivation and relative profitability of the production of high value vegetable crops in flower-based cropping systems. All the data for the study were collected by the survey method. The information obtained is related to the agricultural year 2010-11. Following flower-based cropping sequences covering the cultivation of high value vegetables have been identified -- Marigold-Bean, Marigold-Pea, Marigold-Cauliflower, Marigold-Cabbage, Marigold-Tomato, Aster-Pea, Aster-Bean, Aster-Tomato, Cock's Comb-Lady's Finger, Cock's Comb-Tomato, Annual Chrysanthemum-Lady's Finger, etc. The cost of cultivation includes the costs of labour, ploughing, seedling, manures and fertilizer, irrigation, insecticides and pesticides and miscellaneous expenses. These are the production costs. The study shows that average cost A_1/ha is ₹1,32,310.29 (highest) in case of the Aster-Pea cropping sequence and is ₹ 79,288.33 (lowest) in case of the Cock's Comb-Tomato cropping sequence. The average Cost D/ha is ₹1,86,707.64 (highest) in case of the Annual Chrysanthemum-Lady's Finger and is ₹ 1,08,105.18 (lowest) in case of the Cock's Comb-Tomato cropping sequence. The average gross return is ₹5,47,225.33 (highest) in the case of Aster-Bean and is ₹ 2,37,677.55 (lowest) in the case of Cock's Comb-Tomato cropping sequence. The average net return over Cost A_1/ha is in the case of Aster-Bean cropping sequence is ₹4,25,083.09 (highest) and is ₹1,39,269.07 (lowest) in case of the Cock's Comb-Lady's Finger cropping sequence. The average net return over Cost D/ha in the case of Aster-Bean is ₹ 3,71,750.98 (highest) and in case of Cock's Comb-Lady's Finger cropping sequence is ₹ 65,307.41 (lowest). From the study, we found that average output-input ratio at Cost A_1/ha is in case of Marigold-Bean is 5.19 (highest) and in case of Cock's Comb-Lady's Finger is 2.27 (lowest). The average output-input ratio at Cost D/ha is in case of Aster-Bean is 3.11(highest) and in case of Cock's Comb-Lady's Finger is 1.35 (lowest).

Keywords
Vegetables, flowers, cropping pattern, costs, returns

INTRODUCTION
Cultivation of flowers is can be very remunerative. With the passage of time, farmers are becoming more interested to grow flower crops in a greater area and the production and productivity of flower crops are increasing day by day. But, a considerable portion of flower growers are also growing high value vegetable crops in the flower-based cropping system. Cultivation of seasonal vegetables has been matched with the seasonal flowers considering the

flowers as the main crops. Banerjee and Ali (2000) identified some economic aspects of Tuberose cultivation in West Bengal. They calculated the cost of cultivation per *bigha* of this flower is about Rs. 3927.00 at Cost A_1 and Rs. 5696.00 at Cost D. Mandal (1991) in his study has found that total marketing margin was Rs. 8.52 which is 47.36 % of the consumer's rupee in Tuberose and he trader's profit ranged between 58% to 64% of the marketing margin. Saraf and Mishra (1987) reported that economics of vegetables farming has to be considered with regard to the input-output structure of the market. The important vegetables grown in the vicinity of Jabalpur city were cauliflower, eggplant, tomato, potato etc. The study showed that, average size of holding of small, medium and large groups came to 2.77, 5.4 and 9.85 acres (1 ha = 2.4 acres) respectively. The cropping intensity declines with an increase in the size of the holding. As regards material cost potato accounts for 55 % of the total cost followed by cauliflower (47 %), eggplant (39 %), and tomato (35 %). A study by Jain and Tegar (2003) examined the costs and returns of tomato production on various sizes of farms as well as the channels, margins and efficiency of tomato marketing in Jaspur district, Chhattisgarh, India. Data were obtained from a sample of 90 farmers and from market intermediaries. Results shows total production costs and returns were highest on large farms.

But, there is lack of sufficient information about economic aspects of production of high value vegetables in the flower-based cropping system. Given this background, the present study intends to analyze some economic aspects of cultivation and marketing of important vegetables in the flower-based cropping system in Nadia District of West Bengal province of India.

The specific objectives of the study were as follows:

1. To examine the various costs related to the production of vegetables and flowers in the sample areas of the district of Nadia, West Bengal.

2. To work out the net returns and output-input ratios of individual vegetables and flowers.

3. To find out the various costs related to the production of the flower-vegetables crop sequences in the sample areas of the district of Nadia, West Bengal.

4. To calculate the net returns and output-input related ratios within the production of flower-vegetables crop sequences in the sample areas of the district of Nadia, West Bengal.

MATERIALS AND METHODS

District Nadia and Kalyani sub-division were purposively selected for the study. Similarly, the Ranaghat-II Block within Nadia District has been selected purposively for detailed study. The reason behind this selection of the particular area lies in the fact that high value vegetables are cultivated extensively in the flower-based cropping system in the study area.

A cluster of three villages of Nokari, Dhantala and Purnanagar were selected to study the economic aspects of production of the high value vegetables in flower-based cropping system in the study.

SAMPLING

Fifty sample growers have been ultimately selected from this complete list with the help of Simple Random Sampling Without Replacement Method (SRSWOR). Data have been collected by personally interrogating the individual farmers with the help of a pre-tested survey schedule.

COST CONCEPTS:

There are many cost concepts used in farm management studies in India, viz. Cost A_1, Cost A_2, Cost C and Cost D.

A brief account of these concepts is as follows:

i) Cost A_1: It includes following 16 items of costs:

1. Value of hired human labour (permanent and casual).
2. Value of consumed bullock labour.
3. Value of hired bullock labour.
4. Value of owned machinery.
5. Hired machinery charges.
6. Value of fertilizers.
7. Value of manures (owned and purchased).
8. Value of seed (both from produced and purchased).
9. Value of insecticide and pesticides.
10. Irrigation charges (both owned and hired machines).
11. Casual water charges.
12. Land revenue and other taxes.
13. Depreciation on farm implements (both bullock drawn and used by human labour).
14. Depreciation on farm building, farm machinery and irrigation structure.
15. Interest on working capital.
16. Miscellaneous expenses (artisans, ropes and repairs to small farm implements).

ii) Cost A_2: It is cost A_1 + 17. Rent paid for leased land.

iii) Cost B: It is cost A_2 + 18. Imputed rental value owned land (less land revenue paid thereupon) + 19. Interest on fixed capital.

iv) Cost C: It is cost B + 20. Imputed value of family labour.

v) Cost D: It is cost A_1 + 21. Imputed value of family labour.

RESULTS AND DISCUSSION

Table 1 shows that among the vegetables, beans brings the highest gross return followed by cauliflower and cabbage. In case of flowers, the highest gross return is noted in the Annual Chrysanthemum followed by Aster and Marigold. CostA1 is noted to be highest in Lady's Fingers and lowest in Tomato. In case of flowers, CostA1 is noted to be highest in Aster and lowest in Cock's Comb. In the case of vegetables, Cost D is observed to be highest in Cauliflower and lowest in Tomato. In the case of Flowers, Cost D is highest in Aster and lowest in Cock's Comb.

From Table 2, it is noted that in case of vegetables net returns over Cost A1 and Cost D are found in Bean and lowest in Bhindi. In case of flowers, net returns over Cost A1 and Cost D are found in Aster and lowest in Cock's Comb.

From Table 3, it is noted that in case of vegetables, input-input ratio at CostA1 is found in beans and lowest in Lady's Fingers and that at Cost D is highest in tomato and lowest in Lady's Finger. In case of flowers, input-input ratio at Cost A1 is highest in Annual Chrysanthemum and lowest in Aster and that at Cost D are found highest in Annual Chrysanthemum and lowest in Cock's Comb.

Table 4 shows that highest gross return is obtained from the Aster-Bean crop sequence and lowest in the case of Cock's comb-Tomato sequence. Cost A1 is noted to be highest in Aster-Pea and lowest in Cock's comb-Tomato. Cost D is observed to be highest in case of Annual Chrysanthemum- Lady's Finger sequence and lowest in case Cock's comb-Tomato sequence.

From Table 5, it is noted that net returns over cost A_1 and Cost D are found to be highest in Aster-Bean and lowest in Cock's comb- Lady's Finger.

From Table 6, it is noted input-input ratio at Cost A1 is found to be highest in Marigold-Bean and lowest in Cocks comb- Lady's Finger and that at Cost D is highest in Aster-Bean and lowest in Cocks comb- Lady's Finger.

Mukherjee et al (1991) studied that there is distinct increase in gross returns per ha in case of cauliflower with the increase in the size of total operational holdings. There is a negative correspondence between the size of operational holding on one hand and gross returns, net returns and output-input ratios and output-input ratios at Cost A_1 and Cost D are 3.03 and 2.38 respectively. This was also reported by Banerjee et al (1999). Ali et al. (1999) showed that producer-sellers of cock's comb flower in Midnapore district obtained more than 70 per cent of the consumer's rupee at maximum price level and 45 per cent at the minimum price level. Output-input ratios of Annual Chrysanthemum grown in Midnapore (east) district at Cost A_1 and Cost D are 4.89 and 3.45 respectively as studied by Banerjee et al .(2000). Ali et al (2001) found that net returns over Cost A_1 and Cost D of eggplant crops grown in Hooghly district are Rs. 46,459.71 and Rs. 42,877.70 respectively.

CONCLUSIONS

From the above study, it may be summarised that the cultivation of vegetable crops in flower lands is highly profitable without hampering the normal cultivation of the flower crops. High value vegetables may wisely be incorporated into the flower-based cropping sequence. Returns obtained from the flower-vegetables cropping sequence is very lucrative and encouraging to the flower growers to follow the as a step towards increased commercialization.

References

Ali, Md. H. and Banerjee, B.N., Marketing Costs and Margins of Cock's Comb Flower in Midnapur (East) District of West Bengal, *Agricultural Marketing, October to December, 1999, Pp. 34-37.*

Ali, Md. H. and Gupta , D. S., Some Economic Aspects of Cultivation of Brinjal in West Bengal, *Environment and Ecology, 19(4), 912-915, 2001*

Banerjee, B.N., Ali, Md. H. and Das, K.K., An Economic Analysis on Aster (Aster amellus) Flower Cultivation in West Bengal – A Case Study, *Journal of Interacademicia, 3(1):91-96, 1999.*

Banerjee, B.N. and Ali, Md. H., Economics of Annual Chrysanthemum var. Cherrygold (Chryanthemum carinatum) Flower in West Bengal, *Environment and Ecology, 18(1), 167-170, 2000*

Banerjee, B.N. and Ali, Md. H., Some Economic Aspects of Tuberose (Polyanthes tuberosa) Cultivation in West Bengal, *The Horticultural Journal, 13(1): 93-98, 2000*.

Banerjee, B.N. and Ali, Md. H. Marketing of Cherrygold Flower in West Bengal, *The Bihar Journal of Agricultural Marketing, Vol. X, No.2, April-June, 2002*

Jain, B. C., and Tegar, A. 2003. Economics of production and marketing of tomato in Jaspur district of Chhattisgarh. Agricultural Marketing 46(3): 5-10.

Mandal, P (1991), An Economic Analysis On Production & Marketing Of Tuberose In Nadia District, Published dissertation, M.Sc (Ag) in Agriculture Economics *.B.C.K.V.*

Mukherjee A.K., Ali, Md. H., Sengupta, A. and Sarkar, S.C. (1991), Economics of Cauliflower Cultivation in West Bengal - A Case Study, Economic Affairs, Vol. 36, Qr.2 (June0, pp.120-124.

Saraf, G. P., and Mishra, R. S. 1987. Cost and returns, labour employment and marketing of vegetable crops in Jabalpur city of M. P. *Indian Journal of Agricultural Economics* 52(3):462.

Sinha, M., Ali, Md. H., Banerjee, B.N. and Choudhury, A., Economic Analysis of Production of Marigold Flower in Ranaghat Region of West Bengal, *Economic Affairs,Vol.53, Qr.1Pp. 15-20, , March 2008.*

Sinha, M., Ali, Md. H., Banerjee, B.N. and Choudhury, A., Economic Analysis on the Production of Tuberose Flower in Ranaghat Region of West Bengal, *Journal of Interacademicia, 13(3), 349-357, 2009.*

Table 1. Gross Return, Cost A1 and Cost D of Different Vegetables and Flowers in the Study Area (2010-11) (₹ per ha.)

Sl.No.	CROPS	Gross Return	Cost A_1	Cost D
1	Bean	3,00,000.00	44,281.50	72,886.50
2	Tomato	1,82,512.27.27	32,415.32	36,322.31
3	Pea	1,35,000.00	54,449.55	82,882.05
4	Lady's Finger	1,11,825.00	62,773.20	93,750.00
5	Cabbage	1,87,500.00	40,576.80	66,000.00
6	Cauliflower	2,34,375.00	50,721,.00	82,500.00
7	Marigold	2,25,000.00	56,842.50	1,01,925.00
8	Annual Chrysanthemum	2,74,686.69	55,243.00	74,882.00
9	Aster	2,47,225.33	77,860.74	1,02,587.85
10	Cock's comb	1, 55,165.28	46,873,01	71,782.87

Table 2. Net Returns of Different Vegetables and Flowers (2010-11) (₹ per ha.)

Sl.No	CROPS	Net return over Cost A_1	Net return over cost D
1	Bean	2,55,718.50	2,27,113.50
2	Tomato	1,50,096.95	1,46,189.96
3	Pea	80,550.45	52,117.95
4	Lady's Finger	49,051.80	18,075.00
5	Cabbage	1,21,500.00	1,21,500.00
6	Cauliflower	1,83,654.00	1,51,875.00
7	Marigold	1,68,157.50	1,23,075.00
8	Annual Chrysanthemum	2,19,443.69	1,99,804.05
9	Aster	1,69,364.59	1,44,637.48
10	Cock's comb	1,08,292.27	83,382.41

Table 3. Output-Input Ratios of Different Vegetables and Flowers (2010-11)

Sl.No.	CROPS	Output input ratios	
		at cost A1	at cost D
1	Bean	6.77	4.12
2	Tomato	5.63	5.02
3	Pea	2.48	1.63
4	Lady's Finger	1.78	1.19
5	Cabbage	4.62	2.84
6	Cauliflower	4.62	2.84
7	Marigold	3.96	2.20
8	Annual Chrysanthemum	4.97	3.67
9	Aster	3.17	2.41
10	Cock's comb	3.31	2.16

Table 4. Gross Return, Cost A1 and Cost D of Different Flower-Vegetables Cropping Sequences in the Study Area (2010-11)(₹ per ha.)

Sl.No.		Gross Return	Cost A1	Cost D
1	Marigold-Bean	5,25,000.00	1,01,124.00	1,74,811.50
2	Marigold-Pea	3,60,000.00	1,11,292.05	1,84,807.05
3	Marigold-Tomato	4,07,512.00	89,257.82	1,38,247.30
4	Marigold-Cauliflower	4,59,375.00	1,07,563.50	1,84,425.00
5	Marigold-Cabbage	4,12,500.00	97,419.30	1,67,925.00
6	Aster-Pea	3,82,225.33	1,32,310.29	1,85,469.90
7	Aster-Bean	5,47,225.33	1,22,142.24	1,75,474.35
8	Aster-Tomato	4,29,737.60	1,10,276.06	1,38,910.16
9	Aster-Marigold	4,72,225.33	1,34,703.24	2,04,512.85
10	Cock's comb- Lady's Finger	2,48,915.28	1,09,646.21	1,83,607.87
11	Cock's comb-Tomato	2,37,677.55	79,288.33	1,08,105.18
12	Annual Chrysanthemum- Lady's Finger	3,68,436.69	1,18,016.20	1,86,707.64

Table 5. Net Returns of Different Flower-Vegetables Cropping Sequence (2010-11) (₹ per ha.)

Sl. No.		Net Return over cost A_1	Net Return over cost
1	Marigold-Bean	4,23,876.00	3,50,188.50
2	Marigold-Pea	2,48,707.95	1,75,192.95
3	Marigold-Tomato	3,18,254.18	2,69,264.70
4	Marigold-Cauliflower	3,51,811.50	2,74,950.00
5	Marigold-Cabbage	3,15,080.70	2,44,575.00
6	Aster-Pea	2,49,915.04	1,96,755.43
7	Aster-Bean	4,25,083.09	3,71,750.98
8	Aster-Tomato	3,19,461.54	2,90,827.44
9	Aster-Marigold	3,37,522.09	2,67,712.48
10	Cock's comb- Lady's Finger	1,39,269.07	65,307.41
11	Cock's comb-Tomato	1,58,389.22	1,29,572.37
12	Annual Chrysanthemum-Lady's Finger	2,50,420.49	1,81,729.05

Table 6. Output-Input Ratios of Different Flower-Vegetables Cropping Sequences (2010-11)

Sl. No.		Output-input Ratios at cost A_1	Output-input Ratios at Cost D
1	Marigold-Bean	5.19	3.00
2	Marigold-Pea	3.23	1.95
3	Marigold-Tomato	4.56	2.95
4	Marigold-Cauliflower	4.27	2.49
5	Marigold-Cabbage	4.23	2.46
6	Aster-Pea	2.88	2.06
7	Aster-Bean	4.48	3.11
8	AsterTomato	3.89	3.09
9	Aster-Marigold	3.50	2.30
10	Cock’s comb-Lady’s Finger	2.27	1.35
11	Cock’s comb-Tomato	2.99	2.20
12	Annual Chrysanthemum-Lady’s Finger	3.12	1.97

Importance of vegetables to achieve food and nutrition security in Southeast Asia

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ABSTRACT

Without nutrition security, food security cannot be achieved. Although the Southeast Asian region is blessed with fertile land, its people still suffer from double-burden malnutrition, i.e., micronutrient deficiencies and non-communicable chronic diseases (NCD). Unfortunately, both of these trends are mainly found among lower income population groups, especially the increasing NCD problem. Vegetables as good sources of dietary fiber, vitamins, minerals and phytochemicals are not consumed adequately among Southeast Asian people. Consumption of fruits and vegetables is only 50-60% of the recommended amount (400 g/day). Logistics can be a problem for accessibility and affordability of fruits and vegetables among this population group. Promotion of local plants may be a more appropriate strategy for increasing vegetable consumption in the region. Studies have shown that local plants and herbs, which are widely consumed in the region, have anti-oxidative, anti-mutagenicity and anti-inflammatory properties. Many local plants in the region are also good sources of dietary fiber, vitamins and minerals and have the potential to reduce the risk of NCD.

Keywords

Food security, nutrition security, micronutrient, non-communicable chronic diseases, phytochemical

INTRODUCTION

Food Security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO 2006). Without nutrition security, food security cannot exist. To achieve nutrition security, quality diets must be consumed at the right amounts to obtain appropriate nutrients with safety. However, the diets must correspond to people's health statuses, food preferences, eating cultures and beliefs.

To be simpler and more practical, the World Health Organization has introduced a food-based dietary guideline as a resource for achieving good health by the public and as a resource for countries in developing their own guidelines (WHO 1998). Increasing consumption of fruits and vegetables is included in the guidelines of most countries (FAO 2009).

Fruits and vegetables mainly provide water, dietary fiber, vitamins and minerals for bodily functions, as well as unique phytochemicals for physiological functions. The high pH value of vegetables is also beneficial to the human gastrointestinal tract (Farnworth 2000; Mediterraneanbook.com 2010). In addition, most vegetables, as compared to fruits, do not contain high sugar content (USDA 2011). Quality and quantity of phytochemicals in fruits and vegetables are quite unique depending on variety, weather, soil and other environmental factors. Traditional fruits and vegetables, therefore, have provided nutrition security to people living in many parts of the world for centuries.

Generally, fruits and vegetables should be consumed at a level of 400 grams daily, though this recommendation may vary by population age group (Table 1). To be more practical, at least one half of each meal should contain fruits and vegetables (FAO 2001; USDA 2012).

Table 1. Theoretical-minimum-risk for fruit and vegetable consumption

Age (yr.)	Daily per capita consumption (g)
0-4	330±50
5-14	480±50
$\geq$15	600±50

Source: Lock et al, 2005

Health impact from inadequate fruit and vegetable consumption

Low fruit and vegetable consumption is related to ischemic heart disease, ischemic stroke, lung cancer, stomach cancer, esophageal cancer and colorectal cancer. Risks of these diseases can be significantly reduced by increasing consumption of these foods (Table 2). Low fruit and vegetable consumption was listed as one of the top three diet-related risks accounting for global deaths in 2000 (Lock et al. 2005). Unfortunately, the deaths due to low fruit and vegetable consumption occurred mostly among low and medium income populations (WHO 2009). In 2009, moreover, the World Health Organization (WHO) reported that low fruit and vegetable consumption was among the top six diet-related risks and physical activity causes of global deaths and DALY, and there was no difference between high and low/medium income population groups (WHO 2009). However, most health impacts from low consumption of fruits and vegetables were related to NCDs and not micronutrient deficiencies.

Table 2. Relative risks associated with an increase in intake of fruit and vegetable[a] for selected health outcomes, by age group

Age group (yr.)	outcome[b]					
	IHD	IS	LC	GC	OC	CC
0-4	1.00	1.00	1.00	1.00	1.00	1.00
5-14	1.00	1.00	1.00	1.00	1.00	1.00
15-29	0.90	0.94	0.96	0.94	0.94	0.99
30-44	0.90	0.94	0.96	0.94	0.94	0.99
45-59	0.90	0.94	0.96	0.94	0.94	0.99
60-69	0.90	0.94	0.96	0.94	0.94	0.99
70-79	0.93	0.95	0.97	0.95	0.95	0.99
$\geq$80	0.95	0.97	0.98	0.97	0.97	1.00

Source: Lock et al, 2005

[a] Unit of change in risk = change per increase of 80 g per day in intake of fruit and vegetables (equivalent to the size of one standard serving).

[b] Outcome: IHD=Ischaemic heart disease; IS=Ishaemic stroke; LC=Lung cancer; OC=Oesophageal cancer; CC=Colorectal cancer

Double burden nutrition problems in Southeast Asia

Undernutrition is still a major problem for some Southeast Asian countries. Low birth weight in certain countries, such as the Maldives, Myanmar and Timor-Leste, were reported to be higher than 10% and even up to 22% (WHO 2010), while underweight for age and stunting was as high as 40% and 50%, respectively (WHO 2011). Some causes of these problems are related to micronutrient deficiencies. Over 30% of preschool children in countries such as Myanmar and Timor-Leste suffer from vitamin A deficiency disorder (serum retinol < 70 ug/liter) (WHO 2009). In 2010, it was estimated that 20% of children in Southeast Asia had subclinical vitamin A deficiency problem (WHO 2010). In addition, iron deficiency is another major micronutrient deficiency problem in this region. Anemia in pre-school children and pregnant women ranges from 25-81% and 22-75%, respectively (WHO 2008). In non-pregnant women, anemia was almost 40% (WHO 2010).

NCDs, i.e. heart disease, stroke, cancer and chronic lung disease, are responsible for 60% of deaths in the Southeast Asian region (Dans et al. 2011). An unhealthy diet is one of the behavioral risk factors (WHO 2009). Similar to other regions of the world, trends in obesity and overweight are increasing. In Thailand, overweight and obesity among all population groups, especially school children, are now major concerns.

Fruit and vegetable consumption in Southeast Asia

From 1979 to 2000, the supply of vegetables in Asia had increased by 105.3%. However, on average Asian people could access only 318.4 grams of vegetables per day (WHO 2003). Table 3 shows the estimated levels of fruits and vegetables consumed in certain Southeast and South Asia countries. These levels are much lower than those recommended for all age groups and all countries. Socio-economic class did not have an effect on the amount of fruits and vegetables consumed in Southeast Asian countries. Figure 1 shows that 80% of people of all economic classes in half of the ASEAN countries did not consume enough fruits and vegetables. The same problem at the same degree was also found throughout Thailand regardless of age and sex (Health Information System Development Office 2006). In many developing countries, as well as urban areas, accessibility and affordability may be one main cause for low fruit and vegetable consumption, especially among low and medium income people. Even in the Southeast Asia region, where plenty of fruits and vegetables are available, logistics is another main problem that causes huge damage to agricultural produce and, in turn, affects availability and price.

Table 3. Estimated regional intake of fruit and vegetable in Southeast Asia (Lock et al, 2005)

Age (yr.)	Daily per capita consumption (g)	
	low child and adult mortality region[a]	high child and adult mortality region[b]
Male		
0-4	108	94
5-14	198	177
15-29	245	258
30-44	243	262
45-59	258	262
60-69	248	259
70-79	244	259
≥80	225	234
Female		
0-4	107	95
5-14	183	170
15-29	201	224
30-44	195	229
45-59	202	227
60-69	201	229
70-79	201	228
≥80	173	205

Source: Lock et al. 2005

[a] Countries: Indonesia, Sri Lanka, Thailand

[b] Countries: Bangladesh, Bhutan, Korea, India, Maldives, Myanmar, Nepal

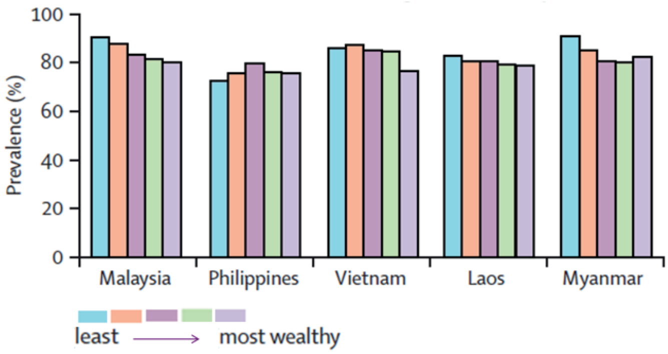

Figure 1. Prevalence of insufficient fruit and vegetable consumption in selected Southeast Asian countries in 2003. Source: Dans, 2009

Vegetable safety

Good Agricultural Practices (GAP) is not successfully implemented in the Southeast Asia region. Residual pesticide in agricultural produce is a major unsolvable problem. The severest cases are found in most nontraditional plants, such as Chinese-style vegetables and temperate vegetables. Annually, Thailand imports several thousand metric tons of herbicides, fungicides, and insecticides .Pressures to sustain high crop yields have led to heavy usage of pesticides. Residues, especially organochlorine and organophosphate compounds, have been found in soil, water and agricultural products throughout the country (Thapinta and Hudak, 2000). Up to 30% of vegetables, such as peppers and cabbage, have been found to be contaminated with pesticide at unacceptable levels (Chaiprasart et al. 2006; Food Safety Operation Centre 2008). Unsafe vegetables can lead to acute and chronic illnesses, which leads to insecurities of food and nutrition.

Indigenous plants: choice of vegetables for nutrtion security

Indigenous plants that naturally grow in the Southeast Asian region are good sources of vitamins, minerals, dietary fiber, as well as unique phytochemicals (Chanwitheesuk et al. 2005; FAO 1999; Nakahara and Trakoontivakorn 1999; Umamaheswari et al. 2007). Many of them have been forgotten by younger generations of people, while others may still be consumed but in declining amounts. Disappearance of this tradition can be a disaster for food and nutrition security in this region, even though most countries are blessed with fertility and many varieties of these health-beneficial plants. As they are still rooted in nature, most of these plants can adapt and become immune to tropical insects and diseases. Hence, there is very low, to no, need for chemical pesticides. Warm weather with adequate water and sunlight support the production of phytochemicals as both nutrients and non-nutrients.

Different parts of these traditional plants, i.e., leaf, flower, stem and root, can be consumed as vegetables and herbs. Many parts are sources of vitamins, such as carotenoids and niacin. Some are sources of minerals, such as calcium and iron. The unique benefits are their antioxidant and antimutagenic activities, which are found widely among these plants (Chanwitheesuk et al. 2005; Nakahara and Trakoontivakorn 1999; Umamaheswari et al. 2007).

Traditionally, these plants are consumed in several ways, for instance, as fresh vegetables, herbs for flavoring, vegetables for dipping, ingredients for many dishes, or even as wrappings for transporting food to the mouth.

By promoting the consumption of indigenous plants, Southeast Asian countries will be able to increase fruit and vegetable consumption in the region, which can lead to nutrition security and greater confidence in their health benefits and in food safety.

References

Chaiprasart P, Hansawasdi C, Thanoi S, Suwanpaiboon V, Nate-Chei A, Bamrungthai N. 2006 . Research on Safety Status of Vegetables and Fruit: Market Fair and Mobile Shop Case Study in Lower Northern Part of Thailand (Thai). Knowledge Network Institute of Thailand.

Chanvitheesuk A, Teerawutgulrag A, Rakariyatham N. 2005. Screening of antioxidant activity and antioxidant compounds of some edible plants of Thailand. *Food chem* 92: 491-497.
Dans A, Ng N, Varghese C, Tai E, Firestone R, Bonita R. 2011. The rise of chronic non-communicable diseases in southeast Asia: time for action. *Lancet* 337: 680-689.
Farnworth E. 2000. The acidity of food. Retrieved February 27, 2012. from: http://www.medical foodnews.com/vol04/issue4/acidity.htm.
Food and Agricultural Organization of the United Nations. 2001. Improving nutrition through home gardening. Ensuring good family nutrition on a daily basis. Rome, Italy.
Food and Agricultural Organization of the United Nations. 2006. An introduction to basic conceps of food security. Rome, Italy.
Food and Agricultural Organization of the United Nations. 2009. Food-based Dietary Guidelines: Food Guidelines by Country. Retrieved February 27, 2012. from: http://www.fao.org/ag/humanutrition/nutritioneducation/fbdg/en/.
Food Safety Operation Centre. 2008. Situation and the Food Safety Fiscal in 2008. Thailand.
Health Information System Development Office. 2006. Consumption of fruits and vegetables of the Thai people (Thai).*Health situation in Thailand* 15: 1-6.
Lock K, Pomerleau J, Causer L, Dan R, Mckee M. 2005. The global burden of disease attributable to low consumption of fruit and vegetable: implications for the global strategy on diet. *Bull WHO* 83(2): 100-108.
Mediterraneanbook.com. 2010. List of good low acid food to eat that reduce stomach acid. Retrieved February 27, 2012. From: http://www.mediterraneanbook.com/2010/08/15/list-good-acid-foods-eat-reduce-stomach-.
Nakahara K and Trakoontivakorn G.1999. "Antioxidative and antimutagenic properties of some local agricultural products in Thailand". from JIRCAS Seminar. March 3, 1999. Bangkok.
Thapinta A and Hudak P. 1999. Pesticide use and residual occurrence in Thailand. *Environ Monit Assess* 60: 103-114.
Umamaheswari M, AsokKumar K, Somasundaram A, Sivashanmugam T, Subhadradevi, Ravi K. Xanthine oxidase inhibitory activity of some Indian medical plants. *J Ethnopharmacol* 3: 547-551.
United states Department of Agriculture. 2011.Nutrient data products and services: SR24. Retrieved February 27, 2012. from: http://www.ars.usda.gov/Services/docs.htm?docid=22112.
United states Department of Agriculture. 2012. USDA and HHS Announce New Dietary Guidelines to Help Americans Make Healthier Food Choices and Confront Obesity Epidemic. Retrieved February 27, 2012. from: http://origin.www.fns.usda.gov/cga/pressreleases /2011/0040.htm.
World Health Organization. 1997. Development of food based dietary guidelines for the Asian region/ Final report of the recommendations of the Asian nutrition forum/ WHO Symposium on diet related chronic diseases in ASIA. New Delhi.
World Health Organization. 2003. Global and regional food consumption patterns and trends. Diet, Nutrition and the Prevention of Chronic Diseases. p. 13-30. Geneva, Switzerland.
World Health Organization. 2008. Worldwide prevalence of anaemia 1993–2005. Spain.
World Health Organization. 2009. Global health risk: Mortality and burden of disease attributable to selected major risks.France
World Health Organization. 2009. Global prevalence of vitamin A deficiency in populations at risk 1995–2005.France.
World Health Organization. 2010. World health statistic. France.
World Health Organization. 2011. World health statistic. France.
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Aquaponics: Protein and vegetables for developing countries

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ABSTRACT
Aquaponics is the land based production of fish in tanks combined with the recirculation of the water from the fish tanks through hydroponic systems to produce high value horticultural crops. The waste products from the fish are converted by a bio-filter into soluble nutrients which are absorbed by the plants, and allow "clean" water to be returned back to the fish. Thus it produces valuable fish protein with a minimal pollution of fresh water resources, while at the same time producing horticultural (usually vegetable) crops. The production of fertilizers is becoming increasingly expensive due to the high prices of fossil fuels, and this may have long term implications for nutrient use in agriculture in the future, particularly in developing countries. Aquaponics uses waste products derived from animals and plants which are fed to the fish, and thus converted into valuable animal protein and fresh vegetables. With the world's fresh water resources limited, aquaponics would appear to have considerable potential for developing countries.

Keywords
Fish, hydroponics, environmentally friendly, water efficient

INTRODUCTION
In many (if not all) populations of developing countries there are major nutritional deficiencies in protein and in essential minerals and vitamins. The basic carbohydrate diet does little to provide adequate levels of these essential nutrients.

Aquaponics may provide an effective and efficient means to provide both animal protein (fish) and mineral and vitamin sources (fresh vegetables) to populations where water/and or fertilizer resources are limited yet with a minimum of environmental pollution.

The basic principles of aquaponics are that fish are fed "waste plant and animal material", which they convert into protein. The waste material from the fish is then used by plants as the nutrient source, and the water is then re-circulated back into the fish tank. An essential component of this is a bio-filter (between the fish and the plants) which essentially comprises bacteria which convert the waste products from the fish into soluble nutrients for the plants. An absolutely critical component of this is the conversion of urea (excreted by the fish) into nitrite, and then nitrate because high levels of urea in the water are toxic to fish. The solid waste (fish feces and unconsumed food) is usually filtered off and converted into soluble nutrients in a separate bypass.

Aquaponics was developed as an extension of aquaculture, and thus the people developing it have normally had strong aquaculture backgrounds, and (usually) very limited horticultural backgrounds. This has proved a major limitation to development, because the bulk of the income is normally derived from the horticulture stream (70%), but the expertise is usually not in this area. The horticultural product has to compete with conventionally grown horticultural products on a "level playing field" with the result that in many cases, although the aquaponics component is effective, the lack of horticultural skills causes the project to fail. Essentially the fish must be regarded simply as manure producers for the plants, with the added bonus that there is a small income stream from them also.

Fish farming is popular in many parts of the world—particularly in Asia, but the systems used tend to pollute the waterways, or are limited to ponds in which a permanent fish/simple plant ecosystem exists, without any recirculation.

A re-circulating aquaponics system not only is capable of providing a regular supply of fresh vegetables, but also does so in a non-polluting situation.

It is usual to have a number of fish tanks (usually a minimum of 4), so that fish can be segregated in terms of size (age) in case of cannibalism, and this also ensures a steady stream of nutrient to the plants. If all the fish were the same size, then they would all be harvested at the same time, but by having a range of different ages, then a continuous supply of nutrients to the plants is assured, because only the fish from a single tank are harvested when they reach the appropriate size. Similarly it is desirable to have crops of different ages in the "hydroponic system" to ensure a steady uptake of nutrients.

Fish species

There is no real limitation on the types of fish which can be used, although they should be fresh water types, and should not prefer low water temperatures (e.g. trout), as the temperature of the water will be too low for good plant growth. In Australia barramundi and Murray Cod have been used successfully, but internationally the favored fish is Tilapia. This will perform satisfactorily at pH below 7.0 which is an important factor for plant growth in hydroponics.

Fish require a regular supply of oxygen in the water, and this is controlled by bubblers in the tanks, which are connected to electric air pumps. A secure supply of electricity is therefore absolutely essential. In DPR Korea (North Korea) an EU project has developed an aquaponics system in a country were the electricity supply is very unreliable by integrating into the system a back up using solar cells which keep a battery continuously charged. Note the amount of power required to run an air pump is very small.

Of course there are other pumps in the system for example for pumping the "nutrient solution" through the system, but these can be out of action for some time without the fish dying from lack of oxygen.

Essentially the role of the fish to provide the plants with a cheap source of nutrients.

The bio-filter

Bio-filters come in all shapes and sizes, but their essential role is to provide a large surface area for the ammonia in the solution to come into contact with the bacteria which are needed to convert it to first nitrite and then nitrate. Ammonia at high concentrations is toxic to fish, so this conversion is an essential part of the aquaponic process. In any case plants prefer to absorb nitrogen as nitrate rather than as ammonia.

The simplest bio-filter is simply a clump of nylon fishing net, on which the bacteria and other microorganisms are established. This should be cleaned every month or so. Other bio-filters include containers filled with polystyrene balls, in fact anything with a large surface to volume ratio.

Water source

This is a re-circulating hydroponic system, and the less frequently it is necessary to "dump" the nutrient solution the better. Thus the purer the source of water the better, and simplistically the lower the sodium and chloride content of the fish feed the better. The best water source is rain water, and this can be collected if necessary using plastic sheets (e.g. rain shelters) and stored in small plastic lined dams.

Horticultural aspects

There are many ways of growing horticultural crops hydroponically, but the simplest system is to use the floating raft system. This involves polystyrene sheets which float in a shallow canal filled with nutrient solution which flows from the bio-filter to a sump, from where it is then pumped back to the fish.

This system is relatively cheap, simple, and nearly foolproof. Bubbles are required the length of the canal to provide the plant roots with oxygen, but if these are not working for an hour or so, due to air pump problems, this is not a fatal issue, as the plants (unlike the fish) can survive. In fact it is possible to grow many vegetables crops without aeration if there is a small gap between the polystyrene raft and the nutrient solution. (Kratky 2009)

Starting up can be a problem, as the fish are likely to be small, and the plant nutrient supply limited, particularly if the appropriate bacteria are not in the system, but a small quantity of solution from an existing aquaponics set up will act as a starter solution.

Many of the fruit vegetables (tomato, pepper, cucumber, melon, etc.) appear to require higher levels of nutrients in hydroponics, than the leafy vegetables. However at the University of the American Virgin Islands they have successfully produced such crops using aquaponics and a floating raft system. Certainly the level of nutrients measured in aquaponic solutions are considerably lower than those required for conventional hydroponics. (Rakocy et al. 2004; Rakocy et al. 2007), possibly because the nutrients are organically derived is the reason?

One of the major difficulties with aquaponics is deciding on the appropriate pH for the solution. Fish tend to prefer a pH in excess of 7.0, while for plants such a pH is likely to result in major trace element problems, particularly of iron deficiency.

The UVI approach has been to keep the pH at about 7.0 and to use high rates of chelated iron in the nutrient solution, but at Brooks it has been found preferable to run the system at a ph of 6.7-6.8, at which level the Tilapia appear to thrive, as do the plants (Savidov et al. 2007).

Pest and disease control

Fish are an integral part of the system thus it is impossible to use any pesticides which might harm the fish. Because of this, it is general practice to rely only on biological control methods. It does appear that some of the root disease problems of conventional hydroponic systems (such as *Pythium* and *Phytophthora*) are reduced due to the balance of microorganisms in the aquaponic solution exerting some form of biological control.

Conventional hydroponics vs. aquaponics

There have been few studies undertaken which have compared conventional hydroponic systems with aquaponics. In Italy, Pantanella (2011) showed that in the first cycle the conventional system was superior, but in the next cycle there was no significant difference in yields between conventional hydroponics and aquaponics (Table 1). In New Zealand, Lennard and Nichols (2011) have demonstrated that aquaponics production can exceed conventional hydroponic production in the right situation (Table 2 and 3). They found lower productivity from the aquaponic system in the winter when the fish were relatively inactive due to low water temperatures, and the feeding rate was reduced, resulting in a lower production of plant nutrients, but higher yields from the aquaponic system during the warmer summer months.

CONCLUSION

Aquaponics would appear to offer developing countries where animal protein and fresh vegetable supplies are limited with the opportunity to produce both in a single simple production system which predominantly uses waste animal and plant material to produce fish protein and vegetables rich in minerals, vitamins and fiber. The value of the fish might be further enhanced because of the potential of containing such importance micro-nutrients as $\omega 3$.

References

Kratky, BA (2009) “Three non re-circulating hydroponic methods of growing lettuce” Acta Hort., 843, 65-71.

Nichols M A & Lennard W (2010) Aquaponics in New Zealand. Practical hydroponics and Greenhouses. 115, 46-51.

Pantanella, E, Cardarelli, M, Colla, G, Rea, E & Marcucci, A (2010) Aquaponics vs hydroponics: Production and quality of lettuce crop. 28th IHC Abstracts I, 35.

Rakocy, DS, Schulz, JE, Bailey, RC & Thoman, ES (2004) “Aquaponic production of tilapia and basil: comparing a batch and staggered cropping system”. Acta Hort., 742, 63-69.

Rakocy, JE, Bailey, DS, Schulz, RC & Danahar, JJ (2007) "Preliminary evaluation of organic waste from two aquaculture systems as a source of inorganic nutrients for hydroponics". Acta Hort., 648, 201-207.
Savidov, N A, Hutchings, E & Rakocy, J E (2007) "Fish and plant production in a recirculating aquaponic system: A new approach to sustainable agriculture in Canada" Acta Hort., 742, 209-221.

TABLES

Table 1. Comparison between aquaponics and hydroponics

	Lettuce yield (kg/m2)
1st experiment	
Aquaponics LD	2.37 b
Aquaponics HD	2.71 a
Hydroponics	2.84 a
Significance	*
LD = Low Fish Density (5kg/m3)	
HD = High Fish Density (8kg/m3)	
2nd experiment	
Aquaponics LD	5.67
Aquaponics HD	5.7
Hydroponics	6.02
Significance	ns
LD = Low Fish Density (6kg/m3)	
HD = High Fish Density (20kg/m3)	

Table 2. Aquaponic and hydroponic NFT lettuce variety comparisons – Summer (February) 2010

Variety	Top Weight (g) Hydroponic	Top Weight (g) Aquaponic	Sig Diff?	Better System	Difference (%)
Gaugin	130.83	168.00	Yes	Aquaponic	28
Princess	117.00	246.63	Yes	Aquaponic	111
Explore	211.86	293.78	Yes	Aquaponic	39
Ashbrook	220.25	266.38	Yes	Aquaponic	21
Satre	173.11	223.56	Yes	Aquaponic	29
Robinio	177.88	204.43	No	Neither	
Obregon	142.50	223.40	Yes	Aquaponic	57

Table 3. Aquaponic and hydroponic NFT lettuce variety comparisons – Winter (August) 2010

Variety	Top Weight (g) Hydroponic	Top Weight (g) Aquaponic	Sig Diff?	Better System	Difference (%)
Gaugin	271.61	327.44	Yes	Aquaponic	21
Princess	177.38	204.94	No	Neither	
Explore	709.47	625.93	No	Neither	
Ashbrook	497.67	453.17	No	Neither	
Satre	322.20	349.20	No	Neither	
Robinio	293.22	345.78	Yes	Aquaponic	18
Obregon	354.87	341.53	No	Neither	

Potential of aquatic vegetables in the Asian diet

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ABSTRACT
The continent of Asia houses the largest water bodies-fresh, saline, brackish. By 2020 Asia will be inhabited by 4-5 billion people and the flora has to sustain an ever growing population. Edible aquatic plants with the potential to be used as vegetables are needed to supplement and substitute existing terrestrial vegetables of Asia. With advances in food processing technology and food biotechnology, many of the aquatic vegetables are raw materials to synthesize new food items suited to the palate of Asian people. The present prevalence of undernourishment leading to chronic energy deficiency can be partly met by production and use of aquatic plants. Poor people in South-East Asia spend as high as 72% of income on food alone leaving limited income to take care shelter, clothing, education and health. Aquatic vegetables being eco-friendly and affordable, poor people can as well get required nutrients and phytochemicals from these water plants.

Keywords
Aquatic vegetables, MDG, WFS, heavy metals, food habit

INTRODUCTION
The first world food summit was held in 1974 to eradicate world hunger within a decade. Since then 48 years have passed and 3 food summits were held at short intervals in 1996, 2000 and 2006 which resolved to reduce world hunger to half by 2015. Unfortunately even this target is not likely to be met due to a range of reasons both at lopsided policy level and occurrence of natural calamities. To quote Kofi Annan Former Secretary General of the United Nations, "Hunger is one of the worst violations of human dignity. In a world of plenty, ending hunger is within our reach. Failure to reach this goal should fill every one of us with shame." In September 2000, 189 world leaders met at the UN and endorsed the Millennium Declaration, a commitment to work together to build a safer, more prosperous and equitable world. The declaration was translated to a roadmap setting out 8 time bound and measurable goals to be achieved by 2015 known as the Millennium Development Goals-Eradicate extreme poverty and hunger, achieve universal primary education, promote gender equity and empower women, reduce child mortality, improve maternal health, combat HIV and AIDS, malaria and other diseases, ensure environmental sustainability and develop a global partnership for development. Vegetables provide minerals, vitamins, much needed fiber, anti-oxidants and a quantum of their consumption measures the level of nutritional security. With depleting land under vegetables and irrigation water being costly, need has arisen to look out further aquatic vegetables for human consumption. Food habit being so personal, a change to eating more aquatic vegetables may take time.

DISCUSSION
Southeast Asia comprising Cambodia, Indonesia, the Lao Peoples' Democratic Republic, Malaysia, Philippines, Thailand and Viet Nam has 11 to 25 % of its population undernourished (Table 1). Cambodia has 25% of a population of 14.3 million people undernourished. Viet Nam has the lowest percentage of people undernourished (11% in 2006-08). Affordability of the poor to purchase land-based vegetables is a growing challenge.

Table 1. Prevalence of undernourishment and progress towards the World Food Summit (WFS)[1] and the Millennium Development Goal (MDG)[2] targets in developing countries[3]

WORLD Region/ subregion/ country	Total population	Number of people undernourished					Proportion of undernourished in total population				
	2006-08	1990-92	1995-97	2000-02	2006-08	Change so far	1990-92	1995-97	2000-02	2006-08	Change so far
	millions	million				%	%				%
South-Eastern Asia[10]	**564.0**	**105.8**	**86.0**	**89.6**	**77.4**	**-26.9**	**24**	**18**	**17**	**14**	**-42**
Cambodia	14.3	3.8	4.7	3.8	3.6	-4.5	38	40	29	25	-33
Indonesia	224.7	28.9	22.0	30.4	29.7	2.9	16	11	15	13	-17
Lao People's Dem. Rep.	6.1	1.3	1.4	1.4	1.4	3.1	31	29	26	22	-27
Malaysia	26.6	ns	ns	ns	ns	na	-	-	-	-	na
Philippines	88.7	15.3	14.1	14.6	11.8	-22.9	24	20	18	13	-44
Thailand	67.0	15.0	11.1	11.5	10.7	-28.9	26	18	18	16	-39
Viet Nam	86.1	21.0	16.7	13.3	9.6	-54.5	31	22	17	11	-64

Source: The State of Food and Agriculture 2010-11 FAO Rome, 2011

Southeast Asia is predominantly rural in character (51.8% in 2010) and the female population is higher (50.2% in 2010) (Table 2). Cambodia has 77.2% rural population share with 51% female population. Singapore is uniquely placed with no rural share and is the financial and trade capital of the region. Chronic Energy Deficiency (CED) and underweight children are stark realities of the region (Table 3).

Table 2. Total population, female share of population and rural share of population in 1980, 1995 and 2010.

	Total (Thousands)			Population Female share (% of total)			Rural share (% of total)		
South-Eastern Asia	355 774	479 834	589 616	50.2	50.2	50.2	74.5	64.7	51.8
Brunei Darussalam	193	295	407	46.6	47.5	48.4	39.9	31.5	24.3
Cambodia	6 748	11 380	15 053	53.7	51.9	51.0	91.0	85.8	77.2
Indonesia	146 582	191 501	232 517	49.9	49.9	50.1	77.9	64.4	46.3
Lao People's Democratic Republic	3 238	4 809	6 436	50.3	50.0	50.1	87.6	82.6	66.8
Malaysia	13 763	20 594	27 914	49.7	49.2	49.2	58.0	44.3	27.8
Myanmar	33 561	43 864	50 496	50.6	50.7	51.2	76.0	73.9	66.1
Philippines	48 112	69 965	93 617	49.6	49.6	49.6	62.5	46.0	33.6
Singapore	2 415	3 480	4 837	48.9	49.7	49.8	0.0	0.0	0.0
Thailand	47 264	60 140	68 139	49.9	50.5	50.8	73.2	69.7	66.0
Viet Nam	53 317	72 957	89 029	51.5	51.3	50.6	80.8	77.8	71.2

Source: The State of Food Insecurity in the World 2011 FAO Rome 2011.

Table 3. Share of adult population with chronic energy deficiency (CED-body mass index less than 18.5) by sex and share of children underweight by sex, residence and household wealth quintile, most recent observations.

	Share of adult population with CED (% of total)		By sex		Share of children underweight (% of total) By residence		By household wealth quintile	
	Women	Men	Male	Female	Urban	Rural	Poorest	Richest
Southeastern Asia	18.2	14.1	25.3	25.3	23.4	30.4		
Brunei Darussalam	--	--	--	--	--	--	--	--
Cambodia	16.1	--	35.0	36.0	35.0	36.0	43.0	23.0
Indonesia	--	--	--	--	25.0	30.0	--	--
Lao People's Democratic Republic	14.8	12.1	37.0	38.0	26.0	39.0	44.0	18.0
Malaysia	10.0	9.2	19.0	19.0	16.0	23.0	--	--
Myanmar	--	--	31.0	32.0	25.0	34.0	--	--
Philippines	14.2	10.6	--	--	--	--	--	--
Singapore	14.6	4.4	4.0	3.0	--	--	--	--
Thailand	9.6	11.6	9.0	10.0	6.0	11.0	15.0	4.0
Timor-Leste	37.7	26.4	46.0	45.0	42.0	48.0	18.0	10.0
Viet Nam	28.3	24.4	21.0	19.0	12.0	22.0	29.0	10.0
India	35.6	33.7	46.0	49.0	38.0	51.0	61.0	25.0

Source: The State of Food insecurity in the world.FAO Rome-2011

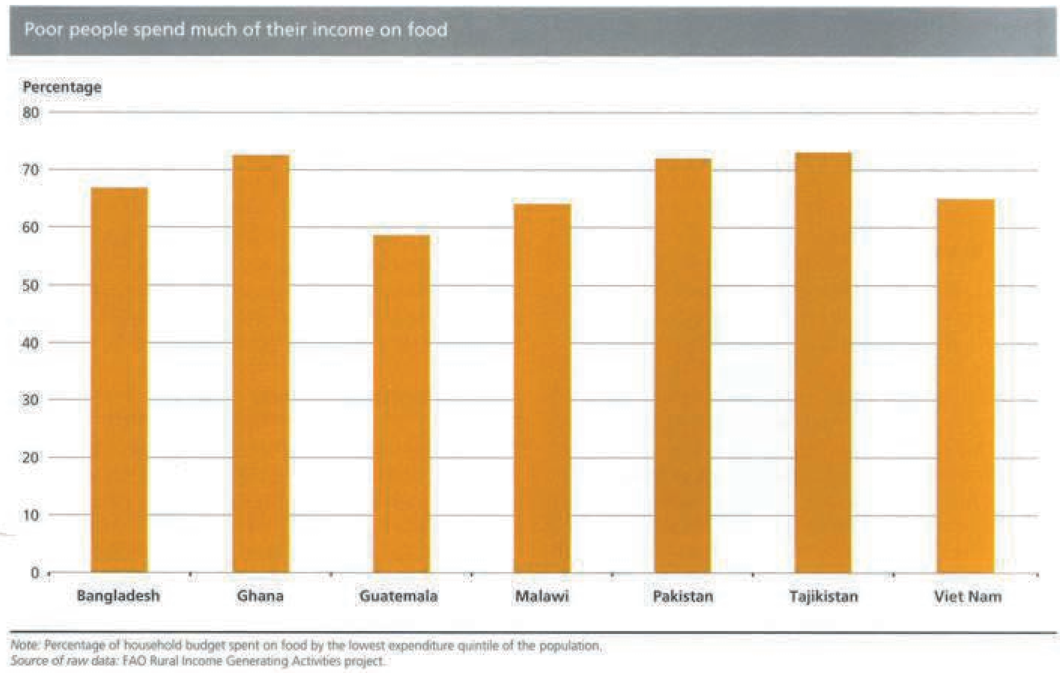

Figure 1. Poor people spend much of their income on food.
Source: The State of Food Insecurity in the World FAO Rome-2012

Aquatic vegetables are underexploited and underutilized crops with a natural habitat providing space, water, energy and the required nutrients for growth. A comparison has been made in its protein value (Table 4) Water hyacinth, a very common water floating plant was analyzed for amino acid content. It is rich in cystine, phenylanaline and lysine. Vegetables are known for their health and wellness properties. They are alkaline in reaction, rich in fibers and with low calorific value. Many health and medicinal properties are attributed to their consumption (Table 5). A large number of aquatic plants are reported with prospective use as vegetables (Table 6).

Table 4. A Comparison of amino acid content in aquatic plant and others foodstuffs (%).

Amino acid	Water hyacinth	FAO ref. pattern	Cow's milk	Corn grits	Leaf protein conc.
Methionine	0.7	2.2	2.4	2.5	2.1
Cystine	11.6	1.9	-	1.1	0.7
Phenylanaline	4.7	2.8	4.9	6.4	6.0
Tyrosine	3.0	2.8	5.1	6.7	4.2
Threonine	4.3	2.8	4.6	4.1	5.2
Lysine	5.3	4.2	7.8	0.8	6.3
Isoleucine	4.3	4.2	6.4	6.4	5.3
Valine	0.3	4.2	6.9	5.3	6.3
Leucine	7.2	4.8	9.9	15.0	9.8

Source: Pandey (2011)

Table 5. Aquatic vegetables and their medicinal value.

Aquatic vegetables	Medicinal Properties
Water spinach (*Ipomoea aquatica*)	Emetic, purgative; in Assam, the plant is given for nervous and general disability. It is also used for piles. In Cambodia, the herb is applied in febrile delirium.
Cattail (*Typha angustifolia* and *T. Latipholia*)	Plant is useful in angina, cystitis, diarrhea, urethritis, menstrual cramps, burns, insect bites etc.
Eel grass (*Vallisneria spiralis*)	It is used in the treatment of leucorrhoea.
Duck-lettuce (*Ottelia alismoides*)	Cures Hemorrhoids and has rubeficient properties
Common water plantain (*Alisma plantago-aquatica* L.)	The root is used in the treatment of oliguria, oedema, nephritis etc.
Water shield (*Brasenia schreberi* J.F. Gmel)	Leaves contain Gallic acid and traces of vitamin B12
Papyrus (*Cyperus papyrus* L)	The pith is recommended for the widening and drying of fistula.
Wasabi (*Wasabia japonica* (Miq.) Matsum)	It suppresses the growth of stomach cancer cells. It also possesses anti - diarrheal property. All parts of plant possess bactericidal activities against *Helicobacter pylori* strain NCTC 11637, YS 27 and YS 50
Fragrant Water Lily (*Nymphaea odorata* Ait.)	The rhizomes are cooling, sweet, bitter and tonic and useful in diarrhea, dysentery, dipsia and general debility. The flowers are astringent and cardio tonic.
Sonneratia (*Sonneratia caseolaris* (L.) Engler)	In Myanmar, fruits are used for poultices. Malayans use old fruit walls for worms, half-ripe fruits for coughs, and pounded leaves for hematuria and smallpox.
Chinese arrowhead (*Sagittaria trifolia*)	Four new biologically active diterpenes, trifoliones A, B, C, and D, have been isolated from this tuber.
Paracress (*Spilanthes acmella* L)	The flower heads are chewed to relieve toothache.
Indian blue water Lily (*Nymphaea stellata* Willd.)	It is used for blennorrrhagia and diseases of the urinary tract. Plant possesses hypoglycemic activity.
Keysoor (*Scirpus grossus*)	Has astringent properties, and is given to check diarrhea and vomiting. The root possesses cooling and laxative properties and acts as a liver tonic.

Source: Pandey (2011)

Table 6. Aquatic vegetables, their scientific name, family and edible parts.

Common Name	Scientific Name	Family	Edible parts
Velvet leaf	*Limnocharis flava* (L.) Buch	Limnocharitaceae	Leaf vegetable
Indian blue water Lily	*Nymphaea stellata* Willd.	Nymphaeaceae	Rhizome
Water lettuce	*Pistia stratiotes* L.	Araceae	Leaf vegetable
Marsilea	*Marsilea minuta*	Marsileaceae	Pot herb
Pygmy water lily)	*Nymphaea tetragona* Georgi	Nymphaeaceae	leaf buds and seeds
Manchurian Rice	*Zizania latifolia*	Poaceae	Infected culms
Common Water plantain	*Alisma plantago-aquatica* L.	*Alismataceae*	Roots, leaves and petioles
Water mimosa	*Neptunia oleracea* Loureiro	Fabaceae	Young shoots
Parrot's Feather	*Myriophyllum aquaticum* (J. M. da ConceicaoVellozo) Verdc.	Haloragaceae	Edible leaves
Duck lettuce	*Ottelia alismoides*	Hydrocharitaceae	Petioles and tender leaves
Aponogeton	*Aponogeton crispum*	Aponogetonaceae	Starchy tuberous rhizome
Keysoor	*Scirpus grossus* Linn. f. Tikiu	Cyperaceae	Starchy root
Achyranthe	*Achyranthes aquatica*	Amaranthaceae	Tender leaves and twigs
Hydrolea	*Hydrolea zeylanica* (L.) Vahl	Hydroleaceae	Young shoots
Water pepper	*Polygonum* hydropiper L.	Polygonaceae	Leaf vegetable
Water fern	*Dentella repens* J.R. Forst. & G. Forst.	Rubiaceae	Leaf
Giantchickweed	*Stellaria aquatica* L.Scop.	Caryophyllaceae	Young leaves and stem
Eel grass	*Vallisneria spiralis* L.	Hydrocharitaceae	Leaf vegetable
Water shield	*Brasenia schreberi* J.F. Gmel	Cabombaceae	Leaf vegetable
Frog bit	*Hydrocharis dubia* (Blume) Backer	Hydrocharitaceae	Mucilaginous leaves and inflorescence
Paracress	*Spilanthes acmella* AH Moore	Asteraceae	Leaf vegetable, salad
Goldenclub	*Orontium aquaticum* L.	Araceae	Edible root
Papyrus	*Cyperus papyrus* L.	Cyperaceae	Pith of young shoots
Chinese Arrowhead	*Sagitaria trifolia*	Alismataceae	Tuberous root
Cattail	*Typha angustifolia* L.	Typhaceae	Rhizome. petiole
Indian Red water lily	*Nymphaea nouchali*	Nymphaeaceae	Rhizome
Fragrant Water Lily	*Nymphaea odorata*	Nymphaeaceae	Rhizome
Swamp taro	*Cyrtosperma hamissonis* (Schott) Merr.	Araceae	Rhizome
Sonneratia	*Sonneratia caseolaris* (L.) Engler	Sonneratiaceae.	Immature fruit
Water spinach	*Ipomoea aquatica* Forsskal	Convolvulaceae	Leaf vegetable
Lotus	*Nelumbo nucifera*	Nymphaeaceae	Rhizomes, young leaves and lower buds
Water chest nut	*Trapa bispinosa*	Trapaceae	Kernel
Buffalo spinach	*Enydra fluctuans* Loureiro	Asteraceae	Leaf vegetable
Gorgon nut	*Euryale ferox*	Nymphaeaceae	Nut
Water dropwort	*Oenanthe stolonifera* DC.	Apiaceae	Pot herb
Monochoria	*Monochoria hastata*	Pontederiaceae	Leaf vegetable
water cress	*Rorippa nasturtium-aquaticum*	Cruciferae	Leaf vegetable
Chinese water chest nut	*Eleocharis* sp.,	Cyperaceae	Rhizome
Water sprite	(*Ceratopteris thalictroides* (L.) Brongn	Parkeriaceae	Edible fern

Source: Pandey (2011)

CONCLUSION

With land under vegetables under threat of reduction, irrigation water becoming scarcer and land-based vegetables often unaffordable to the poor, the need has arisen to further consider for aquatic vegetables for health, nutrition and human wellness. Aquatic vegetables are deemed to be nature friendly and are not protected from pests and diseases by pesticides and thus obviously are residue free. They are organic in all senses. Aquaculture of vegetables is a new hope to millions of people in Asia for a nutritious diet. Much head way has to be made to work out appropriate package of agronomic practices for these future crops which are reported to have useful medicinal values as well.

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References

FAO 2011.The State of Food Insecurity in the World.Office of Knowledge Exchange, Research and Extension, FAO. Rome, Italy.

FAO 2011.The State of Food and Agriculture: Women in Agriculture-Closing the gender gap for development. Office of Knowledge Exchange, Research and Extension, FAO, Rome, Italy,

Pandey,A K 2011.Aquatic Vegetables Agrotech Publishing Academy Udaipur, India.

Sprouts, microgreens, and edible flowers: the potential for high value specialty produce in Asia

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ABSTRACT
Sprouts, microgreens, and edible flowers constitute a growing market segment in developed countries, where restaurant chefs use these plants and plant parts to add exotic flavors, colors and creative presentation to dishes offered to health-conscious, upscale consumers. Mungbean sprouts, and, to a lesser extent, soybean sprouts, which have been grown in Asia since ancient times, have now found their way into Western cuisine. Apart from pulses, cereals and oilseed crops, a number of vegetables and herbs are used for sprouting, including cress, mustard, snow peas, cabbage, kale, radish, spring onion, broccoli, basil, etc. Sprouts are usually densely packed in special sprouting cells and grown in high humidity and low light; such conditions favor the proliferation of dangerous bacteria that may cause severe food poisoning. Factors affecting seed and produce contamination as well as seed treatment measures for effective control of microbial growth are extensively discussed. In contrast to sprouts, microgreens are grown in soil or soil substitutes such as peat moss or other fibrous materials (cellulose pulp), and under light—and thus are less susceptible to contamination. Several crops or different varieties of the same crop can be mixed to create attractive combinations of textures, flavors, and colors. Edible flowers include ornamentals such as begonia, calendula, daylilies, hibiscus, and honeysuckle; fruit flowers such as banana and citrus blossoms; herb flowers such as angelica, borage, cilantro, fennel, ginger, jasmine, lemon verbena, marjoram, mint, rosemary, and safflower; and vegetable flowers such as alliums (leek, chives, garlic), arugula, artichoke, broccoli florets, okra, pak choi, pea, radish, scarlet runner beans, and squash blossoms. Many of these crops are indigenous to Southeast Asia, are quite popular, and can be grown inside homes, in kitchen gardens, or commercially. If properly promoted, microgreens could gain importance in Asia to diversify and enrich diets and add flavor, texture and color to dishes prepared at home or in fine dining restaurants.

Keywords
High value specialty vegetables, sprouts, microgreens, edible flowers, Asia

INTRODUCTION
Population growth, the increased frequency of extreme weather events due to climate change, high and volatile food prices and the on-going financial and economic crises make the attainment of the Millennium Development Goal of reducing the proportion of people who suffer from hunger by half by 2015 very unlikely. Increased investment in agriculture to enhance productivity, sustainability and reduce vulnerability is seen as crucial to sustainable long-term food security (FAO 2011). In addition to the lack of protein and energy intake from staple foods, normally understood as hunger, malnutrition refers to the lack of micronutrients and can be described as hidden hunger. Micronutrients are mainly derived from the consumption of fruit and vegetables. Although malnutrition as measured by stunting has fallen from 47% in 1980 to 33% in 2000, malnutrition of one out of three children below five years of age remains a major concern in many developing countries (de Onis et al. 2000). Geographically, about 70% of malnourished children live in Asia, 26% in Africa and four percent in Latin America and the Caribbean.

A third form of malnutrition is caused by imbalanced diets due to overconsumption of calories and poor food choices leading to obesity, type two diabetes and other chronicle diseases which are becoming an increasing burden in both developed and developing countries. Mineral and vitamin deficiencies associated with malnutrition and chronicle diseases can be best addressed with a diverse diet making use of pulses, fruit and vegetables (Yang et al. 2007; Keatinge et al. 2011; Jamnadass et al. 2011).

To counter the ill effects of malnutrition and the negative impact of modern agriculture and the food sector on the environment and climate, multiple initiatives are underway worldwide to change current food production and consumption patterns, to enhance the consumption of healthy and safe food and to promote more sustainable products and services. An example of the multiple initiatives can be found in the 'Roadmap to a Resource Efficient Europe' by 2050 (European Commission 2011).

Among those initiatives is the 'Slow Food' movement founded 1986 in Italy which focuses on traditional and wholesome means of food production and defends biodiversity in food supply. The current financial, environmental and energy crises are boosting this movement which has activities in over 160 countries (The China Post 2011a). Just like AVRDC – The World Vegetable Center is attributing a major role to school, community and disaster-recovery gardens and other types of nutrition gardens to overcome malnutrition and to provide better nutrition education, especially to the young generation (Keatinge et al. 2012), the 'Slow Food' movement is implementing 'A Thousand Gardens in Africa' project to serve as source of healthy food, to generate supplementary income and to demonstrate sustainable agriculture (Slow Food Foundation 2011).

Due to health, ecological and religious concerns the number of vegetarians who abstain from eating meat, fish, and poultry is growing. Vegans also abstain from consuming dairy products and eggs and from using animal products such as silk, wool, and leather. According to a recent poll undertaken by the Vegetarian Resource Group, approximately one-third of adults in the U.S. are frequently eating vegetarian meals and five percent of the population are vegetarians, out of which about half are vegans (Stahler 2011). With celebrities like actress Katie Holmes, Alec Baldwin or even Bill Clinton frequenting upscale restaurants which only serve vegan and raw food, the image of vegetarians and vegans is changing and is becoming more mainstream (The China Post 2011b). Books are available trying to guide consumers following this trend with raw food recipes for radiant health (Daniel and Daniel 2011).

Similar trends already existed in Europe as expressed in the 'life reform movement' which started in Germany and Switzerland in the middle of the 19th century under the motto 'back to nature' (Intentional Community Wiki 2011). This reform movement also included nutritional reforms which emphasized the consumption of wholemeal bread and raw fruit and vegetables, among others. During this same period the spread of vegetarianism began in Great Britain and Germany. These trends have recently seen a revival and expansion in the *haute cuisine*. Sprouts, microgreens and edible flowers are increasingly used by chefs to add exotic flavors, colors and creative presentation to dishes offered to health-conscious, upscale consumers. This paper describes the potential of this high value specialty produce for Asia.

Sprouts

Sprouts can be easily grown from a wide range of crop seeds, all year round, either at home or on a large industrial scale. Untreated seeds of good quality and high germination rate are washed, soaked in lukewarm water for 6 to 12 hours at room temperature. The seeds are then densely packed into sprouting cells or vessels (glass jar, plastic pan) and covered with cheese cloth or a greenhouse tent to maintain temperature and moisture (Meyerowitz 2010). The seeds need to be rinsed or sprinkled several times per day to keep humidity high and facilitate sprouting. Well, spring, or distilled water should be used for rinsing as chlorinated water may result in poor sprouting (Bass and Sanders 1999). Sprouts take 5 to 14 days to mature, depending on the crop (Meyerowitz 2010).

Crop groups used for sprouting are: (1) *legumes* (alfalfa, azuki bean, blackgram, chickpea, lentil, mungbean, soybean); (2) *cereals* (barley, maize, oat, rice, rye, wheat); (3) *pseudocereals* (amaranth, buckwheat, quinoa); (4) *oilseeds* (almond, hazelnut, linseed, sesame, sunflower); and (5) *vegetables and herbs* (broccoli, cabbage, carrot, celery, clover, fennel, fenugreek, kale, leek, lettuce, mustard, parsley, radish, rocket or arugula, snow and garden peas, spinach, spring onion, turnip, watercress).

Among the bean sprouts, mungbean sprouts are the most common and most consumed sprouts and are now found worldwide (Fig. 1). Mungbean, and, to a lesser extent, soybean sprouts have long been a staple of Oriental and vegetarian diets. Soybean sprouts are known for their appealing nutty taste and good texture (Shurtleff and Aoyagi 2007). They are produced from special small-seeded soybean varieties and are the most popular sprouts in Korea. In Japan, blackgram (*Vigna mungo*) is preferred as its sprouts are whiter and stay fresh for longer than mungbean sprouts.

Mungbean sprouts are sold in market stalls in most of Asia, Central America and East Africa and in recent years have also become quite popular in western countries where most large supermarkets stock them. Mungbeans can be grown in about five days to 5 cm long mature sprouts. Within eight days they can grow up to 8 to 9 cm long sprouts, but longer growth above 10 cm should be avoided as sprouts then tend to become bitter (Bass and Sanders 1999). Mature sprouts are placed in a water-filled container for washing and removal of the seed coats and fibrous roots. The sprouts will sink to the bottom and the seed hulls will float to the top and can then easily be removed with a wire strainer. Sprouts are then allowed to drain.

Sprouts are best when consumed immediately after washing, but they can also be kept inside closed glass and plastic containers or freezer bags for a few days up to one week in a refrigerator. Sprouts can be eaten raw or cooked. The crispy sprouts are often added fresh to appetizers, salads, soups, sandwiches and even desserts to add texture and flavor. Cereal sprouts are also used in casseroles, pasta and baked products (Lorenz 1980). Sprouts can also be canned or frozen if there is excess produce for fresh consumption, but this might lead to a deterioration of their nutritional value.

Nutritional and health value of sprouts

Sprouts are commonly considered highly nutritious and are sometimes also called miracle food. Soybean sprouts have the highest level of protein (28%) of all sprouts, followed by lentil and pea sprouts with 26%. Soybean sprouts thus have twice the protein of eggs, but only $1/10^{th}$ the fat (Meyerowitz 2010). Due to respiration during the sprouting process, there is a loss in total dry matter, an increase in total protein, a decrease in starch, an increase in sugars, and a slight increase in some vitamins and minerals (Lorenz 1980). As total carbohydrates decrease during germination, the percentage of other nutrients increases.

The flatulence-producing carbohydrates in legumes largely disappear during sprout formation resulting in low levels of stachyose and raffinose (van Hofsten 1979). Due to the biochemical changes during germination sprouts contain significantly higher levels of vitamins than the respective dry seeds. Some sprouts such as mungbean are very good sources of ascorbic acid reaching over 50 mg ascorbic acid/100 g fresh weight (van Hofsten 1979). Vitamins of the B-group increase 100 to 300% during germination and sprouts are, therefore, often a good source of vitamin B_{12}. Moreover, phytic acid in the seed is degraded during germination due to phytase enzyme activity resulting in higher availability of the trace minerals compared to the dry seed (van Hofsten 1979).

Isoflavonoids, which protect against cancer, cardiovascular disease and osteoporosis are found in relatively high concentration in soybeans, but their level is much lower in other legume crops (Nakamura et al. 2001). The composition of isoflavonoids differs significantly between soybean sprouts, immature beans and mature beans. The highest levels of isoflavonoids in aglycone form - known to be of stronger biological activity than the glycoside form – are found in soybean sprouts and progressively decrease from sprouts via immature beans to mature beans, the latter having the lowest levels. The percentage of the glucoside form of isoflavonoids increases in reverse order.

Rocket or arugula (*Eruca sativa* Mill.) is a popular cruciferous vegetable which is found worldwide and is known for its typical spicy taste. It is usually consumed fresh in the form of leaves or sprouts. It is highly nutritious and contains a range of health-promoting ingredients such as carotenoids, vitamin C, fibers, flavonoids, and glucosinolates. Specific research on rocket revealed direct antioxidant activity of purified glucoerucin, a major glucosinolate found in rocket seeds and sprouts (Barillari et al. 2005). Glucosinolates are the precursors of isothiocyanates, which are released through the enzyme myrosinase during cutting, chewing, or processing of this vegetable. Isothiacyanates have been identified as potent inducers of phase II enzymes which are involved in the detoxification of electrophiles and protect against oxidative stress. The glucosinolate glucoerucin comprises 95% of total glucosinolates in rocket seeds. This content is largely preserved in sprouts (79% of total glucosinolates), but to a much lesser extent in adult leaves (Barillari et al. 2005).

The health-promoting effect of cruciferous (and legume) sprouts was confirmed in a human diet study conducted by Gill and co-workers (2004). These researchers found a significant antigenotoxic effect against H_2O_2-induced DNA damage in peripheral blood lymphocytes of volunteers who were fed 113 g of cruciferous and legume sprouts daily for 14 days compared to the group fed with the control diet. The consumption of cruciferous vegetables can thus be linked to a reduced risk of cancer.

Earlier feeding studies with rats supported the cancer preventing effect of cruciferous vegetables. Deng and co-workers (1998) studied the effects of Brussels sprouts, some non-cruciferous vegetables and isolated glucosinolates on spontaneous and induced oxidative DNA damage in male rats. A short oral administration of 3g of cooked Brussels sprouts homogenate for only four days significantly reduced the spontaneous urinary 8-oxodG excretion by 31% as opposed to raw sprouts, beans and endive and isolated indolyl glucosinolates which did not have a significant effect. Cooking of Brussels sprouts appears to activate substances which have the potential to reduce physiological as well as oxidative stress induced oxidative DNA damage.

Studies on broccoli, another cruciferous vegetable, revealed that broccoli sprouts contain on a gram-fresh-weight basis up to 50 times more glucoraphanin, the glucosinolate precursor of sulforaphane compared with mature broccoli plants (Fahey et al. 1997; Fahey and Stephenson 1999; Fahey et al. 2001). Sulforaphane is the most potent natural phase II enzyme-inducer known. Extracts of 3-day old broccoli sprouts were highly effective in reducing the incidence and rate of development of mammary tumors in rats (Fahey et al. 1997).

Broccoli sprouts also contain negligible or no detectable amounts of the indole and β-hydroxyalkenyl glucosinolates that predominate in the mature vegetable and may give rise to degradation products (e.g., indole-3-carbinol) that can enhance tumorigenesis (Fahey et al. 1997; Shapiro et al. 2001). The latter authors concluded that myrosinase activity in intact broccoli sprouts contribute significantly to the bioavailability of isothiocyanates by boosting the glucosinolate-to-isothiocyanate conversion. Dithiocarbamate excretion was clearly enhanced when fresh sprouts were chewed thoroughly rather than swallowed whole. Isothiocyanates are about six times more bioavailable than glucosinolates (Shapiro et al. 2001). Thorough chewing facilitates hydrolysis by releasing myrosinase and glucosinolates from their sequestered sites within the plant cells (Barillari et al. 2005).

Dietary alfalfa administration (*Medicago sativa* L.), a leguminous vegetable, led to reduced serum or plasma cholesterol in several experimental animal species, such as rats, rabbits, and monkeys. Cholesterol-saponin interactions have been postulated as mechanisms for the hypocholesterolemic effects of alfalfa (Story et al. 1984). These researchers demonstrated that alfalfa plant saponins bind significant quantities of cholesterol. Alfalfa sprout saponins also interacted significantly with cholesterol, but to a lesser extent than mature plants.

To ensure microbial safety of fruits and vegetables, irradiation is one of several measures that have been proposed. When alfalfa sprouts were irradiated with gamma rays and stored at 6 ^oC for 14 days, this had only a minimal effect on total ascorbic acid (TAA) content when compared with the decrease of TAA during storage (Fan and Thayer 2001). However, antioxidant power increased linearly with radiation dose at one and seven days of storage and carotenoid content of sprouts was also enhanced at higher radiation doses compared to control sprouts at seven days of storage.

Health concerns associated with the consumption of sprouts

Sprouts are usually densely packed in special sprouting cells and grown in high humidity and low light; such conditions favor the proliferation of dangerous bacteria that may cause severe food poisoning. Documented outbreaks of food poisoning in humans linked with the consumption of raw fruits, vegetables and unpasteurized juices have substantially increased in the United States in the recent past (DeRoever 1998; Buck et al. 2003).

This may be partially attributable to enhanced epidemiologic and surveillance techniques which are now at the disposal of public health agencies which allow disease outbreaks to be linked with the probable source of infectious microorganisms (Burnett and Beuchat 2001). Other contributing factors are changes in dietary habits which include a higher per capita consumption of fresh or minimally processed fruits and vegetables, and the increased use of salad bars and meals eaten away from home (Altekruse and Swerdlow 1996). Especially in industrialized countries consumers have become much more health-conscious and want to maintain a healthier diet and thus eat much more raw fruit and vegetables. The year-round availability of high-quality fresh produce due to globalization contributes to this trend.

Other factors which may have contributed to a higher frequency of foodborne illness outbreaks associated with the consumption of raw fruits and vegetables are changes in production and processing methods, new sources of produce and the emergence of pathogens previously not associated with raw produce (Hedberg et al. 1994).

The danger of widespread outbreaks of foodborne illness became evident in 1996 in Japan where more than 6000 *Escherichia coli* infections were reported (Guiterrez 1997). Raw radish sprouts prepared in central school kitchens appear to have transmitted the pathogen leading to four deaths and 4000 ill school children in and around Sakai City, the center of the outbreak. In the U.S. nine outbreaks of foodborne illness were reported between 1995 and 1998 which could be traced to the consumption of fresh vegetable sprouts (NACMCF 1999). In most of these cases, alfalfa or clover seed were identified as the initial inoculum source. Other sprout-related disease outbreaks have been reported in Japan, Great Britain, Finland, Denmark, Sweden, and Canada which could be traced to alfalfa, cress, radish, and mungbean sprouts (Puohiniemi et al. 1997; Taormina et al. 1999; Taylor et al. 2002).

The most recent and perhaps most dramatic outbreak of gastroenteritis and the hemolytic-uremic syndrome caused by a shiga-toxin producing *E. coli* strain in Germany in May/June 2011 has also been linked to sprout consumption implicating an organic sprout farm in Lower Saxony near Hamburg as the potential pathogen source (Frank et al. 2011; Kuijper et al. 2011). A total of 3816 cases including 54 deaths were reported during this outbreak, 845 of which involved the hemolytic-uremic syndrome (Frank et al. 2011).

Sources of contamination and measures to avoid contamination

In many cases, the seeds used for sprout production are considered as significant inoculum source for foodborne illnesses associated with sprout consumption (NACMCF 1999; Taormina et al. 1999). However, due to the common practice of blending seedlots, the original source of contaminated seed can often not be determined (Mahon et al. 1997). During the production of seeds intended for sprouting, the practice of animal grazing to initiate flowering in alfalfa may result in the unintentional introduction of enteric bacteria from feces into the seed production field (Buck et al. 2003). The same may happen if wild animals have access to seed fields. Manure used as fertilizer or soil amendment should be properly treated to eliminate pathogenic microorganisms and animals should be excluded from sprout seed production fields. Irrigation wells and water used for irrigation should be monitored for the presence of human pathogens.

There are also many factors which may introduce contamination during post-harvest operations. Such factors include human handling, harvesting and processing equipment, transport containers and vehicles, wild and domestic animals having access to the produce, insects, dust, rinse water, and ice (Burnett and Beuchat 2001).

Small initial populations of pathogens can reach high numbers during sprout production thanks to favorable conditions of high relative humidity and temperature, together with nutrient-rich root exudates (Prokopowich and Blank 1991). Pathogenic bacteria easily survive for prolonged periods in or on stored dried seed and survival is enhanced at lower temperatures in seed storage (Taormina and Beuchat 1999). Physical seed damage during seed processing may also enhance bacterial survival and cross-contamination.

Conventional methods to eliminate human pathogens from fresh produce

Washing and rinsing fruits and vegetables is perhaps the easiest way to partially reduce the number of microorganisms on the surface and thus prolong shelf life (Burnett and Beuchat 2001). The addition of disinfectants to wash water enhances the efficacy of decontamination by up to 100-fold (Beuchat 1998). However, pathogens differ in their sensitivity to sanitizers. There are also mechanical barriers in fruit and vegetable structures and tissues harboring pathogens that render sanitizers ineffective.

Pathogenic bacteria may infiltrate protected areas of produce such as cracks and intercellular spaces of seeds and fruit or vegetable surfaces (Buck et al. 2003). Pathogen infiltration into plant tissues depends on temperature, time of exposure and pressure and occurs only when water pressure on the surface of the produce exceeds internal gas pressure as well as the hydrophobic nature of the surface of the produce (Burnett and Beuchat 2001; Beuchat 2002). Bacterial infiltration is enhanced by the presence of surfactants and with produce temperatures higher than the temperature of the water suspension harboring the pathogen. Growth of microorganisms in such protected areas of produce can result in the formation of biofilms that are difficult for sanitizers to penetrate (Carmichael et al. 1999).

Seed treatment

The reduction of microbial contamination can be more easily achieved by sanitizing seeds, rather than sprouts. To reduce the risks of sprout-borne illnesses, chemical or physical seed treatments are routinely applied. Chemical seed treatments for sprout seeds include chlorine compounds (calcium and sodium hypochlorite), ethanol, hydrogen peroxide, calcium EDTA, ozonated water, and commercial disinfectants (Beuchat 1997, 1998; Beuchat et al. 2001; Lang et al. 2000; Taormina and Beuchat 1999; Weissinger and Beuchat 2000). Seed used for sprouting can also be treated with gaseous chemicals (Delaquis et al. 1999; Weissinger et al. 2001).

While chlorine compounds are still widely used in the fresh-cut industry for disinfection purposes, there is growing public health concern about the formation of chlorinated organic compounds such as chloramines and trihalomethanes that are linked to a higher rate of cancer in humans. The emergence of new, more tolerant pathogens also calls for alternative treatment options (Singh et al. 2002). Moreover, the prolonged exposure to chlorine vapors may lead to irritation of the skin and respiratory tract of workers (Beuchat 1999). In many European countries the application of chlorine or other disinfectants is not allowed for the production of organic food (Bari et al. 2011). In response to these concerns, acidic electrolyzed water, a novel non-thermal food sanitizer has been developed in Japan which has strong bactericidal and virucidal and moderate fungicidal properties (Issa-Zacharia et al. 2010).

Hot water treatment has also been explored for seed disinfection (Grondeau and Samson 1994). Seeds are, in general, exposed for about 10 min to 57 to 60^{o}C. While hot water will kill seedborne bacteria, there might be a negative impact on seed germination and sprout vigor. In Japan, hot water treatment at 85^{o}C for 40 seconds followed by cooling in cold water for 30 seconds and soaking in chlorine water is currently still considered as safe and effective treatment to inactivate pathogens on mungbean seeds intended for sprout production without compromising seed viability, germination and vigor (Bari et al. 2011). However, consumers in Japan are advised to consume sprouts only after cooking. When used for salads, mungbean and soybean sprouts should be dipped in boiling water for about 10 seconds to minimize the risk of foodborne illnesses.

With large seed batches it is difficult to maintain uniform temperature within the water bath and this method is thus of little practical value for commercial application. Combinations of thermotherapy with chlorine resulted in the reduction, but not complete elimination, of *Salmonella* (Jaquette et al. 1996) and *E. coli* O157:H7 (Beuchat and Scouten 2002) populations on alfalfa seeds.

Gamma radiation has been successfully tested for the elimination of *E. coli* and *Salmonella* from seeds intended for sprouting, without affecting seed germination (Rajkowski and Thayer 2000) and is commonly used for food preservation (Farkas 2006). Radiation energy is an attractive treatment for seeds as it can penetrate seed tissues and eliminate bacteria located in protected tissues (Buck et al. 2003). However, high levels of radiation can negatively affect the physiology of sprouts, hence more research is needed to establish the potential and risks of this treatment. Other non-thermal approaches for reducing foodborne pathogens include super-critical carbon dioxide (Mazzoni et al. 2001), ultraviolet radiation, ultrasound treatments (Scouten and Beuchat 2002) and magnetic resonance fields.

The complete elimination of bacteria on seeds is difficult to achieve for two major reasons: (1) treatment dosage must not harm seed viability and might, thus, be suboptimal for complete disinfection; (2) to be effective, sanitizers must fully reach the pathogens which might be located in protected seed tissues. Greater success may be achieved by combining compatible seed treatments without compromising seed viability or physiology (Buck et al. 2003). This approach to inhibit the growth of microorganisms in produce is known as hurdle technology in food preservation (Leistner 2000; Zhang 2007). In this approach, suitable combinations of microbe growth-limiting factors (hurdles) such as temperature (high or low), water activity (a_w), acidity (pH), redox potential (E_h), preservatives, and competitive microorganisms (e.g. lactic acid bacteria) are applied to ensure microbial safety and stability as well as the sensory and nutritional quality of the produce or food product.

Microgreens

Just like sprouts, microgreens are grown from the seeds of a wide range of crops such as vegetables, herbs and other plants. Microgreens are defined as salad crop shoots harvested for consumption within 10-20 days of seedling emergence (Lee et al. 2004). They are larger than sprouts, but are smaller than 'baby' greens. Microgreens have a central stem with two fully developed cotyledon leaves and mostly one pair of small true leaves.

Commonly grown microgreens include amaranth, basil, beet, cabbage, celery, chervil, Chinese kale, cilantro, fennel, garden cress, mustard, parsley, radish, rocket or arugula, snow pea, sorrel, and Swiss chard.

Unlike sprouts, microgreens are not grown in water, but in soil or soil substitutes such as peat moss or other fibrous materials (cellulose pulp), and under light—and thus are less susceptible to bacterial contamination. Although wood or paper fiber mulches have a lower cost than peat-lite as growth media for microgreens, the latter was found superior for beet, rocket and amaranth microgreens (Murphy 2006). Insufficient nutrient levels, low cation exchange capacity, and excessive liquid retention leading to inadequate aeration are factors that might have contributed to reduced growth of microgreens on mulches compared with peat-lite. The production of beet microgreens in troughs using the hydroponic nutrient film technique (NFT) resulted in higher shoot fresh weight per m^2 than production in trays containing peat-lite (Murphy et al. 2010). Maximum shoot fresh weight was obtained using beet seed balls pre-germinated in moist vermiculite followed by subsequent growth in troughs with NFT.

As microgreens are in contact with soil or soil substrates, they are prone to pre- and post-emergence damping-off caused by soilborne pathogenic fungi. Due to the very short pre-harvest period biological control of damping-off is preferred over chemical treatments for the safe production of microgreens. The combination of *Trichoderma harzianum (Th)* and *T. virens (Tv)* strains was successfully used to control damping-off in beet microgreens (Pill at al. 2011). Increased levels of *ThTv* to beet seed balls or growth media resulted in a decreased incidence of damping-off with concomitant increase in shoot fresh weight per m^2 at 14 days after planting which is attributable to an increased percentage of plant survival.

Microgreens are usually grown in high light conditions with low humidity and good air circulation. The seed density is much lower than with sprouts. Therefore, microgreens have much better developed flavors and taste than sprouts and are an ideal component of any meal, adding a broad range of leaf shapes, textures, color and distinct flavors (Fig. 2). In addition, several varieties of the same crop or different crops can be grown together to create attractive combinations of tastes, textures, and colors. These mixtures are available commercially and are known as 'mesclun' (Franks and Richardson 2009).

Just like sprouts, microgreens can easily be grown at home, in containers on a terrace or windowsill. Popular guides to growing microgreens are available for the hobby gardener, along with information on their nutritional value, ideas on how to use them, and recipes (Franks and Richardson 2009; Hill 2011).

Microgreens are increasingly used as a fresh flavor accent in fine dining restaurants where creative presentation, fresh appearance, and distinct flavor elements are expected from the upscale customers. There are a number of commercial microgreen growers catering to this new dining trend. Companies usually briefly describe the special flavors and taste of each product and make suggestions for dishes to which these microgreens can best be added to. Lines used to grow these microgreens are a trade secret and often patented. Many of the lines commercially grown have been sourced in Asia and most likely have not undergone major breeding efforts, but might rather have been obtained from a wild or semi-domesticated state to guarantee its original richness in flavors and taste.

Edible flowers

Edible flowers which greatly differ in shape, color and taste stimulate not only the eyes, but also other senses like taste and smell. From east to west and since ancient times, flowers have not only been used for decoration and aesthetic appearance, but as relishes and flavor enhancers for many savory dishes, salads (Fig. 2) and desserts as well. Capers, the flower buds of *Capparis spinosa* L. have been used as condiment in Europe for over 2000 years (Smythe 2011). A variety of edible flowers such as roses, elder flowers, and hawthorn blossoms were used in the Anglo-Norman cuisine during the 13th and 14th century. The flowers of calendula were used for the preparation of salads in medieval France (Mlcek and Rop 2011). During the Victorian era in the 19th century edible flowers were also very popular and often used as part of salads (Smythe 2011).

During the past 15 to 20 years, edible flowers have seen a revival, both in *haute cuisine* as well as in home-cooked meals. Flowers are served as a garnish and/or as edible component of soups, savory dishes, and cold buffet food and petals are used to decorate salads, desserts, and drinks. In addition to the aesthetic appearance, flowers have also to correspond with the specific taste and smell of a creative dish. For example, flowers of borage, acacia or roses serve as aromatic enhancers of pastry (Mlcek and Rop 2011).

In some countries, edible flowers are now being promoted as a healthy food. The Thai Health Promotion Foundation has initiated a campaign under the name ‘Food Safety: Edible Flowers” promoting a range of dishes and drinks containing edible flowers (Wongwattanasathien et al. 2010).

Edible flowers can be marketed fresh, dried, sugarcoated, in bulk, as singles or by weight and offer good opportunities for small-scale enterprises (Handwerker et al. 1990). They include ornamentals such as begonia, calendula, daylilies, hibiscus, chrysanthemum, dianthus, dandelion, geranium, garden nasturtium, pansy, rose, honeysuckle, and blue violets; fruit flowers such as banana, citrus, and elderberry blossoms; herb flowers such as angelica, basil, borage, cilantro, fennel, ginger, jasmine, lemon verbena, marjoram, mint, rosemary, sage, and safflower; and vegetable flowers such as alliums (leek, chives, garlic), arugula, artichoke, broccoli florets, okra, pak choi, pea, radish, scarlet runner beans, okra, pumpkin and squash blossoms.

For consumption as food, edible flowers should be obtained from a reliable source, preferably from organic production to ensure that they are free from pesticide residues. Flowers should be thoroughly washed before use as food. It is preferable to introduce flowers only in small quantities and one species at a time into the diet to avoid problems with the digestive system. It is usually recommended to remove stamens and styles from the flowers before eating. Although pollen is a rich source of proteins, amino acids and carbohydrates, carotenoids and flavonoids (Mlcek and Rop 2011), it is not recommended to eat the pollen as it may detract from the distinct flavor of the flowers and may cause allergic reactions.

Edible flowers are either eaten whole or parts thereof, such as petals of tulips, chrysanthemums or roses (Mlcek and Rop 2011). When only the petals are eaten, they should be separated from the rest of the flower just prior to use to minimize wilting. For some edible flowers like roses, it is necessary to remove the basal part of the petals as these parts are bitter. In the case of cucurbits, baby squashes with attached blossoms are now standard in the upscale restaurant trade (Schneider 2001). The squash flowers are amenable to stuffing which can easily be done with a pastry tube. When prepared in a microwave, the color and crunch of the baby squashes and the form of the filled pouches is maintained.

Perceived sensory characteristics such as attractive appearance, size, shape, taste, aroma and coloring are the most important quality criteria of edible flowers, apart from their freshness. In general, consumers prefer yellow and orange colors; blue and combinations of other colors are liked less (Kelley et al. 2001, 2002).

Flowers are quite delicate and sensitive and prone to microbial decay if not carefully handled. After picking, they should be immediately placed into plastic (zip-lock) bags and/or other containers which provide protection against contamination and wilting. Plastic bags must be perforated to prevent condensation of vapors on their inner surface. Harvested flowers are quickly cooled and cleaned and can then be stored at a temperature of 1-4^{o}C for a period of 2 up to 14 days (Kelley et al. 2003). Picking time is also important for some crops. Squash blossoms, for example, should be collected in the early morning as they will wilt on the vine by late morning (Schneider 2001). Once picked at the right time, squash blossoms stay fresh for a few days in the refrigerator. Compounds with antioxidant activity are very important for the keeping quality of flowers as these substances delay the process of senescence and decay which is caused by the action of reactive oxygen radicals on biomembranes (Panavas and Rubinstein 1998).

Multiple uses have been reported for a range of native and non-native *Hibiscus* species in the U.S. (Puckhaber et al. 2002). Whole fresh, dehydrated or freeze-dried or frozen petals can be used as edible flowers in the restaurant business, for use in nutraceutical products and specialty gourmet foods due to their relatively high levels of flavonoid aglycones, and for the extraction of natural food colorants for applications in the food and beverage industry. Other potential applications for fresh and processed *Hibiscus* blossoms are the formulation of skin-care products or cellulosic and mucilaginous dietary products (Puckhaber et al. 2002).

Many edible flowers have chemoprotective effects as they are rich sources of phenolic compounds, carotenoids and flavonoids with high antioxidant and free radical suppressing properties (Kaisoon et al. 2011; Mlcek and Rop 2011) or have curative medicinal effects. Friedman and co-workers (2007) highlighted the antioxidant activity in flowers of begonias, roses or garden nasturtiums and Que and co-workers (2007) observed a strong scavenging activity of reactive oxygen radicals and lipid peroxidation in extracts of daylily. The antioxidant activity of stored flowers seems to be quite stable as even after one week of cold storage their values did not change much. This is attributed to the high content of gallic acid, one of the essential antioxidants occurring in edible flowers (Anesini and Perez 1993).

Rojanapo and Tepsuwan (1992) attributed antimutagenic activity to some vegetable flowers like neem (*Azadirachta indica* A. Juss., sesbania (*Sesbania grandiflora* (L.) Pers.), and cassia (*Senna siamea* (Lam.) H.S. Irwin & Barneby). Methanol extracts of turmeric (*Curcuma sessilis* Gage) and pomegranate (*Punica granatum* L.) flowers also revealed high antimutagenic effects (Wongwattanasathien et al. 2010).

CONCLUSION

Many of the crops used to grow sprouts, microgreens or edible flowers around the world are indigenous to Asia or have been introduced to Asia. They are widely known and at least partially used in the Oriental cuisine. These crops can easily be grown inside homes, in kitchen gardens, or commercially. If properly promoted and safely produced, packaged and served, sprouts, microgreens and edible flowers could gain growing importance in Asia. They are an attractive component to diversify and enrich diets and add flavor, texture and color to dishes prepared at home or in fine dining restaurants.

References

Altekruse SF, Swerdlow DL. 1996. The changing epidemiology of foodborne diseases. *Am. J. Med. Sci*. 311: 23-29.

Anesini C, Perez C. 1993. Screening of plants used in Argentine folk medicine for antimicrobial activity. J. Ethnopharmacology 39: 119-128.

Bari L, Enomoto K, Nei D, Kawamoto S. 2011. Development of effective seed decontamination technology to inactivate pathogens on mung bean seeds and its practical application in Japan. *JARQ* 45(2): 153-161.

Barillari J, Canistro D,, Paolini M, Ferroni F, Pedulli GF, Iori R, Valgimigli L. 2005. Direct antioxidant activity of purified glucoerucin, the dietary secondary metabolite contained in rocket (*Eruca sativa* Mill.) seeds and sprouts. *J. Agric. Food Chem.* 53(7): 2475-2482.
Bass L, Sanders DC. 1999. Bean sprouts and other vegetable seed sprouts. Horticulture Information Leaflet No. 8106, published by North Carolina Cooperative Extension Service, North Carolina State University.
Beuchat LR. 1997. Comparison of chemical treatments to kill *Salmonella* on alfalfa seeds destined for sprout production. Intl. *J. Food Microbiol*. 34: 329-333.
Beuchat LR. 1998. Surface decontamination of fruits and vegetables eaten raw: a review. Food Safety Unit, World Health Organization. WHO/FSF/FOS/98.2. 42 pp.
Beuchat LR. 1999. Survival of enterohemorrhagic *Escherichia coli* O157:H7 in bovine feces applied to lettuce and the effectiveness of chlorinated water as a disinfectant. *J. Food Prot.* 62: 845-849.
Beuchat LR. 2002. Ecological factors influencing survival and growth of human pathogens on raw fruits and vegetables. *Microbes Infect.* 4: 413-423.
Beuchat LR, Scouten AJ. 2002. Combined effects of water activity, temperature and chemical treatments on the survival of *Salmonella* and *Escherichia coli* O157:H7 on alfalfa seeds. *J. Appl. Microbiol.* 92: 382-395.
Beuchat LR, Ward TE, Pettigrew CA. 2001. Comparison of chlorine and a prototype produce wash product for effectiveness in killing *Salmonella* and *Escherichia coli* O157:H7 on alfalfa seeds. *J. Food Prot.* 64: 152-158.
Buck JW, Walcott RR, Beuchat LR. 2003. Recent trends in microbiological safety of fruits and vegetables. Online. *Plant Health Progress*. doi: 10.1094/PHP-2003-0121-01-RV.
Burnett SL, Beuchat LR. 2001. Food-borne pathogens – human pathogens associated with raw produce and unpasteurized juices, and difficulties in decontamination. *J.Indust. Microbiol. & Biotechnol.* 27: 104-110.
Burnett SL, Beuchat LR. 2001. Human pathogens associated with raw produce and unpasteurized juices, and difficulties in contamination. *J. Indust. Microbiol.& Biotechnol.* 27: 104-110.
Carmichael I, Harper IS, Coventry MJ, Taylor PWJ, Wan J, Hickey MW. 1999. Bacterial colonization and biofilm-development on minimally processed vegetables. *J. Appl. Microbiol.* 85 (Symposium Suppl.): 45S-51S.
Daniel P, Daniel B. 2011. Rawlicious: delicious raw recipes for radiant health. North Atlantic Books, Berkeley, California.
Delaquis PJ, Sholberg PL, Stanich K. 1999. Disinfection of mung bean seed with gaseous acetic acid. *J, Food Prot.* 62: 953-957.
Deng XS, Tuo J, Poulsen HE, Loft S. 1998. Prevention of oxidative DNA damage in rats by Brussels sprouts. *Free Radical Research* 28(3): 323-333.
De Onis M, Frongillo EA, Blössner M. 2000. Is mulnitrition declining? An analysis of changes in levels of child malnutrition since 1980. *Bulletin of the World Health Organization* 78: 1222-1233.
DeRoever C. 1998. Microbiological safety evaluations and recommendations on fresh produce. *Food Control* 9: 321-347.
European Commission, 2011. Roadmap to a resource efficient Europe, 25 p. http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf
Fahey JW, Zhang Y, Talaly P. 1997. Broccoli sprouts: an exceptionally rich source of inducers of enzymes that protect against chemical carcinogens. *Proc. Natl. Acad. Sci.* USA 94: 10367-10372.
Fahey JW, Stephenson KK. 1999. Cancer chemoprotective effects of cruciferous vegetables. *HortScience* 34: 1159-1163.
Fahey JW, Zalcmann AT, Talalay P. 2001. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochemistry* 56: 5-51.
Fan X, Thayer DW. 2001. Quality of irradiated alfalfa sprouts. *Journal of Food Protection* 64(10): 1574-1578.
FAO. 2011. The state of food insecurity in the world. Food and Agriculture Organization of the United Nations, Rome. 55 pp.
Farkas J. 2006. Irradiation for better foods. *Trends in Food Science & Technology* 17: 148-152.
Frank C, Werber D, Cramer JP, Askar M, Faber M, an der Heiden M, Bernard, H, Fruth A, Prager R, Spode A, Wadl M, Zoufaly A, Jordan S, Kemper MJ, Follin P, Müller L, King LA, Rosner B, Buchholz U, Stark K, Krause G. 2011. Epidemic profile of shiga-toxin-producing *Escherichia coli* O104:H4 outbreak in Germany. *N. Engl. J. Med.* 365: 1771-1780.
Franks E, Richardson J. 2009. Microgreens: A guide to growing nutrient-packed greens. Gibbs Smith, Layton, Utah.
Friedman H, Rot I, Agami O, Vinokur Y, Rodov V, Resnick N et.al. 2007. Edible flowers: new crops with potential health benefits. *Acta Horticulturae* 755: 283-289.
Gill CIR, Haldar S, Porter S, Matthews S, Sullivan S, Coulter J, McGlynn H, Rowland I. 2004. The effect of cruciferous and leguminous sprouts on genotoxicity,*in vitro* and *in vivo*. *Cancer Epidemiology Biomarkers & Prevention* 13:1199-1205.
Grondeau C, Samson R. 1994. A review of thermotherapy to free plant materials from pathogens, especially seeds from bacteria. *Crit. Rev. Plant Sci.* 13: 57-75.
Guiterrez E. 1997. Japan prepares as O157 strikes again. *Lancet* 349: 1156. http://sfp.ucdavis.edu/pubs/brochures/specialtyflo.html.Hedberg, CW, MacDonald KL,, Osterholm MT. 1994. Changing epidemiology of foodborne disease: A Minnesota perspective. *Clin. Infect. Dis.* 18: 671-682.
Hill F. 2011. How to grow micrtogreens - nature's own superfood. CSIRO Publishing, Collingwood Victoria 3066, Australia..
Intentional Community Wiki. 2011. Lebensreform. Online: . http://wiki.ic.org/wiki/Lebensreform#Nutritional_reforms_and_ecological_agriculture:
Issa-Zacharia A, Kamitani Y, Muhimbula HS, Ndabikunze BK. 2010. A review of microbiological safety of fruits and vegetables and the introduction of electrolyzed water as an alternative to sodium hypochlorite solution.
Jamnadass RH, Dawson IK, Franzel S, Leakey RRB, Mithofer D, Akinnifesi FK, Tchoundjeu Z. 2011. Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallhoders' agroforestry systems: a review. International Forestry Review 13, 1-17.
Jaquette CB, Beuchat LR, Mahon BE. 1996. Efficacy of chlorine and heat treatment in killing *Salmonella* Stanley inoculated onto alfalfa seeds and growth and survival of the pathogen during sprouting and storage. *Appl. Environ. Microbiol.* 62: 2212-2215.

Kaisoon O, Siriamornpun S, Weerapreeyakul N, Meeso N. 2011. Phenolic compounds and antioxidant activities of edible flowers from Thailand. *J. Functional Foods* 3: 88-99.
Keatinge JDH, Yang R-Y, Hughes J d'A, Easdown WJ, Holmer R. 2011. The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals. Food Security 3: 491-501.
Keatinge JDH, Chadha ML, Hughes J d'A., Easdown WJ, Holmer RJ, Tenkuano A, Yang RY, Mavlyanova R, Neave S, Afari-Sefa V, Luther G, Ravishankar M, Ojiewo C, Belarmino M, Ebert A, Wang JF, Lin LJ. 2012. Vegetable home, school, community and disaster recovery gardens and their impact on the attainment of the Millennium Development Goals: Retrospective and perspective for research and development (in preparation).
Kelley KM, Behe BK, Biernbaum JA, Poff KL. 2001. Consumer ratings of edible flower quality, mix and color. *HortTechnology* 11: 644-647.
Kelley KM, Behe BK, Biernbaum JA, Poff KL. 2002. Combinations of colors and species of containerized edible flowers: effect on consumer preferences. *HortScience* 37: 218-221.
Kelley KM, Cameron AC, Biernbaum JA, Poff KL. 2003. Effect of storage temperature on the quality of edible flowers. *Postharvest Biology and Technology* 27: 341-344.
Kuijper EJ, Soonawala D, Vermont C, van Dissel JT. 2011. Household transmission of haemolytic uraemic syndrome associated with *Escherichia coli* O104:H4 in the Netherlands, May 2011. Euro Surveill. 2011; 16(25):pii=19897. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=19897.
Lang MM, Ingham BH, Ingham SC. 2000. Efficacy of novel organic acid and hypochlorite treatments for eliminating *Escherichia coli* O157:H7 from alfalfa seeds prior to sprouting. Intl. J. Food Microbiol. 58: 73-82.
Lee JS, Pill WG, Cobb BB, Olszewski M. 2004. Seed treatments to advance greenhouse establishment of beet and chard microgreens. *J. Hort. Sci. Biotechnol.* 79: 565-570.
Leistner L. 2000. Basis aspects of food preservation by hurdle technology. *Intl. J. Food Microbiol*. 55: 181-186.
Lorenz K. 1980. Cereal sprouts: composition, nutritive value, food applications. *Critical Reviews in Food Science and Nutrition* 13(4): 353-385.
Mahon BE, Ponka A, Hall WN, Komatsu K, Dietrich SE, Siitonen A, Cage G, Hayes PS, LambertFair MA, Bean NH, Griffin PM, Slutsker L. 1997. An international outbreak of *Salmonella* infections caused by alfalfa sprouts grown from contaminated seeds. *J. Inf. Dis.* 175: 876-882.
Mazzoni AM, Sharma RR, Demirci A, Ziegler GR. 2001. Supercritical carbon dioxide treatment to inactivate aerobic microorganisms on alfalfa seeds. *J. Food Safety* 21: 215-223.
Meyerowitz S. 2010. Sprouts, the miracle food: the complete guide to sprouting. Sproutman Publication, Great Barrington, Mass. 01230, USA, 8th edition.
Mlcek J, Rop O. 2011. Fresh edible flowers of ornamental plants - a new source of neutraceutical foods. *Trends in Food Science & Technology* 22: 561-569.
Murphy CJ. 2006. Greenhouse production of microgreens: growth media, fertilization and seed treatments. M.S. Dissertation, University of Delaware, 89 p.
Murphy CJ, Llort KF, Pill WG. 2010. Factors affecting the growth of microgreen table beet. Intern. J. Vegetable Science 16(3): 253-266.
NACMCF (National Advisory Committee on Microbiological Criteria for Foods). 1999. Microbiological safety evaluations and recommendations on sprouted seeds. *Int. J. Food Microbiol.* 52: 123-153.
Nakamura Y, Kaihara A, Yoshii K, Tsumura Y, Ishimitsu S, Tonogai Y. 2001. Content and composition of isoflavonoids in mature or immature beans and bean sprouts consumed in Japan. *Journal of Health Science* 47(4): 394-396.
Panavas T, Rubinstein B. 1998. Oxidative events during programmed cell death of daylily (*Hemerocallis* hybrid) petals. *Plant Science* 133: 125-138.
Pill WG, Collins CM, Gregory N, Evans TA. 2011. Application method and rate of Trichoderma species as a biological control agaisnt Pythium aphanidermatum (Edson) Fitzp. in the production of microgreen table beets (Beta vulgaris L.). *Scientiae Horticulturae* 129: 914-918.
Prokopowich D, Blank G. 1991. Microbiological evaluation of vegetable sprouts and seeds. *J. Food Prot.* 54: 560-562.
Puckhaber LS, Stipanovic D, Bost GA. 2002. Analyses for flavonoid aglycones in fresh and preserved *Hibiscus* flowers. In: Janick J and Whipkey A (eds.). *Trends in new crops and new uses.* ASHS Press, Alexandria, VA, U.S.A. pp. 556-563.
Puohiniemi R, Heiskanen T, Siitonen A. 1997. Molecular epidemiology of two international sprout-borne Salmonella outbreaks. *J. Clin. Microbiol*. 35: 2487-2491.
Que F, Mao LC, Zheng XJ. 2007. In vitro and in vivo antioxidant activities of daylily flowers and the involvement of phenolic compounds. *Asia Pacific J. Clinical Nutrition* 16: 196-203.
Rajkowski KT, Thayer DW. 2000. Reduction of *Salmonella* spp. and strains of *Escherichia coli* O157:H7 by gamma radiation of inoculated sprouts. *J. Food Prot.* 63: 871-875.
Rojanapo W, Tepsuwan A. 1992. Mutagenic and antimutagenic activities of some vegetables. *Bull. Dept. Med. Serv.* 17: 461-469.
Schneider E. 2001. The essential reference: Vegetables from amaranth to zucchini. HarperCollins Publishers Inc. New York, U.S.A. 777 p.
Scouten AJ, Beuchat LR. 2002. Combined effects of chemical, heat and ultrasound treatments to kill Salmonella and Escherichia coli O157:H7 on alfalfa seeds. *J. Appl. Microbiol.* 92: 668-674.
Shapiro TA, Fahey JW, Wade KL, Stephenson KK, Talalay P. 2001. Chemoprotective glucosinolates and isothiocyanates of broccoli sprouts: metabolism and excretion in humans. *Cancer Epidemiology Biomarkers & Prevention* 10:501-508.
Shurtleff W, Aoyagi A. 2007. History of soy sprouts. In: History of soybeans and soyfoods: 1100 B.C. to the 1980s (unpublished manuscript). Copyright 2007 Soyinfo Center, Lafayette, California. http://www.soyinfocenter.com/HSS/sprouts.php.
Singh N, Singh RK, Bhunia AK, Stroshine RL. 2002. Effect of inoculation and washing methods on the efficacy of different sanitizers against *Escherichia coli* O147:H7 on lettuce. *Food Microbiol.* 19: 183-193.
Slow Food Foundation. 2011. A thousand gardens in Africa. http://www.slowfoodfoundation.org/filemanager/I%20progetti/Mille%20orti%20in%20Africa/INGL-a5%20vademecum.pdf.
Smythe L. 2011. History of edible flowers. Online. http://voices.yahoo.com/shared/print.shtml?content_type=article&content_type_id=399382.

Stahler, C. 2011. How many of the Americans eat vegetarian meals? And how many adults in the U.S. are vegan? http://www.vrg.org/journal/vj2011issue4/vj2011issue4poll.php.
Story JA, LePage SL, Petro MS, West LG, Cassidy MM, Lightfoot FG, Vahouny GV. 1984. Interactions of alfalfa plant and sprout saponins with cholesterol in vitro and in cholesterol-fed rats. *The American Journal of Clinical Nutrition* 39: 917-929.
Taormina PJ, Beuchat LR, Slutsker L. 1999. Infections associated with eating seed sprouts: An international concern. *Emerg. Infect. Dis.* 5: 626-634.
Taormina PJ, Beuchat LR. 1999. Comparison of chemical treatments to eliminate enterohemorrhagic Escherichia coli O157:H7 on alfalfa seeds. *J. Food Prot.* 62: 318-324.
Taylor E, Bates J, Kenyon D, Maccaferri M, Thomas J. 2002. Modern molecular methods for characterization and diagnosis of seed-borne fungal pathogens. *J. Plant Pathology* 83: 75-81.
The China Post. 2011a. Economic crisis gives boos to 'Slow Food' movement. The China Post, Arts & Leisure, November 20, 2011, p. 7.
The China Post, 2011b. Celebs go vegan. The China Post, December 4, 2011, p. 1.
van Hofsten B. 1979. Legume sprouts as a source of protein and other nutrients. *J. Am. Oil Chemists' Soc.* 56: 382.
Yang R-Y, Hanson PM, Lumpkin TA . 2007. Better health through horticulture – AVRDC's approach to improved nutrition of the poor. *Acta Hort*. 744: 71-77.
Weissinger WR, Beuchat LR. 2000. Comparison of aqueous chemical treatments to eliminate Salmonella on alfalfa seeds. *J. Food Prot.* 63: 1475-1482.
Weissinger WR, McWatters KH, Beuchat LR. 2001. Evaluation of volatile chemical treatments for lethality to *Salmonella* on alfalfa seeds and sprouts. *J. Food Prot.* 64: 442-450.
Wongwattanasathien O, Kangsadalampai K, Tongyonk L. 2010. Antimutagenicity of some flowers grown in Thailand. *Food and Chemical Toxicology* 48: 1045-1051.
Zhang X. 2007. New approaches on improving the quality and safety of fresh cut fruits and vegetables. Proc. IC on Qual. Manag. Fresh Cut Produce. *Acta Hort*. 746: 97-102.

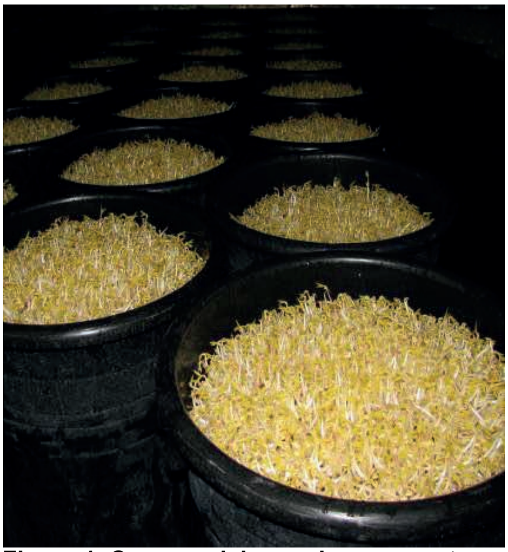

Figure 1. Commercial mungbean sprout production.

Figure 2. Microgreens and edible flowers enhancing a salad

Developing farmer seed enterprises to preserve and promote underutilized indigenous vegetables

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ABSTRACT
Informal seed systems, such as farmer-to-farmer exchanges and farmer self-saved seed, are critical components of resource poor farming systems. This local seed production and distribution facilitates maintenance of crop bio-diversity by preserving in situ locally adapted vegetable varieties and by broadening the genetic base of production with multiple varieties adapted to specific production systems and micro-climates. They also enhance seed and food security during periods of instability or natural disaster, including changing environmental conditions. A rich diversity of underutilized vegetable species function within these informal seed systems in Southeast Asia, yet current efforts to conserve, improve, and disseminate indigenous species are failing. A strategy was developed to link an innovative seed bank, local farmers and non-commercial seed traders, with developing markets, supported by accessible information made available through a local outreach network. Impacts included identification of key vegetable seed traders and farmers functioning within targeted regions of high species diversity, inventories of important indigenous vegetable species, documentation of specific indigenous knowledge surrounding the culture of key vegetable crops, and expanded exchange and distribution of locally adapted underutilized species. This project paves the way for potential longer term benefits including formation of seed bank-farmer linkages that allow non-commercial seed producers to access new varieties, hybrids and high-value seed resources not available from traditional sources, development of value chains around key indigenous vegetable species, and regional distribution of important seed resources to less developed neighbor nations.

Keywords
germplasm, informal seed system, seed bank

INTRODUCTION
In much of the developing world, local or informal seed systems are critically important sources of seed for smallholder farmers (Seboka and Deressa 2000; Thiele 1999). The formal

seed system, comprised of government entities, private and commercial seed companies are reported to supply less than 20% of seed for most food crops in developing countries (Almekinders et al. 1994; Sperling and McGuire 2010). Thus, local seed production and distribution facilitates maintenance of crop bio-diversity by preserving in situ locally adapted varieties and by broadening the genetic base of production with multiple varieties adapted to specific production systems and micro-climates (Louette et al. 1997; Van Dusen 2000; Bellon et al. 2003). These informal seed systems are also critical for seed and food security during periods of instability or natural disaster, including changing environmental conditions (Sperling 2002).

Underutilized species are central to local seed systems and play an important role in smallholder farmer livelihoods. Additionally, many of these lesser known species have significant untapped potential for commercialization. Currently very few crop species form the foundation of the world's agriculture system. Studies indicate that less than 150 plant species are commercialized and in use on a global scale-just 12 of these provide approximately 75% of the world's food (Bermejo and Leon 1994; Padulosi and Frison 1999). In Southeast Asia alone however, there are an estimated 1,500 to 2,000 plant species supplementing the food system, and the Indo-Burma region has been identified as one of the world's "biodiversity hotspots" in need of conservation (Engle and Faustino 2007; Myers et al. 2000).

Opportunities exist for underutilized plant species, including indigenous and traditional vegetables, to be used as a potent development tool. Wise use of this genetic resource can contribute substantially to food security, increased incomes among the poor, improved nutrition and health, and sustainable, healthy ecosystems. Indeed, others such as the Strategic Framework for Underutilized Plant Species Research and Development have suggested the following areas of focus: 1) generation of new knowledge through mapping of indigenous knowledge and additional research to increase the global knowledge base, 2) better communication of this information to raise awareness and build capacity among stakeholders and increase demand for underutilized plants, 3) influence policy to remove barriers to production and marketing, and 4) improved market development through practical interventions, entrepreneurship and fostering public-private partnerships (Hoeschle-Zeledon and Jaenicke 2007).

With support from USAID's Horticulture Collaborative Research Support Program (Hort CRSP), managed through the University of California, Davis, efforts were initiated in 2010 to begin strengthening indigenous informal seed systems in northern Thailand and Cambodia. The project was premised on several well-established facts:

- Informal seed systems, such as farmer-to-farmer exchanges and farmer self-saved seed, are critical components of resource poor farming systems in Southeast Asia.
- A rich diversity of underutilized species function within these systems, particularly among ethnic groups and smallholder farmers.
- Current efforts to conserve, improve, and disseminate local species are insufficient, and the indigenous knowledge surrounding this local seed system is threatened, and/or eroding.
- To optimize these informal seed systems we need to better understand their characteristics, pathways and gatekeepers, and we need to improve local stakeholder capacity, and access to information, technology and high quality seed.

A key project goal was the characterization of the informal seed system, including the documentation of indigenous annual and perennial vegetable crops, seed pathways and "germplasm gatekeepers", along with the conservation of the knowledge surrounding the local system. Additional objectives included facilitation of the exchange, preservation and dissemination of important genetic resources identified during farmer community surveys, and improvement of local access to quality seed and important seed information.

MATERIALS AND METHODS

In much of the developing world, formal centralized seed production systems have limited interaction with the local, informal seed systems responsible for 80-90% of the seed sown in farmer's fields (Cooper 1993; Sperling and McGuire 2010). A consequence of this situation is low adoption rates of modern or improved varieties among smallholder farmers. In recent years, increased attention and resources have been devoted to farmer seed enterprises (FSEs) as a means of improving the informal seed system. While FSEs have been shown to positively impact certain problems associated with seed supply bottlenecks, the challenges of such systems remain formidable (David 2004). A component of the project strategy described here includes linking an innovative, NGO-based seed bank to the local, informal seed system, and supporting this relationship via an NGO-university partnership. Additionally, the research team spent significant amounts of time in focus village clusters, interacting with the various local seed system actors.

Researchers employed several data collection approaches: photo card sorts with small groups; targeted, semi-structured household interviews and observations with wealth-stratified samples; and inter-village seed swaps to foster information exchange and discussion among different villages. Interviews were conducted in each home and garden/farm to permit observation of actual seed-saving and storage practices. Interviews covered specific examples of novel and annual seed acquisition, seed trade pathways, and seed selection and saving practices.

Farmer-innovated seed preservation and storage methods were also recorded in each of the village clusters. Selected households that were identified during the village card sorts were visited for more in-depth interviews over 2 weeks and as an opportunity to acquire farmer-saved seeds for the ECHO Asia Regional seed bank, and for research. Four villages were selected in each of three village clusters, and at least 10% of the households were interviewed in each village.

During the interview, households were asked to share about their various indigenous vegetable seeds, donate seeds to the seed bank and research project, and describe their seed harvest, preservation and storage methods. Researchers asked for typical seed that farmers would plant in their field as a way to acquire a representative sample of farmer-selected germplasm. Seed viability experiments were conducted at the village-level to procure real-time germination data while the social surveys were being conducted, and to stimulate interest in simple research methodologies within the village. A portion of donated seed was also transferred to the ECHO seed bank for additional evaluation, and potential grow-out and distribution to development workers across the region.

RESULTS AND DISCUSSION

Although successful attempts to document underutilized species, seed pathways and other parts of the informal seed system have been conducted across the world (Louette et al. 1997; Mazhar 2000; Seboka and Deressa 2000), this research extends these approaches into a holistic appraisal of the informal seed system in ethnic communities of northern Thailand and Cambodia. This effort specifically reveals the value and effectiveness of strategies such as seed fairs, and linking the local informal seed system to an established NGO-based seed bank. Such an approach also demonstrates the general value of investing in local, indigenous informal seed systems, as it leads to an optimization of the functionality of the system, providing multiple benefits beyond simply the local communities directly involved.

Seed system inventories

Village surveys resulted in accurate identification and compilation of key annual and perennial vegetable species, germplasm maps, and identification of key "gatekeepers" within the informal seed systems of target villages. Thus far, seed accessions of 95 species have been collected from the three village clusters for seed germination and vigor trials, and evaluation for future value chain development.

It is notable that much of the robust diversity present within the northern Thailand food system is due to perennial species used as vegetables. Locally important perennial plants often contribute to family nutrition in significant ways, but are sometimes overlooked during inventories of underutilized indigenous vegetables. This is particularly true if the species are foraged from the wild, versus tended in garden plots or farmer's fields. Underutilized perennial species are also important from an ecosystem sustainability perspective. In northern Thailand, fields of hill tribe farmers tend to be steep and highly erodible. A shift to more conventional annual crop species would present numerous challenges to the long-term productivity and sustainability of the hill tribe farming system. Tables 1 and 2 provide a partial list of some of the more important underutilized perennial species resulting from this survey.

A great deal of phenotypic variation within single species was also noted. For example, whereas eggplant was commonly grown across all village clusters, numerous "types" were present and farmers showed preferences based on these variations as related to specific growing conditions and locations. Many other underutilized traditional or indigenous vegetable species are valuable from the standpoint of variability. In many cases this local adaptability could be exploited and warrants further study.

Local seed exchange and education

At the conclusion of each 1-month survey period in each village cluster, a regional seed fair was conducted, along with educational activities related to relevant seed technology topics. These activities were successful on a variety of levels, and were highly valued by the farmers and villagers in attendance.

The seed fair events gave many participating farmers a new perspective by showing them in concrete terms that they are, in fact, in control of their own seed system. In many respects, these seed fairs served as a catalyst, inspiring farmers to self-organize and conduct additional seed fairs in the future on a more regular basis. The fairs also created opportunities for farmers to exchange seed which is locally adapted to their conditions and largely unavailable from formal, commercial seed sources. Farmers at the fairs valued the diversity of the seed present, and often left with new varieties they had not previously grown.

The seed fairs also served as a venue to encourage new interactions between different villages, and socio-economic groups within the same village. Our survey results revealed that seed trading pathways in the hill tribes are more confined to ethnic lines than anticipated, with just a few reported cases of seed being traded across ethno-linguistic lines. Additionally, poor villagers tend to trade with poor villagers rather than approaching wealthier members to trade or borrow seed. The seed fairs reduced barriers and brought people together in new ways, under new circumstances. This allowed for improved communication and education around topics such as seed production, harvest and storage.

The seed fairs conducted in the three village clusters strengthened the local seed system in a variety of ways-local seed culture was strengthened, farmers knowledge was improved, and farmers were motivated to mobilized and self-organize. Steps should be taken by community leaders, NGO personnel, and seed professionals to promote seed fairs and further develop and improve upon their effectiveness and impact.

NGO seed bank-farmer linkages

A unique aspect of this project was the development of linkages between the ECHO Asia Impact Center (Chiang Mai, Thailand), its seed bank located on the farm of the Upland Holistic Development Project (Mae Ai, Thailand) and actors within the local, informal seed system. Varieties of important but underutilized crops that are often difficult to access are evaluated at the ECHO seed bank facility. Additionally, seeds from proven open-pollinated varieties are either produced by the seed bank, or accessed from local farmers, for distribution among ECHO's clientele. Crops being evaluated, produced and distributed by the seed bank include nitrogen-fixing trees, vegetables, green manure cover crops, oil crops and agroforest species. The seed bank also promotes seed saving and seed sharing among its network and provides educational support. Crops promoted and distributed are traditional, indigenous or regionally adapted. ECHO partners who receive plant material from the seed bank are invited to offer feedback on the performance of each crop under their particular growing conditions. Such information helps ECHO to better evaluate the suitability of its seed bank varieties to natural conditions in those locations and to offer informed recommendations for potential crop selections by development partners.

The model suggested here, involving farmers and farmer associations within the informal seed system, local NGO's and an NGO-based seed bank, and broader based support from either regional NGO's or universities, is versatile and has certain advantages. Many of the underutilized species revealed in the village surveys have potential and are being evaluated in a regional development context (Table 1 and 2). The relationship between the local hill tribe seed system and the ECHO-based seed bank potentially improves system sustainability, offers new economic opportunities for local farmers, and increases distribution of high quality, locally adapted seed to other farmers and development workers in the region. Our results indicate that seed produced by local farmers is generally similar in quality to seed from commercial sources. As particular species become more visible, and gain in popularity, increasing supply to meet demand could be a constraint. However, this scenario does offer new market opportunities-particularly to hill tribe women farmers. Because the seed bank also distributes seed to poor farmers, as well as development workers, the system described here could also facilitate the movement and adoption of improved seed from the formal seed system. It builds upon existing local experience, knowledge and skills. It provides poor farmers who may not be able to afford commercial seed, access to high quality, locally adapted varieties. And, it represents a holistic and inherently strong approach, as it relies upon partnerships and networks from all aspects of the informal seed system. It is also important to note that this project was preliminary and limited in scope and duration-weaknesses and bottlenecks identified in this study warrant further testing and modification.

CONCLUSION

This research outlines practical steps and activities for strengthening indigenous seed systems in northern Thai and Cambodian communities and potentially extending the reach and impact of valuable, locally-adapted crop species. The key to success is the adoption of a holistic approach that empowers resource-poor households and communities, fortifies indigenous seed pathways, promotes seed system best practices, and preserves and improves the rich genetic biodiversity of the system. In order to continue strengthening of informal seed systems within the region, there is the need to expand this research and extend it into other communities and countries. This scale-up is critical to preserving biodiversity, ensuring food security and facilitating the sustainable development of these rural agroecosystems. For maximum impact, it is hoped that this methodological approach to strengthening informal seed systems can be extended into other countries in South and Southeast Asia faced with community food insecurity, including Bangladesh, Cambodia, Laos, and Vietnam.

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References

Almekinders, C.J.M., N.P. Louwaars and G.H. de Bruijn. 1994. Local seed systems and their importance for an improved seed supply in developing countries. Euphytica 78:207-216.

Bellon, M., J. Berthaud, M. Smale, J.A. Aguirre, S. Taba, F. Aragón, J. Díaz, and H. Castro. 2003. Participatory landrace selection for on farm conservation: An example from the Central Valleys of Oaxaca, Mexico. Genetic Resources and Crop Evolution 50:401–416. Berthaud, J., J.C. Clement, L. Emperaire, D.

Bermejo, J.EH and Leon, J. (eds.). 1994. Neglected crops: 1492 from a different perspective. Plant Production and Protection Series No. 26. FAO, Rome Italy p.181-191.

Cooper, D. 1993. Plant genetic diversity and small farmers: Issues and options for IFAD.

Staff Working Paper No. 13. Rome: International Fund for Agricultural Development.

David, Soniia. 2004. Farmer seed enterprises: A sustainable approach to seed delivery? Agriculture and Human Values 21:387-397.

Engle, L.M. and F.C. Faustino. 2007. Conserving the indigenous vegetable germplasm of Southeast Asia. Acta Hort. 752:55-60.
Hoeschle-Zeledon, I. and H. Jaenicke. 2007. A strategic framework for global research and development of underutilized plant species: a contribution to the enhancement of indigenous vegetables and legumes. Proc. 1st IC on Indig. Veg. and Legumes. P. 103-110.
Louette, D., A. Charrier, and J. Berthaud. 1997. In situ conservation of maize in Mexico: Genetic diversity and maize seed management in a traditional community. Economic Botany 51:20–38.
Mazhar, F. 2000. Seed conservation and management: participatory approaches of Nayahrishi Seed Network in Bangladesh. In: E. Friis-Hansen and B. Sthapit (eds.), Participatory Approaches to the Conservation and Use of Plant Genetic Resources, International Plant Genetic Resources Institute, Rome, Italy, pp. 149–153.
Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.
Padulosi, S. and E. Frison. 1999. The role of underutilized plant species in the 21st Century. Global Forum for Agriculture Research, Rome, Italy.
Seboka, B., and A. Deressa. 2000. Validating farmers' indigenous social networks for local seed supply in Central Rift Valley of Ethiopia. Journal of Agricultural Education and Extension 6:245–254.
Sperling, L., and S. McGuire. 2010. Understanding and strengthening informal seed markets. Experimental Agriculture 46(2):119-136.
Sperling, L. 2002. Emergency seed aid in Kenya: Some case study insights from lessons
learned during the 1990's. Journal of Disaster Studies, Policy and Management 26(4):283-287.
Thiele, G. 1999. Informal potato seed systems in the Andes: Why are they important and what should we do with them? World Development 27:83–99.
Van Dusen, M. E. 2000. In Situ Conservation of Crop Genetic Resources in the Mexican Milpa System. Ph D. dissertation. University of California, Davis.

TABLES

Table 1. Partial list of underutilized but regionally important annual and perennial species often consumed as vegetables in hill tribe communities of northern Thailand. These species are rarely used as vegetables outside the research focus area.

Family	Scientific Name	Common Name	Thai Name (ภาษาไทย)	Edible Portion
Perennials				
Araceae	*Lasia spinosa*	spiny vegetable	phak naam/ผักหนาม	stems
Araliaceae	*Trevesia palmata*	snowflake tree	tang luang/ต้างหลวง	shoots/flowers
Arecacea	*Caryota mitis*	fish tail palm	tao rang daeng/เต่าร้างแดง	inner core (heart)
Asclepiadaceae	*Gymnema inodorum*	chiang daa	chiang daa/เชียงดา	shoots
Bignoniaceae	*Oroxylum indicum*	indian trumpet	pheka/เพกา	flowers/pods
Fabaceae	*Acacia concinna*	shikakai	sompoi/ส้มป่อย	shoots/flowers/pods
Moraceae	*Broussonetia kurzii*	mulberry leaf	salae/สะแล	fruit/young leaves
Moraceae	*Ficus racemosa*	cluster fig	madeua kliang/มะเดื่อเกลี้ยง	leaf shoots
Moraceae	*Ficus virens*	red shoot fig	phak hued/ผักเฮือด	leaf shoots
Verbenaceae	*Clerodendrum glandulosum*	clerodendrum	nang yaem pa/นางแย้มป่า	leaf shoots
Annuals				
Amaranthaceae	*Celosia argentea*	celosia/cockscomb	dawk ngawn kai/ดอกหงอนไก่	shoots/flowers

Table 2. Partial list of fairly underutilized but regionally important annual and perennial species often consumed as vegetables in hill tribe communities of northern Thailand. Use of these vegetables outside the research focus area is uncommon, and/or plant part consumed is atypical.

Family	Scientific Name	Common Name	Thai Name (ภาษาไทย)	Edible Portion
Perennials				
Anacardiaceae	*Spondias pinnata*	hog plum	makawk pa/มะกอก	flowers/fruit/leaf shoots
Araliaceae	*Eleutherococcus trifoliatus*	climbing ginseng	phak paem/ผักแปม	leaves
Arecacea	*Calamus siamensis*	white thorn rattan	wai khom/หวายขม	shoots
Arecacea	*Calamus viminalis*	white thorn rattan	wai nam khao/หวายหนามขาว	shoots
Athyriaceae	*Diplazium esculentum*	vegetable fern	phak kuut/ ผักกูด	shoots
Cucurbitaceae	*Coccinia grandis*	ivy gourd	phak tam leung/ ตำลึง	fruit
Fabaceae	*Acacia pennata*	climbing wattle	cha-om/ชะอม	leaf shoots
Piperaceae	*Piper sarmentosum*	leaf pepper	chaphlu/ชาพลู	leaves
Annuals				
Fabaceae	*Canavalia gladiata*	sword bean	thua daap/ถั่วดาบ	seeds
Asteraceae	*Lactuca indica*	tropical lettuce	phak kaat hawm baan/ นางแย้มป่า	leaves

Improving the supply chain management for vegetables through contract farming and organized food retail chains: Indian experience

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ABSTRACT

Indian agriculture is diversifying towards high value commodities comprising of vegetables, fruits, livestock and fisheries due to changing consumption patterns, fast urbanization and increase in income levels. The vegetable production has recorded a growth rate of 4.5 percent per annum during 1991- 2010 period as compared to the average growth of 2.5 percent per annum of the agricultural sector as a whole. Vegetable production represents an important area for income growth, especially for small and marginal famers who constitute bulk of the agricultural households. Vegetables being perishable, bulky with low shelf life, the supply chain management issues have become complicated. Most often, the supply chain for vegetables is unorganized, fragmented and exploitative resulting in low producers share in consumers' rupee. In this study, the backward integration approach adopted by the corporate and food retail chains in improving the supply chain for vegetables have been analysed.

The experiences of contracting firms both of foreign and domestic origin in India indicate strong evidence of backward and forward linkages benefitting farmers. These firms provided quality inputs such as branded seeds, fertilizers, and plant protection chemicals to the farmers at their farm gate coupled with the technical advice on production aspects. This enabled the farmers to reduce their working capital needs. The linkage substantially reduced their transaction cost per unit of output as the marketing was taken care by the firm. Specifically, contract farming helped farmers to improve their income levels by adopting intensified agriculture in high value crops and reduction in transaction costs. However, due to the poor resource and capital base, most small and marginal farmers appeared to be excluded from such institutional arrangement.

The Food Retail Chains (FRC) are evolving and growing at a fast pace in India. The FRCs were found to depend mostly on the existing channels of marketing to source fresh vegetables and not practicing backward integration because of the restrictions from the existing market laws besides operational difficulties. In the recent years, amendments in market regulation Act in some states of India have enabled few of the FRCs to establish backward linkages with farmers for procuring fresh vegetables following a Farmer - Vendor model wherein FRC directly purchased vegetables from selected famers without entering in to a contract. This arrangement reduced the market risks and transaction costs to the farmers. Enabling direct supply of vegetables by farmers enabled FRCs to increase their control over quality, supply reliability and price stability. Farmer's who had opportunities to tie up with FRCs have realised higher returns through growing high value vegetables including exotic types, following improved agricultural practices and reduction in transaction cost. The concept of Ready to

Retail adopted by the FRC is to the benefit of the farmer –vendors as they realised higher returns by performing additional marketing functions such as sorting, cleaning, grading and packing at the farm level. Again, limited number of small and marginal farmers participated in this model because of their limitation to invest in creating irrigational facilities which is crucial for growing quality vegetables.

Keywords
Contract, retail, linkages, integration and consolidation

INTRODUCTION

The supply chain aims at integrating supplier and producer processes leading to improved marketing efficiency and reduction in wastages. The concept of a supply chain refers to the flow of materials from their sources (suppliers/producers) to the market or places where they are needed involving a chain of business players viz., processor, logistic providers and retailer. The concept of supply chain management emerged in the 1980s to manage the total flow of goods from suppliers/producers to the ultimate end users and evolved to consider a broad integration of business processes along the chain of supply (Cooper *et al*., 1997; Supply Chain Council, 2005). Supply chain is mainly about the integration of producer with wholesaler/ retailer and the end consumer. Thus, supply chain focuses upstream on integrating supplier and producer processes, improving efficiency and reducing wastages. However, in order to optimize business performance, most of the present day supply chain models, i.e., third generation supply chain, have been synchronizing supply chains and value chains with a view to optimize their business performance.

Recent studies have indicated that agriculture in many countries, more so in Asian countries is diversifying towards high value agriculture and India is no exception. The recent trend in agriculture sector growth implied a shift from low value to High Value Commodities (HVCs) like fruits, vegetables, milk, meat, egg, and also fish. The demand for and supply of these commodities has grown at a much faster rate than that of food grains (Joshi *et al.,* 2004) with the shift being prominent in the last two decades. It has been evident that with increased income, consumers increase their consumption expenditure towards HVCs as they play major role in giving balanced diet (Mittal, 2006). The changes in consumption of HVCs are more conspicuous in quantity terms compared to staple food products. Agricultural diversification is strongly influenced by price policy, infrastructure, urbanization, technological improvements and marketing arrangement. Production of HVCs is associated with vertically coordinated marketing channels, super markets and export-oriented agri-business. In this backdrop, it is interesting to analyze whether the supply chain issues are in tune with the changing demand for HVCs, particularly vegetables an important component in the Indian diet. Specifically, this paper addresses two key issues: 1) whether contract farming has contributed in improving the supply chain management of vegetables, and 2) whether the emerging food retail chains contributed in enhancing the efficiency of supply chain management of vegetables in the Indian context.

Improving the supply chain management in vegetables through contract farming

Contract farming is an institutional economics intervention to provide an environment of competition in the background of an institutional set up. In India, it can be traced back to the colonial period when cotton and indigo were produced by the Indian farmers for factories in United Kingdom (Asokan and Singh 2003). Contract farming is the contractual arrangement between farmers and the company, whether oral or written, specifying one or more conditions of production and/or marketing (Roy 1963). The new agricultural policy of Government of India envisages promoting growth of private sector participation in agribusiness through the contract farming; accelerates technology transfer, capital flow and assured markets for crops.

Contract farming is in vogue in different parts of India for produce *inter alia*, baby corn, chillies, poultry, dairy, sweet corn, papaya, maize, capsicum, onion and gherkins. This section of the paper presents some of the results relating to a survey conducted on contract farming; to examine the effect of vertical coordination on supply chain management of selected vegetables in the state of Karnataka, India. The study has examined the conditions under which contract farming performs effectively for enhancing income and technology transfer to farmers. Specifically, this part of the paper is focused on:

- Relative comparison of features of contract farming offered by domestic and foreign firms.
- Comparison of income, technology and credit access of contract and non-contract farmers.
- Linking of small farmers to contract farming.

Sampling, nature and source of data

A multistage sampling method was used to choose sample farmers. In the first stage, based on the concentration of area under baby corn and chilli contract farming, one domestic firm and one foreign firm were selected. In the second stage, upon discussion with the production manager of the company, a cluster of villages participating in contract farming was chosen. Finally, based on the details maintained by the firm about farmers, around 180 contract farmers, 45 each growing baby corn and green chilli under foreign contracting firm and domestic contracting firm were selected. A sample of 40 farmers who are not involved in contract farming but cultivating baby corn and green chilli in the same area were chosen as control.

Primary data were obtained from the selected farmers using pre-tested survey instruments through personal interview for evaluating objectives of the study. Efforts were made to elicit accurate information from the sample farmers with the assistance of company. The primary data was processed and analysed using measures of central tendency, ratios and proportions. The costs and returns of baby corn and chilli production have been calculated on per acre basis. The costs include: explicit costs, implicit costs and marketing costs. In order to assess the differential impact of contract farming across different classes of farmers Gini coefficients were computed for the income and employment variables. The value of Gini coefficient varies between 0 and 1. If the Gini coefficient is zero, it indicates perfect equality, whereas, if it is one, it implies perfect inequality.

Gini coefficient is calculated by using the formula,

$$G = 1 + \frac{1}{n} - \frac{1}{n^2 y}[Y_1 + 2Y_2 + 3Y_3 + ... + nYn]$$

Where,

G = Gini coefficient
Y = Mean income
$Y_{1 \ldots\ldots\ldots} Y_n$ = Individual net income per farm in descending order in size
n = Size of population.

Area allocation under contract and non-contract farmers

The average gross cropped area of chilli was the highest for farmers under foreign contract firm (8.47 acres) as against 6.27 acres and 5.16 acres for farmers under domestic contract firm and non-contract farmers respectively. Farmers under foreign firm had two times the area under non-contract than contract crops, while domestic firm farmers have two and half times higher area under contract crops than non-contract crops that accounted for 72 per cent. This indicated that major source of income was from contract crop. Around 20 per cent of the total gross cropped area was devoted towards cultivation of chilli in the case of non-contract farmers (Table 1). The average gross cropped area of baby corn was the highest for non-contract farmers (8.79 acres) as against contract farmers (5.22 acres for farmers under domestic contract firm and 5.14 acres for farmers under foreign contract firm). Farmers under domestic firm had equal proportion of area under contract and non-contract crops out of the gross cultivated area. Farmers under foreign firm had about 36 per cent of gross cultivated area under contract crops. Around 30 per cent of the total gross cropped area was devoted towards cultivation of baby corn in the case of non-contract farmers.

Table 1. Area allocation under contract and non-contract by the sample farmers

Particulars	Foreign contract		Domestic contract		Non-contract	
	Baby corn	Chilli	Baby corn	Chilli	Baby corn	Chilli
Area under non-contract crops (acres)	3.27 (63.62)	5.52 (65.16)	2.57 (49.23)	1.73 (27.59)	6.16 (70.08)	4.16 (80.62)
Area under other contract crops (acres) (other than chilli and baby corn)	0.13 (2.53)	2.1 (24.79)	1.84 (35.25)	3.9 (62.20)	NA	NA
Area under baby corn / chilli (acres)	1.74 (33.85)	0.85 (10.05)	0.81 (15.52)	0.64 (10.21)	2.63 (29.92)	1 (19.38)
Gross cropped area	5.14 (100)	8.47 (100)	5.22 (100)	6.27 (100)	8.79 (100)	5.16 (100)

NA: Not applicable

Note: The figures in parentheses indicate per cent to gross cropped area.

Features of contract farming companies

There are some parallel features between the domestic and foreign contract firms. Entrepreneurship and resource endowment of the farmers were the main criteria for choosing farmers for contract by both the category of firms. The company provides the quality inputs such as seeds, fertilizers, plant protection chemicals and the technical know-how and procures output, clearly establishing vertical linkage between firm and farmer (Table 2). Farmers are flexible to grow crops of other companies. Payments are made after deducting the cost of inputs provided.

No compensation was given in the event of crop failure. However, the domestic firm indirectly shared a part of the production risk in the event of crop failure, by way of allotting larger area in the next season to compensate the loss incurred by contract farmer in the previous season. The most striking difference between the domestic and foreign company was the fact that the foreign company was totally export oriented, while the domestic company was mainly producing for local markets with little of the produce for international market (Table 2).

Table 2. Salient features of the contract farming companies

S. No	Particulars	Foreign company	Domestic company
1	Year of establishment in the state	2002	2000
2	Type of contract	Written/Oral	Oral
3	Criteria for choosing farmers	Entrepreneurship, resource endowment (specifically assured groundwater irrigation)	Entrepreneurship, resource endowment (specifically water assured groundwater irrigation)
4	No. of farmers under contract	1500	2500
5	Input supply made	Seeds, fertilizers, plant protection chemicals	Seeds, fertilizers, plant protection chemicals
6	Flexibility to grow crops of other company	Allowed	Allowed
7	Mode of payment	Payment is made after deducting the cost of inputs	Payment is made after deducting the cost of inputs
8	Advanced payment	There is no provision	Sometimes provided.
9	Form of payment	Cheque	Cash
10	Time of payment	20-25 days from the day of last delivery of the produce	15-20 days from the day of last delivery of the produce
11	Compensation in the event of failure of crops	No compensation	Indirectly provided by allocating larger acreage in the ensuring season
12	Crops contracted	Gherkin, chilli, baby corn	Okra, gourds, brinjal, chilli, beans, green peas, carrots, asparagus, baby corn, cole crops, capsicum, onion, lettuces, tomato, cucumbers, greens melons, vegetables,
13	Area	3300 acres (all outsourced)	300 acres (captive) 1200 acres (outsourced)
14	Most common type of contract violation	Selling to other Buyers	Using prohibited pesticides, selling to other buyers,
15	Catchment area	Parts of Bangalore rural and Tumkur Districts.	Parts of Bangalore rural and Ooty.
16	Price fixation	Pre-determined	Pre-determined
17	Research and development unit	Absent	Present
18	Technical guidelines	Provided	Provided
19	Processing unit	Semi processing unit	Processing unit with sophisticated refrigeration for fresh packing of commodities
20	Value added commodities traded	Canned and pickled items	Fresh frozen
21	Market Destination	International market	Mostly local and limited international market

Comparison of crop loan borrowings

In the case of baby corn, around 38 per cent of the non-contract farmers borrowed credit as crop loan as against 33 and 24 per cent in the case of foreign and domestic firm contract farmers. The average amount of loan borrowed ranged from Rs. 18,600 to Rs 29,893 for contract and non-contract farmers of baby corn respectively (Table 3). In the case of chilli around 53 per cent of the non-contract farmers borrowed credit as crop loan as against 42 and 29 per cent in the case of foreign and domestic firm contract farmers. The average amount of loan borrowed ranged from Rs. 21,263 to 31,276 between contract and non-contract farms in case of chilli.

Table 3. Comparison of crop loan borrowing between contract and non-contract farmers

Credit	Foreign contract		Domestic contract		Non-contract	
	Baby corn	Chilli	Baby corn	Chilli	Baby corn	Chilli
Percentage of farmers borrowing crop loan	33	42	24	29	38	53
Average amount borrowed per farm (Rs)	18600	21263	20625	20846	29893	31276
Percentage of farmers borrowing from Commercial banks	20	16	37	18	47	43
Percentage of farmers borrowing from Cooperatives	73	20	45	9	47	8
Percentage of farmers borrowing from Non institutional agencies	7	7	18	2	6	3

Irrespective of contract farming or otherwise, majority of the farmers borrowed from the institutional sources. Crop loan borrowed by non-contract farmers was 33 per cent higher than contract farmers, as they had to buy material inputs as compared to contract farmers who received support from firms.

Relative share of inputs

The ratio of purchased inputs to owned inputs and purchased inputs to the inputs supplied by the company (Table 4) indicates that for every one unit of owned input, the purchased inputs (and or company supplied inputs) were 5 units in the case of non-contract farmers as against 4 and 3.5 in the case of farmers under foreign and domestic contract respectively for baby corn farmers. Similarly, for every one unit of inputs supplied by the company, the farmers purchased around 1.7 units of inputs and owned input use was 0.7 units in both the type of contracts. Similarly, for the chilli farmers, for every one unit of owned input, the purchased inputs (and or company supplied inputs) were 3 units in the case of non-contract farmers as against 1.2 in the case of farmers under foreign and domestic contract firm. Similarly, for every one unit of inputs supplied by the company, purchased and owned inputs by the contract farmers was around Thus, the contract farmers were greatly benefited due to the provision of cash inputs supplied by the company.

Table 4. Relative share of inputs by domestic and foreign contract firms in the cultivation of baby corn/chilli in Karnataka

Particulars	Foreign contract		Domestic contract		Non-contract	
	Baby corn	Chilli	Baby corn	Chilli	Baby corn	Chilli
Inputs supplied by the company (%)	29.85	47	28.64	25	NA	NA
Inputs purchased by the farmers (%)	50.01	29	49.36	40	83.14	75
Inputs owned by farmers (%)	20.13	24	21.98	35	16.85	25
Ratio of purchased inputs (and or company supplied) to owned inputs	3.96	1.22	3.55	1.15	4.93	3.1
Ratio of owned inputs to inputs supplied by the company	0.69	0.56	0.77	1.41	NA	NA
Ratio of purchased inputs to inputs supplied by the company	1.69	0.61	1.72	1.59	NA	NA

Note: NA: not applicable

Returns realized by contract and non-contract farmers

The production cost of baby corn per acre was Rs 8,499 for contract farmers under foreign firm, while it was Rs 9,948 for contract farmers under domestic firm and Rs 9,653 (Table 8) for non-contract farmers (Table 5). Similarly, production cost of chilli per acre was Rs. 26,657 Rs.24, 484 and Rs. 23,493 per acre for farmers under foreign, domestic contract firms and no-contract respectively. Out of the total cost in baby corn and chilli, the major items of expenditure was towards labour accounting for about 30 per cent and 32 per cent of the total cost in contract farming as against 23 per cent and 32 per cent in non-contract farming respectively. The transaction cost per acre of baby corn and per acre of chilli was Rs 89 and Rs 79 for farmers under foreign firm respectively and Rs 6 under domestic firms for both the crops. While it was Rs. 2,318 per acre for baby corn and Rs. 4,991 per acre for chilli in case of non-contract farmers.

Table 5. Comparison of costs, yield and net returns realized by contract and non-contract farmers

Particulars	Foreign contract		Domestic contract		Non-contract	
	Baby corn	Chilli	Baby corn	Chilli	Baby corn	Chilli
Yield (in Kg)						
I grade	1954	4071	2259	4307	1619	2894
II grade	-	214	-	227	-	-
Price (Rs per kg)						
I grade	7	8	7	8	6.59	10.15
II grade	-	5	-	5	-	-
Returns (Rs per acre)						
Main product	13678	33638	15814	35591	10669	29374
By-product	2871	-	4745	-	2019	-
Gross Returns	16549	33638	20558	35591	12688	29374
Cost of production	8499	26657	9948	24484	9653	23273
Net returns	8050	6981	10610	11108	3035	6101
Cost of production per kg	4.34	6.20	4.40	5.40	5.96	8.00
Returns per kg	4.12	7.9	4.70	7.50	1.87	10.15
Returns per rupee invested	1.95	1.26	2.06	1.45	1.31	1.26

For baby corn, the farmers under domestic contract firm realized higher productivity of 22.59 quintals per acre compared to 19.54 quintals per acre for farmers under foreign firm followed by 16.19 quintals per acre for non-contract farmers. The domestic contract farmers derived higher net return than foreign contract farmers. However, in the case of non-contract, the net return realized (Rs 3,035) was almost three times lesser than domestic contract (Rs 10,610) and almost 2.5 times lesser than foreign contract (Rs 8,050). In the case of chilli, net returns realized per acre under foreign, domestic and non-contract farmers were Rs. 6,981, Rs. 11,108, and Rs.6, 101 respectively.

Effect of contract farming on income

As evident from the results of the study, for small and medium farmers growing baby corn, the proportion of gross contract area to total gross cropped area was around 40 per cent deriving 74 per cent and 63 per cent of their total income from crop enterprises respectively from contract farming. On the contrary, 37 per cent of income was derived from 17 per cent of gross cropped area in case of large farmers. But the income derived from contract crop per acre was highest in small farmers (Rs 7,547), followed by medium farmers (Rs 7,244) and by large farmers (Rs 6,778). In the case of small and medium farmers growing chilli, the proportion of gross contract area to total gross cropped area was around 36 per cent and 28 per cent deriving 58 per cent and 38 per cent of their total income from crop enterprises respectively from contract farming. On the contrary, 32 per cent of income was derived from 21 per cent of gross cropped area in the case of large farmers. But the income derived from contract crop per acre was the highest in large farmers (Rs 15,002), followed by small farmers (Rs 10,878) and by medium farmers (Rs 7,635). It is evident that more than 50 per cent of small and medium farmers derived 74 per cent of their total income from contract farming of baby corn. In the case of large farmers, around 54 per cent of their total income was derived from contract farming with 37 per cent of their gross cropped area under contract. The income derived from contract crop per acre was the highest for small farmers (Rs 14,625) followed by large farmers (Rs 13,131) and medium farmers (Rs 10,287). In the case of small and medium farmers growing chilli under domestic contract, the proportion of gross contract area to total gross cropped area was around 57 per cent and 42 per cent deriving 54 per cent and 43 per cent of their total income from crop enterprises respectively from contract farming. On the contrary, 33 per cent of income was derived from 24 per cent of gross cropped area in case of large farmers. But the income derived from contract crop per acre was highest in large farmers (Rs 13,603), followed by medium farmers (11,231) and then by small farmers (Rs 10,485).

Impact of contract farming on income

The existence of inequity in income distribution between contract and non-contract farmers was evident from the Gini ratio values. The inequity in distribution of income was higher for non-contract farmers when compared to contract farmers (Table 6).Contrary to this, among different categories of chilli growing farmers, the inequity of income was high for farmers under domestic contract firm (0.87), followed by contract farmers under foreign contract firm (0.81) and non-contract farmers (0.80). Within the contract farmers, the small farmers had lesser instability of income compared to large farmers indicating that small and medium farmers performed better and realised higher production and better incomes.

Table 6. Gini coefficient for net returns from contract and non-contract crops (per farm per year)

Type of farmer	Foreign contract		Domestic contract		Non-contract	
	Baby corn	Chilli	Baby corn	Chilli	Baby corn	Chilli
Small farmers	0.76	0.81	0.66	0.88	0.87	0.87
Medium farmers	0.77	0.74	0.69	0.94	0.87	0.71
Large farmers	0.86	0.87	0.78	0.81	0.77	0.83
All	0.75	0.81	0.64	0.87	0.81	0.80

Constraints and advantages in contract farming

In order to study advantages and constraints of contract farming, responses were elicited from the sample farmers. The Garret's ranking technique, which is basically a changed order of advantages and constraints into numerical scores, was used in the present study.

It is evident from the Table 7, delay in payment ranked as the primary constraint followed by delay in delivery of inputs. The third main problem faced by the contract farmers related to delay in lifting the produce followed by access to seeds, buyers manipulating grades and high cost of inputs. The different benefits derived from contract farming related to the provision of vital inputs such as seeds, fertilizers and plat protection chemicals without making any cash payment, which helped the farmers a great deal. The second most important factor is assured contract price and buy back guarding them against fluctuating prices in the open market. Third, is access to inputs as contract farmers are relieved of procurement of inputs as timely supply of inputs is assured.

Table 7: Constraints and advantages in contract farming

Constraints	Rank	Advantages
Delay in payments	1	Low initial investment due to provision of inputs
Delay in delivery of inputs	2	Fair price for the produce
Delay in lifting the produce	3	Assured market, less risk
Access to seeds	4	Information on how to produce
Buyers manipulating grade	5	Access to inputs
High cost of inputs	6	Transportation facilities

Impact of food retail chains on supply chain management of vegetables

In India, the concept of organized food retailing emerged in the 1990s with the advent of international formats of retailing by the leading corporate hoses. These food retail chains/super markets have brought in several changes in the supply chain management and logistics through the use of quasi-formal and formal contracts to ensure timely delivery of products with desired quality attributes. Organized FRCs procure their requirements of fruits and vegetables from the primary wholesale regulated market yards (APMC yards) making use of the existing commission agents or themselves acting as commission agents. They also procure through consolidators - a new class of market functionaries. It is being practiced to comply with the APMC Act, which stipulates that all wholesale marketing of agriculture produce should be carried out at designated market yard, by paying the prescribed market fees and commission charges. Moreover, direct marketing by farmers is allowed in limited cases. Fruits and vegetables procured from the wholesalers at the APMC yards or consolidators are cleaned, sorted, graded and packed at godowns of the retail chains, thus creating further value addition. Most retail chains repack the commodities under private labels. Fresh fruits and vegetables marketing is characterized by fragmentation of the supply chain, concentration of market power with the wholesalers, existence of large number of intermediaries, little or no quality control, absence of standards, lack of product innovation, small volume of transactions and low inventories. The world-over, despite food retail chains reaching saturation, the penetration into fruits and vegetables section is limited (Reardon and Berdegue, 2002, Weatherspoon and Reardon, 2003). The situation is more precarious in India, where food retail chains are in infant stage.. The retail food chains in India have not been able to make an impact on the supply chain and continue to depend on the existing channels of marketing. However, recently few of the food retail chains have established backward linkages with farmers for procuring fresh fruits and vegetables. These linkages have been able to change the method of farming as well as marketing arrangements. In this context the impact of the new institutional arrangement on producer's resource-use pattern, income and marketing arrangements has been analysed..

Methodology

The spoke and hub model adopted by the 'Spencers' was purposively selected for the study as this model is the first of its kind started by a FRC and in operation since 1996. Spencers has established a fruits and vegetables Consolidation Centre in Hoskote near Bangalore, for procuring fresh fruits and vegetables. This Centre collects about 163 locally grown varieties of vegetables (some exotic ones) and to a small extent, some fruits. The number of farmer-vendors registered with the Consolidation Centre is small; 19 regular suppliers and 11 seasonal suppliers. To study the impact of new institutional arrangements on producer's resource-use pattern and income, all the nineteen farmers who regularly supply vegetables, were surveyed. To compare this system of marketing with the traditional system of marketing, 30 other farmers from the same area, selected at random, were surveyed for the study.

Logistic Regression Analysis

Logistic regression was estimated to identify the factors that have a bearing on farmers' supply of vegetables to food retail chain consolidation centre. A limited dependent variable model was used for capturing the influence of several factors on the selling behaviour of the farmers.

Logit Regression Function

Let $$Pi = E\left\langle Y = 1 \middle| Xi \right\rangle = \frac{1}{1 + e^{-Z}} = \frac{e^{Z}}{1 + e^{Z}}$$

Where,

$$Z = b_o + b_1X_1 + b_2X_2 + b_1X_1 + b_3X_3 + b_4X_4 + b_5X_5$$

$$Odds\ Ratio = \left(\frac{P}{1 - P}\right) = e^{\hat{b}_0 + \hat{b}_i \overline{X}_i + u_i}$$

$$Log - Odds = Li = Ln\left(\frac{P}{1 - P}\right) = \hat{b}_0 + \hat{b}_i \overline{X} + u_i$$

where,

P_i = Probability that farmers will supply vegetables to the Consolidation Centre.

1 – P_i = Probability that farmer not be willing to supply vegetables to Consolidation Centre

Y_i = Farmer willing to supply or not willing to supply vegetables to Consolidation Centre (Willing to supply =1, Not willing to supply = 0)

X_1 = Age (Number of years)

X_2 = Education (Number of years of schooling)

X_3 = Transport vehicle (dummy variable: Owning = 1, Not owning = 0)

X_4 = Area under vegetables (acres)

The consolidation centre covers a radius of about 160 km, and currently handles around 50 tonnes of fruits and vegetables per day. At present, it meets about 70 per cent of its requirement of fresh fruits and vegetables and the remaining 30 per cent is procured locally from the Modern Auction System (MAS) market, established by the National Dairy Development Board (NDDB) through a consolidator. The consolidation centre follows the 'Farmer-Vendor' model, which is characterized by the absence of intermediaries in the supply chain, i.e. the farmers themselves are the preferred suppliers. In this model, farmers registered with the consolidation centre, are known as 'vendors', and under each vendor a group (usually 10) of farmer-members (independently) cultivates and supply fruits and vegetables. The consolidation centre provides technical information on 'Good Agricultural Practices' (GAP) to farmers, who cultivate crops based on the specifications. The relationship of consolidation centre with farmer-vendors has been informal, with no written contracts, but is based on oral confirmations of volumes to be delivered. Assured irrigation is a must for farmers who wish to register with the consolidation centre. The selection of vendors is also determined by their business management skills. Supply to the centre also involves more formal transaction methods as well as stringent delivery conditions, frequency of supply and quality standards for the product. The registered farmer-vendors collect the produce from other farmer-members and deliver it to the consolidation centre; quality controls in production and packaging being the responsibility of farmer-vendors. The concept adopted by Spencer's - 'Ready to Retail' is achieved at the farm level wherein fruits and vegetables are graded and packed as per the specification of the retail chain in by the suppliers (farmer-vendors). The packaging materials are provided by food retail chain for specialty products and for general packaging the materials are purchased by the farmers. Every package is labeled and depicts its weight. This practice is diametrically opposite to the handling of fruits and vegetables in the traditional markets, wherein they are just dumped in market yards. At the consolidation centre, packed produce are bar coded and transported to the central warehouse in Bangalore, from where it is further transported to other south Indian cities viz., Chennai, Hyderabad, Thiruvanthapuram. The new model of Spencer's has helped in shrinking the traditional supply chain for fresh fruits and vegetables, as depicted in Fig.1.

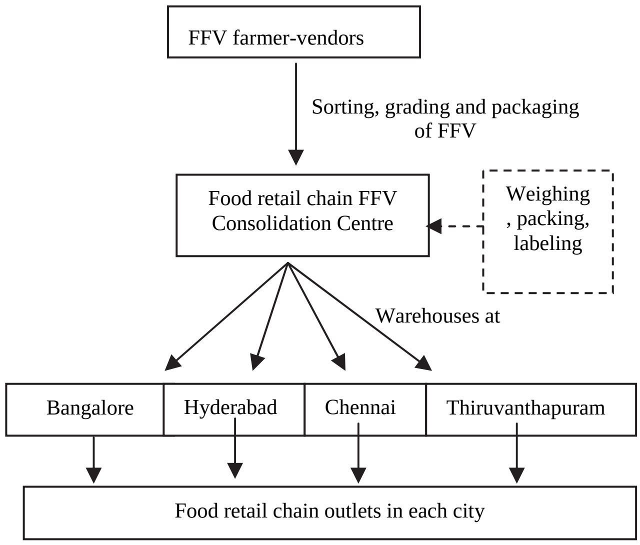

Fig.1. Supply chain of Spencers for Fresh Fruits and Vegetables (FFV)

The Consolidation Centre plans to serve as a captive supply centre to meet the requirements of their own outlets, as well as other retail chains, bulk purchasers and processors, which would ultimately benefit the farmers. With plans to set-up more retail outlets in major cities, the procurement at the Consolidation Centre is set to increase.

Quality control practices at Consolidation Centre

Quality of produce is maintained at three levels, referred to as QG (Quality grading) (Quality Logistics), QC_1 (Quality control) and QC_2 (Quality Care). The QG is the concern of the consolidation centre; the QC_1 is the maintenance of quality of packed products till it reaches the retail outlets, i.e. in loading, transporting and unloading of the produce. The QC_2 refers to the quality to be maintained at the display section of the retail outlets. Fruits and vegetables are graded based on uniformity of size, maturity and colour, physical appearance and freshness. The consolidation centre supplied the materials needed for packaging (for both speciality products and general packaging). Farmers themselves carry out grading and packing; it reduces the number of people handling the produce before it reaches the consumers. At the consolidation centre, each packed product is labelled with details like product name, weight and price; some of them are bar-coded, also.

Changes in cultivation practices introduced by FRC Consolidation Centre

The FRC consolidation centre has introduced changes in the way crops, particularly vegetables are cultivated. Crops to be cultivated are assigned to each farmer based on farmer's proficiency and history of production, which is documented at the time of enlistment. Investments in irrigation systems are preferred, as it provides the farmers greater control over quality and allows them to produce round-the year. A crop calendar is drawn up, keeping in view the requirements of the FRC retail outlets. Once the crop to be cultivated has been decided, farmers are provided with a package of ‘Good Agricultural Practices’ (GAP). This package ensures the optimum use of resources with emphasis on minimum use of pesticides. The farmer-vendor ensures that the practices are strictly adhered to. Direct supplies by farms also allow the centre to inspect farm and growing practices, first-hand. There is no formal contract or vertical integration for production or marketing under this arrangement. The Centre neither supplies any production inputs nor does it formally agree to procure the produce, which makes the farmers risk-bearers. The Centre has no system of providing production credit to the farmers, but helps farmers in procuring inputs from suppliers at reduced rates. Technical guidance on aspects like the time of planting, crop production and management, harvest time, quantity to be harvested per acre, etc., to ensure quality and marketability, are provided by the Consolidation Centre.

Generally, the Centre procures the entire quantity of fresh fruits and vegetables supplied by the vendors, except in cases where the specified quality requirement is not met. During the initial stages of establishment, the percentage of rejection in procurement from farmers was high because the farmers were not accustomed to producing good quality produce in a scientific manner. The large-scale rejection of their produce for failing to meet the quality specifications led farmers to change their cultivation practices, following which the rate of rejection reduced and now stands at 8 per cent. The impact of adhering to Good Agricultural Practices (GAP) and production practices such as staggered sowing introduced by the centre has led to increase in the intensity of cultivation as well the production.

Pricing policy of Consolidation Centre

Prices of fresh fruits and vegetables are determined on the basis of the prices prevailing at different markets in Bangalore. The benchmark price is determined by considering the prices prevailing at SAFAL market, Horticultural Produce Cooperative Market Society Ltd and Krishna Rajendra market in Bangalore. In this mechanism, consolidation centre ensures a sort of support price even during the glut in the market, so that farmers do not incur losses. The consolidation centre procures limited quantities from a limited number of farmers. Hence, it has limited liability to each farmer who also cultivates a given crop on a limited area. This produce is bought from food retail chains by consumers, who are quality-conscious than price-conscious. Under this format, the centre ensures input cost plus minimum profit for a limited quantity of produce. During the lean season, farmers are naturally benefited with good prices on par with market with assured market. It was found that farmers preferred to supply their produce to the consolidation centre, as it provided them stable prices and assured market, compared to the highly volatile prices at the wholesale market.

Socioeconomic implications of linkage of food Consolidation Centre with farmers

It was found that younger and educated farmers had entered into tie–ups with food retail chain consolidation centre, which could be due to their enthusiasm and better awareness to take risks and experiment with a new business model (Table 8). Family size was relatively larger for farmer families associated with the centre compared to the traditional market farmers. Larger family size was advantageous to the consolidation centre, as family labour was totally devoted to post-harvest operating like washing, sorting, grading, packing, labeling and also reduced the cost on hired labour.

Table 8. Socio-economic characteristics of fruits and vegetable growing farmers

Particulars	Food retail chain farmers	Traditional market farmers
Number of farmers	19	30
Age (years)	39	48
Literate (%)	100	67
Family size (No.)	7	5
Total land holding size (Acres)	6	2
(a) Irrigated land (b) Dry land	4.5 1.5	1.5 0.5
Bore wells per farmer	2	1
Gross income from Agriculture (Rs)	1,72,000	70,000
Category of farmer		
Marginal (< 2.5 acres)	3 (15.8)	28 (93.3)
Small (2.5 -5 acres)	9 (47.4)	2 (6.7)
Large (> 5 acres)	7 (36.8)	0 (0.00)

Note: Figures within the parentheses are percentages to the total number of farmers, in columns 2 and 3.

The average size of landholding of FRC farmer was six acres, while that of non-FRC farmers was two acres. The share of area under well command was also higher for FRC farmers compared to that of traditional market farmers. The gross income from agriculture of FRC farmer was Rs.1, 72,000 per year while that of traditional market farmer was Rs. 70,000, due to higher acreage under vegetable cultivation, adoption of improved agricultural practices and growing of exotic vegetables for FRC round-the-year which provided extra income to these farmers.

Cropping pattern

The FRC farmers along with traditional vegetables also cultivated exotic vegetables, such as broccoli, iceberg, lettuce, parsley, leek, red cabbage, Chinese cabbage, coloured capsicum, green onion, turnip, basil, table radish, etc.,. Thus, the crop diversity was higher for FRC than traditional market farmers. This diversity in crops had increased after their association with FRC consolidation centre, as their marketing risks were reduced under the new institutional arrangement. The cropped area of FRC farmers varied from 500 sq. ft to 10 acres. Exotic vegetables were grown in staggered small multiple plots, to ensure supply round-the-year, as per the requirements of FRC consolidation centre. Seasonal vegetables like cauliflower, carrots, potatoes, tomatoes, etc., were grown on large plots by both FRC and non-FRC farmers.

Comparison of unit cost of production and net returns of vegetable crops under FRC and traditional marketing channels

In this section, profitability and transaction costs of four major crops, namely, cabbage, cauliflower, carrot, and tomato under the two institutional arrangements have been assessed. The differences in profits and transaction costs have been used as indicators of the performance of an institutional arrangement in the marketing of agricultural commodities. Noticeable differences in net return per quintal can be seen for all vegetable crops in Table 9. The increase in net returns was the highest for cabbage growers (48 %), followed by cauliflower (40 %). The figures for carrot and tomato were 34 per cent and 18 per cent, respectively.

Table 9. Comparison of net returns from vegetables production under FRC and traditional marketing channels

Particulars	Cabbage		Cauliflower		Carrot		Tomato	
	FRCF	TMF	FRCF	TMF	FRCF	TMF	FRCF	TMF
Yield (T/ acre)	33	30	12.5	12	12	13	30	25
Market price (Rs/T)	3490	3000	8430	7000	15500	14000	6540	5500
Input cost (Rs/T)	897 (83)	1039 (60)	1871 (91)	2019 (63)	2589 (77)	2188 (53.5)	1396 (69)	1550 (61)
Transaction cost (Rs/T)	180 (17)	700 (40)	189 (9)	1200 (37)	775 (23)	1905 (46.5)	640 (31)	1000 (39)
Total cost (Rs/T)	1077 (100)	1739 (100)	2060 (100)	3219 (100)	3364 (100)	4093 (100)	2036 (100)	2550 (100)
Net returns (Rs/T)	2413	1261	6370	3781	12136	9908	4504	2950
Net returns (Rs/Q)	241	126	637	378	1214	991	450	295
Increase in net returns (%)	48		40		18		34	

Note: Figures in the parentheses are percentages to the total cost

The high net returns for FRC farmers were due to drastic reduction in transaction costs, particularly transportation cost and commission charges. The present study has indicated that the FRC linkage has been able to change the method of farming. The small and marginal farmers, through their intensive cultivation and crop diversification have been able to earn higher incomes. In contrast to Kenya, where supermarkets have to deal with a fewer and larger suppliers (Neven and Reardon, 2004), in the present study, food retail chain consolidation centre has obtained supplies from small and marginal farmers.

Factors influencing farmer's choice of different marketing channels

The factors influencing the probability of selecting food retail chain marketing channel as against traditional marketing channel was analyzed using the logistic regression analysis model because the farmers' decision to choose a particular marketing channel follows a binary choice. The log of odds in favour of selling vegetables, at consolidation centre was positively associated with education, owning transportation facility and area cropped under vegetables and is negatively associated with age. The coefficient of age factor of the farmers was negative, which indicated that the young farmers preferred FRC marketing channel than the traditional channel. The education of the farmer had a positive impact on selection of FRC marketing channel. With improvement in level of education, probability of selling vegetables at FRC consolidation centre increases. The farmer having own transport vehicle influenced them to sell through FRC marketing channel.

Table 10. Logistic regression coefficients of determinants of supply to Consolidation Centre

Variables	b	e^b	Sig	Elasticity of probability
Age (years)	-0.03	0.971	0.63	-0.15
Education (No. of years of schooling)	2.394	10.958	0.09**	0.29
Transportation (own=1, otherwise=0)	3.681	39.693	0.02*	-
Area under vegetables (acres)	1.409	4.093	0.04*	0.44
Constant	-6.44	0.002	0.11	-
Correctly predicted cases	91.8			
Chi- square	48.13			
Odds ratio	7:1			
Probability	0.88			

Note: * Significant at 5 per cent level, ** Significant at 10 per cent level

CONCLUSIONS

The experiences in India of contracting firms indicate strong evidence of backward and forward linkages benefitting farmers. These firms provided quality inputs such as branded seeds, fertilizers, and plant protection chemicals to the farmers at their gate coupled with the technical advice on production aspects. This enabled the farmers to reduce their working capital needs. The linkage substantially reduced their transaction cost per unit of output as the marketing was taken care by the firm. In general, contract farming helped farmers to improve their income levels by adopting intensified agriculture in high value crops and reduction in transaction costs. However, due to the poor resource base, most small and marginal farmers appear to be not part of such institutional arrangement.

The food retail chains are evolving and growing at a fast pace in India. The food retail chains have not been able to make an impact on the supply chain, and continue to depend on the existing channels of marketing. However, recently few of the food retail chains have established backward linkages with farmers for procuring fresh fruits and vegetables. One of the leading food retail chain, Spencers has organized a fruit and vegetable consolidation center following a farmer-vendor model. This new institutional arrangement, FRC consolidation center, though operating relatively in small scale has emerged as an alternate channel for farmers to break away from the clutches of traditional brokers/ wholesaler/ commission agents. The marketing arrangement by FRC, also, reduced the market risks and transaction costs to the farmers. Direct supply by farmers allowed the retail chain to simultaneously increase control over quality, supply reliability and price stability. Farmer's income has increased because of improved agricultural practices, growing of exotic vegetables and variety of vegetable throughout the year. The concept of Ready to Retail adopted by the FRC is to the benefit of the farmer –vendors as they realized higher returns by performing additional marketing functions such as cleaning, grading and packing. The fact that the consolidation centre of FRC purchased only good quality fruits and vegetables has resulted in farmers not finding the market for rejects.

References

Asokan RS and Singh G. 2003. Role and Constraints of Contract Farming in Agro Processing Industry. *Indian Journal of Agricultural Economics*, 58(3): 566-575.

Cooper, Martha C Lambert, Douglas M and Pagh Janus D. 1997. Supply chain management: More than a new name for logistics, *The International Journal of Logistics Management,* 8(1): 1-14.

Dileep BK, Grover RK and Rai KN. 2002. Contract Farming in Tomato: An economic Analysis. *Indian Journal of Agricultural Economics*, 57(2): 197-210.

Guo H, Jolly Robert W Zhu and Jianhua. 2007. Contract farming in China: Perspectives of farm households and agribusiness firms. *Comparative Economic Studies*, 49(2): 285-312.

Joshi PK, Gulati A, Birthal PS and Tewari L. 2004. Agricultural Diversification in South Asia: Patterns, Determinants and Policy Implications. *Economic and Political Weekly*, 39(24), pp 2457-68.

Joshi PK, Birthal PS and Gulati A. 2006. Vertical co-ordination by Nestle in Punjab. *Proceedings of the paper presented at IFPRI-IEG workshop on From Plate to Plough: Agricultural diversification and its implications for the smallholders.* ICAR, New Delhi, 1-51.

Kumar DS, Suresh and Chari Y. 1999. Economics of Gherkin production. *South Indian Horticulture*, 47(1): 288-289.

Mittal Surabhi. 2006. Structural shift in demand for food: India's prospects in 2020, *International Council for Research on International Economic Relations Working paper* No.184.

Kumar Praduman. 1997. Food Security: Supply and Demand Perspective. *Indian Farming*, December, 4-9.

Nagaraj N, Chandrakanth MG, Chengappa PG, Roopa HS and Promod M Chandakavate. 2008. Contract Farming and its Implications for Input-supply, Linkages between Markets and Farmers in Karnataka. *Agricultural Economics Research Review*, 21: 307-316.

Neven D and Reardon T. 2004. The rise of Kenyan supermarkets and the evolution of their horticulture product procurement systems. *Development Policy Review*, 226: 669-699.

Prathima R. 2004. Economics of vegetable seed production and marketing- An analysis of contract farming in Karnataka. *M.Sc (Agri) Thesis* (unpublished), University of Agricultural Sciences, Bangalore.

Ramasundharam P, Ingle Rajendra, Dhote Sonali and Singh M. 2005. Contract farming in Cotton. *Financing Agriculture:* 49-53.

Reardon T and Berdegue JA. 2002. The rapid rise of supermarkets in Latin America - Challenges and opportunities for development. *Development Policy Review*, 20(4): 371-388.

Roy EP. 1963. Contract Farming- USA. The interstate Printers and Publishers, Inc. Danville. Illinois.

Singh S. 2000. Theory and practice of contract farming: A review. *Journal of Social and Economic Development*, 2(1): 228-246.

Singh, S. 2000b. Contract farming for agricultural diversification in the Indian Punjab: A study of performance and problems. *Indian Journal of Agricultural Economics*, 35 (3): 241-261.

Weatherspoon DD and Reardon T. 2003. The rise of supermarkets in Africa: Implications for agrifood systems and the rural poor. *Development Policy Review,* 21(3): 333-355.

Developing vegetable e-Trading: Characterization from vegetable marketing practices in Northern Mindanao, Philippines

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ABSTRACT
This research seeks to assess the marketing practices of vegetables in Region 10 using a descriptive survey research design. Viewed from the research output of 1080 farmer-respondents, characteristic of vegetable marketing practices showed the following description: vegetables were usually delivered (76%); bought by wholesaler (63%) through a *suki*-interpersonal business relation (85.8%); buyers were dictating the price (78.5%) whose price was quoted by the buyer based on their own prevailing market price (87.8%) with less farmers reporting haggling for a better price (8.9%). Moreover, farmers have ranked in the order unstable prices (82.9%), buyers dictating the price (49.4%), high transportation cost (40.8%) and the absence of price information (69.5%) as their major problems in vegetable marketing. Turning data to market insights and insights to practical applications have directed this research into an innovative way to improve the marketing of vegetables in the region: vegetable electronic trading in Northern Mindanao is proposed.

Keywords
Vegetable buyers, Northern Mindanao, unit cost to produce, e-trading

INTRODUCTION
In 2002-03 there were 5.7 million households in the Philippines that were actively involved in vegetable production (Aquino 2003). Though growing vegetables is an important source of income and employment in the country (Piadozo et al. 2007), it is only a minor component of the Philippine agriculture sector. In terms of production area, only one-tenth of the total agricultural land in the country is planted to vegetables and fruits (Briones 2009). Rice and corn are the country's major component of the sector in the crops category.

Of the three major islands in the Philippines, Luzon produces at least 73 percent of the country's vegetables, 16 percent being from Mindanao and 11 percent from the Visayas (Remotigue 2005; Bacho et al. 2010). In Luzon, the major vegetable production areas are in Central and East Cordillera, the Zambales, and Cagayan Valley (Librero and Rola 2000). In the Visayas, Cebu Island and Negros provinces have been well known for their vegetable production. In Mindanao, the province of Bukidnon in Northern Mindanao region and in

Marilog District in Davao region (Batt et al. 2007) produce upland and lowland vegetables for the local market and inter-island export.

Despite its relatively small contribution to the national agricultural productivity measure, vegetables are an integral food component among Filipino diets, after rice. Factors which have been identified that contributed to low productivity were the high incidence of pest and diseases (Lantican and Rola 1996), an insufficient supply of good quality seeds, high cost of inputs, limited access to credit and inadequate irrigation facilities (Lantican 2000).Vegetables are a commodity dependent on weather and elevation (Johnson et al. 2008; Librero and Rola 2000).

In addition to production related problems, the marketing of vegetables is a major problem (Manalili 2000) faced by farmers in Northern Mindanao. Its complexity is attributed to the market power of its key players that command the direction of trading, and importantly, the price of vegetables from farmgate to wholesale and to retail. In one case study in Laguna and Benguet (Piadozo et al. 2007), the findings suggest that vegetable farmers have weak bargaining power, and inefficient systems of physical distribution. At the farmer level, there is the usual practice of planting immediately and looking for the market later when it's time to harvest (Nuevo and Lizada 2000). This results in low prices and untimely production for effective market demand.

The trading of vegetables is highly concentrated among wholesalers, assembler-wholesalers, barrio agents, and wholesaler-retailers. Each of these traders has a distinct function in vegetable trading in Northern Mindanao; making price information less transparent and highly variable in the supply chain. Tautho (1993) has indicated that the traders have higher retail price benefits than the farmers in Northern Mindanao. In addition, longer marketing channels increase the price for consumers (Lantican and Rola 1996) and helps generate a price margin in favor of the traders.

Agriculture e-commerce is the kind of trading model whereby buying and selling of agricultural products and services are transacted electronically with the use of computer systems linked together over network protocols and standards (Folorunso et al. 2004). E-trading for vegetables and also in the agriculture sector as a whole is a recent development. China (Xioping et al. 2009), the world's biggest producer of vegetable, and the United States of America (Mueller 2000) launched e-trading schemes in 2000. This development produces a new business relationship between participants with new markets and new marketing paradigms (Barua et al. 1996). Theoretical benefits include the promotion of information flow, better market transparency and price discovery; facilitation of industry coordination; and reduction of transaction costs (Nicolaisen, 2001).

A well-established pattern of economic development is when there is growth in per capita income. Rosegrant and Hazel (2000) suggested that as economies grow; there is a gradual movement from subsistence production system to a more diversified market-oriented production system. Such a development is intrinsically linked to the expansion and integration of markets (Horton, 1987).

OBJECTIVES

This study starts from post production activities towards the market which determines the share of income for farmers and traders from these vegetables. As the marketing of vegetables requires a significant link to production, the importance of understanding its characteristics at regional level is an important missing link required to describe how vegetable farmers in Northern Mindanao can increase their appropriate share of market gains. In addressing this goal, this study seeks to:

1. Describe the socio-demographic characteristics and production schedules of vegetable farmers in Northern Mindanao;
2. Describe the marketing practices of vegetable farmers in Northern Mindanao;
3. Describe the dynamics of farmgate prices and the profitability in vegetable farming in Northern Mindanao;
4. Describe the problems associated with vegetable marketing in Northern Mindanao.

METHODOLOGY

The research method used in this study was anchored to its objectives and translated into a definitive action plan. It employed a two-tier sampling stratification of the farmers and the traders in Northern Mindanao.

This is descriptive research. It utilizes both quantitative and qualitative approaches. The quantitative approach used the survey research format to generate information based on a set of pre-determined and pre-tested questionnaires. Complimentary to the quantification of data, a qualitative approach was also used such as an in-depth interviews and observations from the industry's players, to the traders and to the farmers.

As descriptive research, this marketing assessment study for vegetables used a purposive scooping sampling design. The scooping purposive sample procedure was adopted for the following reasons: (1) no exhaustive and complete list of all existing vegetable farmers could be established, and (2) it was assumed that the type of vegetables and land allocation were not exclusive to one type of vegetable; hence the type of vegetables planted differed by cropping season depending on market opportunities as perceived by farmers.

There were 1080 respondents of this survey that covered 13 vegetable commodities in four vegetable producing provinces in the region: Bukidnon, Misamis Oriental, Misamis Occidental and Lanao del Norte. This study focused on two major categories of vegetable: tropical vegetables for lowland production and semi-temperate vegetables for upland production. Specifically, there are thirteen vegetables covered in this study: in the tropical category are (1) ampalaya, also known as bitter gourd, (2) eggplant, (3) stringbean, (4) squash, and (5) okra; and in the semi-temperate category: (6) broccoli, (7) cabbage, (8) carrot, (9) lettuce, (10) sweetpea, (11) sweet pepper and (13) tomato.

The unit of analysis for this study was by commodity. This was instrumental as it covered 13 vegetables and each vegetable has its own agro-economic and marketing practices. Descriptive and cross-tabulation statistics were run using the Statistical Package for Social Science (SPSS) software Version 16.

RESULTS AND DISCUSSION

This section discusses the results of this research. It describes the output of the research and its implications for the characterization of vegetable marketing practices in Northern Mindanao. Research objectives are discussed in order.

Objective one describes the socio-demographic characteristic and production schedules of vegetable farmers in Northern Mindanao.

Socio-demographic characteristics of vegetable farmers in Northern Mindanao

Age and experience are important variables in describing the potential responsiveness to change of vegetable farmers in Northern Mindanao (Table 1). Data showed the average age of 1080 vegetable farmer-respondents was 44.74 years), suggesting a relatively agile vegetable sector in Northern Mindanao. Previous estimates from the Bureau of Agricultural Statistics (BAS) in 2003 was for an average age of 67 years old for all farmers in the Philippines, 40.79 years old for potato farmers in Bukidnon (Bacho 2002), 46.76 years among rice farmers in Agusan del Norte in 1988 (Mallonga 1988) and 45.6 years old among lettuce farmers in Bukidnon (Ansale 2006). This varying data suggests that age may influence the type of crops or commodity cultivated.

In Northern Mindanao, the mean age among respondents varies by type of vegetable. Ampalaya farmers (49 years), eggplant farmers (49 years old) and squash farmers (48 years old) were older than stringbean farmers (46 years old). The average age of these tropical vegetable farmers was approximately 48.6 years old. This corroborates with BAS age profile of eggplant farmers with a national average of 49 years old and 48 years old for Misamis Oriental in Region 10, while 44 years old is the national average of ampalaya farmers; Region 10 was not included in the ampalaya crop survey by BAS (BAS 2000a, 2000b).

Semi-temperate vegetable farmers were younger than tropical vegetable farmers. The youngest among this group were farmers of broccoli (38 years old), carrot (39 years old) and cauliflower (39 years old) that were below 40 years old. The remaining group of these farmers was between 41 and 45 years old: there was a mean of 42 years old for tomato farmers, 41 years old for sweet pea farmers, 42 years old for cabbage and 42 years old for lettuce farmers. The average age for a semi-temperate vegetable farmer was about 40.90 years old.

Research implications for age profiling among vegetable farmers are the following: (1) semi-temperate vegetable farming is labor intensive and requires younger farmers to cope with the demand of robust agronomic practices including pest and disease management, (2) semi-temperate vegetables are usually short season crop types that demand fast and more active harvesting windows, hence younger farmers are needed to fast-track production related to price-related marketing opportunities, (3) tropical vegetables are grown over a longer cropping season that extends for more than 3 months of cultivation and may be harvested in staggered manner with less labour-demanding care and maintenance.

In terms of farming experience, these data indicated that tropical vegetable farmers have an average of 12.4 years of experience compared with 10.5 years for the semi-temperate vegetable farmers (Table 1).

In the tropical vegetable category, for example, okra farming was more recently developed in terms of years of farming experience. Though there were a few farmers whose experience was in 10 to 15 years category, but due to the many new farmers who were cultivating this crop, the average length of experience was only 6 years. In addition, ampalaya and eggplant farmers both have an average of 14 years' experience, 13 years for stringbean farmers and 15 years for squash farmers. Surveys from BAS Costs and Returns (2000a, 2000b) indicated that ampalaya farmers in the Philippine have an average of 10 years farming experience, while eggplant farmers had garnered 15 years of farming experience both at the national average level and in Misamis Oriental level in Northern Mindanao.

In the semi-temperate vegetable category, lettuce and sweet pea farmers were noted as the recent additions in the semi-temperate vegetable farming experience. Farmers of lettuce have an average of 6 growing years, while sweet peas have an average of 7 years in farming experience. In addition, new entrants of lettuce and sweet pea farmers have pulled these vegetables farming experience to levels lower than expected from the farming experience average.

Moreover, tomato farmers in the region registered the longest average farming experience of 16 years. This implies that tomato has been cultivated by very experienced farmers. In addition, broccoli farmers have an average farming experience of 10 years, cabbage farmers with 13 years, carrot farmers and cauliflower farmers with both 11 years and sweet pepper farmers with 10 years.

Research implications regarding the number years of farming experience highlight the following: (1) a more experienced farmer has better yield stability than a non-experienced farmer, and (2) experience does not necessarily mean best practices, since experienced farmers tend to follow their traditional practices in farming rather than to adopt new scientific best-practice innovations for the crop.

Planting and harvesting schedules of Northern Mindanao's vegetable farmers

Planting of vegetables in Northern Mindanao can be characterized as all-year round production. The cropping season is characterized by a two month spread of the cropping window based on a typical rainfall pattern. Of the 1,080 farmers interviewed, the consolidated data suggests that first cropping was between May (7.0%) and June (7.7%), second cropping between August (8.3%) and September (13.3%) and last cropping between November (12.2%) and December (10.0%).

Most farmers termed the first cropping as *panuig* or annual planting as the months of May and June are the usual start of the rainy season. The month of April has the lowest number of reported farmers planting at 4 percent because low rainfall occurs across most of the vegetable growing areas in Northern Mindanao.

Harvesting was commonly done between July (7.0%) and August (9.1%) for the first cropping, November (12.3%) and December (16.3 %) for the second cropping and January (10.1%) and February (12.1%) for the third cropping. The months having most farmers reporting harvesting were the months from November to February, which occurred during the last quarter of the year. Months with lowest number of farmers reporting harvesting were in the months of April (4.2%), June (2.9%) and September (5.2%)

There are therefore three time windows in which farmers tend to make their decision to plant or not to plant vegetables: April, August, and November. These months indicated a close proximity to the number of farmers actually planting and harvesting. The research implication of these findings are: (1) vegetable farmers are "sensing" what kind of vegetables to plant for next cropping season, and (2) these are marketing windows that can influence market demand has and have a repercussion on future price mark-ups and farmers margins - the first one who plants often earns the best price margin as other farmers tend to follow a "bandwagon" effect on adopting the type of crop cultivated.

Objective two describes the marketing practices of vegetable farmers in Northern Mindanao. This section covers the post-production practices from farm-to-market access, mode of sale, type of vegetable buyers and market characteristics by crops, and market price determination characteristics amongst vegetable farmers.

Farm-to-market access of vegetable farmers

Farmer accessibility to market is one of the challenges in bringing the produce appropriately to its target consumer. It can influence the type of buyers operating in each vegetable farming village. Data showed that vegetables in most farms were carried by "men's shoulder" from their farm to the main road. Four (4) in every 10 farmers interviewed reported that they hired labor to carry their vegetables from their farms to the main road before it could be transported to market In addition, 2 out of every 10 farmer-respondents used animal draft and 1 in every 10 farmers used horses to carry their vegetable produce to the main road; 24.8% used animal drawn-carts and 16.8% used horseback alone (Table 2).

This finding has implications for the relative inaccessibility of most farms to the main access road and its subsequent deleterious effect on the quality of vegetables as they arrive at their market destination. This concern is significant for semi-temperate vegetables which are highly perishable and more so than tropical vegetables. Bruising of vegetables that leads to excessive entry of post-harvest pathogens can lead to crop losses and low marketability. Another significant implication is the cost of transportation as these vegetables need to be appropriately covered and boxed to allow their natural protection against bruises to be brought into play which will result in less loss of yield, quality and overall spoilage. Cost of spoilage which is seldom measured by farmers is an additional cost in the post-harvest loss equation. In one estimate of a cabbage farmer who delivered produce into the Agora market suggested that there was a decrease of between 5 to 20 percent of cabbage weight after being trimmed, sorted and re-packed or re-sacked.

From the main road to its market destination, most vegetables were transported using private trucks or an improvised 6 to 10-wheeler trucks (60.1%). When public utility vehicles were available in the barangay or village loading area, about 28.3 percent of farmers used an improvised jeep. Broadly this highlights the lack of appropriate road conditions in connecting vegetable farms that are mostly located at higher elevation in the region (Table 2.01).

Mode of sale

In Northern Mindanao, the mode of sale influences price structure. This study examined two modes of sale: delivery and pick-up. Seventy six percent of vegetable farmers interviewed chose delivery, and 22% chose pick-up as their preferred modes of sale.

Type of buyers and reasons of farmer's choice

Either a farmer chooses to sell his vegetable via delivery or pick-up sale; farmers will then have developed a transaction relationship with the vegetable buyers. Farmers were asked to identify these vegetable traders or buyers by the following simplified description: *wholesalers* if they buy by bulk usually in Agora markets and ship their vegetables to other destinations; *assembler-wholesalers* also known as *viajeros (transient buyers)* are buying vegetables directly at the farm *tabo-an* or loading centers found in each barangay and thus buying wholesale; *wholesaler-financiers* if the buyer had pre-financed the vegetable production which is often the case with a tie-up with agrochemical dealers; and *wholesaler-retailers* if the buyer buys wholesale and also retails the vegetables. Wholesaler-retailers are usually based in Agora and have permanent stalls in the market. The ability of these farmers to easily identify and recall these types of buyers suggests that a close interpersonal relationship that exists between them.

The data in Table 3 indicated that most farmers preferred to transact business with wholesalers (63%) and less with wholesaler-financiers (2%). In addition, about 2 in every 10 farmers interviewed had transacted through a wholesaler-assembler (17%) and a wholesaler-retailer (18%). These data confirmed the mode of sale that majority of farmers' preferred was the delivery mode of sale as 63 percent of them were transacting through a wholesaler.

This research also asked respondents to choose one of the major reasons in choosing a vegetable buyer. Data shown in Table 4 indicated that 8 of every 10 farmers (85.8%) interviewed were regularly transacting business with the same type of buyer that developed into a *suki,* or interpersonal business relationship. It is interesting to note that most farmers were not bargaining for better prices as only 10.3 percent were obtaining higher and better prices in transacting business with these buyers.

Investigating such issues further using an in-depth interview suggested that respondents would take the apparent price difference rather than risk breaking their bond with their respective buyers. It should also be understood that most vegetable farmers when lacking finance or being "short" of necessary chemicals during pest infestations or when encountering any unexpected farm expense during production period or harvesting, then these buyers act to lend the farmers additional money to meet their needs. This is sometimes referred to as "dextrose"; a term used by farmer-respondent to describe the financial help needed to "inject" into their farm or household expenses.

Buyers' characteristics by crops

The channels of vegetable marketing in Northern Mindanao region were influenced by the type of buyer. The variability in buyers' characteristics was influenced by the type of vegetable sold. For instance, okra was mostly sold to wholesaler-retailers (41%) in public wet markets rather than to wholesalers (30%), and about 29 percent to assemblers or *viajeros*as also with stringbean (59%), eggplant (57%), squash (52%), and ampalaya (56%) were the vegetables commonly sold to wholesalers.

Moreover, there was a growing proportion of assemblers contracting with these farmers. On average, 2 out of every 10 farmers interviewed sold their vegetables to an assembler-wholesaler (23%), about the same amount of farmers who sold their vegetables to a wholesaler-retailer (26%) in the tropical vegetable category.

In the semi-temperate category, 7 out of every 10 farmers sold their vegetables to wholesalers (72%). Wholesalers become the catch basin for these vegetables such that they have control over the distribution of these vegetables in domestic and inter-island markets. For example, tomato (90%) and sweetpea (85%) vegetables were mostly sold to wholesalers who were major distributors of these vegetables in the market.

As wholesalers captured a big share of the semi-temperate vegetable market, there was a growing proportion of assembler-wholesalers that sourced out vegetables at the farm-level or at the barangay trading post. Data showed that almost 2 in every 10 farmers interviewed sold their vegetables such as cauliflower (26%), broccoli (21%) and lettuce (14%) directly to assembler-wholesalers.

Data revealed that on average there were more semi-temperate vegetable farmers that were financed (3%) by wholesaler-financers than with tropical vegetable farmers (1%). Vegetable financing was concentrated in crops such as lettuce (8%), carrot (6%), cabbage (6%) and tomato (3%). More so, in the semi-temperate category, 1 in every 10 farmers interviewed sold their vegetables to wholesaler-retailers (12%). This transaction was attributed to interpersonal reason; the *suki* system. Thus, semi-temperate farmers preferred wholesaler buyers (72%) to assembler-wholesalers (13%), wholesaler-retailers (12%) and wholesaler-financiers (3%).

Market insights gathered using observation and in-depth inquiry with farmers and traders suggest the following scenarios: Farmers believed that wholesalers make better price quotations than the wholesaler-retailers. Wholesaler-retailers directly reflect their price quotations based on immediate buying trends at market level compared with the trend of supply at the farm level by the wholesaler. When supply was low and prices were up, wholesalers who knew the local supply situation translate this scenario into higher price quotations. When supply was abundant, wholesalers do not necessarily reflect this in their buying price as it considers other market distribution or the *labog or pasa* (transfer) to other potential market outlets of these vegetables; thereby quoting higher farmgate prices than the wholesaler-retailer. Thus, the wholesaler-retailer reflects price quotations more on market demand compared with the wholesaler that reflects more on supply availability.

Price determination

Price is the value of agricultural goods offered in the market. Market prices are determined by the interaction between the forces of supply and demand, subject to the constraints imposed by the conditions of competition in a particular market (Goodwin 1994). As a general rule, when supply is low, prices tend to rise as demand increases. It is with this condition that prices tend to vary by time and place, where these transactions occur, and the type of market that exists.

Data shown in Table 5 indicated about 8 of every 10 farmers interviewed reported prices of most vegetables were determined by the buyers (78.5%), and around 1 in every 10 farmers (12.5%) were reported to bargain on the pricing of their vegetables. Farmers negotiating with buyers on vegetable price was less than 1 in every 10 farmers (9.0%) interviewed.

However, price determination varies by type of vegetables. In the tropical vegetable category, farmers of okra (22.5%) and stringbean (21.1%) were negotiating prices with traders more readily when compared with the ampalaya (15.6%) and eggplant (17.7%) farmers. In this category, data showed that about 6.9 percent of such farmers were negotiating for better price offers.

In the semi-temperate vegetable category, buyer's influence on the price of vegetables was significant with about 9 of every 10 farmers interviewed in the cauliflower (90.0%), carrot (91.6%) and cabbage (88.8%) vegetables making this assertion. In addition, lettuce (67.4%), broccoli (62.5%) and sweetpea (69.2%) farmers also showed confidence in the price negotiation of buyers for these vegetables.

There was an increasing trend when both farmers and buyers were reportedly negotiating the price of semi-temperate vegetables. This trend was exhibited with sweetpea (20.5%) and lettuce (32.6%) farmers who had participated in the price negotiation. Broccoli (11.3%) and tomato (10.0%) farmers were also following this bargaining trend.

In summary, farmers in the tropical vegetables category have a higher influence on price determination by 16.4 percent (category mean) compared with the semi-temperate vegetables with 10.4 percent (category mean). Investigating these responses through a follow-up questionnaire revealed that prevailing prices (87.8%) set the pricing of vegetables in the market (Table 6). Only a small percentage of farmer-respondents (8.9%) were reported to "haggle" for better prices while a few use quality and volume (3.3%) considerations to negotiate the better pricing of their vegetables.

This data suggests the following implications: (1) vegetable farmers in Northern Mindanao are price takers; (2) the basis of the vegetable price is determined by the prevailing market price but it lacks a price reference where prices are viewed by all players with transparency and (3) most vegetable farmers are fragmented as they lack "market power" over the price negotiation through insufficient volume and quality considerations.

Mode of payment

As traders' determine the price of most vegetables in the market, farmers preferred to be paid in cash (92.1%) as the mode of payment. The preference with this mode of payment was logical given the economic conditions of most vegetable farmers in the region. Except for farmers cultivating about a hectare or more, vegetable farmers in the region can be characterized as marginal using limited technology attributed to lack of funds and the inaccessibility of their production holdings.

There were farmers who opted for consignment (6.5%). Consignment refers to the situation when the remaining unsold vegetables were left at the stall at the discretion of the stall-owner since the farmers had to return to their respective farms. There were farmers who also paid by credit (1.3%). Credit refers to previous financial obligations usually through a financier-wholesaler to deduct an amount loaned from the previous cropping. This corroborates the findings of Piadozo et al (2007) on the mode of payment in trading relationships.

Objective three describes the dynamics of farmgate prices and the profitability of vegetable farming in Northern Mindanao

Agricultural prices tend to vary according to seasonal patterns. This pattern is contributed by the biological nature of a crop and its demand characteristic. Price movement in the market place is a general indicator of the current situation when supply interacts with demand (Hudson 2007). In addition to these aforementioned factors, changes in expectations about future demand, weather events, political events, temporary disruptions in transportation and other factors that hinder the production and delivery of agricultural crops also have contributed to price fluctuations. For farmers, price is one of major production considerations that influence farm size, crop variety, timing of production, and farm capitalization.

Farmers look at prices as a window of what commodity that sells at higher prices, the occasions when prices are low and high, and the mode of sale. This section covers the prices of vegetables as received by survey-respondents during the last six months of production both by the delivery and pick-up modes of sale. In addition, the unit cost to produce was derived from the regional consolidated data from this survey.

Using the modal farm gate prices, delivery prices were generally higher than pick-up prices. In the tropical vegetable category mean, modal delivered prices have an average of P13.72 per kilo compared with pick-up prices at P10.98 per kilo. In the semi-temperate vegetable category, modal delivered prices were registered at an average of P32.35 per kilo, whereas pick-up prices were noted at P30.57 per kilo. Prices vary by specific vegetable within the category (Table 7).

One exception within this general observation was with okra prices in the tropical vegetable category. Okra pick-up price was reported by farmers at an average of P12.67 per kilo, whereas, delivered prices was reported at P9.50 per kilo (Table 7).

Vegetables in the tropical category which command higher delivered farmgate modal prices were: ampalaya at P22.50; eggplant at P14.38 per kilo; stringbean at P15.60 per kilo and squash at P6.60 per kilo.

In the semi-temperate vegetable category, the highest modal delivered prices were recorded in cauliflower at a modal average price of P53.33 per kilo and sweet pea at P51.74 per kilo. In the P30 to P40 per kilo farmgate price range were broccoli at P34.75 per kilo, and sweet pepper at P37.04 per kilo. Prices lower than P20 per kilo in the delivery mode of farmgate prices include carrot at P18.83 per kilo, cabbage at P11.50 per kilo, and tomato at P11.59 per kilo or at P289.75 per box of 25 kg. Lettuce was an exception with this general observation; the lettuce farmgate price was higher in pick-up than delivered mode. Modal pick-up price was registered at P61.67 per kilo average, whereas delivered price was at P40.00 per kilo.

These findings suggest: that (1) not all vegetable commands higher prices using delivery as the mode of sale; and (2) pick-up prices were most favorable for highly selected and not commonly grown vegetable such as lettuce and okra because such types of vegetables were better contracted than transacted in the spot market. Vegetables were generally sold through arm's-length market transactions in Northern Mindanao.

Farmer's profitability is sensitive to farmgate high and low prices. Farmers were asked about the actual selling price of the low, usual (modal) and the high price range. Using a price spread or price margins between the standardized unit cost to produce and the farmers' reported selling price at these three levels of prices, the profitability of these vegetables was estimated. Table 7 showed this calculation.

In the tropical vegetable category, the average profit margin for delivered vegetables was computed to be P7.25 per kilo and P4.51 per kilo at pick-up rate, while P19.39 per kilo for delivered prices and P17.62 per kilo for pick-up rate in the semi-temperate vegetable category under the modal price classification (Table 7).

The dynamics with these profit margins vary by type of vegetables. In the tropical vegetable category, the top profit earning vegetables were (1) ampalaya at P13.89 per kilo, (2) stringbean at P8.87 per kilo, (3) eggplant at P7.28 per kilo, (4) okra at P3.49 per kilo and (5) squash at P2.72 per kilo in the delivered price mode. The exception with this trend was okra; with a higher price margin in the pick-up mode at P6.66 per kilo average (Table 7).

Squash was a profit-loss sensitive vegetable in the tropical vegetable category; losing at P0.06 per kilo in the delivered mode and P0.55 per kilo in the pick-up mode when prices plummeted at P3.82 per kilo in the delivered mode and at P3.33 per kilo in the pick-up mode. It is worth noting that this losing margin can be minimal but when multiplied by trade volume, losses can be very large (Table 7).

Out of eight (8) vegetables included in the semi-temperate category, the highest profit margin was with (1) cauliflower at P38.61 per kilo, (2) sweet pea at P32.01 per kilo, (3) sweet pepper at P24.49 per kilo, (4) lettuce at P21.13 per kilo, (5) broccoli at P19.60 per kilo, (6) carrot at P9.56 per kilo, (7) tomato at P5.05 per kilo and (8) cabbage at P4.71 per kilo in the delivered in the delivered farmgate price mode. An exception with this trend was lettuce; with a higher price margin in the pick-up mode at P42.80 per kilo than in the delivered mode at P21.13 per kilo (Table 8).

With this estimation, Table 8 showed that profit margins were smore ensitive to the pick-up price mode than in the delivered mode. In the semi-temperate category, for instance, four (4) out of 8 vegetables in the pick-up mode were more sensitive to price margins than in the delivered mode.

In the pick-up mode, the following vegetables were noted to be profit-loss margin sensitive vegetables: (1) broccoli losing at

P6.15 per kilo, (2) cauliflower losing at P2.78 per kilo, (3) carrot losing at P1.77 per kilo, and (4) tomato losing at P0.91 per kilo when farmgate prices plummeted to their lowest levels. In the delivered mode, profit-loss sensitive semi-temperate vegetables were: (1) cauliflower losing at P2.34 per kilo and tomato at P0.15 per kilo when prices fell.

Cauliflower, though it ranks as highly profitable vegetable in semi-temperate category, it was also highly volatile in price movements both from delivered and pick-up prices; losing profit margin when farmgate prices was at its lowest at P12.38 per kilo in the delivered mode and P11.94 per kilo in the pick-up mode.

These findings showed that profitability of vegetable production is influenced by price movements, mode of sale, and type of vegetable.

Objective four describes the problems associated in vegetable marketing in Northern Mindanao. There are two entries in this section: farmer and research observations.

Problems associated with the marketing of vegetables in Northern Mindanao

This sub-section concern itself with knowing what most vegetable farmers believed to be their major problem in marketing vegetables. Several reasons were cited during industry consultations, however, this research narrows down to four major problems by which farmers could select among the listed choices in the questionnaire. Farmer-respondents were asked to rank one (1) as major problem and 4 as the least problem in four major vegetable marketing problems: transportation cost, unstable prices, buyer dictating the price and the absence of price information.

As shown in Table 9, eight (8) of every 10 farmers interviewed have pinpointed that unstable prices (82.9%) was their major problem. Vegetable farmers complained that the prices surged-up in one day, then dropped the following day. This vignette was common when farmers had completed the harvesting process and then prices suddenly plummeted and then surged up again. Price aberrations or iterations are commonly observed in agricultural products. As Goodwin (1994) points out that cyclical high price is associated with cyclical based reductions in product availability.

The second most recognized problem associated with vegetable marketing was when "buyers are dictating the price". Almost 5 of every 10 farmers interviewed (49.4%) posit the idea that the prevailing price in quotation by most traders were discretionary; based only on the traders' reference.

Higher transportation cost (40.8%) was the third most recognized problem. Transportation cost was associated with the distance from the farm to the main road and from main road to the major highways up to their market destinations. The composite of this cost adds up to higher transportation costs that are also dependent on the weather conditions. During the wet season and when roads were not passable by most vehicles, costs increased as it required additional draft animals or men moving the produce from one place to the next vehicle accessible road.

The least perceived problem in vegetable marketing was the absence of price information (69.5%). Most farmers do not recognized the relationship between price information, the instability of vegetable prices and the discretion of traders to dictate the "prevailing price". It can be inferred from this data that most vegetable farmers observed only the direct effect of traders' market power as manifested in price determination rather than its salient impact on the indirect effect on price stability and transparency by price information.

These findings indicated that instability of price was a major problem associated in the marketing of vegetables. As price is a natural phenomenon that reflects the changes in supply availability and demand, one of the mitigating factors is then the availability of transparent price information as a reference in price discovery and determination through an on-line vegetable trading scheme.

In addition to reported marketing problems by farmers, the research team has observed that the *absence of reliable weighing scales* also contributed to vegetable marketing problems in the region. Standardized weighing scales are as important as price information. If farmers have no direct information on the transparency and the reliability of price information, the gains and losses incurred by price fluctuations are aggravated by using unreliable and inaccurate weighing scales.

CONCLUSION AND RECOMMENDATION

In summary, the marketing insights have directed this research to propose innovative ways to improve the marketing of vegetable in the region. These insights characterized the marketing practices of vegetable farmers in Northern Mindanao: vegetables were usually delivered (76%); bought by wholesaler (63%) through a *suki*-interpersonal business relation (85.8); buyers were dictating the price (78.5%) whose price were quoted by the buyer based on their own prevailing market price (87.8%) with less farmers reporting haggling for better prices (8.9%). Moreover, farmers ranked unstable prices (82.9%) as the top vegetable marketing problem, followed by buyers dictating the price (49.4%), high transportation cost (40.8%) and absence of price information (69.5%).

Recommendation

These findings corroborate the proposed action plan to improve the marketing of vegetables in Northern Mindanao. The problem of price information, buyers dictating the price, and the prevalence of the market power of wholesalers can be improved by using vegetable electronic trading or vegetable e-trading. The goal of this e-trading is to: increase price transparency; reduce market-price related intervention power by middlemen e.g., wholesalers, assemblers-consolidators, and other intermediaries; and to increase farmer's profitability thorough fair-price information; and to increase their peso-share in the consumer retail price e.g., benefiting the farmers whenever retail price is high rather than merely benefiting the middlemen alone.

The availability of technology using the internet and intranet networks, business networking among institutional buyers, and the consuming public are the driving factors that make this action plan feasible. Building on existing formal trading centers in the Agora Market and other public markets, and the informal trading centers at the village level in Northern Mindanao, e-trading can make an impact on improving price information that is transparent and reliable.

Groundwork in the establishment of a viable e-vegetable trading requires: (1) active participation of traders and farmers; (2) the presence of common monitored weighing scale; (3) standardization of quality standards per vegetable type based on Good Agricultural Practices (GAP), Organic Agricultural protocols and other modes of production, (4) connectivity of key players to both intranet-e-trade (e.g., within the market) and internet-e-trade (across market) using an on-line communication technology network facility; (5) classification of price quotations based quality parameters (size, color, length) and on GAP and organic compliant practices, or other modes of production. In addition, prices can be adjusted to harvesting windows at 10-days, 5-days, and current harvest schedules in the form of futures markets. Current photos of the traded vegetables will be posted for the appreciation of buyers. Negotiations will be standardized based on volume, mode and point of delivery in the terms of payment. Payment can be made through current mobile applications from Philippines telecommunications network of GLOBE and SMART money and payment centers, in addition to standard VISA or MASTERCARD payment systems. Appendix 1 shows the proposed transactional process of this project

In schematic implementation, farmers and buyers have to log-in whose membership and participation will be verified as to their authenticity, traceability and accountability which will be ensured by the vegetable farmer's association operating as a business unit. Collaboration, commerce, and commitment (3Cs) are the core values that will govern this electronic vegetable trading in order to assure its success and sustainability. This is conceptualized as a business unit of the vegetable industry in Northern Mindanao using the Business-to-Business (B2B) model.

For example, the Northern Mindanao Vegetable Producers Association, Inc. (NorMinVeggies, a group of vegetable producers forming into an association and are known for a vegetable clustering approach) is one strategic conduit to implement e-trading and linking other traders in the Agora Market that serves as central trading center. At the village level, the Local Government Units (LGU) can serve as an initial phase to jump-start e-trading at the downstream level where initial computer terminals can be installed; agricultural technicians and the vegetable farmers' association will be trained for e-trading. This can also be installed at the barangay-village trading posts or in waiting shed areas where minimal improvements can be made to secure the computer. Communication signals will be enhanced using a landline or broadband in each major vegetable trading village.

Vegetable e-trading can improve price integration and lower transaction costs in the marketing of vegetables within the local production area, the domestic markets and inter-island markets. This becomes the platform for commodity clustering, and quality-based pricing systems. Vegetable traders can benefit with this plan as markets are more price integrated across vegetable producing villages. Farmers can benefit with this marketing system by accessing current and reliable price information. Institutional buyers can benefit from this program to use available vegetables in the market currently traded for them to plan menus and increase vegetable consumption among their clientele, and the mass-consuming public should increase consumption where fair-retail prices are assured; thus increasing vegetable demand to motivate a more stable production schedule. The Department of Agriculture in Northern Mindanao will act as regulatory body to safeguard against collusion in vegetable trading. The biggest challenge with this project is not with communication infrastructure as it is already available at an affordable cost, but rather on the human infrastructure network which requires collaboration amongst all the players along the vegetable production and marketing chain.

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References

Ansale, C. 2006. Production Levels and Marketing Patterns of Lettuce (Lactuca sativa, L.) among Active Members of the Northern Mindanao Vegetable Producers Association, Inc. (NORMINVEGGIES) in Bukidnon. Unpublished Masteral Thesis. Mindanao Polytechnic State College, Cagayan de Oro City}.

Aquino, C. 2003. The Philippine Vegetable Industry Almost Comatose. Focus on Global South. Focus on the Philippines, No. 2. http:www.focusweb.org/Philippines/content/view/25/6/ accessed August 8, 2006.

Bacho,A.P. 2002. Social and Cultural Dimensions of Potato Bacterial Wilt Disease Management Practices among Potato Farmers in Bukidnon. Unpublished Masteral Thesis. Xavier University-Ateneo de Cagayan.

Bacho,A.P., Madriaga,C.S.,Valledor,HG.V.2010.Vegetable Marketing Assessment in Northern Mindanao. The Mindanao North Coast Integrated Area Development Project, Department of Agriculture, Region 10:Cagayan de Oro City, Philippines.

Batt,P.J., S. Concepcion, K. Dagupen, M.C., Lizada, and R. Murray-Prior. 2007 "The vegetable industry in the Philippines". Final Report: Small Research and Development Activity. ASEM/2005/062. ACIAR, Canberra. http://www.aciar.gov.au/system/files/sites/aciar/files/aciar/files/node/14189/Final+report/ASEM-2005-062.pdf accessed 11/18/09.

Barua,A., Chcllappa,R., Whinston,A. 1996. The design and development of internet and intranet-based collaboratories, International Journal of Electronic Commerce (pp. 32-58).

Briones, Roehlano M. 2009. Agricultural Diversification and the Fruits and Vegetables Subsector: Policy Issues and Development Constraints in the Philippines. Discussion Paper Series No. 2009-02, Philippine Institute for Development Studies: Makati, Philippines.

Bureau of Agricultural Statistics. 2000a. Costs and Returns of Ampalaya Production, DA-BAS,April 2000.

Bureau of Agricultural Statistics. 2000b. Costs and Returns of Eggplant Production, DA-BAS, April 2000.

Folorunso,O.,H.O.D.Longe,A.D. Akinde and K.A. Ishola.2004. A framework for establishing Agriculture E-Commerce. Agric-ECRC: Resource Centre,. J.Comp.Sci.Applic (10:141-149)

Goodwin, J.W. 1994. Agricultural Price Analysis and Forecasting. New York; John Wiley & Sons, Inc.

Horton, Douglas. 1987. Potatoes: Production, Marketing, and Programs for Developing Countries. Westview Press: Boulder, CO.

Hudson,D. 2007. Agricultural Markets and Prices. MA,USA: Blackwell Publishing.

Johnson,G.I., Weinberger,K., Wu,M.H. 2008. The vegetable industry in tropical Asia: An overview of production and trade with focus on Thailand, Indonesia, the Philippines, Vietnam, and India. Shanhua, Taiwan: AVRDC-The World Vegetable Center (Explorations series; no.1).

Lantican, F. 2000. Vegetable Program Area Research Planning and Prioritization.Discussion Paper Series No. 200-07. Philippine Institute for Development Studies. Makati, Philippines.

Lantican, F. and A.Rola. 1996. Production-Marketing Linkage: Implication for IPM in Vegetable Research and Development. Journal of Agricultural Economics and Development. (Vol.24.Nos.1&2, January-July).

Libreo, A. and A. Rola, 2000. Philippines. In: M. Ali, ed. Dynamics of Vegetables in Asia. World Vegetable Center, Shanhua, Taiwan.

Mallonga, D.D. 1988. The Integration of New Rice Technology in a Mindanao Village. Unpublished Masteral Thesis. UP-Los Banos, Laguna.

Manalili,N.M. 2000. The Quality Assurance Challenge: Can Village Marketing and Cooperatives Respond? Australian Centre for International Agricultural Research Proceedings 100: 388-397.

Mueller,R.A.E. 2003. E-Commerce and Agricultural Commodity Markets: E- Commerce and Entrepreneurship in Agricultural Markets, American Journal of Agricultural Economics (83(5): 1242-1249.

Nicolaisen,R. 2001. How will Agricultural E-Markets Evolve? Paper Presented at the USDA Outlook Forum, Washington DC. February 22-23.

Nuevo,P.A. and Lizada,M.C.C. 2000. The Role of Quality Assurance in the Pooled Marketing of Horticultural Produce from Smallholders. Australian Centre for International Agricultural Research Proceedings, 100: 408-414.

Piadozo, E.S., Fujishima, H., Fujimoto, A., and Koichi Shimizu. 2007. Problems of Marketing System for Vegetables Grown in the Highlands in the Philippines: A case study of vegetable grown in Benguet and Laguna. Electronic copy: http://rms1.agsearch.agropedia.affrc.go.jp/contents/JASI/pdf/society/73-4520.pdf

Remotigue, M.E. 2005. The Mindanao vegetable industry situation. Proceedings of the Second Mindanao Vegetable Congress. Gran Men Seng Hotel. Davao August18-19.

Rosegrant,M. and P. Hazell, 2000. Transforming the Rural Asian Economy: the Unfinished Revolution. Oxford Univesity Press (China) Ltd., Hongkong, for the Asian Development Bank, Manila.

Tautho. C.C. 1993. A Study on Vegetable Production and Marketing in the Philippines. Dissertation. Ehime University, Japan.

Xiaoping, Z., Chunxia,W., Dong,T., Xiaoshuan,Z. 2009. B2B E-Marketplace Adoption in Agriculture. Journal of Software (Vol 4 No.3, May 2009)

TABLES

Table 1. Demographic Profile of Vegetable Farmers in Northern Mindanao 2009

Type of Farmer	Age	Farming Experience
	*in average years**	
I. *Tropical Vegetable*		
1. Ampalaya	49	14
2. Eggplant	49	14
3. Stringbean	46	13
4. Squash	48	15
5. Okra	51	6
Category mean	48.6	12.4
II. *Semi-Temperate Vegetable*		
6. Broccoli	38	10
7. Cabbage	42	13
8. Carrot	39	11
9. Cauliflower	39	11
10. Lettuce	42	6
11. Sweet pea	41	7
12. Sweet pepper	44	10
13. Tomato	42	16
Category mean	40.9	10.5
Over-all average	44.7	11.4

Table 2. Farm-to-Market Access of Vegetable Farmers, Region 10

Mode of Transportation	Farm to Main Road	Main Road to Market
	Percentage Distribution	
Animal Drawn-Cart	24.8	0.0
Horseback	16.8	0.7
Men's shoulder	47.9	0.1
Buyer's Vehicle	0.3	0.8
Financier's Vehicle	1.1	3.2
Public Utility Vehicle	4.6	28.3
Private Truck/Jeep	2.8	60.1
Other vehicle	1.7	6.8
N	612	875

Table 3. Vegetable Buyers in Northern Mindanao

Kind of Buyer	Frequency	Percent
Wholesaler	684	63%
Assembler-wholesaler	180	17%
Wholesaler-Financier	23	2%
Wholesaler-Retailer	193	18%
Total	1080	100%

Table 4. Reason Reported by Respondent on Choosing a Buyer

Reason of Choosing a Buyer	Frequency	Percent
Suki- Regular Buyer	897	85.8
Convenience	29	2.8
Higher Buying Price	108	10.3
Financier	11	1.1
Total N	1045	100.0

Table 5. Who Determines the Price

Market Player	Frequency	Percent
Farmer	135	12.5
Buyer	845	78.5
Both	97	9.0
Total	1077	100.0

Table 6. Basis of Price Determination

Type of Negotiation	Frequency	Percent
Prevailing Market Price	915	87.8
Negotiated Price-Price Haggling	93	8.9
Based on Quality and Volume	34	3.3
Total	1042	100

Table 7. Dynamics of Prices Received by Vegetable Farmers in Region 10 by Crops, January-March 2009

Type of Vegetable	Unit Cost to Produce	Delivered Prices Received (P/kl.) Modal	High	Low	Pick-Up Prices Received (P/kl.) Modal	High	Low
Tropical Vegetable							
Ampalaya	8.61	22.50	27.32	17.20	18.30	26.53	14.20
Eggplant	7.10	14.38	20.77	9.68	9.00	17.40	9.00
Stringbean	6.73	15.60	23.47	11.61	10.08	16.08	7.36
Squash	3.88	6.60	8.33	3.82	4.83	6.66	3.33
Okra	6.01	9.50	14.78	6.22	12.67	17.67	10.67
Mean	6.47	13.72	18.93	9.71	10.98	16.87	8.91
Semi-Temperate							
Broccoli	15.15	34.75	70.00	24.71	33.33	66.66	9.00
Cabbage	6.79	11.50	19.79	7.96	12.40	15.44	9.62
Carrots	9.27	18.83	35.12	10.33	10.00	23.75	7.50
Cauliflower	14.72	53.33	60.00	12.38	38.26	74.52	11.94
Lettuce	18.87	40.00	76.61	24.91	61.67	68.75	45.50
Sweet Pea	19.73	51.74	90.00	27.69	45.00	70.00	40.00
Sweet Pepper	12.55	37.04	63.71	25.27	33.33	43.33	19.44
Tomato	6.54	11.59	18.35	6.69	10.57	13.25	5.63
Mean	12.95	32.35	54.20	17.49	30.57	46.96	18.58

Table 8. Price Margin of Vegetable of Prices Received by Vegetable Farmers in Region 10 by Crops, January-March 2009

Type of Vegetable	Delivered Prices Received *(P/kl.)*			Pick-Up Prices Received (*P/kl.)*		
Farmer Tropical Vegetable	Modal to Unit Cost	High to Unit Cost	Low to Unit Cost	Modal to Unit Cost	High to Unit Cost	Low to Unit Cost
Ampalaya	13.89	18.71	8.59	9.69	17.92	5.59
Eggplant	7.28	13.67	2.58	1.90	10.30	1.90
Stringbean	8.87	16.74	4.88	3.35	9.35	0.63
Squash	2.72	4.45	(0.06)	0.95	2.78	(0.55)
Okra	3.49	8.77	0.21	6.66	11.66	4.66
Category mean	7.25	12.47	3.24	4.51	10.40	2.45
Semi-Temperate						
Broccoli	19.60	54.85	9.56	18.18	51.51	(6.15)
Cabbage	4.71	13.00	1.17	5.61	8.65	2.83
Carrots	9.56	25.85	1.06	0.73	14.48	(1.77)
Cauliflower	38.61	45.28	(2.34)	23.54	59.80	(2.78)
Lettuce	21.13	57.74	6.04	42.80	49.88	26.63
Sweet Pea	32.01	70.27	7.96	25.27	50.27	20.27
Sweet Pepper	24.49	51.16	12.72	20.78	30.78	6.89
Tomato	5.05	11.81	0.15	4.03	6.71	(0.91)
Category mean	19.39	41.24	4.54	17.62	34.01	5.63

Table 9. Problems Associated with Vegetable Marketing, Northern Mindanao

Order of Marketing Problem	Transpo Cost	Unstable Prices	Buyer Dictating Prices	Absence of Price Info
	Percentage Reporting			
Rank 1-Top Most Problem	0.8%	82.9%	16.5%	0.3%
Rank 2	32.8%	17.0%	49.4%	1.5%
Rank 3	40.8%	0.1%	29.5%	28.7%
Rank 4-Least Problem	25.6%	0%	4.5%	69.5%
Total	100%	100%	100%	100%
N	1080	1080	1080	1080

Urban and peri-urban agriculture and vegetables

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ABSTRACT

This millennium has brought about serious challenges as well as excellent opportunities for upliftment of the human kind. The migration of rural population to urban areas is one of the major challenges foreseen. It is expected that much of the population growth is expected to take place in the cities of the developing world. By 2020, about 52% of the developing world's population will be living in urban areas (IFPRI 1999). The rapid urbanization of the developing world and associate changes in life styles will have significant effect on food preferences, demand and sufficiency.

The agricultural areas around cities offer great promise to urban and peri-urban agriculture and provide advantages with respect to other more distant rural areas:

- firstly, the vicinity of the market allowing for daily supply of fresh fruits, vegetables, condiments and herbs to the urban consumers with reduced transport, packaging and storage expenses as well as reduced postharvest losses ;
- secondly, easy access to services including energy, input supply, communication and employment opportunities within and around the city ;
- lastly, the possibility to insert green zones and green belts within and around the cities to improve the urban environment and create possibilities for recycling urban waste materials.

The interventions on Urban and Peri-urban Agriculture (UPA) suggested and initiative undertaken by FAO is timely and valuable in the interest of the teeming population demanding for both nutrition and health. The International Conference on Vegetables (ICV-2002) held during 2002 has emphasized the importance of vegetables; FAO International Workshop on Urban and Peri-urban Agriculture for Asian Countries organized during 2005 had amply emphasized the important role of horticulture; and the International Conference on Horticulture (ICH-2009) held during 2009, has amply illustrated the importance of horticultural crops particularly vegetables in UPA for the benefit of urban population.

The urbanization process is a reality that drives people to go and live in the cities. It is very pronounced in Latin America where already 85% of the population lives in cities; in Asia the average is reaching 60% whereas in Africa the phenomenon has started later and has now reached 35%. Besides the increased demand for food, there has been a rapid increase of poverty, unemployment, hunger and malnutrition in the Urban and Peri-urban environment around the world that are of great concern to central and municipal authorities.

UPA can contribute to feeding the urban population, generate income and employment and thereby reduce poverty. In reality many countries have already UPA related activities going on in areas of horticulture including vegetables, dairy production, small livestock, aquaculture, and forestry. However, it has been realized that very few countries had actually investigated the real opportunities and constraints linked to the urban agriculture sector. The context, nature and scope of Urban and Peri-urban horticulture will be discussed during the presentation.

Background

The new millennium has brought about serious challenges as well as excellent opportunities for upliftment of the human kind. The migration of rural population to urban areas is one of the major challenges foreseen. It is expected that much of the population growth is expected to take place in the cities of the developing world. By 2020, about 52% of the developing world's population will be living in urban areas (IFPRI 1999). The rapid urbanization of the developing world and associate changes in life styles will have significant effect on food preferences, demand and sufficiency.

Since centuries, vegetables and flowers were grown near the towns and cities of Asia and Latin America, utilizing waste water on small holdings in an informal manner. With the lapse of time the city population increased and the number of holdings and of small growers increased. Now that the megacities are coming up, this pre-urban farming needs to be organized and managed utilizing urban resources of water, labour, space with application of modern crop technology coupled with environmentally friendly, and cost-effective activities.

The agriculture areas around cities offer great promise to urban and peri-urban agriculture and provide advantages as compared to other more distant areas (Baudoin 2005);

- firstly, the vicinity of the market allowing for daily supply of fruits, vegetables, condiments and herbs to the urban consumers with reduced transport, packaging and storage expense as well as reduced postharvest losses;
- secondly, easy access to service including energy, input supply, communication and employment opportunities within and around the city;
- lastly, the possibility to insert green zones and green belts within and around the cities to improve the urban environment and create possibilities for recycling urban waste materials.

Successful implementation of urban and peri-urban agriculture is based on an integrated approach aiming at securing the following three areas (Anonymous 2005):

1. basic resources, in order to ensure the availability and use of adequate land and water of good quality in sufficient quantity.
2. production of high quality produce, by applying technologies and practices which are environmentally friendly in the urban context
3. the institutional context, for monitoring and management of the programme

Nature and scope

Worldwide, the urban population is growing at twice the rate of the total population growth (Baudoin, 2005), creating unprecedented demand of food and services, as well as increasing pressure on the environment.

UPA relates to various activities including horticulture, small livestock, dairy production, aquaculture and forestry. In many developing countries, horticulture, livestock and, more specifically, vegetable production is becoming increasingly popular. The comparative advantages for horticulture in urban and peri-urban zones result from the fact that it is highly labour intensive, deals with perishable products and highly productive, high-value and short-cycle crops that require less land and water per unit of produce as compared to other food crops.

Opportunities and risks

The long-term sustainability of UPA will depend on its integration in the urban resource management and environment conservation process. Risk factors relate to land-tenure and competition for water, but also to potential risk for the consumers and environment as a result of over and misuse of pesticides and mineral fertilizers. However, these factors are largely offset by opportunities and synergies that need to be further explored (Baudoin, 2005).

Intensified horticulture units can offer from 10 to 40 remunerative jobs per hectare for small-scale producers. Considering also other derived jobs upstream and downstream that are related to the production-supply chain, it is generally admitted that urban agriculture and related services generate jobs at a ratio of 1 for every 50 to 100 citizens, depending on the level of consumption per capita and productivity of the production systems. Various typologies for horticulture production can be implemented, that range from “allotment schemes” for organized growers associations, to individual homestead and kitchen gardens to micro-gardens in the densely populated areas, where no agricultural land is available for crop production. Depending on the local context, consumers’ preferences and sanitary regulations, different types of livestock are commonly bred in the city: goats, sheep, guinea pigs, pigs, poultry as well as cattle for dairy products. Other options relate to apiary, floriculture, mushrooms production and aquaculture eventually in conjunction with vegetable growing and duck raising.

Urban forestry schemes have their place in UPA to serve as woodlots or as “lung space”. Generally recommendations suggest that at least 30% of the urban space should be kept “green” in order to contribute to the absorption of CO2, the release of O2, the cooling of the air temperature and for enhancing the rainwater infiltration rate. Further opportunities exist for building synergies with the city urban waste management. Organic waste can be usefully converted to high quality organic fertilizer through mechanical composting and vermiculture. Unlike mineral fertilizers, composted organic urban waste materials will contribute to solving the disposal problem and increasing the soil fertility for UPA (Baudoin 2005).

Similarly treated waste water could be recycled to irrigate fruit orchards, wood lots, and ornamental plans as well as fogger crops. Through these recycling process, UPA will contribute to keeping the city clean and have the benefit of a renewal source of water and organic fertilizers thereby reducing the reliance on external inputs.

National and international interventions

In reality many countries have already UPA related activities going on in areas of horticulture including vegetables, dairy production, small live-stock, aquaculture and forestry. In Asia, countries like China, India, Thailand, Cambodia, Vietnam, Laos, Bangladesh and Nepal have developed their programme and action plans (Anonymous, 2005). However, very few countries have actually investigated the real opportunities and constraints linked to horticulture sector.

While some 800 million people are believed to be involved in different forms of urban and peri-urban agriculture, it is only recently that urban and peri-urban agriculture (UPA) has received due recognition (Baudoin 2005). In 1999, FAO was officially mandated to deal with UPA as an integral part of agriculture production systems contributing to feeding the cities, while creating employment and generation income for the urban poor.

FAO recognized the importance and usefulness of UPA and developed world-wide programme and activities were initiated in different regions/countries (Baudoin, 2005). The FAO First International Workshop on UPA for Asian countries was organized by the P. N. Agricultural Science Foundation in Bangalore, India during June 2005, where horticulture crops were recognized as important component of urban and peri-urban agriculture. Earlier during November 2002, the International Conference on Vegetables (ICV-2002) held in Bangalore had highlighted the importance and role of vegetables in the peri-urban horticulture (Anonymous, 2003; Fresco and Baudoin, 2004; Nath and Dutta, 2004). The International Conference on Horticulture (ICH-2009) held in Bangalore during November, 2009 recognized the role of urban and peri-urban horticulture among urban committees.

International interventions like FAO’s programme on “Food for the cities”, RUAF and IDRC programme on Cities Feeding People Programme and “Urban Harvest” programme of CGIAR are gaining momentum in favour of UPA. Other agencies like UNDP, IFAD and NGO’s have their projects in different countries.

In addition, worldwide technical information is available through websites:

- www.fao.org/hortivar on the performance of horticulture cultivars
- www.fao.org/hortivar/ippcards on training message on Good Agricultural Practices
- www.fao.org/ag/AGP?AGPC/doc/themes/5g.html on GAP portal
- www.fao/organicag/defacult.htm on Organic agriculture portal

More countries are accepting UPA as a component of National Food Security Plans and to facilitate assistance for capacity building at policy and technical levels for their successful implementation.

Urban horticulture in Karnataka, India

The programme on training on urban horticulture was started by the Department of Horticulture, Karnataka in the year 2002-03. The main objective of this programme was to create awareness among the general public in the cities about gardening and importance of horticulture, create awareness regarding environmentally pollution, improvement of ecosystem, importance of greenery as well as popularize growing of ornamental plants in the urban household. The major subjects covered under this programme included;

- Kitchen gardening, ornamental and terrace gardening
- Growing of plants in pots (pot culture)
- Organic farming
- Pests and disease management
- Propagation etc.

During the year 2003-04, this programme was implemented in all the districts of the state. In Bangalore, about 84 programmes were conducted. The urban horticulture programme was implemented through non-government organizations and institutes involved in horticulture activities. These activities have enhanced manyfold.

Future outlook

Lessons learned from these projects indicate that the success and sustainability of UPA interventions require national commitment and municipal ownership with the participation of a series of stakeholders both from the public and private sector. This commitment should ultimately result in the integration of UPA in the city development planning process and into the national agricultural development plans.

While rural agriculture will continue to be the primary food source for urban dwellers, UPA is emerging with intensified production systems that often concentrate on supply fresh and perishable products of high value—particularly fruit and vegetables—with the comparative advantage of being produced close to the consumer’s market. However, the lack of country specific strategies and the limited specialised technical capacity are hampering or delaying the implementation of organized intervention in tune with the urban resources management and urbanization process.

The FAO/PNASF International workshop (Anonymous 2005) suggested that government and municipalities pay attention to the following objectives with outputs and activities tailored to the national context and specific environments;

1. raise awareness about UPA;
2. organise adequate technical advisory services and training of extension staff and growers;
3. develop and promote Food Agriculture Practices (GAP) in terms of intensified, cost-efficient and environmentally friendly production packages aiming at high quality project;
4. improve the efficiency of the supply chain and reduce the postharvest losses, including transport marketing and small scale processing strategies; and

5. promote a healthy diet including fruit and vegetables through nutrition education and advantage initiative in conjunction with the FAO-WHO programme on Fruit and Vegetables for Health growth of the regions in future.

Recommendations

The FAO/PNASF International Workshop on UPA had recommended for consideration the policy and strategies related to UPA in Asia. (Anonymous 2005);

1. For decision makers:

1.1. UPA should become a part of agriculture development planning at the country/state/province and city level;
1.2. Emphasis should be placed on building awareness and consensus among cross section of the society to implement UPA;
1.3. Ensure that UPA is part of the city development planning process, besides housing, roads, recreation, education and other essential facilities;
1.4. The government/municipalities may identify the appreciate authorities/bodies to work out land use planning with specific relevance to UPA. The participation of public and private sectors in this land use planning process needs to be ensured;
1.5. Major stakeholders for UPA need to be identified in line with country-specific policies and strong functional linkages among all stakeholders to ensure sustained UPA activities;
1.6. The urban development authorities may promulgate law/pass a precedent to ensure a definite percentage (3.5%) of land/space for implementation of various elements of UPA. This must be made mandatory for all private layouts also;
1.7. The government may create an ombudsman agency comprising of representatives from city development authority, land use planning, private sector, public sector, public/communities and law departments;
1.8. The envisaged UPA activities must generate additional employment opportunities for urban/peri urban poor;
1.9. The urban development authorities/UPA implementation agencies must ensure green zones (protecting, strengthening, expanding) etc;
1.10. The UPA activities may become prospect for eco tourism;

2. For research:

2.1. Identify and develop cost effective appropriate/suitable technologies (economically visible, environmentally friendly and sustainable) for their practice in UPA;
2.2. Develop effective and efficient extension mechanism to disseminate such appropriate technologies to be taken by UPA practitioners;
2.3. The good agricultural practices specific to urban and peri-urban situations need to be identified and applied;
2.4. Develop various models for urban horticulture production systems particularly kitchen gardening terrace garden, container farming, hydroponics etc;

3. For the private sector and NGOs:

3.1. Become involved in the scientific management and recycling of urban waste and its utilization for strengthening of UPA activities with adequate support and cooperation of the municipal authorities;
3.2. Integrate UPA production towards quality labeled produces/commodities;

3.3. To the extent possible, taking advantage of the available labour, the peri urban agriculture may also be looked into from commercial angles and specifically for niche markers of high value products for local and export markers;
3.4. Identification and delineating the role of NGOs needs to be done keeping in mind the advisory services required by the growers, formation and use of groups, towards micro credit;
3.5. Appropriate credit facilities including the micro credit may be extended to urban poor.

4. For training and extension:

4.1. The Human Resource Development component may be added to UPA with the mandate of capacity building programmes/awareness programmes and special skill trainings for extension personnel, UPA practitioners particularly the urban poor, senior citizens, women and youth;
4.2. Quality and safety parameters needed for both food security and market purposes should be integrated in such capacity building programmes;
4.3. Fostering the grass root level initiatives through participatory training process must be ensured under UPA;
4.4. Various components of UPA may a part of curriculum at school level to educate and involve children in UPA activities;
4.5. The peri urban agriculture may support primary and secondary industries located in the fringe areas of cities in relation to postharvest handling, distribution and processing.

CONCLUSION

The Urban and Peri-Urban Horticulture (UPH) supports food and nutrition security, health improvement and income generation. It is time to better define national policy and strategy options with relevant resources and technical support mechanisms for the sustainable management of urban and peri-urban agricultural systems, considering crop and fodder production and animal husbandry in conjunction with water use efficiency and food safety criteria. Equally important is the need to implement innovative approaches for decentralised marketing, small-scale processing and nutrition education in order to address the integrated production, supply and consumption.

References

Anonymous (2003). Proc. Intn. Conf. Vegetables (ICV-2002), Bangalore, ICV-2002 Secretariat, P. N. Agricultural Science Foundation, Bangalore, India. E-Mail: drpremnath@vsnl.net.

Anonymous (2005). Proc. Intn. Workshop on Urban and Peri-Urban Agriculture for Asian Countries, June 29 – July 02, 2005, Bangalore, India; FAO, Rome and PNASF Bangalore; pages 257. E-Mail: drpremnath@vsnl.net.

Anonymous (2010). Proc. and Recommendations of the Intn. Conf. on Hort. (ICH)–2009. Bangalore, ICH–2009 Secretariat, P. N. Agricultural Science Foundation, Bangalore, India. E-Mail: drpremnath@vsnl.net.

Baudoin, W. O. (2005). Urban and Peri-Urban Agriculture: The Concept, Theme and Objectives, Proc. and Recommendations of the Intn. Conf. on Hort; FAO, Rome and P. N. Agricultural Science Foundation, Bangalore. E-Mail: drpremnath@vsnl.net. page 17-20

Fresco, Louise O. and Baudoin, W. O. (2004). Food and Nutrition Security towards Human Security, Food and Security – A Global Perspective, P. N. Agricultural Science Foundation, Bangalore, India, page 7-42. E-Mail: drpremnath@vsnl.net.

IFPRI (1999). World Food Prospects: Critical issues for the Early Twenty – First Century, 2020 Vision – Food Policy Report, IFPRI, Washington, USA.

Nath, Prem (2005). Keynote Address, Proc. and Recommendations of the Intn. Conf. on Hort. (ICH–2009). Bangalore, ICH – 2009 Secretariat, P. N. Agricultural Science Foundation, Bangalore, India. E-Mail: drpremnath@vsnl.net.

Nath, Prem (2011) Role of Horticulture in Livelihood Security, Horticulture and Livelihood Security, Scientific Publishers and P. N. Agricultural Science Foundation, Bangalore, India, page 1-11. E-Mail: drpremnath@vsnl.net.

Nath, Prem and Dutta, O. P. (2004). Food and Nutrition Security and Vegetables, Food Security and Vegetables – A Global Perspective, P. N. Agricultural Science Foundation, Bangalore, India, page 43-54. E-Mail: drpremnath@vsnl.net.

Understanding urban and peri-urban vegetable production and marketing systems through GIS-based community food mapping as part of an interactive collaborative research environment in Southeast Asia – an outlook

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ABSTRACT

Urban and peri-urban vegetable production and marketing systems have the potential to contribute to poverty reduction, food and nutritional security, local economic and community development, social inclusion of marginalized groups, as well as to enhance urban environmental management by increasing biodiversity. There are some major challenges for the production of vegetables in the developing world: On the one hand constraints due to heavily competing and conflicting interests in land which endanger existing production sites and on the other hand climate variability and climate change, which contribute to frequent flooding, prolonged droughts and temperature extremes. However, very often the complexity of urban and peri-urban vegetable systems is not fully understood by regional and urban planners, local authorities, researchers and communities. Its potential for sustainable development of urban and peri-urban areas in developing countries thus has only been utilized to a limited extent. GIS-based community food mapping of urban and peri-urban areas as part of an interactive collaborative research environment is an appropriate, innovative tool enabling researchers, policy makers and the public to find information on a range of factors that affect access to healthy, affordable food, and thus can address the above-mentioned constraints. Although the innovative tool of food mapping is already applied in many developed countries, there is still lack of research in developing countries, such as in the Southeast Asia (SEA) region. This approach aims to identify the geographical areas or communities in SEA that have the greatest needs in terms of access to food (“food deserts”) and will serve as a future database for planning authorities.

A first step comprises the identification, documentation and inventory of existing data sources from both a “top down” (existing data, remote sensing, GPS, etc.) as well as a “bottom up” (crowd sourced communication and information exchange, site surveys, workshops, mobile pictures, social networks, mapping, etc.) view. The gathered information will then be entered into a Geographic Information System (GIS) in order to identify pilot areas and illustrating the spatial distribution of food and nutrition resources.

In the long term an open access, sustainable, interactive collaborative research environment as platform for data exchange and visualisation that furthermore allows the implementation of modeling impacts of climate change and the risk assessment of natural disasters will be created. This is expected to contribute to the development of new adaptation strategies to ensure food and nutrition security in the region.

Keywords
Peri-urban, GIS, community based food mapping, Southeast Asia, collaborative research environment

URBANISATION AND FOOD AND NUTRITION SECURITY

For the first time in human history the majority of the world's population lives in urban areas with almost 180,000 people moving into cities each day. Over the last 50 years the global population living in slums has risen from 35 million to over 1 billion people, which make up the majority of the urban population in many developing countries (UN 2010, 2011). Southeast Asia is one of the world's fastest growing regions in terms of population and urban growth (UN 2010, 2011). In urban and peri-urban areas, specific issues are rising traffic congestion, inadequate water supply and waste treatment, provision of adequate shelter and health services as well as ensuring food and nutritional security, i.e. year-round availability, accessibility and affordability to safe and nutritious food for a rapidly increasing population. Due to the shift in population distribution, agricultural production and food demand will heavily but unpredictably be affected.

Urban and peri-urban vegetables: neglected production systems

Facing these challenges, urban and peri-urban vegetable production and marketing systems have the potential to contribute to poverty reduction, food and nutritional security, local economic and community development, social inclusion of marginalized groups and women in particular, as well as to enhance urban environmental management by increasing biodiversity and the productive reuse of organic wastes. This was successfully demonstrated by pilot projects such as the allotment gardens in the Philippines (Holmer and Drescher 2005; Holmer 2010) or the low-space family business gardens in Sri Lanka (Ranasinghe 2008). Production of vegetables in cities of the developing world faces many challenges. First of all there are major constraints due to heavily competing and conflicting interest in land, endangering existing production sites. Climate change contributes to frequent flooding, prolonged droughts and temperature extremes. To enhance the climate resilience of vegetable growers, appropriate technologies such as raised bed cultivation, micro-irrigation, and grafting, as well as vegetable lines that tolerate or resist abiotic and biotic stress but also address market demands have been developed by AVRDC – The World Vegetable Center, an international agricultural research centres, and its partner institutions. Integrated crop management strategies can reduce contamination from pesticides or other pollutants, while improved storage technologies, and better postharvest management can reduce production losses (Hughes and Keatinge 2009). These strategies can contribute to a stable, year-round supply of accessible, affordable, safe, and nutritious vegetables for consumers, help increase profits for vegetable growers and make cities greener and more liveable.

However, very often the complexity of urban and peri-urban vegetable systems is not fully understood by regional and urban planners, city administrators and policy makers, and hence, the potential for sustainable development of urban and peri-urban areas in developing countries has only been harnessed to a limited extent.

GIS-based community food mapping

Considering the above mentioned constraints and aiming to enhance urban planning processes and to provide access to information on a range of factors that affect access to healthy, affordable food, a very appropriate and innovative tool is GIS-based community food mapping of urban and peri-urban areas. A major task of food maps is to find out where people produce, process, purchase and consume their food (Food Mapping for Community Food Activity 2004). Maps help to discover what the food needs of local people and consumers are and if the supply side can meet this demand. Furthermore, they help to identify the geographical areas or communities that have the greatest needs in terms of access to food, the so-called "food deserts". Besides the information of physical and economic access to food, the food maps will be able to describe how people feel about local food access, for example, how culturally acceptable the access to available food is, how appropriate it is and how convenient it is to access (USDA Food Environment Atlas). Finally food maps are used to describe and measure a community's level of food and nutritional security.

Examples for food mapping

Many food mapping projects have already been carried out, mainly in developed countries. Several maps are available in the United States of America. The Food Desert Locator and the Food Environment Atlas of the United States Department of Agriculture Economic Research Service (USDA ERS) aim to present a spatial overview of where food desert census tracts are located and seek to provide a spatial overview of a community's ability to access healthy food and its success in doing so, respectively (USDA Food Environment Atlas, USDA Food Desert Locator). The Maryland Food System Mapping Resource's objective is "to create an interactive resource for public health, nutrition and agriculture communities who are developing research and activities to strengthen local food systems through improving farm viability, increasing access to healthy food, and addressing health disparities and inequities" (John Hopkins Bloomberg School of Public Health). Similar projects can be found in Europe. The open source research project "Leeds Urban Mapping Project" in the United Kingdom wants to (1) identify housing in Leeds more than 500 m (walking distance with shopping) from a fruit and vegetable outlet and/or more than 300 m from 2 ha of green space (well-being zone), (2) map existing ecosystem service veins, (3) help growers assess and establish new productive sites and (4) explore the relationships between all these to facilitate the development of a self-updating Urban Masterplan for Leeds (Leeds Urban Mapping Project).

Another example is the "Streuobst in Europa" project, which intends to identify the spatial distribution and to characterize the structure of traditional orchards in Europe (Streuobst in Europa). In regards to nutrition security, traditional orchards are very important due to their biodiversity and their non industrial character. The project uses a community-based approach where the local population is consulted to apply their knowledge about the orchards by spatially identifying and characterizing the orchard landscapes and traditional orchard areas in Europe. Their spatial extension can be defined via Google Maps on the project's website. In the next step the areas are classified and described with the aid of a questionnaire about categories, such as the tree population and its density.

Even though a variety of approaches in developed countries can be found, there is still a dire lack of corresponding research in developing countries, where such endeavors would be most needed. In a case study in Moshi, Tanzania spatial patterns of agricultural activities along the rural-urban continuum were analyzed. Schlesinger et al. (2011) developed a tool based on a transect map where collected data was mapped from both a top down and a bottom up view. The in situ mapping of agricultural production within transect rectangles (recent satellite images and cadastral maps as base maps) made up the first step, followed by the digitization of analogue mapping data and its GIS-based processing (e.g. assign attributes, calculate areas). In a household survey within the transects, community-based data about agricultural activities (e.g. yearly production, inputs used, marketing, income generation) was collected, geocoded and later its spatial patterns were analyzed. Finally Schlesinger et al. (2011) determined that agricultural biodiversity was highest in peri-urban areas, which play a crucial role in managing biodiversity as the basis for sufficient food supply for the city.

METHODS & DEFINING STEPS

The approach from the study in Moshi, Tanzania is an appropriate example to be transferred to a three-step approach for Asian countries. A first step comprises the identification, documentation and the inventory of existing data sources from a “top down” view (research results, existing databases, site collections, written documents, satellite images, GPS data, etc.) and a “bottom up” view (crowd sourced communication and information exchange, site surveys, workshops, mobile pictures, social networks, etc.). In a second step, pilot areas will be identified using available datasets, remote sensing *(top down)*, participatory community mapping, crowd sourced communication and information exchange, social networks and site surveys (*bottom up*). To accomplish this, the food and nutrition resources in the pilot areas will have to be collected and inventoried in a (geo)database, described in more detail in the following paragraph. The process of data collection requires building relationships with a variety of community, civic, and educational institutions. In the final step, the data identifying location, type and characteristics of each resource will be entered into a Geographic Information System (GIS). Open source GIS software will be used to encode and digitize the data to create accurate community maps illustrating spatial locations of food and nutrition resources relative to other spatial attributes within project neighborhoods. These maps will be validated together with community.

Collaborative Research Environment as an innovative tool for food and nutrition security

No comprehensive database on the biodiversity and distribution of vegetables and specifically underutilized and neglected species (NUS) in Southeast Asia so far exists. For several reasons the major vegetable production systems are located in peri-urban areas close to the consumer, and near to infrastructure such as roads and airports. This does not exclude niche production in more remote areas.

Sustainable Information and Geo-Communication Technologies (IGCT) comprise a number of instruments and combined technologies such as Geographic Information Systems, remote sensing, participatory community-based mapping and information exchange, interactive geo-communication platforms and systematic, comprehensive database development. Such complex and multiple data and information need an innovative presentation via visualisation, learning modules and interactive features to guarantee a long lasting, “sustainable” existence. Such a new concept should also stimulate growing data input from the involved community and therewith an increase in knowledge and the potential of adaptation of future requirements. Open access and interactivity are further basic conditions for such a server-based “collaborative research environment.”

To fulfil the requirements for a collaborative research environment a suitable infrastructure has to be set-up. To guarantee a flexible, stable and scalable solution the system should

- be based on open source components to minimize license costs or dependency on proprietary software solutions
- easily be able to migrate to other (hardware) platforms
- establish a redundant storage of the data hosted on the system
- guarantee long term availability of data and services

From today's point of view a suitable and sustainable infrastructure should be based on an open source system where the necessary software can be installed and updated from appropriate repositories. Among others, OpenSUSE or Ubuntu are systems that could be used for this purpose.

Particularly with regard to the ‘geo components’ which are developed within the project, GeoServer and adequate requirements like PostgreSQL / PostGIS, OpenLayers or GeoExt are the most reasonable choice. On the one hand they are widely used, well-documented and maintained, and on the other hand GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) standards.

Ease of (hardware) migration and long term availability of data should be achieved by using a virtual server solution that can be established using the resources of the central IT Services of the Albert-Ludwigs-Universität Freiburg (ALU). In a medium-range perspective existent online portals should be refined to also host geo data on the basis of the OGC Standards used within this context.

Next to the technical aspects of the server environment, the design and set-up of an e-learning environment and interactive 'geo-communication' platform is of common interest for the working group.

Technically, the platform is based on a ‘Flash-WebGIS’ and a ‘Mapbender-WebGIS-Client’ using the ‘ogc’-standards and services web-map-service (WMS) as well as transactional web-feature-service (WFS, WFS-T). Mapbender is an open source WebGIS-application implemented in PHP and JavaScript for managing spatial data that are standardized specifications. Data storage is organized with a PostgresSQL, PostGIS or MySQL database. The framework implements user management, authentication and authorization. Management interfaces, depending on authorisation and demand of the user, are stored as configurations in the database. The Mapbender client-software can be used to display, overlay, edit and manage geodata.

OUTLOOK ON EXPECTED RESULTS

If strategies are applied as described above, the following outputs are expected for a preparatory food mapping project in Greater Bangkok:

- Enhance the visibility of vegetables as important components for food and nutrition security
- Lay the fundament for a self growing, interactive, public accessible and comprehensive database on food and nutritional security of project sites
- Prepare a collaborative research environment for data and information exchange and visualisation as a sustainable instrument for science
- Identify the geographical areas or communities that have the greatest needs in terms of access to food (“food deserts”)
- Show the balance between the particular (culturally predefined) food demands of the local population and the supply side (“cultural deserts”)
- Increase the visualisation of local perspectives and views (participatory approach)
- Provide a future map based database for planning authorities
- Endorse the development of new adaptation strategies for climate change impacts and natural disasters to ensure food and nutrition security by implementing models for climate change and risk assessment of natural disasters

References

Food Mapping for Community Food Activity, 2004. A Briefing Paper from the Scottish Community Diet Project (http://www.communityfoodandhealth.org.uk/fileuploads/rtdn9foodmap-5241.pdf)

Holmer RJ, Drescher AW, 2005. Allotment gardens of Cagayan de Oro: Their contribution to food security and urban environmental management. In: Urban and Peri-Urban Development: A Comparison of Conflict Structures and Solutions. Southeast Asian – German Summer School 2005, October 16-29, 2005, Cologne, Germany: 149-155.

Holmer RJ, 2010. Community-based vegetable production systems: an answer to the food and sanitation crisis of urban poor in the Philippines? Acta Horticulturae, 881:125-130.

Hughes Jd'A, Keatinge JDH, 2009. AVRDC - The World Vegetable Center: a unique research and development institution. AVRDC - The World Vegetable Center, Shanhua, Tainan, 21 pp.

John Hopkins Bloomberg School of Public Health. The Maryland Food System Mapping Resource (http://www.jhsph.edu/clf/programs/food_mapping/index.html) (3/2012).

Leeds Urbal Mapping Project (http://www.turnstone.tv/mapping.html) (2/2012).

Ranasinghe TT, 2008. Family Business Garden as an Innovative Enterprise in Urban Agriculture. Urban Agriculture Magazine, 19, 22-24, RUAF, Leusden, Netherlands.

Schlesinger J., Drescher A., Shackleton C., Karg H. 2011. Locating the Margin? Agriculture and Livelihoods Along the Rural-Urban Continuum of African mid-Sized Towns Proceedings of the Tropentag 2011, October 5-7, 2011 in Bonn, 2011.

Streuobst in Europa (http://www.zukunft-streuobst.de/) (3/2012).

United Nations (UN), 2010. World Urbanization Prospects: The 2009 Revision. (http://esa.un.org/unpd/wup/index.htm) (2/2012).

United Nations (UN), 2011. World Population Prospects: The 2010 Revision (http://esa.un.org/unpd/wpp/index.htm) (3/2012).

USDA Food Desert Locator (http://www.ers.usda.gov/data/fooddesert/index.htm) (3/2012).

USDA Food Environment Atlas (http://www.ers.usda.gov/foodatlas/) (3/2012).

Sustainability assessment of urban vegetable cultivation systems in Red River Delta, Vietnam

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ABSTRACT

The living standard of the Vietnamese people has increased during last decade significantly and the demand for fresh vegetables has increased in line with the standard of living. In order to increase production, most vegetable farmers in Vietnam often become trapped in a cycle of ever-higher chemical usage. This paper presents the results of the sustainability assessment by multi-criteria evaluation that was done with weight factors and estimated by pair-wise comparison method based on twelve indicators. The case studies were conducted in three selected communes in urban areas of Ha Dong district in Hanoi in Red River Delta, Vietnam. The farms in those communes are small-scale vegetable and/or mixed vegetable-rice farms, using high inputs of soil amendments and pesticides for diversified cropping systems. The agricultural and vegetable land area in the study area had changed significantly from 2000 to 2009. The agricultural land area was decreased by 53.9% (3,025 hectares in 2000 to 1,479 hectares in 2009, respectively). The vegetable land area in 2009 was decreased of 690 hectares (47.3%) compared with the year 2000 (from 1458 hectares to 768 hectares in 2009 during this period). The agricultural land has been moved to other land use purposes, e.g. residential land, land for business premises, and land for public works. Vegetables grown in the study area included cabbage, bean, cucumber, leafy cabbage, cauliflower, tomato, kohlrabi, and cauliflower. The average farm size was 0.107 hectares with 0.089 hectares for vegetable production. The number of plots was 4.52 and plot size was 0.025 hectares. The aggregate value for environmental sustainability indicators was 0.38, the social sustainability indicator was lowest (0.25), and economic sustainability was highest (0.54). The overall sustainability of vegetable cultivation systems in the study area gave a very low sustainability index (0.36).

Keywords: Sustainability assessment, Vegetable, Red River Delta Vietnam, multi-criteria evaluation.

INTRODUCTION

Rapid urbanization, industrialization and population growth has been leading to shortages of land for agriculture while increasing demand for agricultural products that has necessitated a shift to agricultural intensification. The process of agricultural intensification by increasing inputs of agrochemicals, particularly synthesized nitrogen fertilizer, in order to increase productivity had been applied.

Since 1990, Vietnam has built many industrial zones. From 2005 to 2010, 128 new industrial zones were built on an estimated area of 22,813 hectares. Only in 2011, about 22 large industrial zones will be in operation additionally. These zones are occupying 26,517 hectares of land, alongside hundreds of small-medium industrial zones in 47 provinces and cities nation-wide. Until July 2011, total registered foreign investment in Vietnam amounted to over USD 203 billion in 12,959 projects (Mai 2011).

In the last decade, the urban population has grown at an annual rate of 2.5% compared to an overall population growth of about 1.05% per year (GSO 2011). In Hanoi, the capital of Vietnam with over 6,561.9 thousand inhabitants, the economic development, industrialization and urbanization has quickly expanded in the last ten years. Therefore, during this period 11,000 hectares of farm land were converted into industrial and urban land for 1,736 projects. This conversion of land is a critical situation for about 41,000 agricultural households (HSO 2010).

Nevertheless, vegetables are still being produced in the urban rural interface. Beside the increasing amount of land, another problem appears to be coming from the high contamination of air, water and soil due to industrial pollution and inappropriate use of fertilizers and pesticides. Especially in urban areas such as Hanoi, municipal waste and toxic waste from the industries has resulted in severe soil contamination and environmental pollution (Anh et al. 2004). The research of Uga et al. (2009) revealed that the vegetables purchased at a suburban market in Hanoi were highly contaminated with parasite eggs. A study undertaken by the Institute for Ecology and Biology Resources in 1998-1999 found nitrate levels from fertilizer use much higher than allowed maximum residue levels. The aim of this research was to investigate the characteristics of the existing vegetable cultivation systems in the urban-rural interface and to evaluate the sustainability of those systems in terms of economic, environment and social criteria. The results from this research can guide farmers and policymakers in order to develop strategies for clean vegetable production.

RESEARCH METHODS

Case studies

The case studies were conducted in three selected communes in urban areas of Ha Dong district in Hanoi in Red River Delta, Vietnam. This study has used both qualitative and quantitative approaches of scientific inquiry to find the answers to the stated objectives. The main exploration of this study is based on qualitative analysis using structured questionnaire survey. Primary data was collected at farm/household level. Secondary data was collected from the existing literature, various organizations and departments, including government institutions, data archives, research centers, and NGOs to gain additional information. A workshop was organized to define the score weight of each factor according to Analytic Hierarchy Process, AHP (Saaty 1980).

Data analysis

To achieve the objective of the study, multi-criteria were used to evaluate the suitability based on economic, ecological, and social sustainability (Fig. 1).

Twelve indicators were used such as financial return (FR), index of yield trend (IYT), efficiency of market channel (EMC), use of chemical fertilizer (UCF), use of organic fertilizer (UOF), cultivation of legume crop (CLC), use of chemical control (UCC), human health (HH), input self sufficiency (ISS), employment (EPL), access to credit (AC), and access to agricultural extension (AAE).

Instead of using the raw data for each indicator directly, the data were normalized to obtain a common scale and allow statistical aggregation. Let v_i be the data value of indicator i. Then its normalized value N(v_i) is calculated as in equations 1, 2, 3, 4, and 5 (adopted from Allard et al. 2004). With this approach, the raw values were converted to common membership grades (from 0 to 1.0).

If the target value T(vi) corresponds to maximum:

$$N(v_i) = \begin{cases} \dfrac{v_i - \min(s)}{T(v_i) - \min(s)} \text{ for } v_i \le T(v_i), \text{ and} \\ 1 \text{ for } v_i \ge T(v_i) \end{cases} \qquad (1)$$

If the target value T(vi) corresponds to minimum:

$$N(v_i) = \begin{cases} 1 \text{ for } v_i \le T(v_i), \text{and} \\ \dfrac{\max(s) - v_i}{\max(s) - T(v_i)} \text{ for } v_i \ge T(v_i) \end{cases} \qquad (2)$$

If the target value T(vi) corresponds to an interval:

$$N(v_i) = \begin{cases} \dfrac{v_i - \min(s)}{T(v_i) - \min(s)} \text{ for } v_i \le \min T(v_i), \text{ and} \\ 1 \text{ for } v_i \in [\min T(v_i), \max T(v_i)], \text{ and} \\ \dfrac{\max(s) - v_i}{\max(s) - T(v_i)} \text{ for } v_i \ge \max T(v_i) \end{cases} \tag{3}$$

If the target value T(vi) corresponds to “yes” or “no” statement:

$$N(v_i) = \begin{cases} 0.5 \text{ for } v_i = T(v_i), \text{ and} \\ 0 \text{ for } v_i \ne T(v_i) \end{cases} \tag{4}$$

and the value of each linguistic variable is given by the average aggregation:

$$T = \frac{\sum_i N(v_i)}{n_i} \tag{5}$$

where: n_i = total number of indicators, min(s) = minimum values, max(s) = maximum values, T(v) = target values, data(v) = data values, and N(v) = normalized value.

The method for aggregation of all indicators and the set of weights in multi-criteria decision analysis problem to assess the overall sustainability was chosen as proposed by Allard et al., 2004.

$$I_{sus} = \sum_{i=1}^{n} I_i * w_i \tag{6}$$

where: the overall sustainability indicator (I_{sus}) is the result of the weighing average of all the normalized indicators I_i. w_i represents the weight of the ith indicator.

RESULTS

Field study results

The annual average rainfall in Hanoi from 2005 to 2008 was 1733.3 mm, with more than 50% of the rainfall occurring in the period from July to September. The mean temperature varied between 16.7-29.9°C, with the warmest period occurring during June to August and the coldest during December and February (Figure 2); the relative humidity ranged between 74 to 82.5% (HSO 2010). The soils are classified as alluvial soil (Hoc 2001).

The farms in those communes are small-scale vegetable and/or mixed vegetable-rice farms. Vegetables grown in the study area included head cabbage, bean, cucumber, leafy cabbage, cauliflower, tomato, kohlrabi, and cauliflower.

The average farm size was 0.107 hectares out of which 0.089 hectares were used for vegetable production; the number of plots was 4.52 and average plot size was 0.025 hectares.

The agricultural and vegetable land area in the study area had significantly changed from 2000 to 2009 (Figure 4). The agricultural land decreased by 53.85% (3205 hectares in 2000 and 1,479 hectares in 2009, respectively).

The vegetable land area in 2009 was 1,458 hectares, a decrease of 690 hectares (47.33%) compared with the year 2000. The agricultural land has been moved to other land use purposes, e.g. residential land, land for business premises, and land for public works.

The weight factor was estimated by pair-wise comparison method (Saaty 1980) based on twelve indicators.

After structuring the problem as a hierarchy, workshops were organized and the matrix of pair-wise comparisons was established; the factors were checked for consistency and weight attribution. The results of factors weighing are represented in table 2.

Sustainability assessment results

After quantification of criteria, the normalization method mentioned in equations 1,2,3,4 and 5 was used to normalize the data. Normalized values of quantified data from each indicator can be observed in table 2. Normalized values are constructed in 0 to 1 scale and the higher the value, the better performance in sustainability.

According to normalized values in table 3, the financial return indicator (FR) had the highest sustainability value (0.8) as farmer's main concern is the income from their farm. The results showed that the access to agricultural extension indicator (AAE) had the lowest sustainability value (0.09). This indicated that farmers have limited access to agricultural extension service. Farmers also have limited access to the credit services so the normalized value of sustainability for this indicator was 0.5. The trend of organic fertilizer usage declined, thus the normalized value of sustainability was only 0.18. The trend of chemical fertilizer usage increased and for this reason the normalized value of sustainability was 0.23. The sustainability value of YIT, ECM, EPL, and CLC had low sustainability values such as 0.33, 0.48, 0.20 and 0.42, respectively.

After normalization of the data, aggregation method in equation 6 was used to obtain the aggregate value. In this calculation w_i represents the weight of each indicator (Table 2).

The environmental sustainability indicators were 0.38, the social sustainability indicator was lowest (0.25), and economic sustainability was highest (0.54). The overall sustainability was only 0.36, hence we can conclude that the sustainability of urban vegetable cultivation systems in the Red River Delta of Vietnam is characterized by low sustainability.

CONCLUSION

The agricultural and vegetable land area of the farm households in urban Hanoi in the Red River Delta, Vietnam was small and fragmented and threatened by urbanization.

The organic fertilizer usage declined and the chemical fertilizer usage increased. Farmers main concern was just the income from their farm. Farmers have limited access to the agricultural extension service.

The overall sustainability of urban vegetable cultivation systems in urban Hanoi in the Red River Delta, Vietnam was assessed. It can be concluded that the sustainability of vegetable production in the urban-rural interface is very low. It is necessary to improve the extension service and also to support credit systems for innovative solutions in vegetable production.

Acknowledgment

We would like to pledge our sincere gratitude to the Vietnamese Government for the financial support.

References

Allard, F., F. Cherqui, E. Wurtz and L. Mora. 2004. A methodology to assess the sustainability of rehabilitation projects in urban buildings.

Anh, M.T.P., M. Ali, H.L. Anh, and T.T.T. Ha. 2004. Urban and Peri-urban Agriculture in Hanoi: Opportunities and Constraints for Safe and Sustainable Food Production. Shanhua, Taiwan: AVRDC -The World Vegetable Center, Technical Bulletin No. 32, AVRDC Publication 04-601. 66 pp.

GSO. Vietnamese General Statistic Office. 2011. Agricultural Statistic Year Book. Ministry of Agriculture and Rural Development, Vietnam.

Ha Dong statistic department. 2010. Ha Dong Statistical Yearbook.

Hoc, N. Q.2001. Evaluation and orientation for use of land and water for sustainable agricultural development in Dong Anh - Hanoi. Dissertation. Hanoi Agricultural University.

HSO. 2010. Hanoi Statistics Office. Hanoi Statistical Yearbook.

Mai Nguyen. 2011. Foreign investment in Vietnam (the first seven months in 2011). Available online 5/8/2011.http://www.tapchicongnghiep.vn/News/channel/1/News/152/15793/Chitiet.html
National Institute of Nutrition - United Nations Children's Fund. 2011. A review of the nutrition situation in Vietnam 2009-2010. Medical publishing house, Hanoi, Vietnam.
Saaty, T. L. 1980. The Analytic Hierarchy Process. New York: McGraw-Hill.
Uga, S, NTV Hoa, S Noda, K Moji, L Cong, YAoki, SK Rai and Y Fujimaki, 2009. Parasite egg contamination of vegetables from a suburban market in Hanoi, Vietnam. Nepal Med Coll J 2009; 11(2): 75-78.

TABLES AND FIGURES

Table 1. The weight of indicators for sustainability assessment in this study

Economic		Social		Ecological		Overall sustainability	
Indicators	Weight	Indicators	Weight	Indicators	Weight	Indicators	Weight
FR	0.39	ISS	0.12	UCF	0.05	ECONsus	0.17
YIT	0.44	EPL	0.47	UOF	0.31	SOCsus	0.39
ECM	0.17	AC	0.12	CLC	0.37	ECOLsus	0.44
		AAE	0.30	UCC	0.07		

Synthesized from stakeholder workshops, 2010 by AHP

Table 2. Normalization of sustainability indicators

Indicators	Unit	min(s)	max(s)	T(v)	data (v)	N (v)
FR	Million dong/ha	0	max	50	40.212	0.80
IYT	Index (yield trend)	-1	+1	max(s)	-0.3333	0.33
ECM	Index (market channel trend)	-1	+1	max(s)	-0.0303	0.48
ISS	Index (ratio of local inputs cost to the total inputs cost)	0	1	max(s)	0.55	0.55
EPL	Index (labor involved trend)	-1	+1	max(s)	-0.6061	0.20
AC	Index (yes, no statement)	0	0.5	max(s)	0.50	0.50
AAE	Index (yes, no statement)	0	0.5	max(s)	0.09	0.09
UCF	Index (use of chemical fertilizers trend)	-1	+1	min(s)	0.54546	0.23
UOF	Index (use of organic fertilizers trend)	-1	+1	max(s)	-0.63636	0.18
CLC	Index (ratio of legume crops area/total area)	0	3,528	max(s)	1,476	0.42
UCC	Index (use of chemical control trend)	-1	+1	max(s)	0.0606	0.53
HH	Index (community health status trend)	-1	+1	max(s)	0.2121	0.61

Note: min(s) = minimum values, max(s) = maximum values T(v) = target values, data(v) = data values, N(*v*) = normalized value, 1 USD = 19,700 VND (June 2010)
Analyzed from households survey, 2009-2010

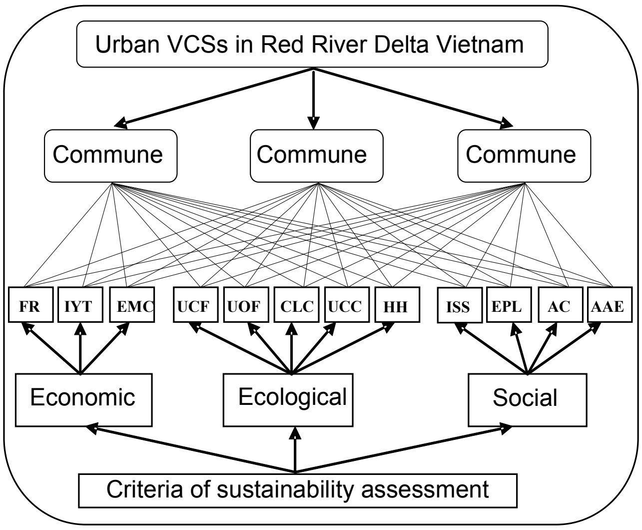

Figure 1. The framework for suitability assessment in this study

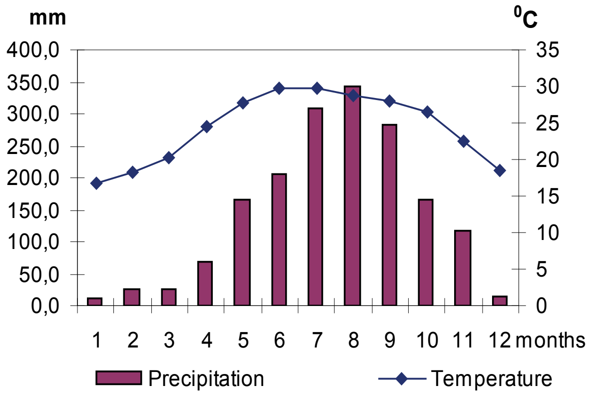

Figure 2. The monthly rainfall and temperature in the study area (2005-2008).

Source: HSO 2009

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice-Rice		Winter-Spring Rice				Summer-Autumn Rice						
Rice, Bean, Leafy cabbage, Head cabbage, Cauliflower,…			Winter-Spring Rice			Bean, Leafy cabbage		Head cabbage, Cauliflower, Tomato or Kohlrabi				
Leafy cabbage, Cucumber, Bean, Cauliflower, Head cabbage…			Leafy cabbage, Cucumber or Bean					Head cabbage, Cauliflower, Tomato or Kohlrabi				

Figure 3. Crop calendar in the study area

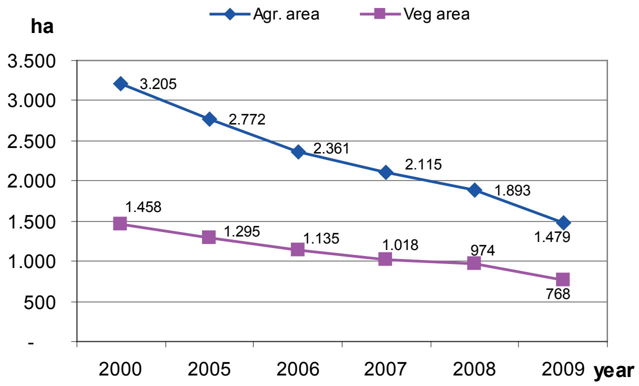

Figure 4. The agricultural and vegetable land area in Ha Dong district
Source: Ha Dong Statistical Department, 2010

Urban hydroponics – facts and vision

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ABSTRACT

Urban hydroponics means growing plants in soilless cultivation in various substrates or strait in nutrient solution. Almost any growth substrate will do, as long as nutrient solution and irrigation intervals will be adapted accordingly. In this way, a variety of different hydroponics systems can be used in urban areas for (1) intensive, high value crop production, for (2) small holding and hobby ornamental and vegetable cultivation, for (3) in and out door beautification and for (4) greening up walls and roofs in residential areas. In many instances, it will reduce air pollution.

Hydroponically grown vegetables on small infertile plots, on flat roofs or on terraces in urban areas add to food security and food safety, where land cost for traditional agriculture/horticulture is too expensive. It enables people, living in squatters but also in residential blocks to grow and consume what they plant, and may sell or trade the surplus for income generation.

Plants in soilless culture or hydroponics need less water and fertiliser compared to cultivation in soil with higher harvested quality and yield and without soil erosion. Environmental contamination can be greatly minimized. Produce is hygienically clean because it has no soil contact. Crop rotation is not necessary.

Urban hydroponics has seen in recent years new inventions such as Air-Dynoponics, a special aeroponics suitable for the tropics and Aquaponics, which allows fish cultivation in tanks by recycling the water with the fishes' feces as organic fertilizer from the tanks to beds for growing vegetables hydroponically.

To exploit best the full potential of urban hydroponics, horticulturists, architects, engineers and city administrators should team-up.

Keywords

Soilless crop production; City environment; Aquaponics; Aeroponics; Vertical farming; Food security

INTRODUCTION

Urban agriculture in tandem with urban horticulture has gained enormous attention and popularity in recent years to such an extent that a wealth of data in articles and technical information is flushed out by the internet all the way crossing into such popular communication platforms as twitter and facebook. Placing the puzzle of urban hydroponics among the big players of this agenda is surprisingly not very difficult because it fits so well to major headlines, e.g. climate change and energy conservation, mega cities and urbanization, increase of the world's population, food security, health and welfare, water scarcity, agricultural resources and so on. This article will provide on overview only, not claiming to be all that comprehensive, though up-to-date. The flow of information is overwhelming and very fast.

The earth's population totaled in 1950 only 2.6 billion inhabitants. A realistic estimation forecasts 9.2 billion in the near future of 2050. The rural population numbered 1.8 billion in 1950 and will reach 2.9 billion in the year 2050 whereas only 800 Million people occupied urban areas in 1950 and will come to 6.3 billion in 2050 (UN 2010). The World Urban Forum 6 will convene in Naples, Italy in September 2012 to discuss the urban future under the heading "More than 50% of humanity lives in towns and cities – a figure projected to grow to two thirds in little over a generation." Demographic trends, although, show that the earth's population will grow differently in various parts of our planet; regardless, certainty of urbanization will continue (Table 1).

This author initiated and supervised in 1997 a European-funded project on Urban and Periurban Small and Medium-sized Enterprise Development for Sustainable Vegetables Production and Marketing Systems with partners from the Philippines, Vietnam, Laos, Germany and France, recognizing that the flight from rural areas will develop into a worldwide trend with rapid change in socioeconomic, cultural and environmental conditions (PUVep 1997).

Will urban hydroponics have any relevance under the premise of rapidly expanding cities? Why should we need such a technology and what facilities are required for implementation? After all, urban hydroponics is only the "little sister" of urban agriculture.

Within the last decade, urban agriculture has found strong support among many actors. This has not always been the case. FAO conducted a symposium in New York in 1997 where the mayor of Lusaka, Zambia stated: *"Authorities are hesitant to be more proactive on urban agriculture because it is largely seen as resulting from a failure to address rural development adequately. It is creating havoc in urban land use planning and management. It is holding up city development and redevelopment."* (FAO 1997)

This context changed some years later, when another mayor, this time Christopher Iga from Kampala, Uganda emphasized: "*Urban agriculture (UA) has several advantages in Kampala. It increases urban food security, produce from rural areas is expensive and less fresh, and it creates sources of income. UA also reduces open space maintenance costs to local government.*" (Mougeot 2006). Experts identified in the 1997 conference organized by the FAO: "What these diverse activities have in common—and in some cases what sets them apart from rural agriculture—is proximity to large settlements of people, thereby creating opportunities as well as risks."

Table 2 summarizes the opportunities and risks of urban agriculture. Urban agriculture has seen in recent years a clear shift to urban horticulture, mainly to produce vegetables for food and ornamentals for beautification. As a matter of facts, the earlier identified risks as listed in Table 2 became diminished by implementation of urban hydroponics. This technology has met the demands of modern cities (1) for physical and psychological in- and out door relaxation; (2) for improving city environment and (3) for food and income security to provide year round a wide variety of fresh fruits and vegetables (FAO 2010). Moreover, urban hydroponics reduces water needs and cultivation space for plant growth, minimizes food health risks of harvested produce and helps to check environmental contamination.

Urban hydroponics needs for successful implementation certain basic prerequisites, but also some restrains have to be recognized (Table 3). In addition, the very nature of urban horticulture and more so of urban hydroponics depends heavily on close cooperation by several actors—horticulturalists, architects, engineers, and government administrators—to make this scheme successful.

Urban hydroponics for greener cities

Urban hydroponics is not an invention of our time. The Hanging Gardens of Babylon and the Floating Gardens of the Aztecs were beautifying the civic centers, in addition, fruit trees and vegetables were cultivated in such places. Today, modern cities use urban hydroponics for physical and psychological in- and out-door relaxation. It is part of the ecological system to manage the urban environment. In arid climate it can increase humidity and lowering temperatures. It captures dust and polluted air by the foliage of the plants. It can contribute to the reduction of the net discharge of CO_2, one of the gases speculated to contribute to global warming, because plants and trees need CO_2 for photosynthesis. The captive action, of course, is at its highest during the vegetation growth phase. In cities, however, much of the carbon stored in vegetation is likely to be quickly released through decomposition to organic matter, so lasting effect is little (Deelstra and Girardet 2005).

Hydroponics gardens often go vertically, since city space is limited. The obvious benefit is the immediate improvement in environmental quality. While traditional building facades serve as massive heat sinks that radiate heat and increase ambient air temperature, living walls thermo regulate buildings by trapping heat in the winter and cooling buildings in the summer.

A recent visit to Bangkok has vividly demonstrated what city management can do. The grey, vertical concrete structures of the road and railway overpasses were greened up with hydroponically grown ornamentals (Fig. 1). Also many multistory car parks were beautified with greeneries (Fig. 2) and commercial centers decorated with indoor hydroponics (Fig. 3). Inside air quality will be improved by living plants growing on interior walls.

All this shows that urban horticulture with emphasis on Hydroponics has positive impact upon the greening and cleaning of the cities, offering green zones for micro-climate changes (shade, temperature, sequestration of $C0_2$). Most importantly, city dwellers will enjoy such green areas, enhancing community self-esteem and stimulating community livelihood, as this has been well pointed out by the RUAF Foundation.

FAO has summed this up under "Cities of despair – or opportunity? The challenge is to steer urbanization from its current, unsustainable path, towards sustainable, greener cities that offer their inhabitants choice, opportunity and hope. The concept of "green cities" – designed for resilience, self-reliance, and social, economic and environmental sustainability should usually associated with urban planning." (FAO 2010).

One example demonstrates best where architects have successfully teamed up with horticulturists, engineers and city planners to create new urban culture.

Singapore has two young architects, Wong Mun Summ and Richard Hassel (WOHA) who have implemented a new living culture for people in tropical cities. Their skyscraper "The Met" in Bangkok has no more huge glass facades but the inhabitants of this multistory building are allowed to live with nature. On the outside walls grow exuberantly dense plant foliage, protecting the building like an umbrella against the heating sun. Staircases, walkways, terraces, balconies, pools create the impression of a parks landscape. Fresh air is no more a luxury. To create such nature within a "concrete jungle" is only possible by a technology such as hydroponics, allowing full control and automation of plant growth.

The expectation of modern urban landscape is dominated by ecological progress and people's health. No wonder that "Green Cities" are demanded by the people, something like a new paradise to harmonize technical advances and nature, urbanization and country side, population explosion and ecological balance. There is a slogan "*Rediscover harvest in your workaday life*". As always, there are contrary opinions by some architects who question "the renaissance of urban agriculture" under the label of sustainable city development. They claim that energy can only be saved by higher building density. They explain that an open housing design is energetically inefficient because of heating and cooling radiation. Such discussions are contra productive, simply by the demonstration of multi talented team work coming up with bold conceptions for changing today's often monstrous megacities into modern lifestyle centers. Needless to mention, that urban hydroponics plays a significant part in it.

Urban hydroponics for food security and income generation

Mariko Sato, Chief UN-HABITAT proclaimed that "*Mainstreaming urban agriculture in global climate change and food security needs highest attention*" (N.N. 2011). This means consequentially, new ways have to be found to connect and integrate agriculture and horticulture with urbanism.

Cities can be vibrant centers of culture and civilization, but for many people they are places of urban poverty, alienation and disadvantage, more so in developing countries. Inequity, unfortunately is under such circumstances prevalent (Holmer 2010). Appropriate measures are needed to overcome such situations. In many cities, where urban horticulture has already been implemented, production is often for self-consumption with surplus for trade or sale. The importance, though, both for volume and economic value must not be underestimated. Urban horticulture can grow food for the cities, utilizing empty lots, along road sides, but also on roof tops and in vertical farming, in any case hydroponically. urban horticulture has, if done properly, always environmental benefits. For one case, it reduces the need to transport produce into cities from distant rural areas, generating fuel savings, fewer carbon dioxide emissions and less air pollution (FAO 2010).

Urban horticulture serves an important purpose in the lesser developed world, often faced with shortages of water and arable land, making traditional agriculture in many instances difficult. Instead, hydroponics provides a far more sustainable and appropriate solution (Hydroponics Guide 2011). Of course, there are many hydroponics systems for the different operations in use: for large commercial enterprises they are quite sophisticated, capital intensive and requiring high technical knowledge from the operators. This scale goes all the way down to simple hydroponics which is more for the low-resource urban population living under poverty conditions. Its produce will add economic and nutritional benefits by securing year-round supply of fresh fruits and vegetables for their own consumption. Simple hydroponics promotes water savings in recycling and decontamination of water for growing of plants in areas with marginal conditions of adverse climate, soil, space limitations, and water scarcity (FAO 2011). Therefore, this is the answer for urban people, including the poor to access and afford healthy and nutritious vegetables, contributing to their wellbeing. The advantage of vegetable production by simple hydroponics technology is based on the fact that large amounts can be produced in a short time from a small area. Field crops such as cereals and tuber crops have no chance to compete (Keatinge et al. 2011).

The author managed an international European financed INCO-MED project with 8 partners from 2002 to 2006, working on "Efficient water use through environmentally sound hydroponic production of high quality vegetables for domestic and export markets in Mediterranean countries". The results of this project are conferrable to benefit large scale vegetable producer, as well as small holders in peri urban areas and city dwellers on small urban lots, mainly by improving the water use efficiency, allowing the application of water with poor quality and the reduction of fertilizers (Fig. 3). The impact of water stress and water quality was identified on the quality of harvested vegetables (Ecoponics 2006).

Many countries in the Middle East have introduced hydroponics as a viable form of urban and peri urban horticulture for growing vegetables. "*Although the idea of planting rooftops isn't new, it has only been carried out in Egypt recently*", says Dr. Ayman Farid Abu Hadid, "*the idea began at the Agricultural Unit in Egypt's Ain Shams University where scientists had been designing new methods of agriculture to suit Egypt's densely populated cities for exhibitional purposes. Then, the Food and Agriculture Organization (FAO) adopted the idea and carried it out in many developing countries such as Kenya, Senegal and Columbia and also suggested it be applied in Egypt as well."* FAO also helped the Egyptian government to launch the "Green food from green roofs" program that encouraged residents to grow their own vegetables in beds and containers filled with rice husks, sand or peat moss, fertigating the plants hydroponically (FAO 2010).

The population of major cities in Egypt still continues to expand. Out of 65 million, almost 40% are living in urban centers like Cairo (16 million) or Alexandria (7 million.). Many of those families have limited resources. The consumption of fresh fruits and vegetables is low since no garden space in the crowded cities is left available and people have to buy products from the markets. This situation is having a negative impact on the nutritional status and overall wellbeing of the population in the poor urban and peri-urban neighborhoods. The "Green food from green roofs" program enables the poor families to grow their own fresh vegetables on rooftops. The program is specifically targeted to the poorer families, living in the densely populated suburbs where it will not only provide fresh vegetables for home consumption but it will also create a source of income, specifically for women at home. Moreover, children will learn to know a variety of vegetables. The technique for growing on rooftops is based on simple hydroponics culture systems, aiming very high water use efficiency. "Green food from green roofs" program not only improves the availability of high quality fresh vegetables for the urban poor, but it also encourages a more efficient use of water which is so scarce in Egypt. In comparison to traditional open field production and conventional irrigation, the water-use efficiency is considerably improved by using closed soilless culture systems. This programme is saving on cost for transport, packaging and storage of the products. Residents also found an additional benefit: It lowers temperature in the homes. Rooftops planted with vegetables are 7° C cooler than those next door – and, when practiced on greenbelts, improves landscapes and citizens' quality of life. For simple implementation of this program, cooperating growers are provided with premixed soluble fertilizers to be added into the tank at the recommended quantity per liter of irrigation water for regular nutrient supply to the plants.

And here is another success story for urban hydroponics, this time in SEA. Cebu municipality, the oldest city of the Philippines with an estimated population of 822,000 (in 2009) is pretty developed with a burgeoning shipping industry and a growing communications sector. But it still experiences poverty among its residents. The city government tries new, innovative ways to tackle poverty with hydroponics, allowing to be implemented in relatively small spaces and by the reuse of plastic containers, helping to reduce urban waste. The Department of Social Welfare and Development and the Department of Science and Technology are both hoping that through education of the hydroponics method it will be possible to decrease the threat of food shortages but to also turn some of the derelict areas of the urban environment into greener, more productive spaces. The project forms part of a wider welfare program of the Philippines government. The use of hydroponics is first of all targeted to families to help themselves. For the municipality, simple hydroponics in urban gardening will be a way of food production in the process of urban regeneration (Hydroponics Guide 2012).

A unique approach of hydroponics and animal feed production is practiced in Peru. Guinea pigs are raised in farms near population centers and in households for roasting at feasts like chicken in other places. The small mammals are fed with wheat sprouts produced hydroponically, allowing a continuous supply of fresh, nutritious and healthy food.

In early 1990 a simple non-circulating hydroponics system was developed at AVRDC in Taiwan, built on the principle of “air roots” and “water roots”. Normally, hydroponics systems need an external energy source to supply mineral nutrients and oxygen to the plants. As the AVRDC system does not need electricity, it can be used in places with no or uncertain supply, such as in many towns and rural areas in developing countries.

The simple set up system only requires a watertight container (e.g. a polystyrene box) to hold the nutrient solution; a lid covering the container and plastic perforated cups with some support medium for the seed or seedling, which are immersed from the cover down into the nutrient solution. The nutrient solution developed at AVRDC (Table 4) gives vegetables a near-optimal supply of mineral nutrients. If the pH level of the solution rises above 7.8, as may occur in long-season crops such as tomatoes, addition of sulphuric acid can bring it down to the preferable pH level of 5.5-6.0. Studies show that the same solution is suitable for fruity and leafy vegetable crops.

Initially, the solution level is set at about 2 cm above the base of the perforated cups. At first, it will drop slowly as capillary rises and evaporation occurs. It falls faster as roots develop and take up solution. A number of roots remain in the air space between the support structure and the surface of the solution. As these aerial roots and the roots floating on the solution surface provide oxygen for normal root function, the solution does not need to be aerated (Midmore and Wu 1999).

Kratky, a horticulturist from the University of Hawaii has worked further and modified the AVRDC system for household and even semi-commercial use. He says, an entire crop can be grown with only an initial application of water and nutrients for his non-circulating hydroponic method. Electricity and pumps are not needed. Tanks are filled nearly to the top with an appropriate nutrient solution (e.g. a plastic juice bottle containing 4 l of water plus 5 g of 10-8-22 hydroponic fertilizer) for the crop to be grown. A cover is placed over the tank with small, perforated plastic cups holding transplanted seedlings in growing medium immersed in nutrient solution. The entire growing medium in the cups becomes wet by capillary action, thus automatically watering and fertilizing the plants. The nutrient solution level in the tank drops below the cups within a few weeks such that direct capillary wetting of the growing medium is no longer possible. However, by this time, roots have emerged out of the perforation of the cups with their lower portion immersed in nutrient solution, while the upper portion of the roots resides in the moist air layer between the cover and the nutrient solution. Most of the time, the crop can be harvested when less than 10 per cent of the original nutrient solution remains. The elementary handling involves filling a 4-liter plastic juice bottle with water, adding fertilizer and planting in a net pot. No additional watering or fertilization is required for the duration of the crop. Larger quantities of lettuce may be produced commercially utilizing the same concept but in shallow (9-14 cm high) boxes filled with nutrient solution and covered with a polystyrene board. Cucumbers and tomatoes may be produced in a similar manner, except they require a larger nutrient solution tank. A plastic trash container can serve (Kratky 2004).

Simplified Hydroponics (SH) has been used by low income families in urban and peri-urban areas of Uruguay to improve their living standards. La Paloma-Chuy is one area of Uruguay under pressure from urbanization. Over the last few years urban areas have experienced an increase in poverty. To overcome this problem, the Departmental Government of Rocha sought new development strategies especially for women who are the traditional heads of the family household. The government decided to promote family-grown vegetable gardens in the home using SH techniques. The aim of the project was to improve the health and quality of life of families in crowded urban communities and to promote similar conditions also for other urban populations in Uruguay and all over Latin America. The project involved training the families themselves, focusing on women and fostering self-employment of idle household labor using the scarce resources available to them. Also for Latin America, SH proved to be an ideal food production system in urban and suburban areas, offering the advantage of using places that have not previously been thought appropriate for food production, such as courtyards, small gardens, walls, balconies and even rooftops.

Caldeyo Stajano (2003) is adding to the report of his project some very interesting social aspects:

> "SH produces high quality, safe food, rich in nutrients and minerals. Since they were grown by the family, they were harvested immediately before their use, thus, the produce was fresh and kept its nutritional qualities intact. Another advantage was that these crops were cultivated above and away from contaminated ground areas. These vegetable gardens have enabled the intake of a broad range of excellent quality fruits and vegetables. Many participants improved their family income. In most cases, the participants did not earn money, but they provided nutritious vegetables for their family and generated sufficient resources to pay for the expenses of having a vegetable garden. Others traded their vegetables to shops in the area for other complementary foodstuff, improving the family diet further. Monetary rewards occurred for those families who had vegetable gardens that exceeded $30m^2$. When participants start to see concrete results (i.e., they consumed top quality hydroponics produce they had grown), they developed greater self-esteem. They felt capable of doing something productive and positive to feed themselves and their family. Besides being a clean plant production system, hydroponics had something special: it is a technology that helps to arouse curiosity, it encourages innovative thinking and presents a challenge for people, and it provides leadership opportunities. Some families had little in common to talk about among their members, but in the hydroponics vegetable garden there was a shared interest. This factor helped reduce family stress levels. Once people acquired a good command of SH techniques, they were able to develop their own personal inventiveness in the use of different containers and growing spaces, which in turn nurtured further motivation. With proper technical assistance, as time passes, the first set of participants in each community acquired more skills and became leading advocates of hydroponics vis-à-vis their neighbors. This happened in two ways: First of all, because of the "attraction factor" they had at home: their own vegetable garden. It conveyed something tangible and they could boast they "had achieved something". This was an actual event that aroused the interest of their neighbors, and was a source of encouragement for others to imitate the positive values experienced by others. Secondly, they were able to convey their knowledge of the technology to their neighbors in a simple manner, because they already knew how to do it. This promoted leadership based on positive values. This was a major social component."

Producing quality temperate vegetables like lettuces under tropical hot and humid environment is most difficult. Geoff Wilson is an agricultural journalist and Australia's representative of a group of 16 national organisations for an international Green Roofs organisation. He is reporting in an article on "Singapore's New Business Opportunity: Food from the Roof" (Wilson 2005), where such obstacles of tropical conditions can be overcome by a new and special aeroponics technology invented in Singapore. In conventional aeroponics, cooled nutrient solution is continuously misted onto the plant roots in a light-proof box. Cooling of the nutrient water lowers the plant root zone temperature and increases root zone aeration to keep it around 10 degrees C lower than the day-time ambient temperature, which would "cook" the roots and cause wilting and plant loss. However such refrigerator-cooling is expensive, even for high priced vegetables in the markets of the rich city state of Singapore.

This has been an economic limitation on the aeroponics technology. Then in 2004 Gregory Chow, lecturer at the Ngee Ann Polytechnic of Singapore has invented the Air-Dynaponics - a much less costly way of maintaining low root-zone temperatures for commercially successful aeroponics. The excellent plant growth and production that has been achieved by the Singapore type aeroponics system is mainly due to control of root zone temperature, nutrition, moisture and the gaseous phase. Researchers theorize that the nutrients infused with oxygen "energized" the entire root system and enhanced the plant top biomass (Chow 2004). It costs only about one fifth to cool the nutrient solution. Air-Dynaponics uses the cooling principles of vaporization by the Venturi nozzle effect in an air-powered operation that not only reduces the temperature of the nutrient solution, but also adds aeration by dissolved oxygen. This special technology can open a new scope for a modified Urban Aeroponics suitable for the tropics and sub-tropics.

In Singapore it is already commercially used to produce high-value vegetable crops such as butter head lettuce, Batavia lettuce and Romaine lettuce with the temperate butter head lettuce forming the greatest quantity.

Professor Lee Sing Kong, Dean, Graduate Programmes and Research, National Institute of Education of Singapore's Nanyang Technological University is taking one step further by advocating "sky farms" based on the Air-Dynaponics technology which has already been pioneered by Singapore's AeroGreen Technology Pte Ltd., initiated by the reputed agro company Sime Derby.

The other types of the traditional leafy vegetables, which are cheaper, for instance, Japanese Cai Xin, Chinese cabbage, kale, Chinese spinach, Chinese Nai Bai, leaf lettuce and herbs are grown in Singapore by the Taiwanese dynamic root floating system of hydroponics. In this growing method, a nutrient sprayer lifts nutrient solution, and sprays it onto the "aerial roots" hanging down through an air gap while infusing oxygen into the nutrient solution. The feeder roots remain constantly submerged in oxygen rich water with nutrients providing most of the nutrition and oxygen for the plants (Chow 2004).

A more recent, very interesting new topic is aquaponics, the marriage of hydroponics with aquaculture. The combination of hydroponics for plant cultivation with nutrient solution and aquaculture for fish farming has created the technology of aquaponics. An aquaponics system is a co-dependent ecosystem that utilizes the benefits of each technology to the largest effect. The growing of both, fish and plants have symbiotic benefits. In the aquaponics system the water with the fish feces is pumped from the fish tank and turn them into nutrition for the plants. In return the plants clean the water to be pumped back into the fish tank. Subsequently, both systems are benefitting, the hydroponics growing is far cheaper and easier as mineral nutrients have not to be purchased, thus, plants are grown completely organically. The fish farm benefits for not having to purify with an additional expense the water and no pesticides harm the fish. Thus, aquaponics is not only cost effective but diseases in both systems are more easily controlled and reduced. It is also an excellent solution for growing in small spaces, making it very suitable for Urban Farming (Hydroponics Guide 2010).

The Canadian scientist Savidov proved that a recirculating aquaponic system results in less root diseases in the crop, resulting in increased crop yield from aquaponics compared with conventional hydroponics. A possible explanation is the organic components in the nutrient solution (possibly humates) which make the trace elements more readily available to the plants for improved growth.

There may be an added marketing advantage created for vegetables produced by the aquaponics technology: since no pesticides and mineral fertilizers are used in the system, the produce should eventually qualify for an organic product certification.

One of the major problems with aquaponics is that nearly all the operators have come to aquaponics from an aquaculture background, and consider that the horticultural part is easy (Nichols and Savidov 2011).

The United Arab Emirates (UAE) import around 85% of its food. The locally managed Baniyas Centre is building an aquaponics operation for an initial 200 tonnes of fish and 300,000 heads of lettuce annually. Currently, the centre is focusing on the production of lettuce, although in the future other produce such as tomatoes, cucumbers, even okra will be cultivated. The system uses a variety of tanks, filters and irrigation equipment to ensure that the fish waste is fed to the plants for nutrition and the plants purifying effects on the water can be circulated back to the fish tanks (Hydroponicswizard 2011[2]).

Japan is always good for new innovations, and the Japanese consumers for their love for freshly prepared vegetables. The latest news is a hydroponics vending machine for use in urban areas where growing fresh vegetables is a problem. The vending machine is labeled the "Chef's Farm". Vegetable seeds are planted in sponge pots which are placed in culture beds in metal frames. The result is that across the five beds, different vegetables can be grown, although lettuce is the most popular. The vending machines cost around $90,000, not cheap but it is expected that the cost of the investment will recoup in approximately five years. The venting machines have already operated since the summer of 2010. It proves just how versatile hydroponics can be for modern urban areas where a lack of fresh vegetables is apparent and cash money is available (Hydroponicswizard 2010).

Visions for urban hydroponics

"The Conversation," an independent journal of analysis and commentary from universities and research sectors in Australia, covered recently the story by Busicchia "Urban farmers on top of the world," which provides quite a realistic picture of the present situation: "North America appears to be leading the way in rooftop farming. Major American supermarket chains have already signaled their interest to build and operate rooftop farms (see also below "Better Food Solutions" by Theduke 2011 and "Gotham Greens' first greenhouse facility in Brooklyn" by Zeveloff 2011).

While setting up new urban farms in new city development may be somewhat easier, integrating farms into old buildings is one of the obstacles that architects and urban planners will have to face. Obtaining permits and resolving zoning issues will definitely require co-operation and shared vision from local authorities.

The future food supply system will need to be resilient in the face of uncertainty, be sustainable while offering healthy food at low social and environmental costs, and be competitive while meeting consumer expectations.

Can urban farming be part of this future? It is perhaps a little too early to predict, but clearly the prospect of a direct-to-consumer model should attract further community and business attention" (Busicchia 2011).

Unquestionable, the consumer desires fresh, locally produced fruits and vegetables in the super market shelves. For those expectations, urban hydroponics can play a major part. Hundreds of miles in transportation cost will be saved. The New York company "Better Food Solutions" has stared with this idea and placed their own hydroponics garden on the roof. The result is a much more environmentally friendly produce that tastes great and can simply be sent downstairs for sale. The benefit for the consumer is fresher produce that has gone from harvest to shelf within a short time. Such a system of rooftop gardens has also considerable potential for restaurants and even residential properties (Theduke 2011).

In lesser developed regions of this world urban hydroponics plays a different role than in industrialized, highly developed countries; in the setting where hunger is not the first worry of each day, growing fruits and vegetables without chemicals and to reduce the amount of food miles that are linked with traditional agriculture has higher priority. Some visionary experts see a future with vertical farms in skyscrapers. For this reason, some protagonists of this idea have created the name Skyfarming (Sauerborn 2010). Such buildings may also incorporate aquaponics to ensure a source of fresh fish.

Small and larger hydroponics operations within city limits are not a special site anymore but not yet in skyscrapers. Vertical racks and trays have been in use for long, because they are mobile, ensuring plants to be exposed to natural light, at least for some time. But vertical farming projects are currently only small, although they could be scaled up, not necessarily right away in sky farms (Hydroponicswizard 2011[1]). By stacking crops vertically, large acreage can be saved. By using hydroponics the amount of water to grow crops will be greatly reduced. This could make hydroponics vertical gardens a space and money saving option for the horticultural industry with environmental benefits. The Vancouver-based company VertiCrop™ is in the market with a system consisting of a series of mechanical plastic trays stacked 8 high that can be placed on urban rooftops and other tight spaces. The trays are planted with vegetables and herbs that grow hydroponically. When plants are ready, conveyer belts bring the trays to the place of harvest and packing. The company claims that cultivation is possible with just 8% of the water and 5% of the space for the same quantity of harvested produce as required by standard farms. Energy efficient LED lights are on standby to supplement waning natural light when necessary (VertiCrop 2011).

Vertical farms could be placed practically anywhere, even in the middle of cities meaning that food can be produced locally, even in urban areas. But hydroponics of a large scale in high rise buildings must be proven to be sustainable and profitable before our cities will start to fill up with hydroponics sky farms (Hydroponicswizard 2010[1]).

The well-established journal "The Economist" published in its section "Technology" a critical article on Vertical Farming in late 2010. It is worthy to reflect on some passages. Dickson Despommier, a professor of public and environmental health at Columbia University in New York is regarded as the progenitor of vertical farming. He recently published his book "The Vertical Farm". A wide variety of designs for vertical farms have been created by architectural firms., but so far, the idea remains on the drawing board (Rajagapal 2010; Saxena 2011). The necessary technology exists. The glasshouse industry has more than a century's experience of growing crops indoors. Today, it is technically and economically possible to tailor the temperature, humidity, lighting, airflow and nutrient conditions by hydroponics technology to get the best productivity and quality out of plants year round, anywhere in the world. But the cost of powering artificial lights will make in-door farming prohibitively expensive. Even though crops growing in a glass skyscraper will get some natural sunlight during the day, it will not be enough. Without artificial lighting the result will be an uneven crop, as the plants closest to the windows are exposed to more sunlight and grow more quickly. Light has to be very tightly controlled to get uniform production. Vertical farming will need cheap, renewable energy for light and temperature control, if it is to work.

Ted Caplow, an environmental engineer and founder of the "New York Sun Works" argues that even using renewable energy, operation of such greenhouses will still be too expensive. Between 2006 and 2009 he and his colleagues operated the Science Barge, a floating hydroponics greenhouse moored in Manhattan. It investigated to grow vegetables in the heart of the city with minimal resource consumption and maximum resource efficiency. Operating all year round, the barge could grow 20 times more compared to a field the same size. Solar panels and wind turbines on the barge were able to produce vegetables with near-zero net carbon emissions. But the greenhouses on the barge were only one storey high, so there was not much need for artificial lighting. But stacking greenhouses on top of each other like in vertical or sky farms requires added light. Based on the experience with the Science Barge, generating enough electricity using solar panels requires an area about 20 times larger than the area being illuminated. For a skyscraper-sized hydroponics farm, that is most probably impractical.

Caplow summarizes that vertical farming will work only if it will make use of natural light. The immediate opportunity may simply be to take advantage of the space available on urban rooftops to pursue urban farming rather than vertical farming. It still needs economic prove, though, how competitive this will be. Rooftop farming may not be able to compete with other suppliers in a global market unless people are prepared to pay a premium for fresh, local food and to be really environmentally conscious (N.N. 2010).

Ricciardi (2011) offers a solution in his article, as it seems that the Swedish architectural design company "Plantagon" has solved the biggest challenges of urban vertical farming: the need for uniform, sufficient natural light to provide an even growth of vertically-farmed plants.

The solution is in their design; the "Plantagon" features a vertical, rotating "corkscrew" platform for the crops and is situated within a huge, curved-glass, geodesic spheroid structure. By offering the dual benefits of cost-cutting and elimination of transportation, these "plantagons" are envisioned to spearhead the green urban living movement of the future.
According to Plantagon information, their urban greenhouse "…*will dramatically change the way we produce organic and functional food. It allows us to produce ecological [resources]*

with clean air and water inside urban environments, even major cities, cutting costs and environmental damage by eliminating transportation and deliver directly to consumers."

The design and concept is not without its critics, however. Some feel that this represents a "resource heavy" concept. At the moment, cultivation is with soil to be disposed after cultivation. Hydroponics would certainly be the better choice for full control of plant growth and development. The company claims that the high-tech greenhouses will grow four times as much produce per square meter as can be grown in traditional one-story greenhouses. The smallest of Plantagon's patented designs is a five-story globular greenhouse that would cost $10 million to $20 million and would grow enough produce to feed 10,000 people per year, according to Plantagon officials (Ricciardi 2011).

In February 2012 a construction site was opened in Stockholm for the first Plantagon greenhouse (Fig. 4). This could well be a tourist attraction, too.

Most city rooftops, particularly the older ones, cannot support the heaviness of greenhouses. Consequently, more than often, realization struggles with locating enough suitable sites that meet the structural requirements to obtain construction licenses. Gotham Greens' first greenhouse facility, located on the rooftop of a large old bowling alley in Greenpoint, Brookyn, New York has found a suitable location and started its first harvesting of leafy vegetables in June 2011. In this innovative new company, the right people have obviously joined forces, an environmental engineer who got his experience earlier at New York Sun Works (see above, N.N. 2010), a commercial expert with a MBA in business administration and banking, and a plant physiologist with specialization in horticultural engineering. Their rooftop greenhouses combine advanced horticultural and engineering techniques to optimize crop production, crop quality, and production efficiency. The climate controlled facility is expected to grow best quality produce, year-round. The business target must certainly be a premium, very fresh quality vegetable for premium costumers (Zeveloff 2011).

With success for urban hydroponics coming up, so do companies to assist in this business. BrightFarms is one of those who have also helped Gotham Greens' in installing their operation. BrightFarms business strategy is to operate hydroponics rooftop greenhouses at grocery retailers, eliminating time, distance and cost from the food supply chain. Their philosophy is to design, finance, develop, build and manage the operations if costumers require.

There is one other concept for urban hydroponics, and these are turn-key units ready for operation to cultivate plants in modified old sea containers. Supposedly, such units can be set and even stacked up anywhere from ground floor, empty unused lots, on roof tops, besides restaurants or food retail shops, as long as zoning by city administration will permit. Basic requirements for electric and water supply as well as drainage should be available.

One of such young companies trying to get into business is Freight Farms from Boston. They offer "*High volume crop production units that can be quickly set up and easily operated to grow food in any environment. Each unit can create local food economy to empower communities to reduce the global footprint of food in a sustainable and profitable manner*". Their plan is to use recycled insulated shipping containers, installed with climate control and a suitable hydroponics system. The top of the container will be equipped with photovoltaic cells (Friedman and McNamara 2011). Certainly an interesting approach, but it still has to prove its commercial usefulness.

CONCLUSION

Capacities and opportunities have to be built by key players, including government policy makers and technocrats to provide awareness, knowledge and training to maximize the benefits of urban horticulture with emphasis on environmentally friendly hydroponics. Such a program will benefit mega cities all over the planet, in developing and developed countries to improve living conditions of their citizens, to assist in food security and to provide employment with special attention to families and the gender issue.

References

BrightFarms (2012). http://brightfarms.com/better-food/
Busicchia, B.(2011). Urban Farmers on top of the world. The Conversation (Australia)
Caldeyro Stajano, M. (2003). Social uses of simplified hydroponics by different: The family grown hydroponics vegetable garden as a food security and nutrition strategy for urban low income population. A case study from Uruguay. Practical Hydroponics and Greenhouses, Nº 73. November-December
Chow, G.K.K. (2004). Singapore: Aeroponics – A new frontier for hydroponics. The Growing Edge, 16, 1, 72
Deelstra, T. & Girardet, H. (2005). Urban agriculture and sustainable cities. RUAF Foundation Growing Cities
Ecoponics (2006) http://www.ecoponics.de
FAO (1997). The Second International Colloquium of Mayors on Governance for Sustainable Growth and Equity
FAO (2010). Growing Greener Cities. http://www.fao.org/ag/agp/greenercities/
FAO (2011). Food for the Cities. http://www.fao.org/fcit/en/
Friedman, J and McNamara, B. (2011). Freight Farms: Grow fresh food in any environment. http://www.freightfarms.com/
Holmer, R. (1010). Periurban Vegetable Project, www.puvep.com
Hydroponicswizard (2012). Hydroponics for social welfare in the Philippines. Hydroponics Guide, Febr. 17, 2012. http://hydroponicsguide.co.uk (Accessed in February 2012)
Hydroponicswizard (20101). Is hydroponics key to success of vertical farming? Aug 12, 2010. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Hydroponicswizard (20102). Japanese hydroponic venting machines. Hydroponics Guide, Nov. 12, 2010. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Hydroponicswizard (20111). Growth and future of urban farming? Hydroponics Guide, Febr. 16, 2011. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Hydroponicswizard (20112). World's largest aquaponics project unveiled in the UAE. Hydroponics Guide, Nov. 11, 2011. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Julie Zeveloff (2011). Tour the hi-tech farm that's growing 100 tons on the roof of a Brooklyn warehouse. Business Insider.TourGothamGreens,AnUrbanRooftopFarmInBrooklyn.html
Keatinge, J.D.H., Yang, R.-Y., Hughes, J.d'A., Easdown, W.J., Holmer, R. (2011). The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium development goals. Food Security, Springer
Kratky, B.A. (2004). A suspended pot, non-circulating hydroponic method. Proceedings of the South Pacific Soilless Culture Conference, Acta Hort. 648, 83-89
Midmore, D. and Wu, D-I. (1999). Work that water! Hydroponics made easy. Waterlines, 17-4
Mougeot, L.J.A. (2006). Growing better cities: urban agriculture for sustainable development. IDRC, International Development Centre, Ottawa, Canada
N.N. (2010).Vertical Farming . The Economist Technology Quarterly, Dec. 11, 2010
N.N. (2011). Bangkok. Resilient food systems in Asian cities. Food for the cities – Regional Workshop, Nov.17-18
Nichols, M.A. and Savidov, N. (2012). Aquaponics: clean, green and organic. Personal correspondence, (submitted)
PUVep (1997). http://puvep.u.edu.ph/project/inco (Accessed in February 2012)
Rajagapal, A. (2010). Vertical Farm comes down to earth. http://www.MetropolisMag.com
Ricciardi, M. (2011).'Plantagon', New Vertical Farm Design, May Provide Produce for Future Cities. Clean Technica. http://s.tt/12wE (Accessed in Feb. 2012)
Sauerborn, J. (2010). The Future of Agriculture – Scenarios, Concepts, Visions Symposium 2010 | 24.08. – 26.08.2010 Communication and Training Centre Königstein . 4.8.2 New Technologies for Agriculture in 2050: Vertical Farming, Agro-Technological Innovations, and Smart Foods
Saxena, R.S. (2011). Ten vertical farms designed to bring farming into the urban world. Greendiary, http://www.greendiary.com (Accessed in February 2012)
Theduke (2010). Organic hydroponics – why not use aquaponics? Hydroponics Guide, Aug. 24, 2010. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Theduke (2011). The supermarket of the future? Hydroponics Guide, Febr. 10, 2011. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
UN World Population Prospects. (2010). The Life Group
Wilson, G. (2005). Singapore's New Business Opportunity: Food from the Roof. City Farmer, Canada's Office of urban agriculture

TABLES AND FIGURES

Table 1. Population changes in some countries between 2010 and 2100 (UN 2010)

Country	Change from 2010 to 2100 (estim. in %)
Tanzania	+ 606
Kenya	+ 295
USA	+ 54
India	+ 27
Europe	- 9
Brazil	- 9
Germany	- 15
China	- 30

Table 2. Opportunities and risks of urban agriculture **(FAO 1997)**

Opportunities	Risks
Less need for packaging, storage and transportation of food	Environmental and health risks from inappropriate agricultural and aquacultural practices
Potential agricultural jobs and incomes	Increased competition for land, water, energy, and labor
Non-market access to food for poor consumers	Reduced environmental capacity for pollution adsorption
Availability of fresh, perishable food	
Proximities to services, including waste treatment facilities	
Waste recycling and re-use possibilities	

Table 3. Basic prerequisites and possible constraints for urban hydroponics **for cities planning**

Prerequisites	Constraints
Fairly flat terrain	Traffic air pollution, e.g. by lead from gasoline
Minimum of electrical power	Criminal intents: Burglary, vandalism
Minimum capital	Envious neighborhood
Some plant cultivation knowledge	Restraining legislation
Uncontaminated water	Unavailable planting sites
Minimum agro material supply	
Support of municipal administration	

Table 4. Recommended nutrient solution for the AVRDC non-circulating system (*Wu Deng-lin)*

Element	Concentration (mg1-1)	Formula
NO3-N	100.00	Ca(NO3)2•4H2O,KNO3
NH4-N	9.30	NH4H2PO4
P	52.80	K2HPO4,KH2PO4,NH4H2OP4
K	195.60	KNO3,K2HPO4,KH2PO4
Ca	80.00	Ca(NO3)2•4H2O
Mg	24.30	MgSO4•7H2O
Fe	3.00	Fe-EDTA
Mn	0.50	MnSO4•H2O
Cu	0.02	CUSO4•5H2O
Zn	0.05	ZnSO4•7H2O
B	0.50	H3BO3
Mo	0.01	NaMoO•2H2O

Figure 1. Green car park in Bangkok (2012)

Figure 2. Indoor beautification with hydroponic plant decoration

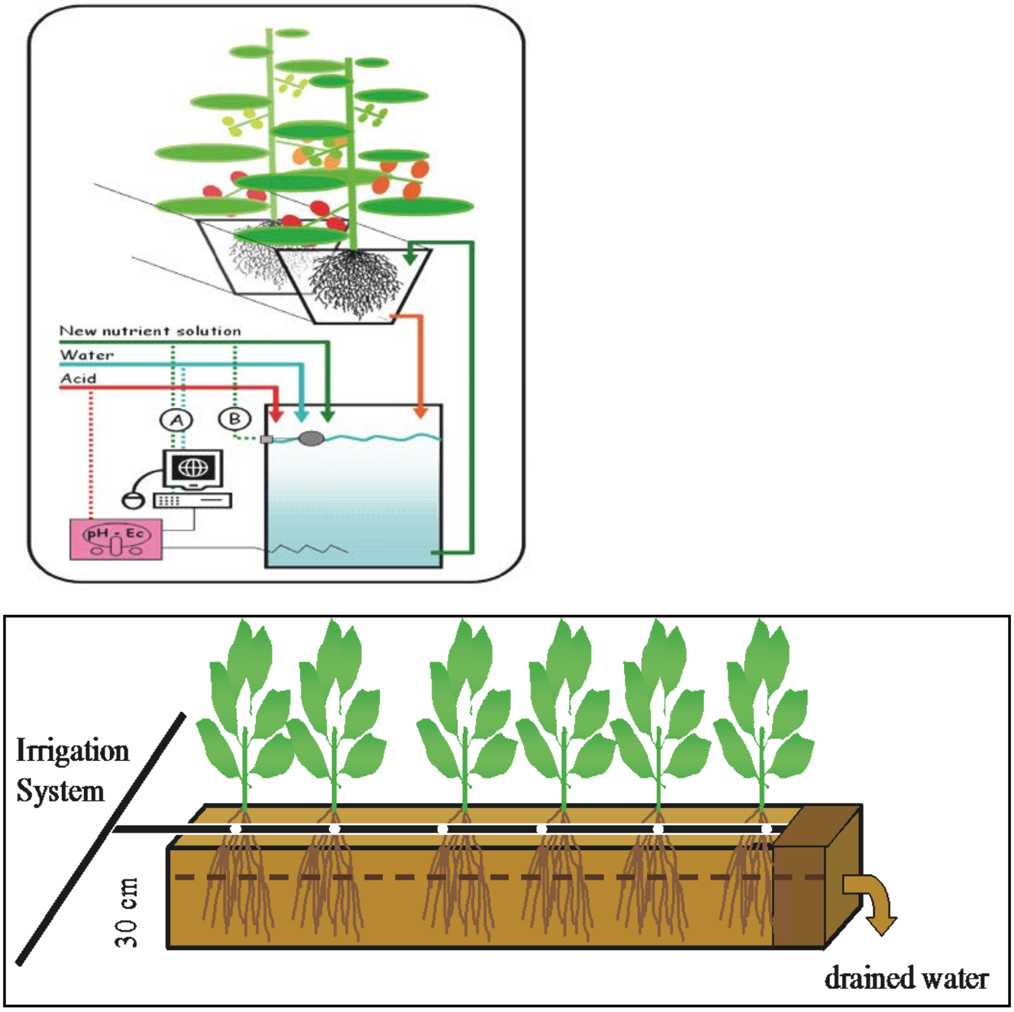

Figure 3. Two simple hydroponics systems for vegetables by ECOPONICS technology

Figure 4. “Plantagon” geodesic dome vertical farm

Promotion and utilization of SNAP hydroponics, a simple and inexpensive system, for urban agriculture and waste management in the Philippines

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ABSTRACT

SNAP hydroponics is a simple, non-circulating low-cost production system for producing vegetables. Developed with the aim of increasing nutrition in urban and rural communities in the Philippines, the system uses recyclable and waste materials, and a locally developed, inexpensive, and highly buffered nutrient solution. Passive aeration of roots is encouraged by allowing plants to adapt to flooded conditions during their early growth stage. Leaf vegetables like lettuce, pakchoi, and mustard are harvested earlier and produce good yields that are similar to those of conventionally grown vegetables.

Since 2000, SNAP hydroponics continuously gained popularity in the Philippines after it was featured in radio, television shows, and newspapers. Three major training courses (3-day course on the complete system with greenhouse visits, 1-day course on how to put up and maintain SNAP hydroponics, and 1-day special course on making nutrient solutions) were developed. More than thirty training courses have been conducted since 2001, with participants coming from all occupations. Seminars were held in forums, agricultural trade fairs, in private companies, and in secondary schools. In 2010, a national research agency chose SNAP hydroponics as their major urban agriculture program in Metro Manila. A group of senior citizens also put up a vegetable farm using the SNAP system. Other practitioners include an employee cooperative, another senior citizens group, and many interested individuals. After the training, trainees may avail themselves of free consultation and technical advice from technical staff of the university.

The viability of the system for commercialization was demonstrated when a pilot farm gave a return to investment of more than 50% in the first year alone. A model shows that home vegetable production can yield an ROI of 79% mainly due to the low cost of production and decreased price of the nutrient solution.

Keywords

SNAP hydroponics, vegetables, urban, extension

INTRODUCTION

In 2000, the Institute of Plant Breeding of the University of the Philippines Los Baños was granted funds by the Philippine Department of Agriculture to conduct studies on the utilization of simple hydroponics for production of high value crops for home consumption and entrepreneurial activities. From this project arose Simple Nutrient Addition Program Hydroponics. Popularly called SNAP hydroponics, it is a low-cost, low-energy, low-maintenance hydroponics system that introduced a modern vegetable production system. It can be adapted in both rural and urban areas making it a sustainable food production system.

SNAP hydroponics differs from other hydroponics systems because about 80 percent of the materials used in the system come from recycled materials such as the styrofoam fruit boxes made up of expanded polystyrene (EPS), 8 ounce-cups from foam polystyrene, and polyethylene bags. The sources of the EPS boxes are the containers of imported fresh grapes. Grape importation in 2010 alone was 18,000 t (International Trade Center 2011), which translates to 1.8 million fruit boxes (at 10 kg grapes/box) that can potentially end up in landfills if not recycled.

The Philippines has a population of 89 million with a growth rate of 2.04% (National Statistics Office 2008). Metro Manila is the most urbanized region in the Philippines, with population of 11.5 million and population density twice the national average. Extended urbanization in Manila to neighbouring provinces of Bulacan, Laguna, Cavite, and Quezon sets the current population estimate at 21,295,000 for these areas (Demographia 2011). Due to the high population densities, land for agriculture has declined, offering opportunities for the urban agriculture technologies. SNAP hydroponics was thus utilized by several government agencies and private groups for vegetable production in Metro Manila and neighbouring localities.

MATERIALS AND METHODS

The SNAP hydroponics system

The development of the SNAP hydroponics system took several years and many experiments on different crops and with various nutrient solutions. Details on these are described elsewhere (Santos and Ocampo 2005). For most practitioners of the technology, expanded polystyrene boxes were the choice for container. Many crops were tested for their performance in SNAP hydroponics in order to test if the system is easy to use in urban areas.

Financial analysis

To demonstrate the feasibility of SNAP hydroponics as a profitable vegetable production system, a cost and return analysis for lettuce production was performed. The data from a farm that was producing lettuce in commercial quantities was used to project the commercial profitability. Data from yield trials conducted at the Institute were used to analyze the income from household level production.

Extension activities

The period during which SNAP hydroponics was developed also coincided with the time when several high-end hydroponics facilities were established in several farms producing high-value vegetables. The technology caught the attention of many farming enthusiasts, but these hydroponics systems were costly. The Institute of Plant Breeding introduced SNAP hydroponics as an inexpensive alternative to hydroponics vegetable production. The Institute conducted training courses for interested individuals starting in 2000 until the present date. The number and profiles of the trainees were recorded.

Short seminars were also presented to different local communities and groups to introduce SNAP hydroponics. These seminars were sponsored by public and private agencies who were also promoting urban agriculture technologies.

SNAP hydroponics was also introduced via radio, television shows and newspaper feature articles. Vegetables growing on SNAP hydroponics were displayed in prominent areas at the Department of Agriculture, the University of the Philippines Los Baños, and in different agricultural and trade fairs.

RESULTS AND DISCUSSION

The SNAP hydroponics system

The SNAP hydroponics system is composed of an expanded polystyrene box which is used for shipping fresh grapes to the Philippines, a reusable polyethylene liner, reusable styrofoam cups or seedling plugs, and a nutrient solution set (Fig. 1). Slits are made on the sides at the bottom of the cups, and then an approximately 2-cm layer of coco coir dust is added. Two- to three-leaf lettuce seedlings are then transplanted to the cups. Nutrient solution is diluted with water and added to the polyethylene-lined box. The seedling cups can then be inserted into the holes that have been made on the box lid. The cup bottoms should be immersed in approximately 2 cm of solution, but only during the initial placement of the seedling plugs. The solution level will deplete with time as evapotranspiration increases with growth. For leaf vegetables with short growth duration, the solution is not topped up, since the initial volume added was calibrated to last for thirty days when the vegetables can then be harvested. Furthermore, the depletion of the nutrient solution will allow the plant to develop adventitious roots that will take in oxygen from the surrounding air. This mechanism allows for passive aeration, and thus no artificial aerator is used in SNAP hydroponics.

Several other vegetables were produced successfully in SNAP hydroponics. These vegetables include the more common leafy vegetables and the fruit vegetables (Fig. 2).

Financial analysis

The commercial viability of SNAP hydroponics for both household level and commercial application was shown in results of financial analyses. Previous analysis of household level leaf lettuce prodcution showed that a 57% return of investment (ROI) can be realized in the first year of operations (Santos and Ocampo 2005). However, as the cost of the nutrient solution was reduced due to economies of scale, ROI was calculated to increase to 85% (data not shown). Data from a farm that was producing a minimum of 240 kg lettuce a week achieved an ROI of 59% despite larger expenses for putting up a greenhouse and transporting the produce from a southern province to Metro Manila (data not shown).

Extension activities

SNAP hydroponics technology was first introduced to visitors to the Institute of Plant Breeding. Visitors were brought to the demo area, which was just the perimeter of a glass-roofed greenhouse at the Institute. To this day, the SNAP hydroponics trials and demo area remain a staple stop for visitors. In 2010 alone, at least four thousand three hundred visitors were able to view the system and were given a briefing on SNAP hydroponics technology. Most of the visitors were students from all levels and their teachers. Some students at the university have also used the technology to conduct their research thesis (Magnaye et al. 2011).

The first training course on the technology was conducted in 2001 with 4 trainees. The original course content included introduction to hydroponics systems, the basics of crop production, hands-on instruction for setting up the system and preparing nutrient solutions, financial analysis advice and practical farm visits. The training course was conducted for 3 days, with the last day reserved for visit to a farm that was producing vegetables using SNAP hydroponics. After three years, the course was reduced to just one day, taking up only the basics, financial analysis and hands-on practice. A separate course was offered for nutrient solution formulation, after an informal survey revealed that most growers and enthusiasts do not have the means to produce their own solutions, and prefer to purchase the SNAP formulation which was also developed at the Institute.

From 2011 until September 2011, 259 individuals have been trained on SNAP hydroponics in 44 training courses (Fig. 3). The trainees had a highly varied profile; they came from all ages, educational and employment backgrounds (Table 1). Most of them were employed gainfully but were looking at the possibility of branching out into agriculture in their respective communities. Some trainees came from schools and research organizations who wanted to try the system for research and teaching.

Aside from training courses, short demonstrations and seminars on the technology were conducted upon invitation in agricultural trade fairs, school science fairs and in other forums. Notable exhibits were at Agrilink, Foodlink, and the Aqualink Expo. Private company foundations have also requested for seminars for their employees who are looking for alternative sources of income. These seminars were presented to large audiences in cities in Manila, Laguna and the Visayas. A showcase of the technology was also maintained at the area fronting the Bureau of Agricultural Research of the Department of Agriculture (Fig. 4). The showcase caught the attention and interest of employees of and visitors to the agency. Aside from seminars, the introduction of SNAP hydroponics was intensified when it was featured in television and radio programs that featured the work of the University of the Philippines Los Baños.

Adoption of SNAP hydroponics in urban areas

A major consideration in carrying out SNAP hydroponics vegetable production is the supply of the fruit boxes that are used as growing containers. Initially, the boxes were sourced from wet markets, where fresh grapes are sold in retail. Supermarket employees used to crush the boxes before discarding them for garbage collection until the time when there was a demand for the boxes, and supermarkets started selling them at very low price. In Manila, large supermarkets return the boxes to the fruit suppliers, and these suppliers eventually started to supply the boxes needed for SNAP hydroponics systems. These fruit boxes are not expected to run out since it has been estimated that there are at least a million of these boxes entering the Philippines as container of fresh grape imports (International Trade Center 2011). In 2009, the Philippines' Department of Science and Technology (DOST) included SNAP hydroponics as one of the technologies for urban agriculture in selected areas in Metro Manila. Among the community groups selected was the Twinville Homeowners Association, Inc. (THAI) (DOST 2011) which is in Marikina City, one of the most flooded area during the Ondoy storm in 2009. Selected members of THAI attended a training course on SNAP hydroponics (Fig. 5), and with full support from DOST, the senior citizens established their vegetable production center for home consumption and are selling excess produce.

Other notable urban agriculture endeavors that utilize SNAP hydroponics is spearheaded by the Pasay City Cooperative Development Office with assistance from the different church groups and the Philippines Department of Agriculture (Agron 2009). Pasay City is within Metro Manila and is home to many poor families. The urban agriculture program is incorporated into the national poverty reduction and social development program, and the youth empowerment program which is supported by the United Nations' Children Fund (UNICEF) (Agron 2009).

Other practitioners of SNAP hydroponics in urban areas are the Los Baños Senior Citizens Organization (Fig. 6), a whole community unit in Sta. Cruz town in Laguna Province, senior citizens who are doing backyard SNAP hydroponics, a former poultry farm owner and a university in a city in the Visayas, to name a few. Many practitioners do not report their activities although they do return to the Institute for their supply of SNAP nutrient solution.

CONCLUSION

SNAP hydroponics was developed to be a cheap alternative to the high-end, high input hydroponics systems that were first introduced in the country. Intensive efforts at introducing the technology to Filipinos have resulted in awareness of hydroponics and vegetable production for both urban and rural areas. Other government agencies and private interest groups have adopted SNAP hydroponics for production of vegetables for personal consumption, as a livelihood program for urban areas, and a means to manage waste and conserve energy.

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References

Agron, E. . 2009. BAR promotes SNAP hydroponics for wider adoption. Retrieved August 4, 2011, from BAR Online: http://www.bar.gov.ph/news/snap_promotion.asp

Demographia. 2011. World Urban Areas (World Agglomerations).7th Annual Edition. Belleville, Illinois, USA.

DOST. 2011. Senior citizens help in a city's reborn. Retrieved December 14, 2011, from Department of Sciene and Technology, NCR Region: http://ncr.dost.gov.ph/index.php?option=com_content&view=article&id=114:senior-citizens-help-in-a-citys-reborn&catid=57:success-stories

International Trade Center. 2011. Market Analysis and Research. Geneva: International Trade Center.

Magnaye, A, Santos, P, Sta Cruz, P. 2011. Responses of yellow corn (Zea mays L.) inbreds to salinity. *Asia Life Sciences* 20(2):521-533.

National Statistics Office. 2008. 2007 Census of Population. Manila, Philippines: National Statistics Office.

Santos, PJA, Ocampo, ETM. 2005. SNAP hydroponics: development and potential for urban vegetable agriculture. *Philippine Journal of Crop Science* 30(2):3-11.

TABLES AND FIGURES

Table 1. Profile of trainees of the SNAP hydroponics technology

DESCRIPTION	Total Number
Gender	
Male	182
Female	79
Age (years)	
21-30	26
31-40	75
41-50	73
51-60	62
61-70	17
71-80	4
81-90	1
91-100	1
Occupation	
Government Employee	27
Private Company Employee	131
Self-Employed	17
Church/Religious Organization	3
Not Declared	78
Education	
College Graduate	176
College Level	3
Post Graduate	33
High School Graduate	2
Not Declared	36
Residence	
Luzon	244
Visayas	11
Mindanao	4

Figure 1. The major components of the SNAP hydroponics system are recycled expanded polystyrene (styrofoam) boxes, styrofoam cups, and a highly buffered nutrient solution.

Figure 2. Some of the vegetables that grow on SNAP hydroponics system successfully.

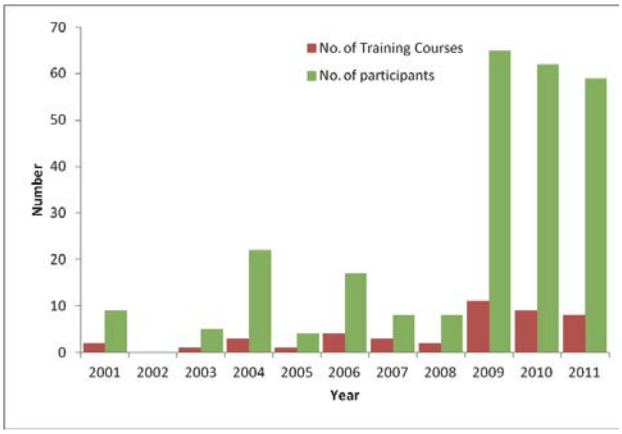

Figure 3. Number of trainings conducted and the number of participants.

Figure 4. SNAP hydroponics showcase at the Department of Agriculture Compound in Quezon City, Philippines, introduced the technology to visitors and department employees.

Figure 5. Members of the Twinville Homeowner's Association during the hands-on portion of a seminar on SNAP hydroponics and other urban agriculture technologies.

Figure 6. Senior citizens of Los Baños, Laguna attending to their vegetables grown using SNPA hydroponics technology (Photo source: PJA Santos).

High value vegetable production using soilless culture

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ABSTRACT

Soil is not a good medium in which to grow plants. It is normally either too dry (and therefore well aerated) or too wet (and therefore poorly aerated). Soilless culture is a relatively new technology and its commercial use is less than 70 years old, and it really did not create impact until 40 years ago, with the development of NFT and of rock wool hydroponics.

In the future soilless culture is likely to increase rapidly in importance because the earth's rapidly increasing human population will put increasing pressure on the resources required for vegetable production. Fertilizer is a finite resource, and should be conserved by using re-circulating systems, while fresh water resources are severely limited in many parts of the world

In the future soilless culture is likely to increase in importance, both in the field and in Controlled Environment Agriculture (CEA), because of the need for increased productivity, environmental concerns due to leaching fertilizer residues and the inevitable increasing price of fertilizer. Biologically efficient systems (such as aquaponics) will increase in importance, and the efficient use of fresh water resources will move conventional soil based crop production towards soilless culture.

Control of root pathogens is another concern in soil based systems, and soilless culture provides the potential for reducing fumigation needs. Rock wool is likely to be replaced in the future for environmental reasons by organic media (such as coir), while even newer media (such as biochar) may eventually provide a medium which can be reused indefinitely. Inevitably much of the current protected cultivation soilless culture will be transferred into plant factories because of enhanced productivity and greater efficiency of resources. Soilless culture, (particularly in greenhouses) provides a simple means to increase the crop productivity per litre of water used for crop production.

Keywords

hydroponics, aquaponics, controlled environment agriculture.

INTRODUCTION

It is now nearly 60 years since I entered the University of Nottingham in England to study for a Bachelor of Science degree in Horticulture. It was a prerequisite of such studies to undertake 12 months of pre-entry practical horticultural experience, and I worked on a local market garden near my home in Oxford, England, where in addition to growing tree fruit, berry fruits, and field vegetables there was a heated greenhouse operation which produced tomatoes and chrysanthemums.

By the standard of those days it was relatively advanced greenhouse operation. Remember this was 1953. The young tomato seedlings received supplementary photosynthetic light (from mercury vapour lamps) during the winter months, the greenhouse soil was sterilized by steam annually, and was heated by low voltage electric cables. All the watering was by hand by hose—(drip irrigation had only just been developed by Blaas), and plants were all grown in SOIL and fed with "dry" fertilizer.

We have come a long way since those days, and we have got much smarter in our greenhouse cropping. Nevertheless the majority of the greenhouse crops throughout the world are still grown in the soil.

There are considered to be something between 0.6 million - 1.2 million ha of greenhouses in the world, but perhaps the more significant figures, is the area of greenhouses using soilless culture: in the region of 35,000ha for vegetables, and possibly a similar area for ornamentals. It is clear that soil based production systems still predominate world-wide, but in the developed world soilless culture predominates.

The reasons for using soilless culture are many, but chiefly they can be summarized by:

1) An improved physical environment, with better aeration, moisture, and nutrition.

Easier control of root pathogens

2) More efficient use of water and fertilizer
3) Higher yields.

Soil is not a good medium in which to grow plants. A well aerated soil (e.g. sandy) is unable to hold adequate water reserves for effective crop production, while a soil with adequate moistures reserves (e.g. clay) has poor aeration characteristics.

Intensive cropping will eventually (inevitably) result in a build up of soil borne pathogens. These are difficult and expensive to eradicate, but with a soilless system we are using only a small volume of solid rooting medium (if any) and sterilizing (if necessary) or similar is not a large operation.

The population of the world is increasing rapidly and our physical resources are dwindling. Fresh water will eventually (inevitably) be a scarce resource, even in Thailand, and we are now well past the time when potassium and phosphate fertilizers can be considered as an unlimited resource.

Because of the opportunity to provide an improved root environment for the crop the yield potential will be increased, although, in fact whether this will be achieved will depend on the overall crop management.

Media

There are essentially two “media” in which soilless culture is undertaken, namely:

1) solid media
2) liquid media

Solid media

These medium has been the main type since hydroponics was initiated. Originally sand or gravel, it has over the years been replaced with lighter material, in which the aeration/water holding characteristics can be more precisely controlled.

The main types of solid media used are:

- Organic products such as peat, sawdust, cocopeat, bark etc, or
- Mineral products such as volcanic tuff, perlite, pumice, vermiculite, etc or
- Manufactured products such as rock wool, foam plastic etc.

The standard system would undoubtedly be rock wool, which is now a huge industry, particularly in NE Europe. However it’s value away from Europe is reduced because of freight costs, and the need to have a reasonably sized industry to warrant establishing a local production factory.

In New Zealand (for example) some growers import rock wool and others use a local product such as pumice or sawdust.

The key with all solid media is to have the correct amount of air space and water holding capacity (EAW), and this is not simply a case of particle size, but also incorporates considerations of the distribution of the different particle sizes, and the type of medium. (Verdonck & Demeyer 2004).

Table 1. Physical properties of composted bark mixtures. (Verdonck & Demeyer, 2004)

Mixtures	0-1 mm	1-2 mm	> 2 mm	Volume % air	Volume % EAW
1	10	50	40	38.2	9.0
2	30	30	40	30.5	14.7
3	50	10	40	12.6	24.6

Liquid media

Essentially there are three systems of using liquid media, namely:

1) Deep Flow
2) Nutrient Film Technique
3) Aeroponics

Deep flow system

The deep flow system appears only to work well for leafy vegetables. The plants are commonly grown on floating polystyrene boards (Massantini 1976) in a large tank of nutrient solution, which is slowly recirculated. Aeration of the nutrient solution is the main problem with this system, as it is physically impossible to load up the solution with more oxygen than the solution will hold at a given specific temperature.

Nutrient film technique

In the mid-1960's Cooper (1979) developed the Nutrient Film Technique (NFT) in which a thin film of nutrient solution flowed down a gulley in which the plants were grown. It was quite a unique system, as it attempted to overcome one of the major problems of using a liquid medium (that of adequate aeration) by having a very shallow film. Nevertheless it was not very suitable for cucurbits, (which demand well aerated roots), and has never become as popular as rock wool because the system had nothing to sell! It was, in its time unique as it introduced the concept of the recirculating system, when at that time, all watering was to "waste". In the light of present knowledge the concept was perhaps too simplistic, in using conductivity and pH to control nutrient levels in the solution.

Aeroponics

Aeroponics involves suspending the plant roots in a light proof box, and spraying them with a nutrient solution. It is one of the few hydroponic systems which permits some control of root temperature and also of the root gas environment. In recent years it has been used in the tropics to produce lettuce, and in North Korea to produce high health seed potatoes. It provides not only a production system, but also a unique research tool (Christie and Nichols 2004).

Water sources

It is desirable that the water source for both recirculating and non-recirculating systems is free from pathogens, and contains no toxic chemicals. Although lakes, rivers, dams, tube wells and streams are a logical source, they may not necessarily be ideal (Schwarz et al. 2004), and rain water from the roof of the greenhouse is now considered the most acceptable; source.

If other sources of water are used, then it may be necessary to undertake some form of sterilization (e.g. using ozone or hydrogen peroxide) to remove pathogens, and reverse flow osmosis to remove excessive "salts".

Non-recirculating systems

By far the simplest way of producing plants hydroponically is to use a non-recirculating system. This overcomes many of the nutritional and root pathogen difficulties. It is relatively easy to ensure that the nutrient solution being supplied to the plants is free from pathogens and also contains the required nutrients at the required levels and ratios for the crop at its particular stage of development.

It is also relatively easy to ensure that excess nutrients are leached from the medium by applying 10-20% more water (as nutrient solution) than the plants transpire.

The difficult part is to dispose of this leachate in a sustainable manner, without causing pollution problems. In fact where greenhouses are the exception, it is probably acceptable to use the leachate as a liquid fertilizer on extensive agriculture, but in many parts of the world this is not an option, and it has become a legal requirement in the Netherlands that only recirculating systems be established.

Re-circulating systems

As soon as we move towards a fully recirculating system, we introduce potential problems of nutrient management, and pathogen control.

Nutrient control

Cooper proposed that the objective must simply be to keep the pH between 5.8 and 6.3, and to ensure that the nutrient solution was at the correct conductivity and that the crop would decide which nutrients to absorb.

This oversimplification has now been superseded, and the objective now is to monitor the major elements in the nutrient solution, and to adjust the levels if the concentration (of a specific ion) moves outside the acceptable range. The acceptable ranges are crop specific. (Bugbee 2004).

Pathogen control

With the move towards recirculating systems there are potential problems with pest and disease management.
These can be approached in a number of different ways:

- Ensuring that only “sterile” nutrient solution is recirculated.
- Using “biological control” via a deep sand filter
- Using “grafted” plants.

Sterile system

At first sight the idea of establishing a completely sterile system is very attractive. The water used to ‘top up” the system can be made free from pathogens by means of ozone or hydrogen peroxide, prior to being added to the nutrient solution. Furthermore the re-circulating solution can be treated in a number of ways to eliminate any pathogens from the initial water supply including:

- ozone treatment
- hydrogen peroxide treatment
- the use of chlorine compounds.

They are not so useful for sterilising re-circulating nutrient solution because they are potentially phytotoxic to plant roots.

In order to free the re-circulating nutrient solution from pathogens the normal techniques are to use either UV light (Runia and Boonstra 2004) or to use heat pasteurisation.
Using UV light has two potential problems:

- if the nutrient solution is turbid there may be problems with the UV actually sterilising the solution;
- UV may precipitate out iron from the solution.

It is possible to add a low concentration of hydrogen peroxide to the solution prior to passing it though the UV source and this may remove some of the turbidity. There is of course a high capital cost and running cost of the UV treatment. Although turbidity is not a problem with pasteurisation, this technique is also both expensive and may precipitate iron as well. Heat pasteurisation is also not cheap in terms of both energy and capital.

Biological control using a deep-sand filter

The principal of the deep sand filter is that it is impossible to ensure complete sterility in hydroponic systems and may therefore be preferable to go for some form of ecological balance, by ensuring that the nutrient solution not only contains pathogens, but also contains to broad-spectrum of biological control organisms (Postma, 2004). In order to achieve this the nutritional chemicals are put onto a deep sand filter which is charged with wide range of biological control organisms such as *Trichoderma* sp, non-pathogenic *Fusarium oxysporum, Gliocladium virens,* and *Coniothyrium minitans*.

This technology appears to be gathering favour in many intensive greenhouse areas in northeast Europe at this point in time.

Grafted plants

Although the benefits of grafting vegetable seedlings onto resistant rootstocks was first published in the 1920s it was not until the 1960's that it first gained any impetus (Lee, 2003). However the technique was time-consuming, and it was not until recently with the development of grafting machines and the increasing interest in producing crops without using pesticides that grafting got a new lease of life.

Like all "new" technology there is a learning phase, and I well recall my first effort to graft greenhouse cucumbers onto *Cucumis ficifolia* rootstock. We used the variety "Princess" (the first of the gynoeacious only types) and the stress of the graft switched the plant into male flower production!

Essentially grafting requires the production of two lots of seedlings, the provision of a high humidity greenhouse area, and a skilled labour force. It must also be remembered that the scion takes on some of the characteristics of the rootstock in terms of vigour (vegetative or generative), comes into production a little later, but if the appropriate rootstock has been selected, it will be resistant to a range of soil borne pests and diseases, and possibly also some viruses.

Organic hydroponics

Organically produced greenhouse crops fill a valuable market niche, but as many organic certification methods require the crop to be grown in the soil, yield is immediately reduced compared with conventional hydroponically grown crops. Although organic organisations are very happy with the IPM technology used in greenhouses, they appear to be unable to accept hydroponics—even if the nutrient solution is made up from organic material e.g. fish meal and sea weed (Atkins and Nichols 2004).

A compromise solution currently being used in New Zealand is to grow the plants in a pots using a peat/pumice medium—(certainly no one could say that this was not soil based), and then water and feed the plants with an organically derived nutrient solution using an ebb and flow system.

Aquaponics

A potential approach to getting better profitability is to combine fish farming with hydroponic crop production. The fish live in the nutrient tank, and are supplied with food, which they eat. The waste products then provide the nutrients which are then circulated over the roots of the crop. This system has been used successfully in the Virgin Islands (Rakocy et al. 2004) to produce 87.4 t/ha of tilapia fish and 5.0 t/ha of basil per year.

THE FUTURE

We have probably gone almost as far as we are able in modifying the aerial environment without considering going into growing rooms (Nichols 2004), and attention should perhaps now be directed to the below ground environment. In this respect probably aeroponics offers the most potential, as it provides an opportunity not only to modify the root temperature (He & Lee 1998), but also the prospect of improving growth by modifying both the oxygen and carbon dioxide levels in the root zone (Nichols et al. 2002).

References

K, Atkin, K & M. A. Nichols (2004) "Organic Hydroponics". Acta Hort, 648, 121-127.

Bugbee, B (2004) "Nutrient management in recirculating hydroponic culture". Acta Hort, 648, 199-112.

Christie, C B & M A Nichols (2004) "Aeroponics – A Production System And Research Tool." Acta Hort, 648, 185-190.

Cooper, A J (1979) "The ABC of NFT". Grower Books 181 pp.

He, J & Lee S K. (1998) Growth and photosynthetic responses of three aeroponically grown lettuce cultivars (*Lactuca sativa* L.) to different root zone temperatures and growth irradiances under tropical aerial conditions. The Journal of Horticultural Science & Biotechnology. 73: 2, 173-180.

Lee, J M (2003) "Advances in vegetable grafting" Chronica Horticulturae, 43 (2), 13-19.

Massantini, F., 1976. Floating hydroponics: A Method of Soilless Culture. Proceedings 4th International Congress on Soilless Culture, Las Palmas, Canary Island, Spain. pps. 91-98.

Nichols, M A, Christie, C B. (2002) "Towards a sustainable "greenhouse" vegetable factory" Acta Hort., 578, 153-156.

Nichols, M A, Woolley, D J, Christie, C B. (2002) "Effect of oxygen and carbon dioxide concentration in the root zone on the growth of vegetables" Acta Hort., 578, 119-122.

Postma, J (2004) "Suppressiveness of root pathogens in closed cultivation systems" Acta Hort., 644, 503-510.

Rakocy, J E, Shultz, R C, Bailey, D S, & Thoman, E S. (2004) " Aquaponic production of tilapia and basil: comparing a batch and staggered cropping system". Acta Hort, 648, 63-70.

Runia, W T & Boonstra, S. (2004) "UV-Oxidation technology for disinfection of recirculating water in protected cultivation". Acta Hort., 644, 549-553.

Schwarz, D, Grosch, R, & Gross, W. (2004) "Water quality for hydroponics: nutrients, bacteria and algae in rainwater ponds." Acta Hort., 644, 533-540

Verdonck, O, & Demeyer, P. (2004) "The influence of particle sizes on the physical properties of growing media". Acta Hort., 644, 99-102.

Climate-smart small scale vegetable production practices in a challenging tropical island environment

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ABSTRACT
Ethnic neighboring island communities of Yap and its 14 atoll islets in the Western Pacific are among the most economically disadvantaged and environmentally vulnerable groups in the Federated States of Micronesia. Most climate change models and studies show that climate change effects will be disproportionately borne by these communities. Decreased rainfall and/or rising sea level cause saltwater intrusion into traditional taro patches, low-lying forestry stands and other ecosystems in the atolls. Environmental and social pressures entice communities to migrate to Yap Proper in search of better living conditions. Migrants coming to Yap Proper with dreams of improving their living standards are often confronted by lack of jobs and any form of livelihood and remain destitute in a challenging environmental setting. This population requires a survival strategy that involves growing vegetables for subsistence. However, atoll communities used to farming on coral sand soils have no experience farming the infertile, red volcanic soils (Hapludox) on Yap Proper. These infertile soils pose severe challenges to the community if they attempt field cultivation. This paper presents the results of a comprehensive extension program extended to the community since 2005 in volcanic soil management coupled with vegetable gardening utilizing climate-smart micro-garden models. Despite limited resource setting and challenging soil conditions, the communities are able to successfully establish family-level vegetable gardens. The sound soil management practices and alternate crop production models offer an added advantage using a locality that was previously thought unsuitable for food production. The community directly engages and participates in building their future. They harvest a broad range of fresh, safe and highly nutritious vegetables daily to improve their diet and income. The advent of climate change and the expected effect on atoll-dwelling populations around the world adds an important international aspect to this study.

Keywords
Climate change, vegetable production, soil management, Yap Island

INTRODUCTION
Until recently people in the Federated States of Micronesia (FSM), as elsewhere in the Pacific, have enjoyed a generally favorable balance between population, resources, and the environment and they were fortunate to be free from absolute poverty. The island communities are known for their 'vegeculture' that is characterized by a pattern of culturally selected traditional crops. These crops mainly include taro, yams, cassava, sweet potato, breadfruit, banana and other fruit trees that provided food security since the arrival of indigenous peoples in Yap. Micronesians protected and nourished much valued traditional land use systems that were built on a foundation of protecting and planting trees (Elevitch 2006). These agroforestry systems made them among the most self-sufficient and well-nourished peoples in the world. However, the

situation has changed over the last few decades as environmental degradation began engulfing the atolls and island states within the region. Environmental problems associated with altered weather patterns, sea level rise, coastal flooding, loss of biodiversity, saltwater intrusion and lack of freshwater, soil degradation, and problems related to energy converge to place the Micronesian Islands, especially the atoll islets and other coastal settings, at the forefront of climate change (Fletcher and Richmond 2010).

The FSM is an oceanic nation of over 600 islands in the western tropical Pacific. Yap is the westernmost State in the FSM and consists of Yap Proper, a group of four conjoined islands, and 14 atoll islets that are inhabited by traditional communities who are dependent on fishing, agroforestry, groundwater and rainfall. Yap's climate is influenced by a number of factors including the paired Hadley cells and Walker circulation and ENSO phenomenon (Chowdhury et al. 2010). Under El Niño conditions the islands typically experience drought and under La Niña conditions the islands experience higher than normal rainfall. Protracted La Niña events in 2007 and 2008 caused marine inundation all over the FSM that caused significant damages to crops and greatly impacted the economy, agriculture, groundwater resources and general livelihood of the island community (FSM Information Service 2008). A nationwide state of emergency was announced on December 2008 and food security was declared the top priority in the islands. Communities that live in the low-lying atoll islets are more vulnerable to climate-related changes in precipitation, sea level, storms, and coastal erosion because of their geographic exposure, low incomes, and greater reliance on traditional agriculture as well as limited capacity to seek alternate livelihoods. Because drought and sea-level rise are amplified by regional ENSO processes, formerly sustainable atoll communities now rely on imported food and water during times of stress. Low adaptive capacity thus induces atoll communities to abandon their homelands and relocate to Yap Proper.

The last decade saw a tremendous influx of atoll communities to Yap Proper. Although such migrations were classed as "sojourning" and recorded in the past (Nelson 1976), today such movements are largely permanent and are synonymous with environmental migration (Gemenne 2008). Atoll migrants to Yap Proper are confronted by lack of jobs, little governmental support, and remain destitute in a challenging environmental setting. Apart from severity of extreme events, they also confront problems with infertile volcanic soils make sustainable agriculture challenging. This paper presents the results of an ongoing agricultural extension program extended to these socially disadvantaged ethnic outer island populations residing at Gargey settlement on Yap Proper. This settlement is considered as a 'safe haven' for the displaced population.

MATERIALS AND METHODS

The Gargey settlement is situated ($9^0 33'24''$N, $138^0 08'15''$E) in Gagil-Tomil plateau on Yap Proper (Fig. 1). The area was barren land until 2004, when migrant populations started colonizing especially after the devastation from typhoon Sudal on Yap Proper and its atoll islets.

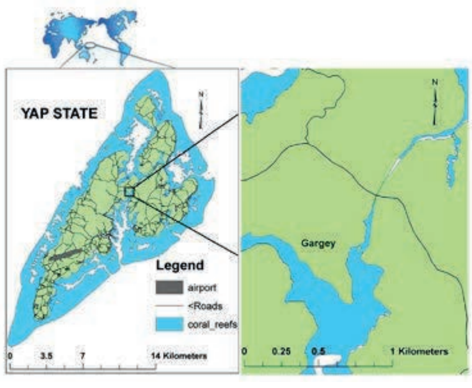

Figure 1. Location of Yap

Since 2005, a range of outreach and technical assistance programs have been extending to the inhabitants to enhance their ability to identify the constraints of soils for crop production and implement corrective measures to restore and maintain their productivity. Extension programs primarily focus on sound volcanic soil management and training on alternate crop production systems utilizing climate-smart agriculture strategies.

Soil characteristics and challenges in vegetable production

Soils on Yap's volcanic landscapes developed in rocks that probably formed during the Miocene but the soils may have formed in the Pleistocene (Johnson et al. 1960). That timeframe allows ample time for deep rock weathering in Yap's humid tropical environment. However, because of heavy rainfall (110-130 inches per year) and warm climate, many of Yap's soils have been depleted of nutrients through leaching. Leaching of nutrients causes a residual buildup of iron and aluminum in many of the soils giving them a reddish color (when oxidized). These soils either sustain forests because of lack of severe topsoil disturbance (Fig. 2) or are degraded through topsoil removal and then support mostly ferns that are adapted to harsh soil conditions (Fig. 3).

Figure 2. Forested volcanic soil with intact topsoil

Figure 3. Degraded soil under ferns with no topsoil

The soils highlighted in this study are mostly degraded, dominated either by ferns or grasses (open savannah). While the origins of these savannahs are still debated (Falanruw 1993; Hunter-Anderson 1991), a more intensive form of agriculture was practiced there mainly in the more fertile areas. Topsoils hold the bulk of nutrients and have higher organic matter content (Fig. 4). Organic matter can complex with soluble aluminum and take it out of solution so that it does not interfere with plant functions. Aluminum becomes soluble when pH drops below 5.2. Plant species and varieties vary in their resistance to the effects of aluminum toxicity; some plants may show toxicity symptoms at 10 percent aluminum saturation whereas other species may tolerate more than 90 percent aluminum saturation. Many agricultural crops cannot tolerate more than 50 percent aluminum saturation, which occurs just below the topsoil in these degraded Yap soils. The ability to hold on to nutrients and the amount of nutrients are both very low in these soils. Ferns are the main vegetation on these soils because they can tolerate the low soil fertility and high amount of soluble aluminum.

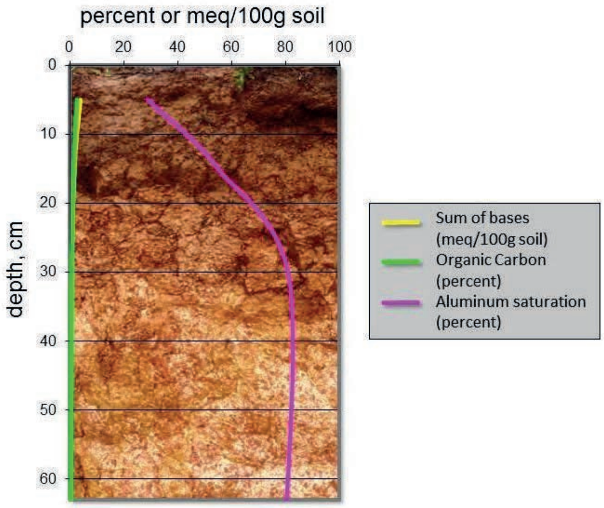

Figure 4. Key soil quality parameters

Soil management basics

The most important management strategy is to maintain existing topsoil through erosion control measures. Building depleted topsoil is accomplished through additions of organic matter either as compost or mulch. Mulch applied to the soil surface will become incorporated into the soil as it decomposes. Soil Organic Matter (SOM) is a source of nutrients and can be thought of as a slow-release fertilizer. If it is economically feasible, additions of lime are useful not only for raising the soil pH and lowering the aluminum content, but the calcium is also a needed plant nutrient. Raising the pH can also increase the negative charge on these variable charge soils and thereby increase the cation-exchange capacity.

Figure 5. Degraded soil with (R) and without mulch (L)

The value of soil organic matter is demonstrated in Figure 5. The soil on the left has lost its topsoil and there is no vegetation growing on it; note the absence of roots. The soil on the right was in a similar state until a layer of mulch/compost was put on top of it. Roots from adjacent trees and shrubs quickly exploited the SOM as a source of nutrients and their roots proliferated. The organic matter is concentrated on the surface (O horizon) but it is also darkening the mineral soil immediately below and starting to convert this subsoil into topsoil (A horizon).

Environmental constraints limiting vegetable production

The threat of climate variability has caused concern among scientists as crop growth could be severely affected by changes in key climate variables such as rainfall and temperature. The crop production environment in the island is a mixture of conditions that varies with season and location. Climatic changes influence the severity of environmental stress imposed on vegetable crops (Boyer 1982). Apart from the challenging soil conditions mentioned above, increasing temperatures, erratic rainfall and increase in intense tropical typhoon activities are the major limiting factors in sustaining vegetable productivity in the island environment. Extreme climatic conditions also negatively impact soil fertility and increase soil erosion. The response of crops to extreme climate variables depends on the type of crops, its developmental stage and the length and severity of the stress factor (Bray 2002). Environmental interactions may make the stress response of plants more complex or influence the degree of impact of climate variables. The Intergovernmental Panel on Climate Change (IPCC) has projected potential impacts of climate change on agricultural production and food security in small islands (IPCC 2007). Being landless and poor, the ethnic atoll communities are among the most disadvantaged and vulnerable groups, who require a strategy to adapt to extreme climate variables and develop and maintain a sustainable crop production system for survival.

Significance of vegetable production

Fresh vegetables are often beyond the family food budget of the vulnerable population due to their high cost, since they are mostly shipped from outside markets in United States. Lack of nutrient-rich vegetable intake is one of the prime reasons for the high incidence of nutrition related disorders, including vitamin A deficiency and iron deficiency related anemia in the State (Sowell et al. 2001). The Household Income and Expenditure Analysis Survey Report of the FSM (HIES Report 2007) estimates that around one-in-five households and almost one-in-three of the population of the FSM lives below the national minimum cost of living or basic needs poverty line. Malnutrition is primarily a “hidden hunger” that severely stunts human potential due to a lack of vital protein and micronutrients such as vitamins or minerals. Smallholder vegetable production has a vital role to play in overcoming this situation. Vegetables are the best resource for overcoming micronutrient deficiencies and provide smallholder farmers with much higher income and more jobs per hectare than staple crops (AVRDC 2006). Improving them is thus critical to poverty reduction and attainment of Millennium Development Goals (FAO 2009; FSM 2010).

With Environmental Vulnerability Index score of 392, the FSM is currently one of the highly vulnerable Small Island States in the Pacific. It contributes the least to the causes of global climate change, yet bears the brunt of all the impacts that hinder the efforts to achieve the Millennium Development Goals. Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and also, essentially, lower output variability in the face of climate risk and risks of an agro-ecological and socio-economic nature.

Climate-smart agriculture: a new paradigm

Coping with chronically variable yields of food crops is critical for the survival of vulnerable populations in marginal environments in small islands like Yap where agro-climatic conditions are challenging. Degraded land brought about through a prolonged interface between human-induced and natural factors, exacerbates low productivity. Managing risk exposure is an important preoccupation of vulnerable populations living in such environments and the only insurance mechanism presently available to these populations is derived from the use of inventive self-reliance, locally available resources and the climate-smart, low-input food production systems.

Climate-smart agriculture is a science-based approach to increasing smallholder productivity under challenging environmental conditions. Climate-smart agriculture seeks to increase sustainable productivity, strengthen farmers' resilience, reduce agriculture's greenhouse gas emissions and increase carbon sequestration (FAO 2010). In subsistence agriculture-based smallholder systems this innovative approach is not only important for food security but also for poverty reduction, as well as for aggregate growth and structural change. Production could be achieved through a number of crop systems which range from smallholder mixed cropping and livestock systems to intensive family farming practices. However, there is no blueprint for climate-smart agriculture and it is often specific to particular locations and productions systems. Its precise nature varies from place to place, influenced by a whole host of local factors, including the climate, the soil, the crops grown, available technologies and the knowledge and skills of individual farmers. The approaches detailed below are some of these techniques that communities successfully adopted at the Gargey settlement.

Figure 6. Vegetables on a raised compost bed

Climate-smart smallholder food production systems

Lack of nitrogen and other essential nutrients in the volcanic red soil is detrimental for any field-based subsistence vegetable production at the study site. This is resolved by the use of more environment friendly low-cost growing systems.

Raised beds

Raised beds are freestanding garden beds constructed above the natural terrain and one of the proven methods for growing a variety of crops to bypass otherwise challenging soil conditions. Poor soil nutrient conditions detailed in the earlier section prevents successful growth of crops on volcanic red soils. Raised bed gardens improve growing conditions for plants by lifting their roots above poor soil (Fig. 6). Soil in the bed is amended with a mixture of compost, coir pith and composted chicken manure to provide a better medium for plants. A variety of traditional root crops and garden vegetables are successfully grown using this system. Raised bed gives greater control over soil quality and nutrition. Higher soil levels and improved soil quality offer better access, less maintenance and easier harvest for communities engaged in vegetable gardening. Dense planting techniques result in higher production per bed and help in controlling weeds. By utilizing harvested rainwater, communities usually manage the freshwater required for irrigation.

Figure 7. Vegetables grown in nursery polybags

Container home gardening

Container home gardening is yet another strategy that is being successfully tested at the study site for growing a range of vegetable crops. Since displaced atoll populations have some experience with home gardening based on traditional methods, container home gardening is a production system that atoll communities are familiar with. Problems such as availability of arable land, degraded soil and extreme weather patterns are easily resolved by using a variety of containers for growing vegetables (Fig. 7). Using the right ingredients such as compost, coir pith and composted chicken manure, the communities have great control over the growing medium, its fertility and drainage, thus making the system simple and sustainable. Use of such simple yet effective methods reduces the need of synthetic fertilizers which, due to high costs and access, are often unavailable to smallholders. Nutrient rich leafy greens such as Chinese cabbage, lettuce, spinach, amaranth can be grown and harvested in a relatively short time.

Micro-gardens

Micro-gardens utilizing simplified hydroponics use low cost, simple technology suited to grow vegetables on limited resource settings. It offers the advantage of using places that have previously been unsuitable for food production. Atoll communities residing at Gargey settlement utilizes this technique to a wide range of vegetables. A variety of low-cost containers, custom-built tables and recycled tires serve as garden beds carrying growth medium (Fig. 8). It integrates horticulture production techniques with environmentally friendly technologies suited to all climates and makes effective use of rainwater and household waste management.

Micro-gardens assist the communities to reduce poverty and food insecurity by yielding fresh vegetables every day, thereby improving their food supply and nutrition. With proper training communities are able to scale up the operations that promote income generation though the sale of production surplus. Micro-gardens are highly productive and easily managed by the communities. Locally grown food decreases island communities' reliance on fossil fuels for transport of food from outside market that reduces society's carbon footprint.

Figure 8. Vegetable grown in wooden trays

Small plot intensive (SPIN) farming

Small Plot Intensive Farming (SPIN Farming) is a non-technical, organic-based, easy to understand and inexpensive to implement vegetable farming system designed specifically for small land bases (Fig. 9). It reduces two big barriers for limited resource farming communities – land and capital. It is geared toward making significant income from farming on a limited space. Some of the notable features of SPIN farming includes intensive relay of cropping practices, balancing production between high-value and low-value crops to produce a steady revenue system, application of organic or low-input growing methods, regimented harvesting techniques and direct marketing. This crop production technique allows farmers to earn a living, or generate a substantial amount of part-time income from a small land base.

DISCUSSION

Climate change projections for small islands are inherently severe that will bring difficulties to people living in atoll islets for whom achieving food security is already problematic, and is perhaps the FSM's the most pressing challenge as the nation seek to nourish its people and to achieve Millennium Development Goals (MDG Report 2010). This uncertainty is compounded by the paucity of arable land to increase the agricultural production. Thus, production impacts are often severe in small island states. For the atoll population who rely on traditional subsistence agriculture, food security is strongly dependent on local food availability. The environmental constraints therefore directly impact the food production systems that eventually spur a whole gamut of social, ecological and environmental issues (Erickson 2009; Liverman and Kapadia 2010).

Traditional agriculture is one of the high priority sectors in the small islands where the impacts of climate change exceed tolerance limits with implications for the livelihoods of impoverished people occupying marginal environments. This has resulted in the forced migration of atoll population to high lands in search of better living opportunities. Lack of arable land adds to the agony of the displaced population and threatens food security at household levels.

Soils represent one of the major natural resources of the small Islands (Morrison 1999). Given the fragile island environments, it is imperative that good soil management be practiced if communities are to sustain traditional food systems. Years of 'slash and burn' and shifting cultivation practiced by the early settlers in the fragile tropical humid island environment left much of Yap's volcanic soils degraded and depleted of nutrients. Such mistakes of environmental management are extremely difficult to rectify. Therefore, sound and sustained soil management practices are central to recover or establish crops in the degraded red soils of Yap. This calls for adoption of special methods to bypass unfavorable soil conditions. The restoration of degraded soils and adoption of improved crop production practices improve soil quality and soil health. Such management practices can at the same time improves food security as well as soil-related environmental services.

Impacts of extreme weather patterns on traditional agriculture are not uniform in all small islands due to obvious differences in the expected effects among islands, island topography and geographic location and production systems (FAO 2008). Therefore, the uniqueness of each island must be at the fore of adaptive strategies implemented to safeguard food security of the affected population. For displaced populations, the nature of assistive strategies depends on their ability to accept improved production practices or diversifying into income generating activities. Food security is the central focus for vulnerable island populations. Since climate-smart alternate crop production systems target the short-term needs of the displaced population, the approach is well accepted by the community.

Improving traditional food systems is critical to reaching poverty reduction and food security objectives of a nation (FAO 2008, 2009; World Development Report 2010; Wageningen Statement 2011). In degraded lands where agricultural productivity is challenging and the means of coping with extreme events are limited, enhancing food production requires agricultural systems to change in the direction of higher productivity. In the present work, the sustainable intensification of production through climate-smart alternate strategies ensured food security and livelihoods because it targeted short term needs of the displaced population. The displaced communities are able to directly participate in rebuilding their future on the barren land by maintaining a sustainable food system. Vegetables that were once beyond the family food menu of this displaced community now supplement their traditional diet of root crops and fish, thus making it rich in nutrients and vitamins. This study demonstrated the 'social value of scientific knowledge' and we continue to promote the whole idea of democratizing vegetable gardening by letting everyone participate in food production without adding any pressure in the fragile island environment.

CONCLUSION

Lessons from this study show that displaced populations have adapted to the challenging island setting by developing a diverse vegetable farming system in response to different opportunities and constraints faced over time. Many of the low cost systems serve as models of sustainability that offer promises to similar vulnerable communities impacted by extreme weather events. Alternate vegetable production strategies have specific merits and demerits. However, a systems approach that combines different methods found most effective under variable climate and soil types. By involving communities to enhance the crop production using a mixture of traditional skills and science-based knowledge will pave the way for community empowerment and self-reliant development in the face of challenging environmental settings.

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References

AVRDC. 2006. Vegetables Matter. AVRDC – The World Vegetable Center. Shanhua, Taiwan.

Boyer JS. 1982. Plant productivity and environment. *Science* 218: 443-448.

Bray EA. 2002. Abscisic acid regulation of gene expression during water-deficit stress in the era of the *Arabidopsis* genome. *Plant Cell Environ*. 25: 153-161.

Elevitch CR. 2006. Traditional Trees of Pacific Islands. Permanent Agriculture Resources, Holualoa, Hawaii 96725 USA. p. 816.

Ericksen PJ. 2009. Conceptualizing food systems for global environmental change research. *Global Environmental Change* 18(1): 234-245.

Falanruw, MVC. 1993. Micronesian Agroforestry: Evidence from the Past, Implications for the Future. USDA Forest Service *Gen Tech Rep* PSW-GTR-140.

FAO. 2008. Climate change and food security in Pacific Island Countries. Food and Agriculture Organization of the United Nations, Rome, p. 265.

FAO. 2009. Food security and Agricultural Mitigation in Developing Countries: Option for Capturing Synergies, Food and Agriculture Organization, Rome.

FAO. 2010. “Climate-Smart” Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. The Hague Conference on Agriculture, Food Security and Climate Change. Hague, Oct 31 – Nov 5, 2010.

Fletcher CH, Richmond BM. 2010. Climate Change in the Federated States of Micronesia: Food and Water Security, Climate Risk Management, and Adaptive Strategies. Report, p. 32.

FSM Information Service. 2008. President Mori Declares a National Emergency, Palikir (December 30, 2008), available at http://www.fsmgov.org/press/pr123008.htm; United Nations Office for the Coordination of Humanitarian Affairs (OCHA). Pacific Islands: Abnormally high sea levels OCHA Situation Report No. 2, available at http://www.reliefweb.int/rw/rwb.nsf/db900sid/MYAI-7MD4C8?OpenDocument7.

Gemenne F. 2008. Environmental Migration [Internet]. Version 11. Knol. 2008 Jul 24. Available from: http://knol.google.com/k/francois-gemenne/environmental-migration/qrmnmkeyllpq/2.

HIES Report. 2007. Household Income and Expenditure Survey Analysis Report 2005, Division of Statistics, Office of Statistics, Budget and Economic Management, Overseas Development Assistance and Compact management, Palikir, Pohnpei, Federated States of Micronesia, November 2007.

MDG Status Report. 2010. Millennium Development Goals Status Report for the Federated States of Micronesia. p. 175.

Hunter-Anderson R. 1991. A review of traditional Micronesian high island horticulture in Belau, Yap, Chuuk, Pohnpei, and Kosrae. *Micronesica* 24: 1-56.

IPCC. 2007. Climate Change 2007. Impacts, Adaptation and Vulnerability. The Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Cambridge University Press, Cambridge.

Johnson CG, Alvis, RJ, Hetzler, RL. 1960. Military Geology of Yap Islands, Caroline Islands. Prepared under the direction of the Chief of Engineers, U.S. Army by the Intelligence Division, Office of the Engineer, Headquarters United States Army Pacific with personnel of the United States Geological Survey. p. 164.

Liverman DM Kapadia, K. 2010. Food systems and the global environment: An overview. In: Ingram JSI, Ericksen, PJ, Liverman D (eds.), Food Security and Global Environmental Change. Earthscan, London.

Morrison RJ. 1999. Soils. In: Rupaport M. (ed.), The Pacific Islands Environment and Society. The Ben Press, Inc., pp. 56-65.

Nelson JM. 1976. “Sojourners Versus New Urbanites: Causes and Consequences of Temporary Versus Permanent Cityward Migration in Developing Countries” *Economic Development and Cultural Change* 24: 721-757.

Sowell A, Gonzaga PS, Engleberger L, Schendel D, Elymore J, Huff D. 2001. Vitamin A deficiency and anemia among preschool children and their mothers or female caregivers in Yap and Kosrae, Federated States of Micronesia. In: XX International Vitamin A Consultative Group (IVACG) Meeting. *25 Years of Progress in Controlling Vitamin A Deficieny: Looking to the future*, Hanoi, Vietnam, 12-15 February, 2001.

The Wageningen Statement. 2011. Global Science Conference on Climate-Smart Agriculture: Climate Smart Agriculture – Science for Action, Oct 26, 2011.

World Development Report. 2010. Development and Climate Change, the World Bank, Washington, D.C.

Trend of horticultural research particularly vegetables in India and its regional prospects

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ABSTRACT

Horticulture, which includes fruits, vegetables, tubers, mushrooms, spices, flowers, medicinal and aromatic plants and plantation crops has emerged as a good option for diversification of the agricultural sector for the food, nutrition, health care and livelihoods of the Indian population since it provides, much enhanced farm income and greater opportunities for employment. The sector has made unprecedented growth in India, during the last few decades, owing to dynamics of improved technologies, investment and policies, leading to increased farm profitability. Currently, horticulture contributes 30.4% to Agricultural Gross Domestic Products (AGDP) only from 11% of the total cropped area, and has maintained an annual growth rate above 6%. The Indian Council of Agricultural Research (ICAR) is the apex organization of the National Agriculture Research System (NARS) in the country, for agricultural research and education with 63 state agricultural universities, 98 institutes, 79 All India Co-ordinated Projects (AICRP's) and 595 *Krishi Vigyan Kendras* (Agriculture Science Centers). Horticultural research is done through 23 Institutes/Directorates/National Research Centers, 14 AICRP's, and departments in State Agricultural Universities. The Indian Institute Vegetable Research, Varanasi and the Indian Institute Horticulture Research, Bangalore, are doing intensive research in vegetable crops, besides the AICRP which has been set up with 5 centers across the country. The total production of horticultural produce is estimated to be 240.5 million t during 2010-11, of which, 146.5 million t is contributed by vegetables. It ranks second in production after China, with a contribution of about 14% to global production.

It is estimated that about a billion of people are hungry and are suffering from various kinds of malnutrition, out of which, half of the population is in Asia. Thus, there is a need to apply the power of science and technology. These efforts have been the utilization of diversity, development of cultivars and technologies which can address the challenges of producing more food from less land and water in the scenario of climate change to ensure, the food, nutrition, health care and livelihood of the Indian people. Although, there has been appreciable change in the growth of horticulture in India, to meet the requirements of growing population, a strategic approach is needed. **The country has envisioned the accelerated development of innovations and technologies to address the challenges of producing more for the growing population with declining land and water within the scenario of climate change.**

This can be achieved through strategies, designed to ensure technology-led development of horticulture, to make it available to all citizens at affordable prices; ensure the availability of new cultivars and technologies, which can withstand biotic and abiotic pressure and provide better profitability to farmers in a given situation and location. To identify new genes and technologies and understand their interaction with the environment; to have a greater proofing against climate change to achieve a more resilient horticulture sector; develop cultivars and technologies, which are rich in nutrients and vitamins and can better protect the population from many diseases, considering that a balanced diet will be a medicine of future; develop technologies which are socially compatible, politically feasible and ecologically sustainable and provide environmental services and develop human resources par excellence, having competence and commitment to take up the forthcoming challenges.

Vegetable crops (more than 50) belonging to different family groups namely cucurbitaceous, leguminous, solanaceous, brassicaceous and root and leafy vegetables are grown across the tropical and temperate regions. But, on the basis of the major area under production, onion, potato, tomato, brinjal, cabbage, cauliflower, okra, peas and cucurbitaceous vegetables are the major crops in demand. India occupies first position in okra, second position in brinjal, cabbage, cauliflower, onion and third position in tomato production worldwide. The present area is estimated to be 8.49 million ha with productivity of 17.2 t/ha. Research output in vegetables cultivation is appreciable. Historically, a total of 410 varieties in 24 vegetable crops have been identified for cultivation in different agro-climatic zones. This includes 256 open pollinated high yielding varieties, 111 hybrids and 43 cultivars resistant to various diseases. Multiple disease resistant variety of tomato (leaf curl virus, bacterial wilt and *Fusarium)* has been developed. Sequencing of potato and tomato are at the final stage of identification for release and finger prints are available for large number of cultivars. In potato, the focus is on development of cultivars suitable for processing and for table purposes, which can give competitive yield even under stress conditions. Transgenic lines in tomato, water melon, brinjal, potato have been developed, which are in process of release. RNAi technologies have been used for gene silencing to check sugar accumulation. The most important feature of research concerns production technologies, plant health management, diagnostic development, seed production and secondary horticulture. Hi-tech agro-techniques like integrated nutrient and water management, fertigation, vermiculture, biofertilizers, organic farming, zero land utilization, protected cultivation through green houses, integrated plant health management, biological control, molecular diagnostic techniques all have helped to increase national productivity and production. Postharvest technologies like grading, packaging including aseptic packaging, storage, cold chain and cold storage facilities, irradiation for increasing shelf life, value addition and diversification of value added products, quality standards, pesticide residue management are some of the initiatives to address newly emerging issues.

In Asia and the Pacific, where 642 million people are undernourished out of total 1017 million hungry people in the world (FAO 2009), AVRDC - The World Vegetable Center, with its headquarters in Taiwan and having 13 regional centres globally, is complementing national efforts by addressing regional vegetable research and development needs. Similarly, the International Potato Center (CIP) based at Lima (Peru), also complements the regional research needs of potato research. However, regional cooperation now becomes more important in order to learn better and more effectively from each other. Many scientists from the regions have been trained in India on various aspects of vegetable production. Many Indian varieties have performed well across the region. The experience of the past and the growing challenges ahead now necessitate closer co-operation. Consequently, technology driven vegetable production will contribute significantly in ensuring better nutrition and livelihoods. Since vegetables have immense potential to address the problem of malnutrition, unemployment and other complex issues, research and development of vegetables through cross learning and use of science would help benefit the region by bringing about substantive economic development. The paper deals with research trends in India and Asia, their accomplishments, and lessons learnt in order to develop a suitable perspective to help in economic development for all.

Keywords
Vegetable crops, research trend in India, regional prospects

INTRODUCTION
Horticulture, which includes fruits, vegetables, tubers, mushrooms, spices, flowers, medicinal and aromatic plants and plantation crops has emerged as a good option for diversification of the agricultural sector for the food, nutrition, health care and livelihoods of the Indian population since it provides, much enhanced farm income and greater opportunities for employment. The sector has made unprecedented growth in India, during the last few decades, owing to dynamics of improved technologies, investment and policies, leading to increased farm profitability. Currently, horticulture contributes 30.4% to Agricultural Gross Domestic Products (AGDP)

only from 11 % of the total cropped area, and has maintained an annual growth rate above 6%. Many crops which were less well known before have emerged as important contributors to the sector and India has become a leader worldwide in the promotion of such crops.

Vegetable crops constitute a key component in horticulture and have assumed much significance both for growers and consumers. During the last decade impressive growth has been recorded due to technological advancements, availability of seeds and technologies. Currently we produce 146.5 million t of vegetables, which is 14% of the world's production (NHB 2011). During the last decade, the country's vegetable production has almost doubled and gross vegetable productivity has also increased by one and half times. Being effective supplements for human nutrition, vegetables form an important part of the daily diet of all categories of people from rich to poor. The demand for fresh vegetables has shown an increasing trend owing to growth of a health conscious population and more generally through enhanced income. In the current scenario however, the challenges ahead are much greater than those overcome before. We are now at a crucial juncture and pressure on land is very high. Indian agriculture supports 17% of world human population, 11% of the animal population from only 2.3% of the world's area and 4.5% of the world's water. Yet, it provides the livelihoods of more than 600 million people (Singh 2010a). In the years to come challenges to agriculture will continue to increase. World population is expected to increase to 9 billion in 2050, people who have to be fed from declining land and water reserves, within the scenario of potentially hostile climate change. The impact of climate change is likely to increase in terms of higher temperatures, greater uncertainty of weather, the emergence of new pests and diseases, besides a threat of a rise in sea level and a decline of water supplies from glacial resources.

Vegetable scenarios for improved food and nutrition

Vegetables comprise a wide range of unique crops which are grown under varying agro-climatic conditions, from cold temperate to equatorial climates, including global vegetables such as tomatoes, cucumbers, cabbage, carrots, peas etc. They play a major and increasing role in ensuring basic food security as well as nutritional security and their consumption is an essential part of a healthy diet. For the rural and urban population in the tropics, vegetables such as potato, sweet potato and yam are also considered as important sources of carbohydrate. The leguminous vegetable crops such as vegetable soybeans, peas and French beans are high in protein. They also contribute vitamins, minerals, roughage, fiber and are rich in health-related phytochemicals, such as antioxidants. They play direct and indirect roles in diversifying human dietary patterns and providing employment, especially to women, and thus help engender income to purchase the components of a balanced diet. For developed countries, vegetables are increasingly the subject of attention for lowering the risk of certain diseases. Vegetable production in developing countries is often highly intensive and multiple and successive cropping sequences are routinely practiced. Concomitant with the rapid economic growth in many of these countries, the demands for high-quality horticultural crop have substantially increased in recent years.

Currently, the average vegetable availability per capita per day is estimated at about 100-110g in South Asia, Southeast Asia and South America, while in Sub-Saharan Africa, it is far below 100 g. These averages are much less than the WHO recommended 300 g that is necessary to provide adequate amounts of essential micronutrients and vitamins. Since both food and nutritional security are important requirements of every nation, all efforts to boost production and supply of quality vegetables are given the utmost importance in most of the countries. Yet, despite their economic role and their importance in the human diet, they have not generally been given the research attention or funding that they deserve, particularly in Africa and some Asian countries, where priority is given to staple grains and food crops, cash crops or industrial crops. Increasing attention paid to vegetable crops is rather recent, in relation to their important role in "food and nutritional security" values as the largest sector of the population depends on vegetables as their major source of proteins, due to lack of "animal proteins" in majority of developing countries. The increasing presence of supermarkets and new global opportunities for trading are also favoring these crops. Vegetables yields are higher per unit area and most of them are high value crops and substantially labor-intensive; thus, they generate more income per unit of labor or land occupied per day than cereal production. In traditional producing countries, as India or China, and new producing countries as well most of the developing countries, where poor and marginal farmers constitute the highest percentage of the poor rural population, vegetable farming is an excellent option for them and will result in their social and economic upliftment. Presently the general trend is that of a shift from small scale production system (small holders) to commercial oriented production system, which generates new needs for research with key words like 'quality', 'competitiveness', ‘human health’, 'environment friendly production, year round supply, factor productivity enhancement etc.

The majority of the vegetable crops cultivated in the South East Asian Region member countries (Bangladesh, Bhutan, China, India, Burma, Nepal, Pakistan, Indonesia, Japan, Malaysia, Philippines, Korea, Sri Lanka, Taiwan and Thailand) are common due to their similar environmental conditions (tropical & sub-tropical) prevailing in these countries. Commonly grown vegetables in these countries are tomato, eggplant, chili, sweet pepper, cucurbits, melons, okra, cole crops, onions, leguminous and leafy vegetables. The ever-increasing population poses a serious threat, as it will cause the per capita vegetable consumption to decline and this throws out a stiff challenge to researchers, calling for proper strategies to boost the productivity of vegetable crops. Both biotic and abiotic stresses have become major production constraints in these countries. To boost productivity, a three pronged approach viz., evolving multiple stress resistant varieties/hybrids through well planned crop improvement programmes, developing sound and environmentally friendly production and protection technologies and supply of quality seeds and seedlings made available at right time for planting are required.

The current scenario of vegetable production

The vegetable crops (more than 50) belong to different family groups namely cucurbitaceous, leguminous, solanaceous, brassicaceous and root and leafy vegetables. These are grown in tropical to temperate regions. India ranks second in area and production of vegetables after China and contributes 14.8% to the area and 14% of the world’s vegetable production (Fig. 1). India occupies first position in okra, second position in brinjal, cabbage, cauliflower, onion and third position in tomato production in the world. But on the basis of major area under production, onion, tomato, brinjal, cabbage, cauliflowers, okra, peas and cucurbitaceous vegetables are the major vegetables in demand.

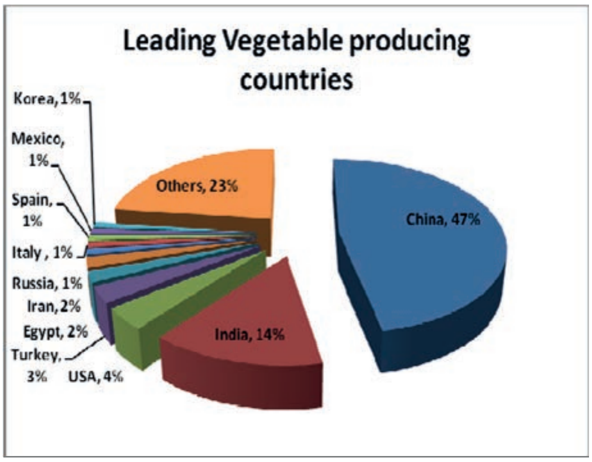

Figure 1. Share of different countries in world vegetable production (NHB 2011).

Presently, India produces about 146.5 million t of vegetables from an area of 8.49 million hectares with an average productivity of 17.2 t/ha (Fig. 2). Compared to the area (2.84 million ha), production (16.5 million tons) and productivity (5.8 t/ha) of vegetables in 1950-51, there had been considerable increase in area (2.8 fold), production (8.1 fold) and productivity (2.9 fold) of vegetables in our country during the last 6 decades. The major vegetable producing states during 2010-11 were Uttar Pradesh (17%), West Bengal (16%), Bihar (10%) and Orissa (7%). The production share of major vegetables in 2010-11 was potato (27%), tomato (9%), onion (9%), brinjal (8%), cabbage (5%), cauliflower (5%) and okra (4%). With current level of vegetable production and considering about 20% postharvest loss and 5% export and processing, per capita availability of vegetables in our country is 227 g compared with the 300 g recommended dietary allowance (RDA) by the WHO. Thus, there is shortage of about 32 million t of vegetables. With the projected population, the demand of vegetables in our country would be 181 million t in 2020 (population 1.326 billions), 200 million t in 2030 (population 1.460 billions), 215 million t in 2040 (population 1.571 billions) and 227 million t in 2050 (population 1.656 billions). In the case of increased export and processing during these periods, the demand of vegetables is likely to increase further. The major contribution of vegetable supply comes from potato, tomato, brinjal, okra, beans and cucurbits. Among the cucurbits, besides melons, gourds, cucumber and gherkins are important. Cucurbits such as pointed gourd and spine gourd are also gaining importance in commerce, as they have much more value for export for their medicinal and therapeutic uses.

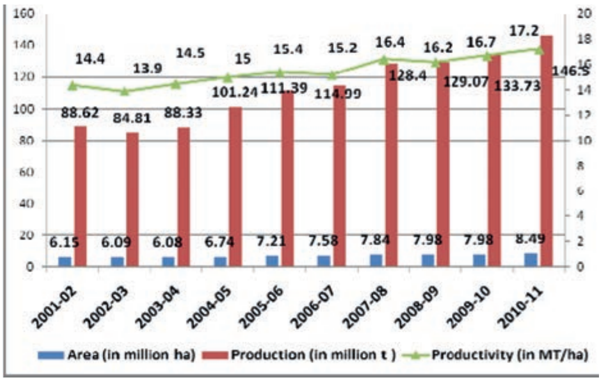

Figure 2: Trend of Vegetable production in India (NHB 2011)

RESEARCH TRENDS

Genetic enhancement

Biodiversity

Food and nutritional security is a priority to fulfill the needs of our growing population, which has to be achieved by improving the production potential of crops through genetic enhancement. The natural resources such as land and water are diminishing at a rapid pace causing great concern globally. As a commitment to provide strong backing to the breeding programmes, germplasm collection efforts were strongly supported by the national research programme which has yielded results. India is endowed with large germplasm pool (72,000 germplasm accessions of cultivated, wild and related taxa) are being scientifically conserved in various institutes, with about 6000 fruits which includes about 1360 accessions of arid zone fruits, 25,400 in vegetables, 15,700 accessions in spices and condiment crops and 10,100 in plantation and tuber crops (Singh 2010b). The National Bureau of Plant Genetic Resources (NBPGR), New Delhi holds the germplasm repository of horticultural crops at National Active Germplasm Sites. These collections have been evaluated but concerted efforts are now required in the search for new genes in land races and wild types to develop stress tolerant varieties. Thus, more efforts are required in documentation, conservation and utilization of plant genetic resources in vegetable crops in the Asia and Pacific region. The collections have been evaluated for many economic characters like resistance to diseases, insect-pests, maturity, adaptability, processing attributes and nutritional qualities. Evaluation studies conducted over years have led to the identification of promising germplasm accessions with multiple resistance/tolerance to various diseases and pests and also possessing other desirable agronomic characters, many such accessions have been registered at the NBPGR, New Delhi. Till now, the major emphasis on germplasm collection and evaluation has been for targeting high yield but now keeping in view the dynamic needs of diverse stakeholders, there is a further need to make more explorations for collection of variability and further sourcing for resistance to diseases, insect-pests and more particularly for processing attributes to develop cultivars for processing industry and export. Keeping in view the nutritional and health care need of the people, it has also become necessary to identify accessions having high nutraceutical values (micro nutrients and vitamins).

Crop improvement programmes in India and South East Asian countries

Varietal development

Research output in vegetable varietal development is appreciable. In India, a total of 410 varieties in 24 vegetable crops have been identified for cultivation in different agro-climatic zones. This includes 256 open pollinated high yielding varieties, 111 hybrids and 43 cultivars resistant to various diseases (Singh and Malhotra 2010). Multiple disease resistant varieties of tomato (leaf curl virus, bacterial wilt and *Fusarium)* have been developed. The sequencing of the potato and tomato genomes are at the final stage of identification for release and finger prints are available for a large number of cultivars. In potato, focus is on development of cultivars suitable for processing and for table purposes, which can give competitive yield even under stress conditions. Transgenic lines in tomato, water melon, brinjal and potato have been developed, which are in process of release. RNAi technologies have been used for gene silencing to check sugar accumulation. The contributions made by the Indian Institute of Horticultural Research, Bangalore, the Indian Institute of Vegetable Research, Varanasi and the Division of Vegetable Crops at IARI, New Delhi for development of a number of high yielding varieties in tomato, brinjal, chillies, peas, beans, cucurbits, okra and many other vegetable crops is highly appreciated. The varieties developed by various other centers under the All India Co-ordinated Research Projects located in different parts of the country have made significant contributions which have impacted substantively on vegetable production. Some of the resistant varieties identified are Arka Alok, Arka Vardhan, BT 10, BRH 2, LE 415 (all for bacterial wilt), FWH 2 (Nematode), H 24 and H 86 (TLCV) in tomato; BB7, BWR 12, SM 6-7, SM 6-6, BB 44, CHES 309, BB64 (all for bacterial wilt) in brinjal; PRS 4, JP 4, JP 83, NDVP 4, DPP 68, KS 245, NDVP 250, DPP 9411, KTP for powdery mildew in garden peas; P7, PB 57, Sel 10, Sel 4, HRB 55, HRB 9-2, VRO 3,4,5,6, NDO 10, HRB 107-4, IIVR 11 and JNDOL 0301 for YVMV in okra; DMDR 1 (CGMV) and DMDR 2 (DM and CGMV) in muskmelon (Singh *et al* 2009a; Singh 2009). There is need to give greater emphasis on breeding for developing resistant varieties against diseases which are impediments to raising profitable crops. Tolerance for abiotic stresses and resistance to insect-pests has yet to receive sufficient attention under the coordinated programs. Varietal development must address nutraceutical values and characteristics, and needs to mitigate the effects of climate change. In the last one and half decades, the research focus has been on the management of the threat of biotic and biotic stresses involving an approach of breeding system for combating multiple stresses. The strong institutional and infrastructural set up and provided by the Government of India, Indian Council of Agricultural Research, particularly at the Indian Institute of Horticultural Research, Bangalore, the Indian Institute of Vegetable Research, Varanasi and the Division of Vegetable Crops at IARI, New Delhi and research projects undertaken have yielded constructive results and these are described here.

Biotic stresses

Bacterial : Bacterial wilt (*Ralstonia solanacearum*) [BW] in tomato, eggplant and capsicum and Bacterial blight in French bean have become serious diseases in India, Srilanka, Bangladesh, Indonesia, Thailand and Taiwan. Bacterial wilt resistant tomato varieties (India-Arka Abha, Arka Alok, Shakthi, Mukthi, BT-1, BT-10) (Srilanka-Ratan), (AVRDC, Taiwan-AVTO series) and F_1 hybrids (India-Arka Shreshta, Arka Abhijit, NS-501, Allrounder) are available for commercial cultivation. In Brinjal also BW resistant varieties (India- Arka Nidhi, Arka Keshav, Surya, Shwetha & BB-1) and F_1 hybrids (India-Arka Anand) are commercially available (Singh and Malhotra 2010). There is a strong need to develop BW resistant varieties/hybrids in capsicum. In chili, BW is expressed as a symptomless carrier. Kerala Cluster is resistant to BW. In French bean varieties with combined resistance to bacterial blight and rust (Arka Anoop) and rust (Arka Bold) are available for commercial cultivation in India. In Indonesia and the Philippines the eggplant variety Dingras Multiple Purple (DMP) has been commercially cultivated and successfully utilized as a donor parent to transfer BW resistance to Indian brinjal varieties.

Begomoviruses: Begomo viruses transmitted by whitefly have become very serious in all the countries in tomato (ToLCV), Chili (ChLCV), Okra (YVMV) and French Bean (MYMV). Commercial varieties and F_1 hybrids are available in India in tomato (Hisar Anmol, Nandi, Vybhav, Sankranti, Arka Ananya, NS-501, US-618 and Abhinav) and Chili (Arka Meghana and Punjab Guchedar). AVRDC has successfully pyramided ToLCV resistance genes (Ty1, Ty-2 and Ty-3) and developed stable ToLCV resistant lines and has distributed these lines (CLN-3125A and 3125P) globally. In India, though resistant varieties of okra like Arka Anamika, Parbhani Kranti, Punjab Padmini and commercial hybrids are commercially cultivated, resistance has broken down in the presence of new YVMV strains. MYMV resistant lines in French bean have been developed in India. As Begomoviruses are highly recombinant in nature, new viruses have emerged in all these countries warranting the survey and molecular characterization of new viruses, screening for new resistance sources and the pyramiding of resistance genes for durable resistance.

Ground nut bud necrosis virus (GBNV): Transmitted by thrips this disease has become very serious in tomato, chili, eggplant and watermelon (WBNV) in India, Bangladesh, Sri Lanka and Pakistan. All the reported resistant tomato varieties have been found to be susceptible to local isolates and research need to be intensified to develop GBNV/WBNV resistant varieties in the respective crops.

Leaf spots/blight diseases: Early blight (*Alternaria solani*) in tomato and purple blotch (*Alternari porii*) in onion has become very serious diseases by causing economic yield losses. Multiple disease (ToLCV+BW+EB) resistant F_1 hybrids in tomato (Arka Samrat and Arka Rakshak) and purple blotch tolerant onion varieties (Arka Kalyan) and F_1 hybrids (Arka Lalima and Arka Kirtiman) have been released for commercial cultivation in India.

Powdery mildews: Powdery mildews **c**ause considerable yield losses in chili, capsicum and garden peas. Powdery mildew resistant chilivariety (Arka Suphal) and hybrids (Arka Meghana & Arka Harita) and pea varieties (Arka Ajit, Arka Sampoorna and Arka Kartik) have been released for commercial cultivation in India.

Abiotic stresses

High temperature stress: Extreme temperature events (>36^0C day & >26^0C night) cause drastic yield loss due to flower / fruit drop in crops like tomato, capsicum, French bean and peas in India, Bangladesh, Pakistan, Sri Lanka, Indonesia, Thailand and Taiwan. AVRDC, Taiwan has done commendable work in developing high temperature tolerant lines in tomato and capsicum. Similarly high temperature tolerant lines have been developed in French bean and peas in India (IIHR, Bangalore). Attempts are being made to develop high temperature tolerant varieties/F_1 hybrids in these crops in other countries in the region. Recently tropical cauliflower varieties (Arka Vimal & Arka Spoorthi) have been released for commercial cultivation in India and these can set seed under tropical conditions (Singh *et al* 2009a).

Low moisture stress (drought): Vegetable crops like onion, chili, tomato and dolichos beans are cultivated on large areas as rainfed crops in India, Bangladesh and Srilanka. Tomato varieties (Arka Vikas, Arka Meghali, Pusa Ruby, PED, Megha and PKM-1) and dolichos bean varieties (Arka Jay and Arka Amogh) are suitable for rainfed cultivation and are available in India. Drought tolerant lines in chili and onion are in the pipe line.

Salinity stress: Salinity stress is also quite wide spread in most parts of the tropics and appropriate amelioration measures are to be adopted regularly in order to maintain the soil productivity and to get better crop yields. Saline soils are characterized by their EC which is more than 4.0 dS m^{-1}, exchangeable sodium percentage of less than 15.0, pH less than 8.5 and sodium absorption ration of less than 10.0. Sodic soils have an EC less than 4.0 dS m^{-1}, ESP more than 15.0, pH of soil more than 10.0 and SAR more than 10.0. Germination and sprouting is the most sensitive stage for salinity. Crops and species which are sensitive at this stage may be tolerant during their growth and flowering stage. The salinity tolerance of varieties vary considerably. It is known that Pusa Sawani of okra, Sabour Suphala of chili, *Lycopersicon cheesmanii*, a wild relative of tomato, are tolerant to salinity compared to other varieties. To induce salt tolerance in vegetable crops, several methods like, a pre-sowing soaking treatment in salts, growth substances, micro-nutrients and other chemicals, spraying with various growth regulators, and grafting on salt tolerant root stocks have been used to induce salt tolerance in different crops.

Hybrid technology

Appreciable progress has been made in the development of hybrids in several vegetable crops and hybrid seeds of tomato, chili, cucumber and muskmelon are being produced at several locations. The All India Co-ordinated Research Projects for vegetable crops has so far recommended 111 hybrids for cultivation including many hybrids of vegetable crops developed and marketed by the private sector. At present, the area under vegetable hybrids is more than 0.5 million ha in India, about 10 % of the total area under vegetables. Hybrid tomatoes are being cultivated on a commercial scale in Karnataka, Maharashtra, Gujarat and Andhra Pradesh. The entire cabbage growing area in the southern part of Maharashtra and West Bengal are mainly F_1 hybrids. The area under high yielding F_1 hybrids in important vegetable crops ranges from 17.8-31.5% in tomato, cabbage and brinjal and areas under capsicum and chili are also under expansion. High production, earliness, superior quality, uniform produce and resistance to biotic and abiotic stresses are the main advantages of F_1 hybrids.

Keeping in view tour changing needs research efforts in various institutes have focused on the development of hybrids with multiple disease resistance, early maturity and utilizing the male sterility system. Advanced lines of tomato (TLBR-1, 2, 3, 4, 5, 6) with combined resistance of bacterial wilt were evolved at IIHR, which can now be utilized for the development of markers and the stacking of resistant genes against ToLCV, and early blight in the parental inbreds. CMS lines have successfully been utilized to produce potential experimental crosses of onion and commercial hybrids of chili. Nuclear male sterile lines (GMS) of tomato, brinjal and chili were introduced/established and are being successfully utilized for developing a number of cost effective experimental crosses at various centers. Considerable success has also been achieved for adoption of hybrids. Hybrid seeds of chili (CH-1, CH-3, CCH-3), brinjal (Kashi Sandesh), tomato (TH-1) are being now produced by the farmers by upgrading their skills. The parental lines of a number of hybrids developed have been sold on a non-exclusive basis to the seed companies with the aim being to promote these hybrids among farmers.

Biotechnology in vegetable crops improvement

New biotechnological tools have provided ample scope for the breeder to improve diverse traits, including yield, disease resistance, abiotic stress tolerance and quality more precisely and in a reduced time. The protoplast fusion technique to produce somatic hybrids has been successfully utilized in a number of vegetables. Anthers of capsicum variety Arka Gaurav and tomato hybrid Avinash 2 responded to culture with an embryogenic like response without the intervening callus phase. Androgenesis has been successfully used for brinjal, pepper, cabbage, cauliflower, potato, asparagus and carrot and gynogenesis in onion. Triploid progenies from immature fruits/seeds of 4n x 2n crosses of watermelon could be salvaged through embryo culture.

Molecular characterization has proved to be an important tool and is being utilized by breeders in understanding the genetic diversity, evolutionary pattern, characterization of genotypes into groups/classes, identification of mutants and synonyms, confirmation of hybridity, identification of useful gene sources and their tagging, settling of disputes over claims on genetic material under patent regime, precision breeding, marker aided selection

(MAS) etc. Efforts are under way to fingerprint a number of solanaceous vegetables (Singh et al. 2011a). In the root-knot nematode resistant (Mi) gene in tomato, the DNA sequence has been isolated that overlaps with parts of the desired gene and, therefore, are more certain to be inherited with its serving marker. These sequences are also being used to isolate the Mi gene to facilitate breeding of this valued trait into new varieties and even other species. Gene pyramiding to converge useful genes in one background variety of commercial interest is the mainstay of biotechnological research and is in progress in all solanaceous vegetables. With the availability of nucleotide sequences of more than 70 different genes δ-endotoxins have been classified into 22 different classes and more than 130 different CRY genes have been reported. A large number of transgenics with *Cry-l* AB gene have been produced. Use of this biotechnological tool to develop resistance to fruit borer in brinjal is in the final stage of release. Besides efforts are being made for developing and testing of transgenics for resistance to diamond back moth in cabbage, borer in tomato and cauliflower, leaf curl virus in tomato, potato virus Y and few other pests (Singh et al. 2011b). Biotechnological tools have augmented conventional approaches in identification and isolation of resistant sources/ genes and the development of crops resistant to specific stresses through transgenic approaches. There is need to tackle key issues through resistance breeding involving biotechnology for biotic and abiotic stresses and specific desirable attributes such as a shorter crop duration, heat, drought, salinity tolerance, high input use efficiency, enhanced nutritional quality and shelf life.

Breeding for improving shelf life and bioactive compounds

A research approach for using the antisense gene has also been started. Improved storage and shelf life of genetically modified vegetables with quality traits would increase their availability and improve the possibilities of having better balanced diets. Active components such as caroteinoids from tomatoes, glucosinolates from Brassica vegetables, phytoestrogenes from soybean and phenolics and antioxidants from various plants protect and prevent numerous diseases such as cancer and cardiovascular disease. These antioxidants are also associated with slowing the ageing process and improving overall health. Phytoestrogens from *Dioscorea* species such as wild yam (*Dioscorea villosa)* also possess numerous physiological benefits. A few sweet potato varieties also seem to have anti-diabetic potential. Most of these bioactive components are plant secondary metabolites. The genes are being used for transformation in the development of transgenics of vegetable crops with such speciality traits. A network project is in operation which involves 6 horticultural crops at ICAR laboratories as a part of mega network project on transgenics (Singh et al. 2011b).

Quality seed supply and seedling production

Seed production is the most important component in the successful production of annual vegetable crops. The seed for sowing needs to be produced under ideal conditions. The varieties need to be selected which are quite popular and cater to the needs of consumers. There are three parameters considered important in quality seed production—physical purity, germinability, health and genetic purity. It is necessary that the quality of the seed should be of the highest possible standards. Seed of only those varieties which are notified under the Seed Act are eligible for certification in India. The necessary field standards consisting of isolation distance, field inspection stages and specific requirements showing maximum permitted limits of off types, other crops and diseased plants have been standardized for different crops. The specific requirement for seed crops of seed spices showing maximum permitted limits for off types, objectionable weeds, and designated diseases are also available for various seed propagated crops (Singh 2010c; Singh et al. 2009).

To ensure quality produce and also high yield, the raising of good seedlings through use of good seeds and appropriate cultural practices is a pre-requisite. The raising of seedlings with nylon net coverings on nursery beds or high-tech mechanized mass production in green houses gives good quality and healthy seedlings. Use of water soluble specialty fertilizers and biofertilizers at the nursery stage has good potential for producing healthy seedlings. Use of micro irrigation and fertigation helps in maintaining uniformity in the growth of seedlings by maintaining good soil moisture and nutrient regimes without the harmful crusting of the soil surface.

Production technology

A wide range of vegetable crops from different groups are grown in the region. The agro-techniques are highly site specific and vary for different vegetable crops. Suitable packages of practices including optimum sowing time, seed rate, nursery management, transplanting, spacing, intercultural practices and weed management have been standardized for different vegetable crops for realizing the optimum potential of improved varieties/hybrids in different agro-climatic conditions. It is only the technology which has made it possible to grow some of the vegetable crops year-round in India. The production technology for off season cultivation has also been worked out for different regions and now increased the availability of any vegetable anytime. In order to boost vegetable production, it is important to popularize improved and innovative production technologies for adoption by farmers. In endeavoring to meet the increasing demand of vegetable crops, it is now essential to make available complete package of practices varying across seasons, zones and production systems (Singh and Palaniswami 2010). There is need to focus on the development of production technologies based on good agricultural practices covering all necessary steps of safety from production till consumption. Popularization of low cost protected cultivation system using locally available resources in specific crops and areas for offseason farming and non-traditional crops and quality produce need emphasis.

Efficient nutrient management

Amongst the various inputs, fertilizers alone account for 20-30% of the total cost of production in horticultural crops. Moreover, the efficacy of fertilizers applied in soil is low due to various losses and soil fixation potential. Fertilizer efficiency studies using isotope labeled fertilizers have shown nutrient derived from fertilizer (NDFF) values of only 0.5 to 30%. There is need for a system which can determine the need of nutrients at all stages of growth and also accounting for the soil's ability to supply those needed nutrients more efficiently. Monitoring soil health and leaf analysis in vegetable crops will be useful to ensure balanced nutrient management and safeguard against hidden hunger as well as luxury consumption by horticultural crops. Phosphate rich organic manure (PROM); a value added product made by co-composting different organic wastes with high grade rich phosphate in fine prill size have been found to be useful in many vegetable crops and is an effective alternative to costly chemical fertilizers. Foliar nutrition methods for some of the vegetable crops have been worked out but there is need to cover more vegetables for high nutrient use efficiency (Singh 2009).

Similarly, growing from the use of single nutrients historically, application of multi-nutrients has now been adopted. Because no single source of nutrient can satisfy the needs of all the essential elements that crop needs for growth and development. Nutrient management in multiple cropping systems is more efficient than in individual crops because there is a residual effect of nutrients for e.g. phosphoric fertilizer and organic sources of plant nutrients. To sustain the productivity of different vegetable crops and cropping systems, efficient nutrient management is vital. Therefore, efficient, economic and integrated systems of nutrient management for realizing high crop productivity without diminishing soil fertility do assume national importance. Use of integrated plant nutrient systems (IPNS) which involves cattle, poultry, animal and plant resources in combination with chemical fertilizer, supplemented with bio-fertilizer such as rhizobium culture, azotobacter, azospirillium, mycorrhiza and phosphate solubilizing bacteria would boost the yield of vegetable crops. These are low technology agricultural inputs which are environmentally friendly and used as seed and soil inoculants. Inoculation of rhizobium, Azotobactor and azospirillum may substitute for 19, 22 and 20 kg N/ha, respectively. Organic sources of nutrients are supplementary to chemical fertilizers and use of biofertilizers are considered as environmentally friendly, in terms of protecting the quality of underground waters, soil properties and the environment in general. Concerted research work for the attainment of high nutrient use efficiency is required to evolve plant types that are highly responsive to both the copious supply of nutrients and also tolerant to marginal soil fertility conditions with assured yields. Use of liquid forms of fertilizers through fertigation appear to be promising for deeper soil applications with thus a sizeable input saving. The use of bio-fertilizers VAM fungi, biological nitrogen fixers and other beneficial microbial agents also need to be optimally used to attain efficient management.

Production of organic vegetables

Organic vegetable production is now a commercial venture which is driven by environmental and food safety concern. Demand for green food is on the increase and harnessing the potential of organic farming which addresses soil health, human health and environmental health issues is considered to be of great significance. It relies upon crop rotations, crop residues, animal and green manures, legumes, mechanical cultivation, biofertilizers and biological pest control to maintain soil productivity, to supply nutrients, and to control insects, diseases, and weeds. In last few years, organic farming has attracted many farmers across the country especially combined with ecotourism and these people have experimented successfully on such systems. The organic market for vegetable and fruit crops for export purposes is increasing and in parallel is gaining momentum for meeting a growing demand for the domestic market. Traders need to know that the trade requirements that exist in developed countries. In India export sales of organic products amounted to 11,925 t and are likely to increase further (Singh and Thomas 2010). The time is now opportune for diversification into high value vegetable crops. The organic production technologies standardized for tomato, cauliflower, French beans, onion, potato and drumstick have been adopted by many farmers in India. Emphasis should be given to develop eco-friendly production technology which could enhance the nutritive value, export and processing qualities of vegetable crops, research on these issues need to be intensified under the co-ordinated programme. A large scale investment in the sector will overcome the marketing constraints of these produce and hence will be a highly remunerative venture in the days to come.

Salt stress management practices

Several agronomic practices such as double row sloping bed sowing, raising transplants in nursery of weakly saline soils, addition of organic matter and chemical fertilizers and keeping soils always moist, have been standardized. Biological methods and use of soil amendments are helpful in growing crops in salt affected soils. The correct soil pH is essential for optimum plant growth. Lime and sulphur are common amendments used to balance soil pH. Dolomitic limestone adds calcium and magnesium as it increases pH, making the soil more alkaline. Elemental sulphur will acidify soil. The amount of amendment to add depends on the current and desired pH - one good reason to have soils checked periodically. Other amendments are added specifically to improve soil nutrient levels. Wood ash and granite meal are sources of potassium. Granite meal is finely ground granite rock which releases its potassium slowly. Other nutritional amendments that can be purchased for garden use include cottonseed meal, kelp meal, leather meal, and worm castings, as well as an array of synthetic fertilizers.

Water productivity

Water is important for growing of crops and with all our efforts only 40% of the total area is irrigated. It is also believed that even if all the resources of water are utilized, the whole area cannot be irrigated. Irrigation efficiency is only to the tune of 30-35%, therefore the only means to provide water is effective management and enhancing water use efficiency. Therefore a lot of initiatives were taken to apply water in such a manner that can provide maximum productive output. When, where and how water should be applied has been worked out. Among various methods tried, drip irrigation has proved successful in exhibiting high water productivity by saving irrigation water from 25-60% in various vegetable crops along with 10-60% increase in yield as compared to conventional method of irrigation. It is one of the latest methods of irrigation, which is becoming popular in areas with water scarcity and salt problems. Fertigation has become the state of the art in vegetables because nutrients can be applied to plants in the correct dosages and at the time appropriate for the specific stage of plant growth. Fertigation requirement in vegetables (tomato, chilies, brinjal, okra, potato, onion, garlic, muskmelon, cucumber) have been standardized to improve the nutrient and water use efficiency which increased from 120 to 290% (Singh 2010a). The complete system of fertigation standardized at the Directorate of Onion and Garlic has been successfully commercialized for onion and garlic cultivation. This could be effectively used for other vegetable crops for efficient water and nutrient management after validation. Even micronutrients such as iron, zinc, copper and manganese can be applied as chelate or sulphate salts in trickle irrigation water. Generally, crop responses to fertilizer application by the trickle method have been excellent and frequent nutrient applications have improved fertilizer application efficiency. A reduction of 20-50% in fertilizer applications using trickle irrigation as compared with surface broadcasting have been reported with no yield reductions in several vegetable crops. Greenhouse studies in which the distribution of water and minerals were examined, showed that the maintenance of nutrients within the sphere of the plant roots with drip irrigation could be accomplished if the proper rates and water application frequencies were used. Similarly, efficient water management practices such as mulches have also been developed to tackle the problem of water scarcity. Studies conducted in India have indicated that micro-fertigation with plastic mulching in vegetable crops have resulted in savings in fertilizer to the tune of 25–30%. Another measure could be the development of drought-tolerant and low water-requiring varieties for which the work has already been started and tangible results are expected in few years.

Mulching in vegetable production

The technique of covering the soil with natural crop residues or plastic films for soil and water conservation is practiced for vegetable production under rained as well as irrigated agro-eco systems. Mulching has been practiced in India for many years using mainly crop residues including dry straw, trash, stalks and leaves and recently plastic mulches have come into use due to the inherent advantages of efficient moisture conservation, weed suppression and maintenance of soil structure. Although a wide variety of vegetables can be successfully grown using mulches, cucumbers, capsicums, melons, tomatoes, cole crops and okra have shown significant increase in earliness, yield and quality. In addition to soil and water conservation, improved yield and quality, suppression of weed growth, mulches can improve the use efficiency of applied fertilizer nutrients and also use of reflective mulches are likely to minimize the incidence of virus diseases and deter the approach of some species of pests. Mulches also help in regulation of soil temperature to a certain degree which can be made use of for growing thermo sensitive vegetables. Photodegradable plastic mulches are an alternative to conventional plastic mulches considering their retrieval and disposal problems. Although photodegradable plastic looks very much like other plastic mulch when it is installed, it can be broken down by ultraviolet sunlight. The actual rate of break-down depends on several factors including temperature, the proportion of the plastic shaded by the crop and the amount of sunlight received during the growing season. Now efforts are on the way of using bio degradable plastic mulches of varying densities to economize and make this an eco-friendly technology.

Cropping/ farming system

The practice of growing two or more crops together or in sequence is not new in the history of Indian agriculture. To maximize system productivity, cropping/farming systems have provided crop diversification, efficient utilization of resources and making intensive use of inputs for sustainable income to marginal farmers. The diverse favourable agro-climatic conditions of the country provides opportunity to cultivate a variety of horticultural crops such as fruits, vegetables including root and tuber crops, flowers, plantation crops, spices crops, medicinal and aromatic crops. Mushrooms also fit well into horticultural crop based systems. In general many vegetable crops fit well in mixed crops. Chili can be rotated with jowar, ragi, cotton, groundnut and castor under rainfed conditions and with sugarcane, turmeric, beans, maize or with vegetables but avoiding brinjal and potato exclusively. In Karnataka and Maharashtra, it is a common practice to grow cotton and onion as intercrops along with chili. These crops provide additional income to farmers. In Dharwad district of Karnataka, short-duration crops like garlic, onion or coriander are also cultivated in black soils. The solanaceous vegetable crops intercropped with garlic/onion consistently recorded lesser infestations of whitefly, thrips, aphids, jassids and borers with high yield. There are several examples of cropping systems involving vegetables as component crops. The efforts so far made were generally concentrated on improving the crop productivity of a single crop/enterprise basis without much attention towards the associated areas that support or influence the crop growth system as a whole. The declining sustainability of agricultural systems can be traced to the exploitation of resources without conservation for sustenance and profits. A systems approach is the need of the hour for overall sustainable development. The changes in cropping pattern alter the diet, nutrition, livestock, rural employment, industry etc., in the region. An appropriate enterprise mix will diffuse the risk of farmers by providing sustainable systems particularly to small and medium farmers (Singh and Malhotra 2010).

Precision farming

Precision farming is concerned with the management of variability in the dimensions of both space and time. It is an application of a holistic management strategy that uses information technology to bring data from multiple sources to bear upon decisions associated with production, marketing, financial and personnel issues. In fact, precision farming is a comprehensive system designed to optimize agriculture production through the application of crop information, advanced technology and management practices. Precision Farming Development Centres (PFDC's) under the sponsorship of NCPAH (Ministry of Agriculture, Govt. of India) have successfully worked out regionally-adapted technologies for adoption of micro irrigation for a large number of crops including vegetable crops and have provided technological support through capacity building. The PFDC's have successfully demonstrated the off season cultivation of vegetables like capsicum, cucumber, chilies, tomato etc. Some advancements have been made in two precision farming applications viz. variable rates of fertilizer application and yield mapping. It is also possible to identify the exact location of the plot with the help of one of the main precision farming technologies using the satellite Global Positioning System (GPS). Yield mapping has become possible with the use of GPS and sensors (Singh 2008). Precision farming in the Indian context is still in its infancy stage. Although, the technology for delivering the required amount of inputs to the crop through fertigation or chemigation have been developed in the country but still the application of precision farming as a package in farmer fields has received little attention.

Protected cultivation

Protected cultivation in a partially modified environment structure is useful in combating both biotic and abiotic stresses that limit the productivity of high yielding varieties and hybrids. This requires careful planning and attention to detail, including timing of production and harvest to coincide with high market prices and a suitable choice of varieties adapted to the off-season environment, and being able to produce economic yields of good quality. In regions where the climate prevents or does not favor year-round production of crops in the open field, vegetable production can take place in protected environments. Use of protected structures for cultivation of crops as a commercial venture is a recent phenomenon, especially in the tropics. Protective structures are a facility to protect crops from biotic and abiotic constraints. Structures for protected cultivation include green houses, plastic/net houses and tunnels. Artificial materials such as glass, fibreglass, polycarbonate, plastic and nets are used for the cover on the structures. The design of the structures depends on the availability of materials, the purpose for crop protection and economic issues. Growing plants under a cover protects the crop from damage by rain and wind, scorching radiation and temperature and dangerous pests and diseases. Greenhouse systems heavily rely on environmental manipulation to achieve high productivity. Greenhouse cultivation facilitates year round production of high quality produce with a minimum labor and irrigation water. Protected cultivation is, actually, also an invention attempting to achieve higher water and nutrient use efficiencies, increasing photosynthetic efficiency and reducing transpiration.

There are many high yielding vegetable varieties identified for growing under cover. Their productivity is mainly governed not only by their genetic makeup but also by the microclimate or environment (soil, solar radiation, temperature, RH and air) around them including most essential growth inputs like water and mineral nutrients. As compared to open field cultivation, under protected cultivation there will be better control over many of the components of micro climates and growth inputs. The closed boundaries of protected structures permit design of systems for raising or lowering to some extent the green house micro climate and moisture and nutrient content of the growing medium in the vicinity of the crop root zone. These structures help in producing quality vegetables with high tonnage throughout the year. This technology is rapidly progressing with China in the lead with nearly half of their vegetable production coming out of protected structures. Cost effective, low cost structures, crop diversification and a precise supply of water and nutrients using micro fertigation in protected cultivation have come into practice (Singh 2008). Because India is a very large country with diverse and extreme agro-climatic conditions, protected cultivation technology is being utilized for the production of high value low volume vegetable crops during the off season, for production of quality seedlings, for hybrid seed production and as a tool helping in disease resistance breeding.

Use of growth regulators

The application of growth regulators is quite successful in increasing the yield and quality of solanaceous vegetables, cucurbits and onions grown under stress conditions. High temperatures during the summer season may drastically reduce or totally affect fruit set in tomato and capsicums and consequently reduce or eliminate fruit yield. In order to overcome such problems application of plant growth substances have helped in improving flowering, fruit set and yield. Application of parachlorophenoxy acetic acid increased fruit set in tomato under high temperature stress conditions. Spraying ethrel 200 ppm, 2-3 days before transplanting improves the rooting system in tomato transplants during the summer season and helps in better absorption of nutrients and soil water. Application of ethrel (50-100 ppm) spray at the 2-3 true leaf stage increases pistillate and hermaphrodite flowers in muskmelon, cucumber, summer squash and pumpkin which are generally grown during hot weather. This practice has improved their nutrient and water use efficiency and yields.

Integrated weed management

Weeds are strong competitors for water and mineral nutrients and reduce their use efficiency. Integrated weed management (IWM) is an important component of a total integrated pest management program. IWM of vegetable crops combines a variety of approaches to suppress weeds and reduce herbicide use. Integrated weed management standardized in vegetable crops has helped in identifying weed problems through scouting and combines preventative, cultural, mechanical, biological, and chemical control methods in a compatible manner to solve them. Integrated weed management avoids relying solely on one management tool and helps reduce the need for chemical weed management, an important step in IWM is to prevent the spread of weeds, which combines a series of approaches to profitably produce a marketable vegetable crop without harming the environment. Cultural weed control is the management of the crop to make it more competitive against weeds. Cultural control involves optimizing planting dates, seeding rate, row spacing, fertility, irrigation, and the use of adapted varieties so that the crop will be growing vigorously and be more competitive with weeds. Mulching practices are now standardized are required to be widely used to improve crop growth and suppress weeds.

Plant health management

Vegetable crops are attacked by a large group of pests and pathogens inflicting moderate to heavy crop losses. Due to the increased demand for vegetables and their products, more efforts are being put into the horticulture sector for boosting production to meet increased demand. Although availability of planting material and designer agro-techniques has increased, biotic factors continue to be the bane of production. Planting material health management during dormancy, crop health management during the active growth phase and post harvest health management assumes substantive significance to reduce losses and increase productivity. In solanaceous and cucurbitaceous vegetable crops, the viruses, bacterial wilts and fusarium wilts and blights very commonly occur in different growing areas. Most of these viruses have a wide host range and many of them are transmitted by mechanical sap inoculation by several species of aphids (*Aphis gossypii, A. craccivora, A. fabae and Myzus persicae*) in a non-persistent manner. Thus, in order to check further spread of these diseases, there is an urgent need to develop diagnostics for detection of different viruses in planting materials. Unlike fungi and bacteria, a plant infected with a virus cannot be cured because of the lack of any effective viricide. Hence the emphasis is then given to integrated disease management involving use of disease free planting material, agronomic practices to control vectors, development and use of resistant varieties and timely diagnosis. Development and utilization of detection and diagnostic methods based on ELISA, PCR and Microarray techniques are gaining in importance. Biotechnological tools have augmented conventional approaches to identification and isolation of resistant sources/genes and development of crops resistant to specific viruses through transgenic approaches. Viral resistant transgenic plants are obtained by inserting segments of viral nucleic acid into plant genomes that leads to silencing of genes of the virus that have homologous sequences, thereby making plants resistant (Singh et al. 2011b).

Biological control and IPM technologies

Biological control has been a most significant approach to plant health management. It promises through modern biotechnology to be even more significant in the twenty-first century. Although the number of biocontrol products is increasing, these products still represent only about 1% of agricultural chemical sales. Yet these are important contributions because biocontrol agents offer disease management alternatives with different mechanisms of action other than chemical pesticides. Trends in research include the increased use of biorational screening processes to identify microorganisms with potential for biocontrol, increased testing under semi commercial and commercial production conditions, increased emphasis on combining biocontrol strains with each other and with other control methods, integrating biocontrol into an overall system with emphasis on botanical formulations, biological, chemical and suitable cultural practices.

Nursery management is helpful particularly to curb the carryover of active and inactive stages of insects and viruses into the main field. Intercropping of brinjal (2 rows) with coriander (one row) or fennel (1 row) minimizes the incidence of brinjal shoot and fruit borer. For fruit and shoot borer, the integrated pest management technique has been found highly effective. This includes installation of sex pheromone baited plastic funnel traps at 10 m distance just above canopy from 20 days after planting followed by weekly removal of infected shoots along with larvae and periodical cleaning of dry leaves and old infested fruits. Diamondback Moth (DBM) population in cabbage can also be managed by growing paired mustard rows with every 25 cabbage rows. The first rows of mustard should be sown 15 days before and second 25 days after cabbage planting. Dichlorovos 0.1% is sprayed at weekly interval on the mustard to kill the trapped DBM larvae. If required, Neem Seed Kernel Extract (NSKE) 5% may be sprayed to control the larval population of DBM. Such practices conserve the population of *Cotesia plutellae,* a dominant natural enemy of DBM. The DBM in cabbage and fruit borer in tomato can be managed through intercropping of respective crops. Soil solarization with transparent polyethylene sheeting during summer is most ideal to suppress the soil borne pathogens in nurseries. Seed treatment with *Trichoderma* spp. @ 5-10 g/kg or soil treatment @ 10-25 g/m^2 nursery area is advised to combat against damping off diseases. Soil solarization also reduces bacterial seedling blight in nurseries of tomato and chili. There is need to intensify research on use of eco-friendly insecticides such as botanicals, biocontrol agents, endomycorhiza etc. under co-ordinated programmes.

Bio-intensive Integrated Pest Management (IPM) technologies to manage damping off with *Trichoderma viride* and *Pseudomonas fluorescens* are also found to be effective in various vegetable crops. The pre emergence and post emergence damping off disease percent was lowest in vegetables with a combined seed treatment of *Trichoderma viride* (@ 4g/ kg) and

Pseudomonas fluorescens (@ 5g/kg). Formulations of *P. fluorescens* (5g/kg) were also effective in reducing infection of wilt and in increasing the seed germination, vigor index and field emergence, followed by *T. harzianum* (5g/kg). Release of the larvae of *Chrysoperla carnea*, a biocontrol agent, once in 15 days, installation of yellow sticky traps to attract and kill insects especially thrips and aphids are helpful in controlling sucking pests that serves as vectors for the major viral diseases in tomato, chilies, cucurbits and okra (Singh 2008; Singh and Thomas 2010).

The future thrust should include identification and cloning of resistant genes and improving the efficiency of conventional and molecular breeding, studies on modes of parasitism to develop resistant lines against nematodes, use of biotechnological interventions wherever resistance sources are lacking in wild and cultivated types. Development of a good certification system for planting material production, keeping vigilant and addressing new emerging diseases and pests is also important. Identification, characterization and efficacy especially multiple efficacy of biocontrol organisms in controlling more than one pathogen and their commercialization, residue analysis in produce, development of integrated package for management of diseases and pests under organic cultivation system all need attention.

Postharvest technology

Prominent processed items are canned and dehydrated vegetables. The technology for processing vegetables, such as fresh cut carrots or lactic acid fermentation, has been standardized. Shrink wrapping in cucumber, capsicum and several other vegetables have proved successful in enhancing shelf life. A good number of varieties suitable for processing of tomato, onion, gherkin etc. have been identified. There is a further need to popularize such technologies for promoting growth in the export of processed vegetable products. More recently produce like frozen vegetables, vegetable curries in restorable pouches, canned mushrooms and mushroom produces have been taken up for manufacture by the industry. The vegetables being exported include okra, tomato, baby corn, cucumber, gherkins, chilies, French bean, capsicum, bitter gourd, bottle gourd, onion and potato. Processed vegetables are also being exported to some countries. During the year 2009-10, India exported processed fruits and vegetables in the quantity of 0.71 Mt amounting to an export value of Rs. 27121.8 million and the key importers are the USA, UK and Middle East Gulf countries (NHB 2011). The vegetable industry in India is highly decentralized. A large number of units are in the cottage/home scale and small-scale sector, having small capacities up to 250 t/an. But big Indian and multinational companies in the sector have large capacities in the range of 30 t/hr or so. Since liberalization and the withdrawal of excise duty on fruit and vegetable products there has been a significant rise in the growth rate of industry. The number of fruit and vegetable processing units licensed under the FPO exceeds 4920, inclusive of over 650 sweetened aerated water units.

Minimal processing is an emerging technological concept which has gained much popularity in the recent past. The technology enables the global marketing of pre-cut vegetables and fruits in pre-packaged form and the products are meant for specific end use viz. curries, salad, pies, stuffing, topping and garnishing. In India, the Agricultural and Processed Food Products Export Development Authority (APEDA) is the nodal organization to access the market, guide and promote the export of agricultural commodities. APEDA has identified traditional vegetables including okra, bitter gourd, chili, onion, potato and non- traditional vegetables like asparagus, celery, sweet pepper, sweet corn, baby corn, green peas, French bean, cucumber, gherkins and cherry tomato as having good export potential. The area and production of gherkins is increasing in Karnataka, Andhra Pradesh and Maharashtra for export. There is need to identify and address researchable issues for promotion of quality vegetable production for export. For preventing postharvest losses proper storage, cold preservation, packaging and transport methods with Hazard Analysis Critical Control Point (HACCP) norms have to be given more thrust. Future research areas may be oriented towards developing varieties with prolonged shelf life with better processing qualities, standardization of Modified Atmosphere Packaging and storage systems with greater emphasis on safety (pesticide free), nutrition and quality (CODEX standards).

For several commodities, our national productivity is less than the world average. Therefore, raising the levels of productivity and quality standards to internationally competitive levels has become one of the major challenges. As a whole, for expansion of vegetable processing, the cooperative and private sectors will have to be associated with the programmes of efficient input supply, besides supporting critical infrastructure in the remote corners of the national production area.

Mechanization in vegetable crops

India is having largest number of tractors in the world, (about 3.2 million) and produces about 0.25 million new units per year. Most of the horticultural operations in India are done both partially manually and mechanically. Wherever, the farming operations are mechanized the crop productivity is high. The machinery developed by different State Agricultural Universities (SAU's) and agricultural research institutes need to be better popularized. Tractor drawn implements have found wide acceptability in potato cultivation, from sowing to harvesting. Suitable varieties of vegetable crops need to be selected and cultivation practices need to be standardized for mechanization. The transplanters for vegetable seedlings developed at the Indian Institute of Horticultural Research (IIHR), Punjab Agricultural University (PAU) and the Central Institute of Agriculture Engineering (CIAE) need to be adopted. Vegetable nurseries need to adopt media seivers, media mixers and plastic bag fillers and these machinery have been developed at the IIHR, Bangalore for healthy seedling production. By using this machinery containerized seedling production under protected structures has become a commercial venture in India to produce healthy seedlings of tomato, capsicums, cauliflower, cabbage, chilies, brinjal hybrids on a large scale. This method has proved useful in realizing better crop stands, more uniform growth and getting better value from costly hybrid seeds. Single and double chisels, side dressers, bed makers, nursery bed rollers, and groove makers are the new tools becoming popular in modern vegetable farming. There are several mechanized operations in the processing industry which are followed with good hygienic practices. Commercially available boom sprayers and air assisted sprayers can only be used in raised bed cultivated crops. Combine harvesters for digging potatoes, detopping and bagging of onions and garlic are urgently required. The mushroom spawn and cultivation machinery developed at the IIHR, Bangalore and the Directorate of Mushroom Research (DMR), Solan should be adopted rapidly to mechanize the Indian mushroom industry.

Urban and peri-urban vegetable production (UPVP)

According to an estimate by 2025 as many as 5.3 billion people or about two thirds of the world's projected population will be living in urban areas. In Asia, by then 70 % of the population will be located in cities. This will generate tremendous additional demand for food especially of high value products like fruits and vegetables. In addition fast growing incomes in urban areas will create demand for better food quality and safety. Unless peri-urban production around cities is properly supported and protected, these trends may end up with Indian states importing large quantities of food from far off places with a risk of increased postharvest losses, higher transport, packaging and storage costs, leading to higher prices for the consumer. Peri-urban vegetable production is referred to as the commercial production of vegetables in the city as well as in its adjacent districts. As urban expansion accelerates, the overall cost of supplying, distributing and accessing food—and, with it, the number of food insecure households—is likely to increase. The challenge is to facilitate consumer access to food and ensure that investments are made in increasing food production, processing and distribution capacities and services under hygienic, healthy and environmentally sound conditions. For food supply issues, urban and peri-urban vegetable production (UPVP) can be an important source of produce for cities. In this regard UPVP helps to grow greener cities and their surrounding areas by contributing to food, nutritional, and environmental security, employment generation, waste management and community well-being. The essential first step towards the sustainable management of urban and peri-urban vegetable production is the official recognition of its positive role in urban development, particularly in the nutrition and livelihoods of the urban poor. It assists governments in framing measures to promote UPVP development as part of national food security strategies, and advises city authorities on integrating horticulture, especially vegetable production, into urban master development plans. In order to help and augment urban and peri-urban vegetable growing, appropriate production technologies using sound and safe vegetable agronomy is required for which more research efforts into container growing, aeroponics, hydroponics, terrace gardening, recycling of urban waste and water, peri-urban farming using protected structures, organic farming etc. is needed.

Research priorities in the region

In the Asia and Pacific region, where 642 million people are undernourished out of total 1017 million hungry people in the world (FAO 2009), the AVRDC - The World Vegetable Center, with its headquarters in Taiwan and having 13 regional centres globally, is helping to address regional vegetable research and development needs. Similarly, the International Potato Center (CIP) based at Lima (Peru), also complements regional research needs in potato and sweet potato. However, regional co-operation now becomes even more important and we need to be able to learn better from each other. Many regional scientists have been trained in India in various aspects of vegetable production from the region. Many of the Indian varieties have performed well in the region. The experience of the past and challenges ahead therefore necessitate closer regional and global inter-cooperation. However, countries such as India, Sri Lanka, Pakistan, Bhutan, Bangladesh and Nepal, in the region differ within their research priorities and accordingly research initiatives have been undertaken to cater better for local and situation specific needs which are listed below country wise.

India

- Germplasm collection, evaluation, maintenance & registration
- Breeding for resistance to multiple stresses in
    - i. Tomato (ToLCV + GBNV + BW + EB + LB + RKN + Heat + Drought), Brinjal (BW + SFB + Phomopsis blight),
    - ii. Chili(CMV + CVMV + ChiLCV + PM + Phytophthora + Thrips + mites + Drought),
    - iii. Capsicum (Viruses+ PM + Phytophthora + BW+ Heat),
    - iv. Onion (Purple blotch + Basal rot + Thrips+drought)
    - v. French bean (Rust + bacterial blight + Stem fly + MYMV + Heat)
    - vi. Garden peas (Rust + PM + Heat)
    - vii. Okra (YVMV + Fusarium wilt + Nematodes + PM)
    - viii. Water melon (WBNV + Fusarium wilt + Gummy stem blight)
    - ix. Must melon (DM + Gummy stem blight + Anthracnose)
    - x. Tropical Cauliflower (black rot + heat)
- Identification of molecular markers linked to major diseases, heat and drought tolerance and male sterility and MAS for pyramiding and stacking of useful/desirable genes.
- Breeding for export (onion), processing (onion, tomato, chili, okra, gherkins & peas) and high nutritive value (tomato, leafy vegetables and chili).
- Breeding for protected cultivation (tomato, coloured capsicum, cucumber, bottle gourd, brinjal and triploid water melon).
- Economic hybrid seed production through male sterility (onion, chili and Okra- already commercialized) (tomato and brinjal to be developed).
- Development of vegetable varieties for mechanization (tomato, capsicum, cauliflower and onion)
- Metabolomics for fruit quality in tomato, chili, capsicum, and watermelon

Sri Lanka

Introduction of germplasm from different sources for screening and selection for the following traits:

- High yield

- Heat tolerance: For growing temperate-type vegetables in the lowland tropics, e.g. tomato, cabbage, Chinese cabbage, capsicum, and carrot
- Good consumer quality (flavor, palatability, color and shape)
- High nutritive value
- Earliness -for growing during off-season
- Disease resistance: e.g. bacterial wilt in the Solanaceae, club root in Brassica and virus diseases in tomato, okra, legumes and cucurbits
- Insect resistance: wherever possible.
- Introduction of segregating populations and screening to select single plants for the above-mentioned characteristics.
- Improvement of the local vegetable varieties resorting to hybridization and selection.
- Production of breeders' seed of local varieties such as tomato, brinjal, beans, cucurbits, radish and capsicum, to ensure a regular supply of true-to type good quality seed.
- With the emergence of export markets for some locally produced vegetables, e.g. gherkins, Chinese cabbage, carrots, red cabbage, cauliflower, head lettuce and broccoli, it is necessary to study suitable varieties with adequate consumer quality for such markets.

Pakistan

- Collection and evaluation of local germplasm to select high-yielding, good quality, disease-resistant varieties of vegetable crops.
- Introduction and selection of high-yielding, good-quality, disease-resistant varieties from the exotic material.
- Varietal improvement through hybridization and selection in selected vegetables like potato, tomato, peas and brinjal.
- Heterosis and combining ability studies in vegetable crops such as tomato and brinjal.
- Standardization of improved production technology through management of agronomic practices.
- Research or intercropping and multiple cropping to determine suitable cropping patterns.
- Research of vegetable forcing to raise out-of-season vegetables under low and high polythene tunnels.
- Production of pre-basic and basic seed of improved varieties of vegetable crops.
- Weed control studies in potato, onion, garlic and carrots.
- Germplasm screening and breeding for higher yield, better quality, resistance to biotic and abiotic stresses and adaptation to different ecological conditions.
- Establishment of appropriate vegetable seed production technology.
- Development of postharvest technology.
- Improvement in production technology.
- Research on marketing within and outside the country.
- Introduction of new vegetables with better nutrition and
- Socioeconomic studies to provide better information for research and development.

Bhutan

- Development of major insect pest and disease-resistant varieties which will fit into tie dominant cropping systems of all agro ecological zones.
- Development of potato varieties that have moderate to high resistance to late blight disease.
- Development of effective control measures for diamondback moth which is a serious problem in all cruciferous species, particularly in the seed production of cauliflower and cabbage.
- Development of integrated pest management for all vegetables, minimizing the use of chemical pesticides and promoting biological means of pest control.
- Off-season production of fresh vegetables with the promotion of plastic greenhouses, especially in the temperate and warm temperate agro ecological zone.

- Production of temperate types of fresh vegetables in the wet subtropical zone in southern fringe lowland areas.
- Improved seed production technologies.
- Development of improved management technologies for all vegetable species in all agro ecological zones.
- Screening of rhizobium and production of inoculum which will have effective symbiosis with all legumes.
- Development of postharvest technologies; and
- Training of national scientists working on vegetable research and development.

Bangladesh

- Collection and evaluation of local germplasm for selection.
- Development of late and early variety of different vegetables.
- Initiation of breeding program to develop high-yielding varieties.
- Development of improved production practices.
- Studies on common pests and diseases and
- Studies on soil and fertility relationship.

Nepal

- Collection, conservation and utilization of local genetic resources, supported by continued introduction of appropriate germplasm from exotic sources.
- Use of hybrid seed production technologies in important vegetable technologies and under varying agro-ecological conditions.
- Development of off-season production in important vegetables to ascertain supply during lean seasons.
- Development of crop production technologies with emphasis on time and method of planting, plant production, weed control, and fertilizer management and pest management.
- Generation of appropriate postharvest technologies for vegetable processing.
- Varietal purification and maintenance and
- Integration of vegetable cultivation with other components of Nepalese farming systems.

Strategies for development

The thrust areas identified for the development of horticulture including vegetables are improving production through productivity enhancement and utilization of wasteland/surplus land, improving productivity through the use of technology, reducing the cost of production by efficient utilization of resources, improving the quality of products by adoption of good agricultural practices, adding value to the produce through efficient post-harvest management and processing, promoting marketing and export, developing markets coupled with price stabilization, reducing the risk through insurance, strengthening the institutional support system to address the needs for human resource development and addressing relevant policy issues. These thrust areas have to be achieved through production and productivity enhancement combined with policy initiatives. Acceptance of vegetables in the high-quality conscious era requires the produce to be of high quality standard, free from toxins and other health hazards, which could be achieved through, popularization of improved agro-techniques, an emphasis on cultivation of specific varieties for the table, better processing and export, an emphasis on harvesting horticultural produce at optimum maturity, better grading, packing and transport, setting up quality control laboratories, widely disseminating international quality standards for various commodities and, ensuring pesticide residues are within permissible limits. With the opening up of the economy and emergence of freer trade there shall be increasing competition to capture markets, which is equally true for horticultural products. Strategies, to overcome the implications for Indian horticulture, would include emphasis on creating awareness about the implications of the WTO regime among horticultural entrepreneurs, identification of horticultural cropping zones, harmonization of sanitary and phytosanitary standards and strengthening of mechanisms to meet the requirement of quality assurance.

Future thrust and new initiatives for research

Vegetable production has been one of success stories of the last decade, and to continue to build on success, the sector has to face challenges. Therefore, there is a need to prioritize the action outlining the needs of research, development and extension to make vegetables a key driver in rural and regional economic development. Demand for high value produce is growing both in domestic and overseas markets and at the same time, competition is also increasing. New changes in retailing, the new participation of the corporate sector means that retailing will depend upon strategic alliances and effective supply chain management to grow profitably. There is an urgent need to strengthen research on impact assessment of climate change on vegetable crops using controlled environmental facilities and simulation models, better analysis of past weather data and fuller integration with productivity changes (including those of extreme events). Production, demand and supply of commodities, economics and trade, sensitive stages and processes during crop development, diversity and dynamics of major insects, microbes and pathogens, intensification of studies on pest, disease and weather relationships etc. all have to be further researched. Therefore, sustainability will depend upon improving competitiveness, reducing the impact on the environment, on quality assurance and food safety and the capability of communities engaged in this sector to manage change appropriately. New initiatives to be taken up to strengthen research activities are as follows:

1. Biotechnological tools must be used in conjunction with conventional breeding to tag genes of interest and to help in marker assisted selection. There is need to develop varieties with durable resistance to multiple diseases and pests; heat, drought and salt tolerance; and varieties with efficient nutrient and water use efficiency. Breeding for nutritional and processing qualities in vegetables like tomato, onion, peas and garlic (dehydration).
2. Eco-regional specific technology generation based on the maximum productivity of available natural resources including climatic conditions, soil fertility and water availability. Develop systems for productive use of water to get enhanced water productivity by increasing the water and nutrient use efficiency. Technology packages to be developed for various vegetable crops should be an integral component of multifunctional agricultural strategies of specific zones. IT based enabling mechanism for technology transfer such as decision support systems needed to be further developed.
3. Understanding the social needs of communities and building their capabilities for undertaking system changes and for the effective utilization of resources and adoption of technology. Also to facilitate the accelerated adoption of improved technologies and best practices and respond better to new needs including bio-security threats.
4. Integrated management of emerging diseases and pests. Emphasis should be placed on the identification of new and effective bio-molecules for management of biotic stresses and agronomic practices should be encouraged to be more ecofriendly and help in the sustainable management of diseases and pests. Development of new innovative diagnostic techniques for the rapid, accurate and cost effective detection of high impact pests and diseases is needed.
5. Develop production and post-harvest technologies to improve product quality and minimize environmental impacts. Increase the value of production by reducing variability in yield, quality, reduce crop losses and increase marketability. Develop the production systems that minimize waste and maximize productive recycling. Standardizing production protocols for urban and peri-urban farming including terrace gardening, hydroponics etc. is needed.
6. Economically viable and technologically feasible green/screenhouse technology is required for different agro-climatic and geographical conditions preferably based

on locally available construction material particularly for low- and medium-cost green/screen houses.

7. Sustainable path for development in needed to meet the challenges in vegetable production through proper technological innovation and intervention and specifically in areas like value chain management which is needed to improve global competitiveness.

8. Inter-institutional mechanisms to network and review ongoing programmes of biotechnology, cost effective production technologies, postharvest technology, farm mechanization, transfer of technology and organic farming are required.

9. Improving the understanding of interactions between native ecosystems and production systems and develop best practices to conserve biodiversity are essential elements of improved sustainable agricultural practices.

CONCLUSION

Horticultural crops comprising fruits, vegetables, root and tuber crops, plantation crops, medicinal and aromatic plants, spices and ornamental crops have emerged as a core of agro-economic strategies accelerating growth in India and in many neighboring countries in the region. Vegetable production in Southeast Asia is an economically very important sector which provides livelihoods to millions of smallholder farmers and large scale agricultural companies.

A large scale development of knowledge/innovations has taken place in India and region and, further adoption of such technologies must now play a vital role in the development of agriculture in general and horticulture in particular. Currently, horticulture contributes 30.4% to the Agricultural Gross Domestic Product (AGDP) yet only from 11% cropped area, and it has maintained an annual growth rate of above 6%. Although, there has been appreciable change in the growth of horticulture in India and region, in order to meet the requirement of the growing population, a clear strategic approach is needed. The country has envisioned the accelerated development of innovations and technologies to address the challenges of producing more food for a growing population with declining land and water in the context of the scenario of climate change. This can be achieved through strategies, such as to ensure the technology-led development of horticulture, to make it available to citizens at affordable prices; ensure the availability of new cultivars and technologies, which can withstand biotic and abiotic pressures and provide better profitability to farmers in a given situation and location; identify new genes and technologies and understand their interaction with environment to have proofing against climate change.

To achieve resilient horticulture; develop cultivars and technologies, which are rich in nutrients and vitamins and can protect humans better against many diseases, considering that better balanced diets are a critical component of the medicines of future; develop technologies which are socially compatible, politically feasible and ecologically sustainable and provide environmental services and develop human resources of excellence, having competence and commitment to take up new challenges. There is an urgent need for more sustainable strategies for intensive vegetable production. The experience of the past and challenges ahead necessitate closer inter-institutional co-operation. Consequently, technology driven vegetable production will contribute significantly to ensuring appropriate nutrition and better livelihoods globally. Since vegetables have immense potential to address the problems of malnutrition, unemployment and other complex issues of development, the research and development of vegetables should be more explicitly funded and through cross learning and use of science would benefit India and the region with enhanced economic development.

References

NHB 2011. National Horticulture Database. National Horticulture Board, Gurgaon, India, p275.

FAO 2009. The state of food insecurity in the world. FAO, Rome.

Singh HP, Parthsarthi VA, Nirmalbabu. 2011a. *Biotechnology in Horticulture- Molecular characterization.* Vol. 3. Westville Publ, New Delhi, 311p.

Singh HP, Parthsarthi VA, Nirmalbabu. 2011b. *Biotechnology in Horticulture- Transgenics.* Vol. 4. Westville Publ, New Delhi, 380p.

Singh HP. 2010a. Dynamics of Indian Horticulture. ISHS - Horticulture congress, International Society of Horticulture Science, 21-26, August, 2010, Lisbon, Portugal.

Singh HP. 2010b. Managing genetic resources of horticultural crops. *Indian Hort.* 55(3): 3-16.

Singh HP. 2010c. Quality seed and planting material as a key to success for horticulture development in the country. *Progressive Hort.* 42(1):1-14

Singh HP, Malhotra SK. 2010. Research and Development in Vegetable crops-issue and strategies. *Indian Horticulture*. 55 (1): 3-9

Singh HP, Palaniswami MS. 2010. *Horticulture in different agro-climatic conditions.* Vol. 1. Westville Publ, New Delhi, 260p.

Singh HP, Thomas J. 2010. *Organic Horticulture – Principles, practices and technologies.* Westville Publ, New Delhi,440 p.

Singh HP. 2009. Accelerating quality production of horticultural crops in India. *Indian Horticulture*. 54(4): 3-9

Singh HP, Rai Mathura, Pandey S, Kumar S. 2009a. *Vegetable Varieties of India.* Studium Press (India) Pvt. Ltd., New Delhi, 325p.

Singh HP, Shukla SK, Malhotra SK. 2009. *Ensuring quality planting material in horticultural crops.* Ed. SA Wani, Technological Innovations for Enhancing Agricultural Income. NAAS Delhi and SKUAST, Srinagar, pp 469-484.

Singh HP. 2008. Technological inventions in Indian horticultural – Away ahead. *Indian Horticulture* 53(1): 3-9.

Modeling subtropical tomato crop production

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ABSTRACT

Crop models are a versatile tool in the integrated management of vegetable crop production. The ability to accurately forecast the time that a tomato crop will be ready for harvest and the yield of fruit from the crop is valuable both for managing the harvest scheduling and informing marketing decisions. Currently available tomato crop models have been developed for greenhouses production in temperate climate US and European production conditions, but have limited application to subtropical and tropical climate field production systems. This project has identified field factors that need to be incorporated into tomato crop models to simulate field production under subtropical conditions. Assessments of crop flowering and fruit development phenology demonstrate significant soil type and site effects. Treatment of seedling transplants, including age at transplanting, affect flowering time and yield. Significant soil type effects on flowering and harvest date have been demonstrated and may be related to variations in soil moisture availability under standard irrigation management practices. Flowering date accounts for approximately 50% of the variation in initial harvest date but other factors such as branching pattern also appear to influence timing of harvest in semi-determinant type tomatoes under field conditions. Development of a model that incorporates these variables will be a useful tool in implementing good agricultural practices in field tomato production in subtropical and tropical climates.

Keywords

Tomato, phenology, crop scheduling

INTRODUCTION

The State of Queensland produces and supplies most of Australia's field grown fresh tomatoes. Queensland production accounts for 56% of the total production in Australia (ABS 2008). The Bundaberg and Bowen regions, located in sub-tropical and tropical climatic zones respectively, are the main production regions for field grown fresh tomato in Queensland, producing more than 80% of the state's tomatoes. The capacity to produce crops year round in Queensland provides an advantage for tomato production compared to other regions of Australia.

As is the case in many countries, an increasing percentage of sales of fresh fruit and vegetables in Australia occur through supermarket chains. The market for field grown fresh tomato is dominated by two supermarket chains, Woolworths, and Coles. These supermarkets contract growers directly to supply agreed quantities of produce within quality specifications, and tend to contract growers able to supply product all year round.

The ability to manage the production of the required quantity of fruit to fulfill the demand of the supermarkets in all seasons is a great challenge for the big producers. The growers need to manage their resources to optimize production otherwise they cannot compete successfully in the market. The capacity to accurately forecast production is critical to efficient crop scheduling and to the management of marketing activities with customers.

Crop modeling has become an important tool in many agricultural industries to assist in crop scheduling, and a wide range of models have been developed covering all significant crops and incorporating a broad range of crop specific inputs (Monteith 1996). Predicting the timing of harvest and the crop yield are the two most important model outputs for decision making in the crop production systems. These outputs help the growers to organize their planting schedules so that there is a regular supply of product to the market. The success of a crop yield forecasting system strongly depends on the crop simulation models ability to quantify the influence of the weather and other parameters over a range of spatial scales (Hansen et al. 2000). Harvest date and yield models vary from relatively simple heat unit models based solely on temperature inputs, for example models developed for pepper (Perry et al. 1993) and cucumber crops (Perry et al. 1986), to complex mechanistic models such as the model described by Marcellis et al. (1998) for cucumber incorporating a range of inputs for a series of components parts covering different processes in the crop. Prediction of the harvest date and yield in the major agricultural crops can be made using several different models, so selection of models is generally made on the basis of the required accuracy of output predictions within the production system in which the model will be used.

Many tomato crop models have been developed over the years to describe crop growth and development, dry matter production, and to predict harvesting date and crop yield. The harvest date and crop yield models range from simple thermal time models (e.g. Perry et al. 1997; Warnok and Isaak 1969) to black box harvest date prediction (e.g. Hoshi et al. 2000) and complex explanatory models include SUKAM (Heuvelink 1994); HORTISIM (Gijzen et al, 1998); TOMGROW (Dayan et al, 1993); TOMSIM (Heuvelink 1996); TOMPOUSE (Abreu et al. 2002); SIMULTOM (Sauviller et al. 2002) and CROPGROW (Scholberg et al. 1999). Other models have focused on specific aspect of crop development such as dry matter partitioning (e.g. Heuvelink 1996) and postharvest aspects such as fruit firmness (e.g. Schouten et al. 2010), fruit quality (e.g. Schouten et al. 2007) and pack house operations (Miller et al. 1997). The complex explanatory models provide the most relevant information for identification of knowledge gaps in the development of a crop model for field grown tomatoes in a sub-tropical climate.

Of the explanatory models, the most widely reported and adopted models are TOMGROW (Dayan et al, 1993), TOMSIM (Heuvelink E 1995), CROPGROW (Scholberg et al. 1999) and TOMPOUSE (Abreu et al. 2002). These models are based on dynamic simulation of dry matter production in which the plant physiological processes and their interaction on environmental conditions are combined. Each of these models has been developed for indeterminate tomato plants grown in green house conditions, but the authors have indicated that the models can be calibrated and validated in different environment with different models input parameters. The applicability of the models to field grown, semi-determinant type tomatoes has not been tested.

Based on plant growth characteristics; tomato cultivars can be classified as determinate, semi-determinate and indeterminate. The growing period of determinate and semi- determinate type tomatoes is short and ranges from 90 to 150 days, whereas the life time of indeterminate type tomatoes is long and normally they can survive up to one year (Scholborg 1996). The growth and development of all types of tomato is sympodial (Child 1979). The shoot branching determines the plants overall architecture and affects many aspects of crop management. The determinate type stops growing when fruit is set at the apical meristem, producing a compact plant with few fruit, and the compact size means that normally they require limited amount of staking for support. This characteristic also makes determinate cultivars suitable for container planting. They are the preferred cultivars for the processing industry as all the fruit can be harvested at the same time, facilitating mechanised harvesting of crops with low production costs as trellising is not required. The semi-determinate and indeterminate type cultivars grow larger and require substantial support. The flowering, fruit ripening and harvesting is continuous in these varieties, therefore all the fruit cannot be harvested at the same time. Production in Queensland is based on semi-determinant type tomatoes, while most greenhouse production systems utilise indeterminate type cultivars.

The vegetative and reproductive growth and development processes in semi-determinate and indeterminate tomato cultivars are continuous. There is a juvenile growth period prior to initiation of the first flower truss during which only vegetative growth occurs, but at the end of this period vegetative, floral and fruit development may also be occurring on the plant. Vegetative shoot growth can be divided into production of individual nodal sections. The shoot apical meristem forms an elongated internode, a leaf and an axillary bud in the leaf axil. The juvenile phase involves formation of 7 to 11 nodes (Lozano et al. 2009). The primary shoot apical meristem is transformed into an inflorescence at floral initiation and develops the 1st inflorescence on the plant. The axillary bud of the node at which the inflorescence initiates develops as a vegetative shoot. Normally after formation of a further three nodes, the apical meristem of this sympodial shoot then initiates an inflorescence. The main axis is again continued by the sympodial shoot in the axil of the youngest leaf primordium. Sympodial shoot growth above the inflorescence is generally vigorous and its leaves cover the inflorescence (Sawhney et al. 1984).

In the tomato plant, axillary buds are formed early in development in all axils of leaf primordial (Tucker, 1979). Growth of lateral shoots from leaf axils below the first inflorescence and between subsequent inflorescences produces a bushy plant structure. Greenhouse production using indeterminate cultivars requires removal of side shoots restricting growth and fruit production to the main stem. Modeling of crop growth is therefore focused on rate of production of main stem nodal segments, and number of nodal segments between inflorescences. Removal of some but not all side shoots is practiced in field production of semi-determinate cultivars, resulting in a more complex pattern of production of nodal segments and inflorescences. Factors regulating branching pattern therefore need to be considered in a field crop model.

The juvenile period of the tomato plant varies with environmental conditions, primarily light intensity and temperature. These factors also influence the flowering time of the inflorescences. In controlled environment studies, light intensity and temperature have been shown to affect days to flowering and number of leaves preceding the first inflorescence to develop in tomato (Uzun 2006). Leaf number below the first fruit cluster declined linearly with decreasing temperature in the range 7.4 to 24.2° C, but the effect was modified by light intensity with little temperature effect at high light intensity. Similarly, it was found that the number of leaves formed before initiation of the first inflorescence was decreased with increased light intensity (Kinet 1977). Time to flower is also considered to be controlled by intra plant competition for assimilates (Dieleman and Heuvelink 1992). It has been concluded that all environmental factors may impact on flowering and no single factor can be regarded as critical for flower induction (Heuvelink 1995).

Most of the research examining different aspects of tomato plant growth and development were conducted under controlled environmental condition in greenhouse. It is easy for grower to adjust conditions in greenhouse production to provide the suitable environments for optimum production of tomato fruits. In contrast, under field condition in the Bundaberg region where crops are grown year round, the environmental factors such as light and temperature that influence crop growth and development may fluctuate significantly within short time period as well as from season to season in a year. Therefore, to develop a model to predict harvesting and crop yield for field production in the Bundaberg region climate, characteristics such as the pattern of truss formation, rate of fruit sets, rate of fruit growth and ripening of the fruit in the plant that have been modeled under greenhouse conditions must be examined under field conditions to determine if additional factors need to be incorporated into the model.

MATERIALS AND METHODS

Investigation of the timing of crop developmental events and variability within and between crops was undertaken to identify plant growth stages and production conditions that have a significant impact on harvest timing and yield. In addition, commercial crop records, including detailed assessments of rates of fruit development and harvest yields, were analysed to assessed if the identified key growth stages and production conditions from the first experimental area are consistent with commercial crop data.

Crop development

Six crops were selected for the trial, with three Roma and Gourmet fruit type crops. The crops were chosen to cover three planting times and three production locations. At each of the three locations, adjacent blocks of the Roma and Gourmet cultivars, planted on the same day or within 7 days of each other, were selected. Planting date varied between the three locations and covered the main crop production times for the Bundaberg region

The crops used in the study were selected one week after planting. The first Roma and Gourmet crops were planted on 23nd and 22rd of February 2011 respectively; the second crops were planted on 10th and 17th of March 2011 and the last two crops were planted on 26th and 28th of April 2011. The soil types at each site were a heavy red clay soil, sandy loam soil and medium clay soil respectively. All crops were managed according to standard commercial practice with trellising, drip irrigation under plastic mulch, fertilization at rates based on soil nutrient and plant sap test result, crop protectant chemical applications for pest and disease management as required.

Within each crop, monitoring and sampling were conducted on five plots, each containing four plants, in each crop. The total number of sample plants in each crop was 20; the four plants in each sampling plot were adjacent in a row and the five plots were distributed randomly within each crop.

The crop monitoring involved assessment of a range of parameters on each of the 20 plants in each crop, as the recorded parameters were:

- Flowering date of first truss (date that the first flower reached anthesis)
- Position (node on the main stem) of the first truss
- Number of leaves (counted at the flowering date of first truss)
- Side shoots and nodes (counted at the flowering date of first truss)
- Flower and fruit number on 1st, 2nd and 4th trusses
- Total number of trusses
- Fruit numbers and harvested fruit weight at each harvest date.

Sampling to measure fruit weight was timed to coincide with commercial harvest. As tomato crops are harvested multiple times, each crop was sampled just prior to or the day of commercial harvest and the number and total weight of harvested fruit from each plant at each harvest sampling date was recorded.

Commercial crop data analysis

Commercial crop data for 288 Roma and Gourmet crops grown between 2008 and 2011 were analysed. Data were collected by the industry partner, SP Exports, and consisted of detailed crop records on crop area, timing of management activities, yield and quality.

Specific parameters recorded in the database included planting time, flowering time, flower numbers, fruit set on each truss, harvest dates, yields and site information for each production block. Climatic information was collected from the Bureau of Meteorology weather records for stations closest to the tomato crop production block. Correlative analysis of climacteric, crop growth and yield data was undertaken.

RESULTS AND DISCUSSION

Variability within crops
Flowering and harvest dates for 5 blocks of 4 plants in each of six crops were measured and used to assess variability within and between crops. While large plant to plant differences were found, a similar level of variability was found in all crops. To demonstrate this variability, harvest date of the first truss varied by up to 19 days between individual plants in a single crop (Fig. 1). The Coefficient of Variation in flowering time was in the range 12-16% for all crops, and for first harvest date was in the range 5-7%. No significant differences between blocks within crops were found, suggesting uniformity within sites for each crop.

Yield patterns
The number of fruit harvested per plant at the times of commercial harvesting followed a cyclical pattern (Fig. 2). The cyclical pattern was concluded to be due to timing of ripening of successive trusses on the plants. Roma crops displayed a greater cyclical range than Gourmet crops. Large differences in the duration of the harvesting window and the total number of fruit harvested were recorded between crops, and this trend was evident even in crops planted only 2 to 3 weeks apart (Fig. 2).

Flowering date vs. harvest date
When individual plant data within crop were analysed, a relationship between flowering date and first harvest date was observed (Fig. 3). Plants that displayed delayed flowering also tended to be ready to harvest at a later date. Regression analysis revealed that flowering date only explained approximately 50% of harvest date variation.

Flowering characteristics
Significant differences in flowering date were demonstrated between crops (Table 1 and 2). These differences between crops were not related to differences in degree days accumulated, suggesting site related management factors may have influenced flowering time. Differences in node number at which the first truss was initiated shows that the variation in flowering time was due to differences in the time of initiation rather than simply plant growth rate.

Small differences between crops in the vegetative structures, expanded leaf number and axillary shoot number, at the time of flowering were noted. Differences in flower number in the first truss existed between crops, and these differences did not appear to be related to flowering time. As fruit number is determined primarily by flower number, identification of the factors causing this variation in flower number will be important in modeling crop development and yield.

The results highlight the importance of the early phase of crop development in determining flowering time, and hence timing of the first harvest, as well as flower number and hence initial harvest yields. Seedling transplant age, physiological status or transplant stress were considered potential factors influencing flowering time and number, and further examination of the effects of these variables on field tomato development are required.

Commercial crop analysis
Analysis of commercial crop records revealed characteristic seasonal trends in timing of first harvest, yield and duration of the harvest period. Two periods of higher yield were noted, corresponding to crop planting in the autumn and late winter/early spring (Fig. 4). Crops planted in later spring and summer (weeks 1 to 6 and 40 to 52) and in winter (weeks 15 to 22) tended to produce lower yields. These times corresponded to periods of fastest and slowest crop growth respectively, as is evident from the seasonal trend in time taken from planting to first harvest (Fig. 5).

The duration of the picking period also demonstrated the effect of seasonal climatic conditions on growth rate, with extended picking duration in crops harvested in the winter period (Fig. 6). Overall yield was not related to picking duration, with high yields recorded in crops planted at times of the year that produced both lengthy (week 11) and short (week 33) picking periods. This observation was consistent with the conclusion from the individual crop analysis that factors affecting early crop development play a significant role in the timing of crop development events and in crop yield. Thus, while climatic factors such as temperature and light are major input components in tomato crop models, refinements are required in models for field production under sub-tropical conditions to account for crop establishment and early crop development factors.

CONCLUSION

A consistent level of variability in key plant development parameters was found within crops. Flowering time and the node at which the first flowering truss was initiated varied between crops, and seedling transplanting was identified as a possible source of this impact on flowering. Flower number in the first truss was also found to vary between crops, and as initiation of the first truss occurs at a low node number, this event may be occurring prior to or shortly after transplanting. Examination of the timing of initiation and effects of transplanting practices on the number of flowers initiated in the first truss is needed to inform a field tomato crop model.

Flowering time explained approximately 50% of variability in initial harvest date, demonstrating the need to incorporate other environmental and resource partitioning processes affecting fruit ripening and hence harvest timing in a field crop model. Glasshouse tomato models incorporate temperature as a major input factor, and seasonal patterns noted in commercial crop data suggest that the temperature components of these models may be able to be extended to field models.

Fruit yield followed a cyclic pattern as different trusses reached harvest maturity at different dates. Models able to simulate the timing and rate of fruit development at the individual truss level are required if this cyclic pattern is to be accurately predicted. At a crop level, plant to plant variability is sufficiently large to mask the cyclic pattern within individual plants.

Length of the harvest window and total yield varied between crops and followed seasonal trends. It was concluded that glasshouse tomato crop models, incorporating temperature and light as input components to predict the seasonal trends, combined with modeling of effects of crop establishment factors on flowering time and flower number, could provide a valuable tool for large scale field tomato producers.

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References

Abreu P, Meneses JF, and Gary C (2000). Tompousse, a model of yield prediction for tomato crops: calibration study for unheated plastic greenhouses. *Acta Horticulturae*, 519: 141-150.

Australian Bureau of Statistics (2008) Year Book 2008. URL(http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/1301.0Main+Features12008?OpenDocument).

Child A (1979). A review of branching patterns in the Solanaceae. In: *The Biology and Taxonomy of the Solanaceae* (ed. JG Hawkes, RN Lesterand, AD Skelding), pp. 345-356. London: Academic Press.

Dayan E, van Keulen H, Jones JW, Jipori I, Shmuel D & Challa H (1993). Development, Calibration and Validation of a Greenhouse Tomato Growth Model: Field Calibration and Validation. *Agricultural Systems* 43: 165-183.

Dielman JA and Heuvelink E (1992). Factors affecting the number of leaves preceding the 1st inflorescence in the tomato. *Journal of Horticultural Science*, 67: 1-10.

Gijzen H, Heuvelink E, Challa H, Marcelis LFM, Dayan E, Cohen S and Fuchs M (1998). HORTISIM: a model for greenhouse crops and greenhouse climate. *Acta Horticulturae* 456, 441-450.

Hansen JW and Jones JW (2000). Scaling–up crop models for climate variability applications. *Agricultural System* 65: 43-72

Heuvelink, E (1995). Growth, development and yield of a tomato crop: periodic destructive measurements in a greenhouse. *Scientia Horticulturae* 61(1-2): 77-99.

Heuvelink, E (1996). Dry matter partitioning in tomato: Validation of a Dynamic Simulation Model. *Annals of Botany* 77: 71-80.

Heuvelink, E (1996) Dry matter partitioning in tomato: Validation of a Dynamic Simulation Model. *Annals of Botany* 77: 71-80.
Heuvelink E, Bertin N. (1994). Dry-matter partitioning in a tomato crop: comparison of two simulation models. *J. Hortic. Sci.* 69 (1994) 885-903.
Hoshi T, Sasaki T, Tsutsui H, Watanable T, Tagawa F, (2000). A daily harvest prediction model of cherry tomatoes by mining from past averaging data and using topological case based modelling. *Computers and Electronics in Agriculture* 29: 149-160.
Kinet JM (1977). Effect of light conditions on the development of the inflorescence in tomato. *Scientia Horticulture* 6: 15-26.
Lozano R, Giminez E, Cara B, Capel J & Angosto T (2009). Genetic analysis of reproductive development in tomato. *International Journal of Developmental Biology*, 53: 1635 – 1648.
Marcelis LFM, Heuvelink E and Goudriaan J (1998). Modelling biomass production and yield of horticultural crops: a review. *Scientia Horticulture* 74: 83-111.
Miller WA, Leung LC, Azhar TM and Sargent S (1997). Fuzzy Production Planning Model for fresh tomato packing. *Int. J. Production Economics* 53: 227-238.
Monteith JL (1996). The quest for balance in crop modelling. *Agronomy Journal* 88:695-697.
Perry KB, Sanders DC, Granberry DM, Garrett JT, Decoteau DR, Nagata RT, Dufault RJ, Batal KD and McLaurin WJ (1993). Heat units, solar radiation and daylength as pepper harvest predictors. *Agric. For. Meteorol.*, 65: 197-205.
Perry KB, Wehner TC, and Johnson GL (1986). Comparison of 14 methods to determine heat unit requirement for cucumber harvest. *Hort. Science* 21: 419-423.
Sauviller C, Baets W, Pien H and Lemeur R (2002). Simultom: a diagnostic tool for greenhouse tomato production. *Acta Horticulturae* 593, 219-226.
Sawhney, V.K. (1983): The role of temperature and its relationship with gibberellic acid in the development of floral organs of tomato (*Lycopersicon esculentum*). *Canadian Journal of Botany* 61, 1258-1265.
Scholberg J, McNeal BL, Jones JW, Boote KJ, Stanley CD and Obreza TA (1999). Field- Grown Tomato: Growth and Canopy Characteristics of Field–Grown Tomato. *Agronomy Journal* 92: 152-159.
Schouten RE, Natalinib A, Tijskens LMM, and Van Kooten O (2010). Modelling the firmness behaviour of cut tomatoes. *Postharvest Biology and Technology* 57: 44-51.
Schouten RE, Huijben TPM, Tijskens LMM, and van Kooten O (2007). Modelling quality attributes of truss tomatoes: Linking colour and firmness maturity. *Postharvest Biology and Technology* 45: 298-306.
Tucker DJ (1979). Axillary Bud Development in the Tomato. *Ann Bot* 43 (3): 393-395.
Uzen S (2006). The quantitative effects of temperature and light on the number of leaves preceding the first fruiting inflorescence on the stem of tomato (*Lycopersicon esculentum*, Mill.) and aubergine (*Solanum melongena* L.). *Scientia Horticulturae*
109 (2): 142-146 .
Warnok SJ and Isaacs RL (1969). A linear heat unit system for tomatoes in California. *Proc. Am. Soc. Hortic. Sci.*, 94: 677-678.

TABLES AND FIGURES

Table 1. Plant assessments at flowering time for Roma crops. DAP = days after flowering.

Crop	R wk08	R wk11	R wk17
Planting date	22-Feb	10-Mar	26-Apr
Flowering (DAP)	23.5	17.5	19.6
Flowering node	9	6.5	7.6
Leaf number	12.4	10.6	8.7
Shoot number	1.4	1.4	0.75
Flowers in truss 1	8.1	7.2	7.2

Table 2. Plant assessments at flowering time for Gourmet crops. DAP = days after flowering.

Crop	G wk08	G wk10	G wk17
Planting date	22-Feb	10-Mar	28-Apr
Flowering (DAP)	24.5	17.7	30.8
Flowering node	7.6	6.6	7.2
Leaf number	11.7	10.8	14
Shoot number	1.3	1.2	3.4
Flowers in truss 1	5.4	6.6	6.3

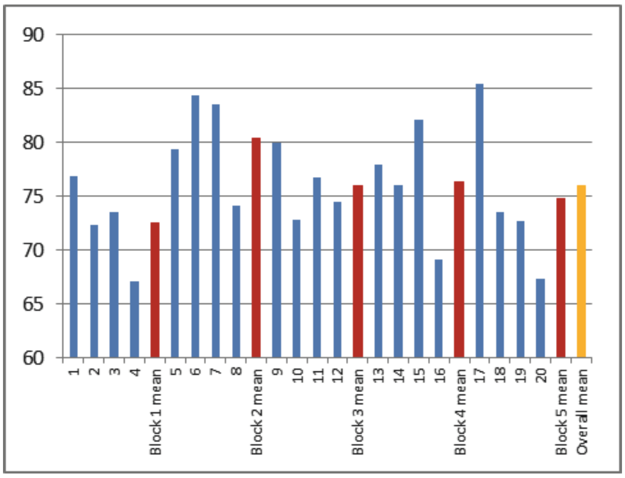

Figure 1. First harvest date (days after planting) for 20 individual plants in 5 blocks within the Roma week 8 planted crop.

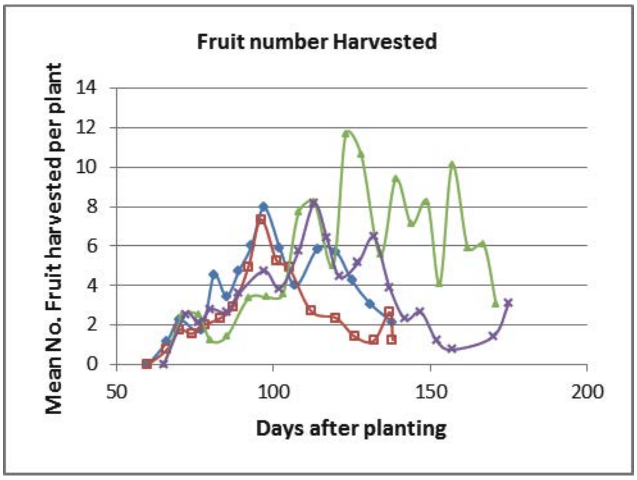

Figure 2. Number of fruit harvested in Roma tomato crops planted in weeks 8 (♦) and 11 (Δ), and Gourmet crops weeks 8(□) and 10(X) respectively.

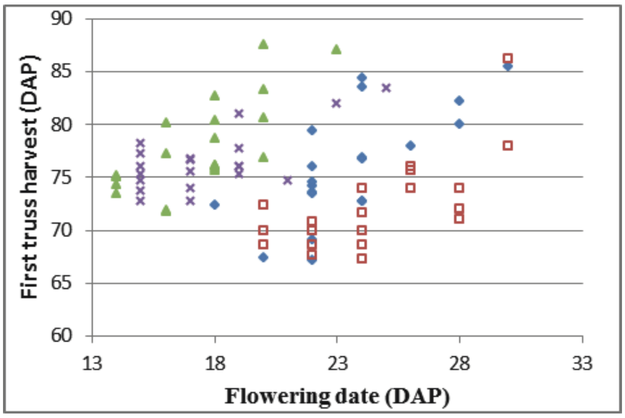

Figure 3. Relationship between flowering date (Days After Planting) and harvest date in Roma tomato crops planted in weeks 8 (♦) and 11 (Δ), and Gourmet crops weeks 8(□) and 10(X) respectively.

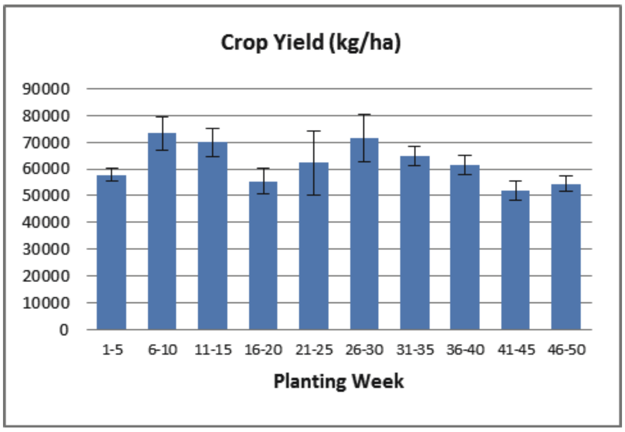

Figure 4. Mean (±SE) crop yield for commercial Gourmet tomato crops.

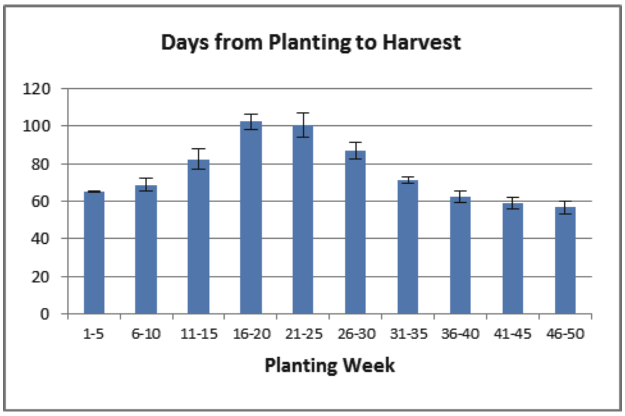

Figure 5. Mean (±SE) time from planting to first harvest for commercial Gourmet tomato crops.

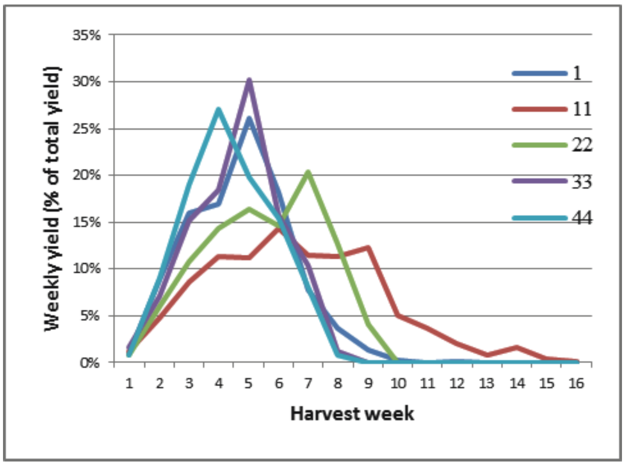

Figure 6. Mean weekly yield, expressed as percentage of total yield, for commercial crops planted in weeks 1, 11, 22, 33 and 44.

Importance of food safety in the vegetable production and supply chain

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ABSTRACT

Food safety has become increasingly important with globalization due to various factors such as volume and diversity of trade in foods, greater public demand for health protection, changing hazards e.g. resistant microbes, more sophisticated methods for detection of hazards, changes in production and consumption pattern, etc. Food safety contributes significantly to food security as unsafe and poor quality food leads to illnesses as well as food wastage. This leads to a strong need to emphasize not only on availability of food but also ensure that the same is safe.

The problems of safety are complex and systemic, often extending from the production environment to the end consumer. The concerns are felt and expressed, not only by the consumers worldwide who have become conscious of safe food and are discerning in their preference for high quality products, but also by the governments, who have recognized their role in protecting the health and safety of their populations by imposing stringent requirements for the product and processes. Major food safety concerns in the vegetable production and supply chain relate to residues of substances used in agricultural production and processing systems, environmental contaminants, microbiological parameters, pests, disease as well as various aspects of hygiene controls.

In this presentation, the relationship between food safety and food security is explained, the major emerging food safety issues in Southeast Asia with specific focus on vegetables production and supply chain are elaborated and the important approaches or focus areas for meeting food safety are highlighted.

FAO plays an important role in supporting the establishment and implementation of international frameworks related to food safety and trade. This includes its involvement in international standards setting mechanisms such as the Codex Alimentarius Commission (Codex) as also support in capacity development. The paper covers some of the activities of Codex and FAO as well as important documents produced in the area of vegetable production and supply chain.

Meeting food safety requirements is a challenging task. Some challenges to address food safety needs are also highlighted and suggested strategies and initiatives to address these are discussed.

Keywords
Food safety, Codex, FAO, vegetable supply chain safety

INTRODUCTION

With globalization and the establishment of the World Trade Organization (WTO) and the signing of the non tariff agreements, the international scenario has rapidly changed and opportunities are available to all countries to benefit from greater access to world markets. Food safety has gained greater importance due to various factors such as increasing volume and diversity of trade in foods, greater public demand for health protection, changing hazards eg resistant microbes, more sophisticated methods for detection of hazards, changes in production and consumption pattern, etc. In this global scenario, countries need to ensure confidence in the quality and safety of their foods, both for protecting the health of the consumers and gaining market access.

In this paper, the relationship between food safety and food security is explained, the major emerging food safety issues in Southeast Asia with specific focus on vegetables production and supply chain are elaborated and the important approaches or focus areas for meeting food safety are highlighted. The presentation covers some of the activities of Codex and FAO as well as important documents produced in the area of the vegetable supply chain in relation to quality and safety. Meeting food safety requirements is a challenging task. Some challenges to address food safety needs are also highlighted and suggested strategies and initiatives to address these are discussed.

Food safety – linkage to food security

Food safety contributes significantly to food security as unsafe and poor quality food leads to illnesses as well as food wastage. This leads to a strong need to emphasize not only on availability of food but also ensure that the same is safe. Food security is defined as "all people, at all times, having physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [World Food Summit, 1996]. There are four pillars of food security and food safety is the major contributing factor to the fourth pillar ie 'Utilization". The pillars of food security and the determinant factors of each pillar are shown in figure 1.

Figure 1. Pillars/dimensions of food security and determinant factors of each pillar

Food safety contributes to food security through a number of ways such as contribution to improved nutrition and health status of population thereby increasing productivity and livelihoods; reducing public health costs through a decrease in food borne illness among vulnerable populations and related social and economic implications; reducing food losses both pre and post harvest thereby resulting in increased food availability, stability, and utilization; increasing market access, purchasing power which results in beneficial effects on farmers, food businesses and consumers.

Major food safety issues with specific focus on vegetables

The problems of food safety are complex and systemic, often extending from the production environment to the end consumer. The concerns are felt and expressed, not only by the consumers worldwide who have become conscious of safe food and are discerning in their preference for high quality products, but also by the governments, who have recognized their role in protecting the health and safety of their populations by imposing stringent requirements for the product and processes. Along with this are private standards, which are being imposed by supermarkets and are at times even more stringent than government requirements.

Major food safety concerns in the vegetable production and supply chain relate to residues of substances used in agricultural production and processing systems, environmental contaminants, microbiological parameters, pests, disease as well as various aspects of hygiene controls. The residues originate primarily from nitrates, fertilizers and pesticides and contamination takes place primarily because of poor agricultural practices and overuse of chemical substances on farm lands.

During the Regional workshop on the "Use of Science throughout the Food Chain for Safe Foods, held in Bali, Indonesia in November 2010, participants identified the foods and contaminants in each food group which in their opinion were a major cause of concern for their countries. These, as related to horticulture sector are reproduced in Table 1.

Table 1. Risk factors in food

Country	Food	Contaminants/Hazards
Bangladesh	Processed foods	Food additives including food colours, artificial sweetners, aflatoxins
Bhutan	Apple/Mandarin	Pesticide residues
Lao PDR	Vegetables and fruits	Pesticide residues, unpermitted food additives
Malaysia	Vegetables	Pesticide residues
Nepal	Leafy vegetables	Pesticide residues, heavy metals, colours
Pakistan	Dry chillies	Aflatoxins
	Mango & citrus fruits	Pesticide residues
Thailand	Fruits and vegetables	Pesticide residues, microbial contaminants
Vietnam	Fruits and vegetables	Pesticide residues

In the Guidelines for risk categorization of food and food establishments developed for ASEAN countries and published by FAO as RAP Publication 2011/22, it is observed that most fruits and vegetables either fresh or processed fall under the category of medium to low risk. However, the food service sector which would include vegetable preparations is covered under high risk category (Table 2).

Meeting food safety requirements – the approach

To meet food safety requirements, some important approaches or strategic developments that have been covered in this paper include food chain approach, responsibility of food safety with all actors in the food chain, implementing a preventative approach based on risk, and implementing effective food control systems.

Over the last few years, the food chain approach has been recognized as an important concept to ensure food safety for the consumers. This approach recognizes the inter-linked nature of food production and acknowledges that food safety hazards may arise at different stages of the food supply chain from production up till consumption. To ensure the safety of food, the hazards associated with different stages namely raw materials, farming practices and food processing activities need to be prevented from entering the chain or reduced to acceptable levels at each and every stage. This requires the commitment of all players in the food chain, involving producers, traders, processors, distributors, government as well as consumers who share responsibility for ensuring food safety as well as quality.

Food control has also now shifted from end-product inspection & testing to a risk-based preventative approach which requires building quality and safety throughout the food chain. In the earlier reactive approach, the focus was on detecting the problem and disposing the food or reworking on the same while in the preventative approach the focus is on ensuring that hazards are prevented to enter into the food chain through implementation of good practices (such as Good Agricultural Practices, Good Manufacturing Practices, etc), HACCP systems and Food safety management systems such as ISO 22,000.

Table 2. Risk categorization of businesses dealing with primary and secondary foods (Guidelines for ASEAN)

Fruits & Vegetables	Main Activity	Risk Categorization		
		High	Medium	Low
Vegetable farm	Farming, harvesting, packaging, fresh handling		X	
Dried fruit	Cutting, sugar mixing, drying, packaging			X
Fruit in vinegar, oil, or brine	Cutting, deeping in vinegar, oil or brine			X
Canned/ bottled (pasteurized) fruit/veg	Cutting, blanching, filling in can/bottle, pasteurization		X	
Jams, jellies, marmalades	Cutting,pressing,sugaring,cooking,setting,pkg			X
Candied fruit	Formulation with sugar, dehydration			X
Pickled vegetable	Cutting, brining, fermentation			X
Paseurized fruit /veg juices	Extracting, filtering, pasteurizing, cooling		X	
Sterilized friut & veg juices	Extracting, filtering, sterilizing, aseptic packaging		X	
Fresh fruit/sugarcane juice	Cutting, extracting, filtering, pasteurizing, aseptic packaging		X	
Retailer level-Fruit/veg raw	Collecting, selling			X
Fruits & veg- processed	Formulating, processing, serving		X	
Food service: Hotels, caterers, canteens, street food vendors, restaurants	Preparing various RTE foods	X		

Implementing effective food controls systems in countries would need to address health and safety for domestic populations (covering both domestic production and imports) as well as for exports to ensure that safe food enters regional and international trade. The basic components of food control systems include the legislative framework; controls systems and procedures; facilities and equipment including laboratories; transportation and communication; and personnel and their training. To be effective, the controls need to be applied at both national levels in countries as well as at the provincial levels. It is also important to cover standards for both, products and processes as well as the conformity assessment aspects which include certification and accreditation procedures in addition to testing and verification.

CODEX/ FAO Activities

FAO plays an important role in supporting the establishment and implementation of international frameworks related to food safety and trade. This includes its involvement in international standards setting mechanisms such as the Codex Alimentarius Commission (Codex), International Plant Protection Convention (IPPC) and World Organization for Animal Health (OIE). The standards set by Codex for food safety have become specifically important as these have been referenced as baseline in the SPS Agreement for meeting human health requirements for international trade. Codex documents as relating to vegetables include commodity standards established through two commodity Committees namely Codex Committee for Fresh Fruits and Vegetables and the 'Codex Committee for Processed fruits and vegetables'. In addition there are general standards also known as horizontal standards which apply to the whole range of products including vegetables and cover various areas namely general principles, food hygiene, contaminants in food, food additives, pesticide residues in Food, food labeling, methods of analysis and sampling, food import and export inspection and certification systems, etc. Some important documents developed by Codex in relation to vegetable sector include:

- Special Publication on fresh fruits and vegetables 1st edition which contains the standards on 27 fresh fruits and vegetables

- Standards on processed and quick frozen fruits and vegetables
- Standards on fruit juices
- The recommended international code of practice for packaging and transport of fresh fruits and vegetables
- Code of hygienic practice for fresh fruits and vegetables
- Maximum residue levels (MRLs) and extraneous maximum residue levels (EMRLs) for pesticides

These are available on the Codex website at www.codexalimentarius.net.

FAO is also working towards meeting the needs for countries in the region for policy guidance, communication and information exchange mechanisms and capacity building in food safety through the provision of technical assistance and implementation of field projects and capacity-building activities. Some FAO activities on food safety with specific focus on vegetable production and supply chain are highlighted below.

Some guidance documents of relevance to the area of vegetable safety include:

- The role of post harvest management in assuring the safety and quality of horticulture produce
- Post harvest management of fruits and vegetables in the Asia Pacific region
- Horticultural chain management for countries of Asia and the Pacific Region – A training package
- A practical manual for producers and exporters from Asia – Regulations, standards and certifications for agricultural exports
- Food Safety Manual for Farmers Field Schools – A training reference guide on food safety in global Farmer Field School programmes
- FAO/WHO Guidelines for developing FSER plans
- FAO/WHO guide for application of risk analysis principles and procedures during food safety emergencies
- A training manual in food hygiene and HACCP systems

On the project front, some current projects on food safety and quality relating to vegetable sector in Asia include:

i) Capacity Building for food inspection systems in Vietnam
ii) Strengthening Vietnamese SPS capacity for trade – improving safety and quality of fresh vegetables through value chain approach
iii) Improving food safety, quality, hygiene and food control in Bangladesh
iv) Enhancement of laboratory capacity on food safety in primary production in Thailand
v) Enhancing Sanitary and Phytosanitary Capacity of Nepalese Ginger Exports through Public Private Partnerships

In addition, some case studies published recently under projects and of relevance to this sector include:

- Group Inspection and Certification for small farmers of Thailand – A case study covering best practices throughout supply chain for domestic and export markets
- SALM inspection and certification scheme of Malaysia
- A case study on the inspection and certification systems for Good Manufacturing Practices (GMP) in processed foods in Indonesia
- A case study on the inspection system for the food service sector including street foods, restaurants and canteens in Vietnam

Further, training material on ASEANGAP implementation, certification and accreditation of fruits and vegetables is currently under development under an ADB funded project.

A case study on QGap protocols and Organic accreditation systems and farmers training programmes in Thailand has also been documented to analyse the strengths and drawbacks of the systems in Thailand and how these could be made more effective.

Challenges to meeting food safety requirements

Meeting food safety requirements is a challenging task. Some challenges to address food safety needs both at international and national levels are highlighted and suggested strategies and initiatives to address these are discussed.

International level

Implementing food safety measures in a world of increasing food insecurity is a major challenge as on the one hand there is already food insecurity while on the other due to issues such as product past “best before” date; residues of pesticides or veterinary drugs, contaminants, etc higher than permitted limits result in the products being declared unsafe for consumption and even destroyed. Such measures would lead to further food insecurity. Further, due to recession and financial crisis, governments and producers tend to invest more on essentialities rather than on non-tangibles such as implementing food safety measures or spending on certifying costs for verification of quality and safety such as for ISO 22 000, GAP schemes, etc;

Communicating or illustrating the value of food safety has always been very difficult as firstly food safety is not very tangible and again the indicators of food safety relating to illnesses are not always demonstrable. Further, not many studies exist on the cost of implementing food safety and quality vs-a-vs the financial benefits.

Scientific progress is important and has led to development of more sensitive detection methods for pathogens/contaminants with has resulted in more stringent limits being imposed by governments. The minimal limits are therefore, dictated by scientific and technical developments rather than risk. The impact of the more stringent requirements is higher costs in meeting these without clear justification of the additional risk of the more stringent requirements.

Hazards are continually changing or new hazards are being detected as in the case of melamine, dioxins, additional pesticides, newer pathogens, etc which reflects the need to keep continuously alert and updated and address the challenges due to emerging hazards.

Another important challenge is meeting the range and diversity of food safety standards including public vs. private, varying requirements of different markets/ countries. These aspects are often debated even at the global level, however, no clear solutions on the same are evident.

Country level

At the country level also the challenges are many and include overlap of responsibilities for food control between different organizations which highlights the need for role clarity and coordination in a country; inadequate regulatory conformity assessment infrastructure in relation to testing and data collection to support a risk-based approach; participation and support to international standards setting; inadequate infrastructure in terms of safe transportation, maintenance of cold chain during storage, transportation as well as at retail level; lack of availability of sufficient and qualified manpower for activities such as inspection and testing that needs to be oriented towards a risk-based preventative approach. A major challenge is the need to have a sound linkage between the processor and primary producers so that the processor can build upon the controls maintained during primary production and also meet the traceability requirements in case of any food safety issues arising in the product at a future period. Low awareness amongst various stakeholders including farmers, input producers, food processors, government authorities on good practices and their linkage to reduce contaminants and improve food safety is also a major challenge.

Strategies and initiatives to address challenges

To address the challenges identified, some strategies are discussed below under five basic areas.

i) Standards: This is a very important area and is the base for ensuring safety of foods. At the international level it is important that Codex standards have a scientific basis for which it is necessary that countries should contribute to the same through provision of data as well as participating in the meetings of Codex. At the National levels, standards need to be adopted for both product as well as process (including GAP). Currently a number of voluntary and private standards are being implemented by retailers, food industry, etc and they have been working with farmers to strengthen the implementation; it is important to take advantage of these private initiatives for food quality and safety and government needs to work out strategies to build on these for ensuring safety of vegetables and vegetable products.

ii) Implementation: Implementation of standards and systems is an important area and would need to address the farm to table approach and cover vegetables used in street foods, retail, restaurants, and the processed foods sector. At the farm level, implementation of GAP should address a range of contaminants/ hazards and not only pesticides and chemicals as is often the case. Another important area requiring focus is the infrastructure in terms of cold chains, transportation, equipment for basic processing at farm level, testing facilities, etc. Traceability aspects are also weak in this sector and specific focus should be given to maintenance of records and having accurate labelling on the products so that these can be traced back to farms.

iii) Governmental regulation & inspection: At the governmental level, it is important to have a policy on safety and quality (covering production, processing, storage, transportation, water/ raw material, etc). In Bangladesh, it is being suggested by stakeholders to cover GAP in the food safety policy so that the area gets specific focus. The independence of inspection and certification is also important for effective results and should be delinked from the promotional, facilitation as well as extension aspects. It is also very important to coordinate activities of central, state and local governments within countries – it may be mentioned that so far the emphasis of providing assistance has generally been focussed towards central governments.

iv) Laboratory/testing aspects: Support is required for the establishment/ strengthening of laboratories for testing for GAP aspects such as pesticide residues, heavy metals, quality of soil and water, microbiological tests. Preparation of test methods manual for identified products would also be useful as well as the use of ready to use validated quick test kits.

v) Training: To address the issue of low awareness of stakeholders on food safety issues, it may be pertinent for international organizations as well as governments of countries to organize awareness and training programmes at various levels in countries and the region to cover GAP trainings including group inspection and certification schemes, trainings to auditors on inspection and audits aspects for various food safety schemes, publishing good practices as well as successful practices on food safety. It is also important for stakeholders to have information on the specification requirements of various markets/ other countries and organize awareness programmes on the same.

vi) Consumers: Awareness and education on safety aspects covering production, storage, cooking of vegetables is important. It is also important for consumers to understand the meaning of safe vegetables or GAP certified as also to read and understand the labeling requirements and clauses. Consumer education can also be built into school curriculum.

CONCLUSION

In conclusion it may be emphasized that food safety for the vegetable production and supply chain is extremely important for maintaining the health and wellbeing of populations as also for market access. There are the existing and emerging food safety hazards which need to be addressed at the international level and by countries. This is not a simple task and there are numerous challenges faced both at international and national levels which need to be collectively strategized and addressed.

References

Guidelines for risk categorization of food and food establishments developed for ASEAN countries. FAO RAP Publication 2011/22.

Transgenic vegetables for Southeast Asia

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ABSTRACT

Asia produces and consumes more than 70% of the world's vegetables. Their production and consumption are rising due to increase in consumer's income. Vegetable production suffers from many biotic stresses and their control requires high amounts of pesticides. About 20% of world's annual pesticides expenditures are for growing vegetables. Insecticides are regularly applied to control pests causing damage directly on the vegetable plants or by transmitting pathogens, particularly viruses. Genetic engineering enables vegetable breeders to incorporate desired transgenes, into elite cultivars, improving their value considerably, and offering unique opportunities for controlling pests, as well as nutritional quality. Host plant resistance or product quality will increase vegetable value throughout the chain, thereby benefiting farmers, traders and consumers. Although horticulture remains in its infancy regarding the use of transgenic crop technology, US vegetables farmers are benefiting from growing transgenic squash cultivars with resistant to viruses and *Bt*-sweet corn. Transgenic *Bt*-eggplant has been bred to provide Asian farmers with cultivars showing host plant resistance to fruit and shoot borer, thereby reducing today´s insecticide spraying during the crop season (40-80 times in India, >50 times in the Philippines). Consumers could benefit further from eating more nutritious transgenic vegetables, e.g. an increase of crop carotenoids by metabolic sink manipulation through genetic engineering appears feasible in some vegetables. Likewise, food safety can be enhanced through transgenic approaches, e.g. resource-poor people in rural Asia and Africa will benefit eating cyanide-free cultivars of cassava. Recently a transgenic bean resistant to *Golden mosaic virus,* which is transmitted by whitefly and causes up to 85% yield loss, was approved in Brazil and will benefit both producers and consumers. Beans are produced mainly by small growers and are the main source of vegetable protein, iron and many vitamins in Brazil and Africa. Transgenic plant breeding can provide therefore genetically enhanced seed embedded technology that contributes to integrated pest management and nutritional improvement for vegetable production. Transgenic vegetable crops could make important contributions to sustainable vegetable production in Southeast Asia if clear advantages and safety are demonstrated to both growers and consumers.

Keywords

Breeding, *Bt*, Integrated Pest Management, Resistance

INTRODUCTION

Vegetables supply essential vitamins and minerals, dietary fiber, and phytochemicals to human diets. Some phytochemicals of vegetables are strong antioxidants and seem to reduce the risk of chronic disease by protecting against free radical damage, by modifying metabolic activation and detoxification of carcinogens, or even by influencing processes that alter the course of tumor cells (Southon 2000; Wargovich 2000). At least half of the preschool children and pregnant women are affected by micronutrient deficiencies in Bangladesh, Cambodia, Nepal and the Philippines (Helen Keller International 2010). Vegetables contain a range of macro- and micronutrients, including pro-vitamin A, iron and zinc, which contribute to the prevention of malnutrition disorders. Small variation in maternal diets, particularly reduction in micronutrient content, can have a significant impact on fetal growth and development. Pregnant women in particular benefit from good vegetable nutrition, particularly during later pregnancy, and lactation. The interplay of the different micronutrients and antioxidants found in vegetables has important health impacts, explaining for instance the higher birth weight of children in India, when mothers consumed higher rates of green leafy vegetables and fruits during pregnancy (Rao et al. 2001). Diets rich in vegetables, in all their many forms ensure an adequate intake of most micronutrients, dietary fibers, and phytochemicals which can bring a much-needed measure of balance back to diets contributing to solve many of these nutrition problems.

Vegetables are grown worldwide, on large and small farms, on good and marginal lands, in urban and rural areas, and by large commercial growers and small subsistence farmers. Short production cycle vegetables allow multiple cropping and a significant volume of the vegetables grown worldwide are produced in small plots, which makes difficult to estimate accurately their production, thereby preventing a clear understanding and appreciation of the value of these crops to the world food supply. According to FAO statistics, the production of vegetables in the world in 2009 was almost 1010 million tons (FAO 2011). Asia produces and consumes more than 70% of the world's vegetables. The per capita consumption of vegetables in Asia, has increased considerably from 41 kg to 141 kg between 1975 and 2003 (FAO 2009), particularly in China, the largest world consumer, where the per capita consumption has increased from 43 kg (1975) to 154 kg (2003). The main reason for this increase was the rapid growth in mean per capita incomes, and awareness of nutritional benefits.

A world vegetable survey showed that 402 vegetable crops are cultivated worldwide, representing 69 families and 230 genera (Kays and Dias 1995; Kays 2011). Leafy vegetables – of which the leaves or young leafy shoots are consumed– were the most often utilized (53% of the total), followed by vegetable fruits (15%), and vegetables with below ground edible organs comprised 17%. Many vegetable crops have more than one part used. Most of the vegetables are marketed fresh with only a small proportion processed because most vegetables are perishable. Consumption shortly after harvest guarantees optimal vegetable quality. Only 67 (17%) of commercial vegetables have attracted investments for crop breeding by multinational seed corporations, due to their large area of production and substantial consumption, 52 (13%) vegetables were considered minor, and other 87 (22%) species were considered rare. In 2010 the global vegetable seed market was estimated at US$ 4.1 billion, of which 36% were for solanaceous, 21% for cucurbits, 13% for roots and bulbs, 12% for large seed, 11% for brassicas, and 7% for leafy and others vegetables (Monsanto 2011). Global commercial vegetable seed sales had an annual growth rate of 5.8% in the last decade.

Vegetable production suffers from many biotic stresses caused by pathogens, pests, and weeds and requires high amounts of pesticides per hectare. Pest loads vary and are complex *vis-à-vis* field crops because of the high diversity of vegetable crops and due to their cultivation intensity. The main method for controlling pathogens, pests, and weeds has been the use of pesticides because vegetables are high-value commodities with high cosmetic standards. Synthetic pesticides have been applied to vegetable crops since the 1950s, and have been highly successful in reducing crop losses to some insects, other pathogens, and weeds. Vegetables account for a significant share of the global pesticide market. About 20% of the world's annual pesticides expenditures (amounting to US$ 8.1 billion) are spent for growing vegetables (Krattinger 1998). Insecticides are regularly applied to control a complex of insect pests that cause damage by feeding directly on the plant or by transmitting pathogens, particularly viruses. Despite pesticide use, insects, pathogens, and weeds continue to cause a heavy toll on world vegetable production. Pre-harvest losses are globally estimated as 15% for insect pests, 13% for damage by pathogens, and about 12% for weeds. Pest and viruses are particularly important in tropical and subtropical countries like many of Southeast Asia. Pesticide residues can affect the health of growers and consumers and contaminate the environment. Vegetables are often consumed in fresh form, so pesticide residue and biological contamination is a serious issue. Consumers worldwide are increasingly concerned about the quality and safety of their food, as well as the social and the environmental conditions under which it is produced. Vegetable prices will therefore increase by enhancing their quality and safety.

Genetic enhancement of vegetables

Vegetable breeding must include improving nutrition value because they are very important for human health (Dias and Ryder 2011). Historically vegetable breeders have applied selection pressure to traits related to agronomic performance, particularly yield and quality, because these are the traits important to the producers. Growers have seldom been recompensed for nutritional factors, so there have been no economic incentives to provide significant attention to these traits. However, consumers are becoming more aware of these traits. Genetic improvement to increase levels of specific micronutrients is complex because there is often a large environmental effect, when the component is present in tiny amounts. Success in vegetable breeding for higher vitamin and mineral content should consider not only substance concentration but also organic components in plants that can either reduce or increase bioavailability (Frossard et al. 2000). Enhanced nutritional content would add value for poor, malnourished populations. Breeding for pro-vitamin A carotenoids, iron, and zinc is of keen interest as a biofortification strategy to alleviate nutrient deficiencies in developing countries (Graham et al. 2007; Hotz and McClafferty 2007).

Transgenic crops, commonly referred to as genetically modified (GM) crops enable plant breeders to bring favorable genes, often previously inaccessible, into already elite cultivars, improving their value considerably and offer unique opportunities for controlling insects, viruses and other pathogens, as well as nutritional quality. Conventional plant breeding that utilizes non-transgenic approaches will remain the backbone of vegetable genetic improvement strategies. However, transgenic crop cultivars should not be excluded as products capable of contributing to more nutritious and healthy food. Many vegetable crops have been genetically modified to include resistance to insects, other pathogens (including viruses), and herbicides and for improved features, such as slow ripening, higher nutritional status, seedless fruit, and increased sweetness. Recently, Dias and Ortiz (2012) did an analysis of the status (until 2010) of transgenic tomato, eggplant, potato, cucurbits, brassicas, lettuce, alliums, sweet corn, cowpea, cassava, sweet potato, and carrots. The most promising traits to reach vegetable growers seem to be host plant resistances to insects and other pathogens, especially for tomato, potato, eggplant, summer squash and sweet corn.The GM-vegetables already grown by farmers are in Table 1.

Table 1. Most promising transgenic vegetables available to farmers

Crop	Trait bred by genetic engineering
Potato	*Bt* against Colorado potato beetle and aphids associated by *Potato leafroll virus.* *RB* gene (from wild *Solanum bulbocastanum*) for host plant resistance to late blight
Squash	Coat protein gene for resisting *Zucchini yellow mosaic virus* (ZYMV), *Watermelon mosaic virus* (WMV), and *Cucumber mosaic virus* (CMV)
Sweet corn	Expressing *cry1 AB* endotoxin against lepidoteran pests damaging ears

After the commercialization of the first transgenic vegetable in 1994 (Flavr Savr™ tomato) for delaying fruit ripening, and further research conducted to manipulate fruit ripening, texture and nutritional quality using transgenic approaches, farmers in the United States are benefiting from growing transgenic squash cultivars resistant to virus, which were deregulated and commercialized since the mid-1990s. Engineered resistance has been so far the only approach to breed squash cultivars with multiple sources of resistance to ZYMV, WMV, and CMV (Fuchs et al. 1998; Schulteis and Walters 1998). Virus-resistant transgenic squash has allowed growers to achieve yields comparable to those obtained in the absence of viruses with a net benefit of US$ 22 million in 2005 (Shankula 2006). *Bt* sweet corn, introduced commercially in 1998, has also proven effective for control of some lepidopterous species and continues to be accepted in the fresh market in the United States, and *Bt* fresh-market hybrids are released each year (Dias and Ortiz 2012).

An economic assessment in Virginia found a gain of US$ 1,777 ha^{-1} for fresh-market sweet corn vs. non-*Bt*-sweet corn sprayed up to six times with pyrethroid insecticides (Speese et al. 2005). Monsanto® announced recently the release, through its vegetable seed brand Seminis®, of a "triple-stack" transgenic sweet corn with host plant resistance to insects, which also tolerates glyphosate sprays for weed control. They expect that this transgenic sweet corn provides protection against damage by European corn borers, corn earworms, fall army worms and corn rootworm larvae, and reduces insecticide sprays up to 85% (vis-à-vis. a non-transgenic sweet corn). The use by farmers of this insect-resistant sweet corn that tolerates glyphosate can also result in eco-efficiency because of less tractor trips across the field that help farmers to save fuel, thereby reducing greenhouse gas emissions and decreasing the carbon footprint per ear of corn grown.

Transgenic *Bt*-eggplant has been bred to provide Asian farmers with cultivars showing host plant resistance to fruit and shoot borer (FSB), thereby reducing today´s insecticide spraying during the crop season (40-80 times in India, >50 times in the Philippines) (Choudhary and Gaur 2009). This *Bt*-eggplant was effective against FSB, with 98% insect mortality in *Bt*-eggplant shoots and 100% in fruits compared to less than 30% mortality in non-*Bt* counterparts (ISAAA 2008). An expert committee was setup in India to examine biosafety issues and data regarding *Bt*-eggplant in 2006. They initially indicated that *Bt*-eggplant was safe and equivalent to its non *Bt*-counterpart but more research and trials were still needed to confirm these findings and ascertain its benefits regarding existing methods for pest management and for reducing pesticide use. In 2009 a second expert committee examined the data from these new trials and concluded that benefits of the available *Bt*-eggplant outweighed the perceived and projected risks, thereby advising the Genetic Engineering Appraisal Committee (GEAC) to recommend its commercialization in India. The GEAC cleared *Bt*-eggplant for commercialization in October 2009 but the Government of India officially announced in February 2010 that more time was needed before its release to farmers due to the successful lobbying made by anti-transgenic crop activists. The Minister of Environment stated that this moratorium for growing *Bt*-eggplant in India will remain until reaching a political, scientific and societal consensus. Recently, Brazil announced the beginning of field testing of a transgenic bean resistant to *Golden mosaic virus*, which is transmitted by whitefly and causes up to 85% yield loss, and will benefit both producers and consumers Beans are produced mainly by small growers and are the main source of vegetable protein, iron and many vitamins in Brazil and Africa.

Consumers could benefit further from eating more nutritious transgenic vegetables, e.g. an increase of crop carotenoids by metabolic sink manipulation through genetic engineering appears feasible in some vegetables. As stated vegetables offer also consumers a diverse mixture of nutrients that promote human health more beneficially than dietary supplements. However, the ingestion of plant-based diets rather than diets that rely primarily on animal products could limit the intake of essential nutrients such as calcium (Ca). Consequently, genetically engineering vegetables containing increase Ca levels may boost Ca uptake, thereby reducing the incidence of Ca deficiencies such as osteoporosis. In this regard, Park et al. (2004) modified carrots to express increased levels of the plant Ca transporter sCAX1. These carrot lines were fertile and displayed no adverse phenotypes. Further mice and human feeding trials demonstrated increased Ca absorption from *sCAX1*-expressing transgenic carrots vis-à-vis controls (Morris et al. 2008). This research supports alternative means of biofortifying vegetables with bioavailable Ca. Zinc is also an essential element in human nutrition, as its deficiency severely impairs organ function. In experiments to fortify lettuce with this element, Zuo et al. (2002) used *Agrobacterium*-mediated gene delivery of a mouse metallothionein mutant β-cDNA in the cv. 'Salinas 88'. The concentration of zinc in the transgenic plants increased to 400 $\mu g\ g^{-1}$ dry weight, which is considerably higher than in wild-type plants. Folate deficiency -regarded as a global health problem, causes neural tube defects and other human diseases. Foliates are synthesized from pteridine, *p*-aminobenzoate (PABA), and glutamate precursos. Díaz de la Garza et al. (2004, 2007) developed trangenic tomatoes by engineering fruit-specific overexpression of GTP cyclohydrolase I that catalizes the first step of pteridine synthesis, and amynodeoxychorismate synthase that catalyzes the first step of PABA synthesis. Vine-ripened fruits contained on average 25-fold more folate than controls by combining PABA- and pteridine- overproduction traits through crossbreeding of transgenic tomato plants. The achieved folate level provides a complete adult daily requirement with less than one standard serving. Vitamin E -which includes tocopherols- are lipid soluble antioxidants. There are α, β, γ, and δ isoforms of tocopherol with relative vitamin E potencies of 100%, 50%, 10%, and 3%, respectively. Conversion of γ-tocopherol to α-tocopherol in food crops could increase their value and importance in human health because vitamin E reduces the risk of several serious disorders (e.g. cardiovascular diseases and cancer), slows ageing and enhances the function of the immune system. Cho et al. (2005) developed transgenic lettuce plants of the cv. 'Chungchima' expressing a cDNA encoding γ-tocopherol methyltransferase from A. thaliana to improve tocopherol composition. Transgene inheritance and expression in transformed plants increased enzyme activity and conversion of γ-tocopherol to the more potent α form. Similarly, resveratrol—a stilbenes—shows cancer chemo-preventative activity and may prevent coronary heart disease and arteriosclerosis. Liu et al. (2006) in a quantitative analysis showed that resveratrol in transgenic lettuce plants was 56.0 ± 5.52 μg^{-1} leaf fresh weight, which is comparable to that in the skin of grape fruit (*Citrus* × *paridisi* Macfad.).

Food safety can also be enhanced through transgenic approaches, e.g. resource-poor people in rural Asia and Africa will benefit eating cyanide-free cultivars of cassava. Other experimental transgenic vegetables show host plant resistance to insects, nematodes, fungi, bacteria, and viruses, extended shelf-life of the produce, herbicide tolerance, enhanced nutritional status, seedless fruit and better flavor, or can be used for vaccine delivery.

Issues for transgenic vegetable breeding

Breeding transgenic pest resistant vegetable cultivars can decrease management costs and release growers' time for other economic activities, while also contributing to a less toxic production environment. Transgenic vegetables with tolerance to abiotic stresses or enhanced input efficiency could also provide various benefits to farmers and the environment. Consumers could also benefit further from the use of more nutritious transgenic vegetables and food safety can be enhanced through transgenic approaches. Host plant resistance or product quality will increase the value of the vegetable throughout the chain, thereby benefiting farmers, traders and consumers.

Genetic engineering has the potential to address some of the most challenging biotic and abiotic constraints faced by vegetables growers, which are not easily addressed through conventional plant breeding alone. However, horticulture remains in its infancy regarding the use of transgenic crop technology because vegetables are considered minor crops (compared to field crops), due to the lower resources invested (especially by the multinational private seed corporations), and derived of the high costs for deregulation. Most biotech research is done in field crops because multinational seed corporations expect the highest rate of return to their investment. While it is becoming less expensive to create transgenic crops for pest management, developing a marketable product and a regulatory package remains costly. Development and regulatory costs can be recouped more readily if the product is grown on an extensive area (as happens with field crops), which is not generally the case for individual vegetable crops. The large multinational seed corporations have, for the most part, abandoned the development of transgenic vegetable crops because of the high costs associated with product development and deregulation.

There are many cultivars of the same vegetable crop, and their expected life can be relatively short. Moreover, introducing a transgene into a breeding program can be complicated and cost prohibitive, especially in crops with difficulty for using backcrossing (e.g. cassava, potato or sweet potato). Furthermore, deregulation of a transgenic trait is event specific in many countries. It may not be therefore possible to develop a single transgenic event that can be converted into many different cultivars of a single or closely related group of vegetable species through conventional breeding.

Transgenic vegetables and pest, virus and weed control

Vegetables are grown worldwide mostly on smaller areas and in more diversified holdings than field crops such as cotton, canola, cereals and soybeans. Vegetables are often in more complex agricultural systems where insects may move from one crop to the next within the same farm. How this will impact the use and effects of transgenic vegetable plants in the agricultural landscape can be complex. Growing multiple insect-resistant transgenic vegetable plants in the same area and exposed of a polyphagous insect to the same *Bt* protein expressed in the different vegetable species will challenge conventional strategies developed for transgenic cotton or maize cultivars. Thoughtful consideration therefore will be needed before choosing what toxins vegetable plants should express. The selection should be based not only on what will be an effective toxin against the target insect but which toxins are already in use in other vegetable crops that may be hosts for the target insect. Additionally, the difficulty of sampling insect populations for resistant alleles will take on a higher level of complexity in a diversified vegetable system.

Significant attention should also be given to the effects of transgenic vegetables on non-target organisms. In this regard, Hoheisel and Fleischer (2007) investigated the seasonal dynamics of coccinellids and their food (aphids and pollen) in a vegetable farm system containing plantings of *Bt*-sweet corn, *Bt*-potato, and transgenic insect-resistant squash in northeastern USA. Their results indicated that the transgenic vegetable crops provided conservation of coccinellids and resulted in a 25% reduction in insecticide use. In a similar study with these same crops, Leslie et al. (2007) compared the soil surface dwelling communities of *Coleoptera* and *Formicidae* in the transgenic crops and their isolines and found no differences in species richness and species composition but found that the transgenic vegetables required fewer insecticide applications. Such results make clear that transgenic technology can be introduced within vegetable integrated pest management (IPM) systems and that transgenic vegetables can offer novel and effective ways of controlling insects and the pathogens they transmit. Such results make clear that transgenic technology can be introduced within vegetable integrated pest management (IPM) systems and that transgenic vegetables can offer novel and effective ways of controlling insects and the pathogens they transmit.

Virus-resistant transgenic plants are particularly valuable if no germplasm source of resistance has been identified or if host plant resistance is difficult to transfer into elite cultivars by traditional breeding methods due to incompatibility barriers or links to undesired traits. In such cases, engineered host plant resistance may be the only viable option to develop virus resistant cultivars. Growers can also use virus-resistant transgenic vegetables as a trap crop by growing it as a border around the non- transgenic vegetable crop and allowing it to cleanse viruliferous aphids.

The challenges for regulatory oversight of transgenic plants are immense in small, diversified vegetable plantings, which are found throughout the developing world. In these countries, farmers will likely save transgenic seed and move transgenic seed between locations, and some transgenic products may move into markets that do not permit these products. These concerns will be lessened if people consume the produce from transgenic vegetables locally after they are released and grown following national biosafety guidelines.

While each vegetable has its own set of one or more key pests, other pests can also be problematic. Traditional broad-spectrum insecticides often control a suite of pest insects. Thus, when transgenic vegetables are introduced into production systems, other methods of control will have to be applied or developed for secondary pests, e.g., biological control of secondary pests or use of selective insecticides, applied either as seed treatments or foliar sprays, may be necessary.

Integrated pest management could benefit from some herbicide-tolerant crops, if alternative nonchemical methods can be applied first to control weeds and the specific herbicide could be used later, only when and where the economic threshold of weeds is surpassed (Krimsky and Wrubel 1996). Herbicide-tolerant transgenic crops can help reducing plough in fields, thereby saving fuel because of less tractor use, which also protects the structure of the soil by reducing its erosion. Repeated use of herbicides in the same area may also create problems of weed herbicide resistance (Wrubel and Gressel 1994). Although the risk of herbicide-resistant genes in vegetables is globally lower than in field crops because many vegetables are consumed in the vegetative stage.

Markets, politics, and the power of advocacy groups

Although transgenic cultivars have proven to be a powerful tool for pest management, and their use has been accompanied by reduced dependence on pesticides, fertilizers and other inputs, and dramatic economic and environmental benefits (Brookes and Barfoot 2009), many countries are still engaged in discussions about potential negative impacts of these crops on the environment, nontarget organisms, food safety, the unintentional spread of transgenic traits into conventionally bred-crop or landrace gene pools of the same species particularly in centers of crop diversity or origin, and questions of seed ownership. Fear about potential negative effects of transgenic crops has led to the implementation of very stringent regulatory systems in several countries and regulations that are far more restrictive for transgenic crops than for other agricultural technologies (Ortiz and Smale 2007). Consumer antagonism has precluded many farmers and consumers from sharing the benefits that these crops can provide. Critics also claim that adoption of transgenic crops benefits multinational seed corporations while hurting small farmers because of the additional investments required for growing these crops successfully. These unfounded concerns are present despite the highly successful and rapid adoption of transgenics in maize, soybeans, canola and cotton in many countries of the world.

Farmers and consumers will try to influence political decision making in favor of any technology if they expect to gain from it. The political power of farmers in the developed world was used effectively to gain access to large farm subsidies supported in part by fiscal resources and in part by artificially high consumer prices. Their market power however gradually deteriorated as consumers gained a greater say in the marketplace for food. On the contrary, developing world farmers possess very limited political power and have been taxed rather than subsidized by their governments.

Another factor that has led to differential perspectives between rich and poor countries is the relative power possessed by civil society groups including advocacy activists opposed to genetic engineering in food and agriculture. These activists have been very successful in influencing the debate, and consumer and government attitudes towards genetically modified food in Europe and are also gaining power in selected developing countries. While the European governments have tended to follow the expressed desires by advocacy groups and a majority of consumers opposed to genetically engineered food, the US and Canadian governments support the farm sector and the private sector engaged in the development and deployment of modern biotechnology crops. The large majority of the population of China and India (the largest consumers of vegetables) also are in favor of the use of modern biotechnology for both human diseases and pest-resistant crops, while the European countries are much more in favor of the use of modern biotechnology for human diseases than for food and agriculture. Some developing countries are considering the commercialization of genetically modified crops but they have been warned by the European Union that they may lose the European market not only for the commodities that have been genetically modified but possibly also for those that have not been geneticaly modified. This situation happened for vegetables with African exporter countries and seems to be also relevant with the decision of the Government of India regarding *Bt*-eggplant. Farmers in the developing world who might wish to use genetic modification to improve agricultural productivity and nutritional qualities of their foods may therefore be faced with a choice between doing so for the domestic market while losing export opportunities or foregoing the potential benefits to its own people while maintaining export opportunities.

OUTLOOK

Transgenic cultivars can improve nutritional quality and make important contributions to sustainable vegetable production by overcoming some limiting factors in production, mainly virus and pests, which are not easily addressed through conventional vegetable breeding alone. They could also help for reducing pesticide residues and human poisoning, and reducing costs in horticulture. However, as noted by Ortiz and Smale (2007), before transgenic cultivars can be made available to vegetables farmers, particularly in the developing world, several hurdles must be overcome. At this time, the most important of these appear to be related to intellectual property management, public awareness, biosafety guidelines, and food safety protocols. Appropriate measures needs to be sought to overcome such hurdles.

The high cost of satisfying biotechnology regulatory requirements is prohibitive for most vegetable crops, restricting the commercial availability of this powerfull technology to a few commodity crops such as cotton, maize, soybean and canola. In addition, high regulatory hurdles reduce or eliminate opportunities for small companies and public institutions to commercialize products that might appeal directly to consumers or address human nutritional needs. The lost opportunity costs and reduced innovations due to underutilization of modern biotechnology methods in vegetable variety development are significant, particularly in light of the documented benefits of these products. Thus it is necessary a policy goal to develop cost-efficient benefit/risk analysis systems for products of biotechnology (Federoff and Brown 2004; Bradford et al. 2005).

Countries vary in their market standards of acceptance of transgenic crops. The advantages of transgenic breeding should provide incentive for integration of this method into the amelioration of vegetables and horticultural production, if consumer fears are overcome or eased. The future of transgenic vegetables may be in the developing world, especially China and India, which account for 40% of the world population, and grow and consume in excess of 60% of the world’s vegetables. They already adopted *Bt*-cotton, and it is likely that *Bt*-rice will be reaching soon farmers in China. The acceptance of transgenic vegetables in both countries will likely hasten their adoption in other parts of the world and allow farmers to use these crops.

Transgenic vegetable crops are not a silver bullet for achieving food security but coupled with traditional knowledge and conventional agriculture may be a powerful tool for making available affordable food to poor farmers and consumers. Modern biotechnology can provide products with the potential for reducing farming costs, enhancing agricultural productivity, ensuring food supply, alleviating rural poverty, promoting sustainable use of natural resources, protecting the environment and preserving biodiversity.

Transgenic vegetable crops will succeed in Southeast Asia farming systems if clear advantages and safety are demonstrated to both growers and consumers.

References

Bradford KJ, Van Deynze A, Gutterson N, Parrott W, Strauss SH. 2005. Regulating transgenic crops sensibly: lessons from plant breeding, biotechnology and genomics. Nature Biotechnology 23:439–444.

Brookes G, Barfoot P. 2009. GM crops: Global Socio-economic and Environmental impacts 1996–2007. PG Economics, Dorchester, Dorset, United Kingdom.

Cho EA, Lee CA, Kim YS, Baek SH, Reyes BG, Yun SJ. 2005. Expression of g-*tocopherol methyltransferase* transgene improves tocopherol composition in lettuce (*Lactuca sativa* L.). Molecules & Cells 19:16–22.

Choudhary B, Gaur K. 2009. The Development and Regulation of *Bt* Brinjal in India. International Service for the Acquisition of Agri-Biotech Applications (ISAAA). ISAAA Brief 38. International Service for Acquisition of Agri-Biotech Applications, Ithaca, New York.

Dias JS, Ryder E. 2011. World vegetable industry: production, breeding, trends. Hort. Rev. 38:299–356.

Dias JS, Ortiz R. 2012. Transgenic vegetable crops: progress, potentials and prospects. Plant Breed. Rev. 35:151–246.

Diaz de la Garza RI, Quinlivan EP, Klaus SMJ, Basset GJC, Gregory JF, Hanson AD. 2004. Folate biofortification in tomatoes by engineering the pteridine branch of folate synthesis. Proc. Natl. Acad. Sci. (USA) 101:13720–13725.

Diaz de la Garza RI, Gregory JF, Hanson AD. 2007. Folate biofortification of tomato fruit. Proc. Proc. Natl. Acad. Sci. (USA) 104:4218–4222.

FAO. 2009. FAOSTAT data. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org.

FAO. 2011. FAOSTAT data. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org.

Federoff NV, Brown NM. 2004. Mendel in the Kitchen. A Scientist’s View of Genetically Modified Foods, Joseph Henry Press, Washington, DC.

Frossard E, Brucher M, Mozafar A, Hurrell R. 2000. Potential for increasing the content and bioavailability of Fe, Zn and Ca in plants for human nutrition. J. Sci. Food Agr. 80:861–879.

Fuchs M, Tricoli DM, McMaster JR, Carney KJ, Schesser M, McFerson JR, Gonsalves D. 1998. Comparative virus resistance and fruit yield of transgenic squash with single and multiple coat protein genes. Plant Dis. 82:1350–1356.

Graham RD, Welch RM, Saunders DA, Ortiz-Monasterio I, Bouis HE, Bonierbale M, Haan S, Burgos G, Thiele G, Dominguez MRL, Meisner CA, Beebe SE, Potts MJ, Kadian M, Hobbs PR, Grupta RK, Twomlow S. 2007. Nutritious subsistence food systems. Adv. Agron. 92:1–74.

Hellen Keller International. 2010. Homestead food production model contributes to improved household food security, nutrition and female empowerment – experience from scaling-up programs in Asia (Bangladesh, Cambodia, Nepal and Philippines). Nutrition Bulletin 8:1-8.

Hoheisel GA, Fleischer SJ. 2007. Coccinelids, aphids, and pollen in diversified vegetable fields with transgenic and isoline cultivars. J. Insect Sci. 7:64.ç

Hotz C, McClafferty B. 2007. From harvest to health: Challenges for developing biofortified staple foods and determining their impact on micronutrient status. Food Nutr. Bul. 28:S271–S279

ISAAA. 2008. *Bt* Brinjal in India. Pocket K 35. International Service for Acquisition of Agri-Biotech Applications, Ithaca, New York.

Kays SJ. 2011. Cultivated vegetables of the world: a multilingual onomasticon. Wageningen Academic Publishers, Wageningen,The Netherlands.

Kays SJ, Dias JS. 1995. Common names of commercially cultivated vegetables of the world in 15 languages. Econ. Bot. 49:115–152

Krattinger A. 1998. The Importance of Ag-biotech to Global Prosperity. Keynote Address ABIC '98 Conference: "Biotechnology—The Science of Success", Saskatoon, Canada, 9-12 June 1998. ISAAA Briefs 6. The International Service for the Acquisition of Agri-biotech Applications, Ithaca, New York.

Krimsky S, Wrubel RP. 1996. Agricultural Biotechnology and the Environment. Univ. Illinois Press, Urbana, Illinois.

Leslie TW, Hoheisel GA, Biddinger DJ, Rohr JR, Fleisher SJ. 2007. Transgenes sustain epigeal insect biodiversity in diversified vegetable farm systems. Env. Entom. 36:234–244.

Liu S, Hu Y, Wang X, Zhong J, Lin Z. 2006. High content of resveratrol in lettuce transformed with a stilbene synthase gene of *Partenocissus henryana*. J. Agr. Food Chem. 54:8082–8085.

Monsanto. 2011. Supplemental toolkit for investors. Updated April 2011. Monsanto.

Morris J, Hawthorne KM, Hotze T, Abrams SA, Hirschi KD. 2008. Nutritional impact of elevated calcium transport activity in carrots. Proc. Natl. Acad. Sci. (USA) 105:1431–1435.

Ortiz R, Smale M. 2007. Transgenic crops: pro-poor or pro-rich? Chronica Hort. 47(4):9–12.

Park S, Kim C-K, Pike LM, Smith RH, Hirschi KD. 2004. Increased calcium in carrots by expression of an *Arabidopsis* H^+/Ca^{2+} transporter. Mol. Breed. 14:275–282.

Rao S, Yajnik CS, Kanade A, Fall DHD, Margetts BM, Jackson AA. 2001. Intake of micronutrient-rich foods in rural Indian mothers is associated with the size of their babies at birth: Pune maternal nutrition study. J. Nutr. 131: 1217–1224.

Schultheis JR, Walters SA. 1998. Yield and virus resistance of summer squash cultivars and breeding lines in North Carolina. HortScience 8:31–39.

Shankula S. 2006. Quantification of the Impacts on US Agriculture of Biotechnology-Derived Crops Planted in 2005. http://www.ncfap.org/.

Southon S. 2000. Increased fruit and vegetable consumption within the EU: Potential health benefits. Food Res. Int. 33: 211–217.

Speese IJ, Kuhar TP, Bratsch AD, Nault BA, Barlow VM, Cordero RJ, Shen Z. 2005. Efficacy and economics of fresh-market *Bt* transgenic sweet corn in Virginia. Crop Protection 24:57–64.

Wargovich MJ. 2000. Anticancer properties of fruits and vegetables. HortScience 35: 573-575.

Wrubel RP, Gressel J. 1994. Are herbicide mixtures useful for delaying the rapid evolution of resistance? A case study. Weed Techn. 8:635–648.

Zuo X, Zhang Y, Wu B, Chang X, Ru B. 2002. Expression of the mouse metallothionein mutant b-cDNA in the lettuces (*Lactuca sativa* L.). Chinese Sci. Bull. 47:558–562.

USAID's Agricultural Research Strategy and the Role of Horticulture

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ABSTRACT
The United States Agency for International Development (USAID) Office of Agricultural Research and Policy manages a global portfolio which supports President Obama's Global Hunger and Food Security Initiative, known as "Feed the Future". Horticultural production, marketing, and research features prominently in Feed the Future's overarching goal to sustainably reduce global hunger and poverty. Shorter term impact is attained through high priority horticultural value chain projects managed by USAID field missions in countries such as Bangladesh, Cambodia, Kenya, Nepal, and Tanzania. Longer term impact is attained through global research activities which pursue sustainable intensification (SI) of agriculture in high priority agro-ecological zones. SI efforts focus on environmentally sustainable productivity gains that will transform production systems in those areas where poverty and malnutrition are concentrated. Feed the Future horticultural research interventions focus on income generation, improved provision of micronutrients, the needs and roles of women as producers, the empowerment of women as nutrition providers, seed production and quality, postharvest handling, and measures to ensure food safety (such as integrated pest management). USAID works with partners such as the U.S. Department of Agriculture, U.S. land grant universities, National Agricultural Research Systems, international centers such as AVRDC (Asian Vegetable Research and Development Center), and the private sector in order to make advances in the productivity, sustainability, nutrition, and food safety associated with horticultural crops.

Keywords
USAID, Feed the Future, Food Security, Horticulture

INTRODUCTION
This paper will describe the USAID Agricultural Research Strategy of the U.S. government's Feed the Future Initiative, and will detail the important role of horticulture in the Strategy. The Strategy is implemented by the Office of Agricultural Research & Policy which is part of the Bureau for Food Security (BFS). This Office (BFS/ARP) fully supports the overall goals of Feed the Future to reduce hunger and poverty through research in horticulture and many other areas, such as grain crops, livestock, and fisheries. BFS/ARP uses a variety of mechanisms to advance horticulture research including support to projects led by U.S. universities and international agricultural research centers and in collaboration with contractor-led horticultural value chain projects and private sector entities. The future vision of BFS/ARP is to use agricultural research to aggressively, yet sustainably, increase productivity on the most appropriate agro-ecosystems where, based on USAID knowledge of local farming practices and agro-ecosystems, there is maximum chance for success in improving poverty, hunger, and malnutrition. USAID's approach of "sustainable intensification" (SI) will be discussed with a view towards the potential specific contributions of horticulture production and research.

Research on horticultural crops presents a unique opportunity to pursue the hunger and poverty alleviation goals of Feed the Future. The relative importance of horticultural research in development was described in a 2005 study (DFID 2005) commissioned by the UK's Department for International Development (DFID). This study (based on 34 global test cases) found that agricultural research and extension have consistently yielded high rates of return to public investment (82% of case studies yielded returns higher than 20%). Social rates of return to agricultural research even exceeded those of primary education. However, compared to other agricultural commodities, research on horticultural products had the highest median rate of return of all – 67%. Additionally, almost one third of those fruit/vegetable cases had return rates in excess of 100%. BFS/ARP recognizes that much of the success and efficiency in horticultural programs is due to the high degree of participation by women. Thus focus on horticultural research as a component of sustainable intensification, and as a tool of empowerment for women, is critically important if food security is to be significantly improved in the selected agro-ecosystems of Feed the Future.

THE FEED THE FUTURE RESEARCH STRATEGY

The following sections explain the linkage between BFS/ARP programs and the overall objectives of Feed the Future. The highest priority BFS/ARP research themes are described, with a focus on the relationship of horticultural research to women and nutrition in general, and "sustainable intensification" in particular.

The challenge of hunger and poverty

"Feed the Future" is President Obama's Global Hunger and Food Security Initiative which has the overarching goal of sustainably reducing global hunger and poverty (www.feedthefuture.gov). By 2050, the world's population is projected to increase by a third, to more than 9 billion. Most of that increase will occur in the developing world, where hunger is already concentrated and more than 3.5 million children die from undernutrition on a yearly basis. Providing sufficient food to this growing global population will require a 70% increase in food production from present levels (Bruinsma 2000). Challenging the need for more food are the ever-changing and increasingly unpredictable changes in climate. Yields are shrinking due to high temperatures, drought, flooding, and changing rainfall patterns, while available arable land is also shrinking due to urbanization and other pressures – such that we simply need to produce more food on less land by 2050. However, this food increase must be accompanied by significant increases in income and food quality. Crop diversification will be needed to promote sustainable landscapes that avoid the perils of intense mono-culture, while at the same time, improving diets and ensuring that the food is "safe"—free from harmful microbes and contaminants. Horticulture will play a vital and unique role in this process of sustainably ensuring a diversified diet high in micronutrients, while at the same time, offering attractive income gains to small-holder producers.

The BFS/ARP research strategy: What is new?

Implementation of Feed the Future programs began in earnest in 2011. What is new about USAID agricultural research under Feed the Future as compared to the previous 10-20 years? One of the newest elements is that agriculture has a new face under Feed the Future which more explicitly links investments to nutritional outcomes than in the past. Simply put, agricultural research and development efforts under Feed the Future, in order to be judged as successful, must be able to demonstrate significant gains towards the improvement of nutrition and health. Particularly important is an increased fight against micro-nutrient malnutrition (Vitamin A, Fe, Zn, iodine, etc.) through agriculture interventions. Expanded programs in horticulture will be one of the most important delivery mechanisms of micronutrients under Feed the Future. Secondly, successful agricultural outcomes under Feed the Future will also be judged on their ability to empower and improve the status of women in agriculture. Focusing on horticulture is seen as a particularly effective way to empower women since women's skill sets, time, and labor needs as allocated in rural household settings are often highly compatible with horticulture. Additionally, women are often best situated to figure out ways to most effectively deliver the micro-nutrients present in horticultural crops into the mouths of young infants and children in the household. With respect to household resource allocation, it can also be important to keep the often high income proceeds associated with horticulture directly in the control of the women which have produced the crop – thus preserving household financial stability and ensuring that the most nutritionally vulnerable in the household are properly fed. Another new aspect of the strategy is that Feed the Future has adopted a "whole of government" approach to implementation. USAID is leading the implementation of Feed the Future in collaboration with inter-agency partners. Feed the Future will leverage the existing competencies of USAID, Department of State, the U.S. Department of Agriculture (USDA), the Millennium Challenge Corporation (MCC), National Science Foundation (NSF), Peace Corps, etc. toward the goal of reducing global hunger and poverty. Thus BFS/ARP will seek to partner with these other agencies in the implementation of all of its research programs, including those in horticulture. The Agricultural Research Service (ARS) of USDA has deep levels of expertise in fruit, vegetable, and associated nutritional research which can be utilized, and horticulture is seen as a particularly compatible and relevant skill area for Peace Corps volunteers as they initiate their tours of service in Feed the Future countries.

Overarching themes of the Feed the Future research strategy

During the 2010-2011 timeframe, research priorities for Feed the Future emerged from an extensive analysis of the geographic distribution of child under-nutrition, poverty and major production systems (USAID/Feed the Future 2011). USAID and USDA jointly convened a consultative process with other stakeholders which clearly showed that poverty and malnutrition are most concentrated in South Asia, the highlands of East and Central Africa, large portions of South Africa, and the Sahel Region of West Africa. The consultative process solicited feedback from a broad range of experts based at U.S. universities, the Consultative Group for International Agricultural Research (CGIAR), the Global Forum for Agricultural Research (GFAR), scientific academies and other institutions as to what were the most strategic researchable constraints by which targeted resources could alleviate hunger and poverty in these production systems (agro-ecologies). Given the new focus on agriculture designed for improved nutrition outcomes, BFS/ARP chose to focus on research opportunities that would improve availability, access, and utilization of high quality micronutrient–dense diets, particularly for women and children. Horticulture, in addition to increased investments in legumes, livestock, poultry, and fisheries, figures prominently in this micronutrient strategy. Three major thematic areas emerged from the Research Strategy consultation process.

Theme #1 – Advancing the Productivity Frontier

These BFS/ARP investments will increase yield potential and provide solutions to production constraints principally through breeding and genetics research for major crops and livestock, and through improved policies and production practices for fisheries. To make sure that these technologies are integrated efficiently into the small farmer environment, this research priority will also address socio-cultural factors and incentive structures related to technology adoption. Sub-themes for this component include pest and disease management; crop resistance to heat, drought, salinity and flooding; improved resource use efficiency of crops, and; strengthening of the genetic resource base. In the area of horticulture, the Asian Vegetable Research and Development Center (AVRDC) leads BFS/ARP efforts in vegetable breeding, genetics, and germplasm conservation, and shares focus with the Horticulture and Integrated Pest Management Collaborative Research Support Programs (CRSPs) on developing small farmer friendly technologies which increase yields and combat pests with minimal use of potentially unsafe agro-chemicals.

Theme #2 – Transforming Key Production Systems

Based on the previously mentioned consultative analytical process, BFS/ARP is focusing its investments in four production systems where agricultural research and development has the highest potential to address poverty and malnutrition across a defined set of agro-ecologies – these are the rice-wheat systems of the South Asian Indo-gangetic plains, the mixed maize systems of East and Southern Africa, the Sudano-Sahelian systems of West Africa, and the highlands of Ethiopia. This Sustainable Intensification (SI) approach integrates resource-conserving technologies, new climate-resilient cereals, improved policies and integrated management of pests, soil and water, and emphasizes diversification with legumes, animals, and small-holder horticulture. More technically, SI for agriculture is defined as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services (Pretty, 2008). The integration of horticulture with cereals will be of highest priority in the mixed maize systems of East and South Africa, and the South Asian cereal based systems. The focus on horticulture integration in these systems aligns with the USAID field mission decisions to prioritize horticulture value chains in these particular regions. In general, there will be a new emphasis to interface the mission-led horticulture value chain projects of Feed the Future with the research projects led by BFS/ARP. The SI efforts in the four primary agro-ecologies will be led by CGIAR centers, which will integrate the research efforts with the programs of the mission-supported value chain projects, AVRDC, CRSPs (Collaborative Research Support Projects), national agriculture research partners and the private sector in order to most efficiently pursue SI in each of the agro-ecological zones. It will be the task of the SI initiative to counter-balance the intense productivity aspects of the horticulture value chain projects (which are primarily driven by efforts to increase yields and scale-up small farmer interventions on limited land) with aspects of *agro-ecosytem resiliency*. With this balance to be achieved through SI, the entire package of Feed the Future-led interventions will serve to both preserve the productive capacity of the land and ensure the economic viability of the small farmer for many years to come.

Theme #3 – Enhancing Nutrition and Food Safety Through Agriculture

This priority area ensures that Feed the Future interventions in agricultural systems contribute to nutrition and health outcomes. There are multiple pathways by which agricultural research can be harnessed to improve nutrition (World Bank, 2007). BFS/ARP prioritizes opportunities to improve availability and access to a high quality diet, particularly for women and young children. Targeted agricultural research in the natural and social sciences is focusing on improved nutrition through crop diversification, enhancing dietary diversity and nutrient density of foods, and reducing postharvest losses. There is also a focus on food safety challenges associated with reducing both microbial and chemical contaminants in the food supply. Horticulture investments made by BFS/ARP play a very important role in these areas. For example, the Harvest Plus Project (led by IFPRI), and the International Potato Center (CIP) have been breeding new lines of orange-fleshed sweet potato with very high levels of beta-carotene, which have been shown to raise serum retinol among low-income schoolchildren and thereby combatting a major source of micro-nutrient malnutrition. The Horticulture CRSP has partnered with AVRDC to develop seed supplies and value chains for the nutrient rich indigenous vegetables of East and South Africa (e.g., African eggplant, spider plant, *Amaranth* spp., etc.) while promoting the nutritional advantages of these vegetables over exotics such as tomato and cabbage. Both the IPM CRSP and the Horticulture CRSP are using technologies such as pest-exclusion netting, natural products, and pheromone traps to greatly reduce pesticide levels on vegetables that are intensively produced by small farmers. Biological control techniques are especially important in the reduction of postharvest losses caused by insect pests of vegetables. BFS/ARP also has a suite of agricultural biotechnology interventions which are increasing the productivity (through pest/disease resistance) of horticultural crops such as eggplant, banana, potato, and papaya while at the same time greatly reducing the need for intensive pesticide spray programs which reduce the safety and marketability of these crops.

USAID HORTICULTURAL PROGRAMS IN FEED THE FUTURE

The following section will briefly describe some of the major projects and programs in Feed the Future which promote horticulture. Although the horticultural research programs of BFS/ARP are essentially global in nature, these programs are becoming more focused on Feed the Future countries where alignment with mission-supported horticulture value chain programs can maximize impact in the field. The Feed the Future countries where horticulture has been designated as a value chain of highest priority are in East/Southern Africa (Kenya, Tanzania, Zambia, Mozambique, South Sudan), West Africa (Liberia), Asia (Bangladesh, Cambodia, Nepal), and Central America/Caribbean (Haiti, Nicaragua, Guatemala, Honduras).

Horticulture CRSP

The Horticulture CRSP is implemented by the University of California – Davis and works on all aspects of horticultural research in partnership with 18 other U.S. universities in 21 developing countries. HortCRSP meets food needs and improves nutrition and human health while providing opportunities for diversification of income and diet.

Current focus of the HortCRSP is on seed systems and innovative technologies. Seed systems research is developing improved seed drying and storage approaches for small-scale growers and entrepreneurs in Bangladesh, Kenya, Nepal, Rwanda, Tanzania and Uganda. Collaboration with AVRDC (see below) is helping to build agribusinesses in Central America that grow and distribute improved seed varieties. HortCRSP is also partnering with AVRDC in Kenya, Tanzania and Zambia to ramp up seed production of highly nutritious African indigenous vegetables, in tandem with other activities focused on production, marketing, and nutritional analysis of these crops. Regional “Centers of Innovation” are being set up in Asia, Central America, and Africa which will showcase, test, and adapt novel horticultural technologies for local conditions. Technologies such as solar drying, solar pumps for drip irrigation and hydroponic applications, solar-powered cool rooms, low cost protective structures (Fig. 1), pest-exclusion netting for insect control and microclimate modification, and drying beads to improve the longevity of seed storage are all serving as focal points for training and demonstration in these centers. HortCRSP pioneers the use of novel technologies to solve horticultural problems, ranging from GIS applications in market analysis to cell-phone enabled advisory services.

HortCRSP also works in the arena of postharvest loss reduction/food safety through establishment of a regional postharvest training center in Tanzania, developing an e-learning postharvest curriculum for dozens of East African trainees, linking small farmers in Zambia to hotels and grocery chains through improvement of the postharvest value chain, and helping vegetable cooperatives in Cambodia and Vietnam develop niche markets for high-value vegetables such as bitter gourd and cucumber through farmer practices which improve food safety.

IPM CRSP

The Integrated Pest Management (IPM) CRSP is led by Virginia Tech University. Over 90% of its activities are engaged with horticultural crops. This CRSP develops and implements a replicable approach to pest management that will help reduce: 1) agricultural losses due to pests; 2) damage to natural ecosystems including loss of biodiversity; and 3) pollution and contamination of food and water supplies. IPM CRSP goals also include increasing farmer income, reducing pesticide use, improving IPM research and education program capabilities, and increasing the empowerment of women in IPM decision making and program design.

The IPM CRSP is disseminating IPM packages for cabbage, eggplant, okra, onion, and tomato in India and Bangladesh in collaboration with NGOs, partner universities and extension services. Technology to produce a beneficial soil fungus, *Trichoderma*, will be transferred to Indonesian NGOs. This same fungus will be used in Kenya to manage *Fusarium* rot in passion fruit as a component of an IPM package. In the Philippines, an IPM strategy for the management of soil-borne diseases of rice-based vegetables will be developed in collaboration with the National PhilRice Center. IPM CRSP scientists work on the management of zebra chip disease in potatoes in Honduras and Guatemala. In Honduras and Guatemala, sweet potato virus diagnostics are being optimized. Eco-climatic modeling is being used to predict the expansion of the weed *Parthenium* across grazing areas of Eastern Africa. In Uganda, activities to facilitate the registration and release of the MT56 tomato variety for its resistance to bacterial wilt are under way. Development and implementation of an IPM package for tomato in Ghana, Mali, and Senegal are a major activity of a regional activity focused on key pests of West Africa.

AVRDC - The World Vegetable Center

AVRDC - The World Vegetable Center) is headquartered in Taiwan and is a key partner of BFS/ARP in the application of horticultural research to improve food security. AVRDC seeks to overcome malnutrition and poverty and facilitate good health for both the rural and urban poor by increasing the production, quality, consumption, and profitability of nutritious and health-promoting vegetables. BFS/ARP funding is through a global core grant, but many of the USAID-supported activities actually take place in high priority African and Asian Feed the Future countries.

AVRDC generates positive impact among the poor in developing countries through the increased production and consumption of nutritious and health-promoting vegetables. Research and development along the vegetable value chain involves conserving germplasm, conventional breeding for yield and quality traits, improving production practices and crop management, postharvest value-addition, marketing, nutritional analysis, and consumer advocacy, all while ensuring that the needs of the farmers and consumers are met. The Center will continue to emphasize research and development work on crops that have good nutritional and/or market value including both exotic (tomato, pepper, onion and eggplant) and indigenous species (nightshade, slippery cabbage, ivy gourd) and globally important vegetables suited to hot/wet and hot/dry tropical environments. AVRDC will seek to develop closer relationships with the CRSPs and Mission value chain projects through the SI initiative. Collaboration with the Horticulture CRSP on African indigenous vegetables has already started, with AVRDC activities focused on seed production and distribution, varietal selection, recipe formulation and nutritional analysis.

ABSP II

The Agricultural Biotechnology Support Project II (ABSPII) is a BFS/ARP-funded consortium of public and private sector institutions led by Cornell University that supports scientists, regulators, extension workers, farmers and the general public in developing countries to make informed decisions about agricultural biotechnology. Where demand exists, and in collaboration with host-country governments and local research partners, ABSPII focuses on the safe and effective development and commercialization of bioengineered crops as a complement to traditional and organic agricultural approaches. The project helps boost food security, economic growth, nutrition and environmental quality. Focus technologies are oriented toward horticulture, and include insect resistant eggplant, disease resistant potato, virus resistant papaya and disease resistant banana.

In India, ABSPII has worked with Indian universities, research institutions and the private sector to develop Bt (*Bacillus thuringiensis*) eggplant and now is continuing to work on the communications front as a political gridlock delays the commercial approval of the new varieties. The Bt technology is effective against the eggplant fruit and shoot borer which typically forces Indian farmers to apply pesticides more than 15 times per crop cycle. It is estimated that adoption of Bt eggplant could result in yearly proceeds of $65 million for small farmers in India alone, not to mention the associated health benefits of greatly reduced pesticide usage. ABSPII is also working on late blight disease resistant potato with several multi-location confined field trials in India either being completed or currently ongoing. ABSPII is also working with USAID/Bangladesh and local research institutions in Bangladesh to conduct multi-location confined field trials on both the pest-resistant eggplant and late blight disease resistant potato technologies. Further, a regulatory dossier is being prepared for submission to the Government of Bangladesh in order to request approval for commercial release of the Bt eggplant for delivery to Bangladeshi farmers. Additional work on Bt eggplant is being conducted in the Philippines through confined trials at multiple sites. A continuing stream of public communications from ABSPII and its national partners will help to provide information to the South Asian public on the potential of the Bt technology in reducing pesticide usage and improving productivity. Work on the late blight resistant potato technology also continues in Indonesia in collaboration with USAID/Indonesia where a confined field trial of the potato technology is planned with local partners. In Africa, ABSPII is collaborating with the National

Agricultural Research Organization in Uganda to conduct laboratory and field trials to develop transgenic East African highland banana varieties with a more durable resistance to black sigatoka disease, banana bacteria wilt and weevils.

Field Mission-led Horticultural Value Chain Projects

Most of the Feed the Future production, marketing, and small farmer capacity-building work in horticulture is implemented by value chain projects funded by USAID field missions. In general, these projects are funded over a 3-5 year period at a minimum level of $20 million. Generally they are implemented by consultancy firms which may not have a lot of experience in horticultural research, and who tend to focus on building relationships with local private sector horticultural entities. For that reason, there is an immediate need to better interface these large, capacity-building driven efforts with the horticultural research programs of BFS/ARP, which have established local relationships with national research agencies and the academic community. Feed the Future has over 10 such value chain projects under implementation or in the process of being awarded as of March 2012. Two of these typical horticultural value chain projects are profiled below.

KHCP (Kenya)

The Kenya Horticulture Competitiveness Project (KHCP) is funded by USAID/Kenya and implemented by Fintrac Inc. KHCP had reached over 30,000 men, women and youth across six regions of Kenya by the end of 2011. The project is improving lives of smallholder farmers and their families through transformational activities by introducing new crop varieties, increasing the use of improved technologies, and scaling-up smallholder commercialization. KHCP has worked to commercialize orange flesh sweet potato root stocks, with over 12 million vines produced and distributed to smallholder farmers. Agronomic training and demonstration sites are dramatically increasing crop yields and farm incomes. KHCP is also strengthening smallholder access to local markets through the establishment of low-cost greenhouse production systems in Nyanza, Rift Valley and Western regions, enabling farmers to earn premium prices for higher quality produce. The program has introduced water harvesting technologies to thousands of farmers to mitigate the effects of climate change and start growing their own vegetables throughout the dry season. In partnership with the HortCRSP and AVRDC, KHCP is ramping up the production and quality of African indigenous vegetables, meeting export market demand in Europe and local demand from HIV-afflicted consumers (Figure 2). KHCP has launched a series of comprehensive market reports on the Kenyan horticultural retail trade covering eight products and over 1,650 local markets to keep the industry informed of major developments and trends in domestic retail trade and encourage investment in market infrastructure. Passion fruit production has been greatly expanded in Kenya by KHCP through the dissemination of high yielding varieties. Eight accredited nurseries have been established with monthly production capacity of over 100,000 seedlings. KHCP commissioned a Regional Market Study which provided an unprecedented analysis of horticulture trade flows in key East African markets. The study identified carrots and processed juices as the two major under-exploited opportunities for Kenyan horticultural producers. Finally, KHCP has scaled up smallholder flower production with farmers supplying *Arabicum* and other varieties with strong income generation potential. Due to KHCP support, more than 2,000 smallholder flower producers are currently selling to multinational buyers through the Dutch auction system.

HARVEST (Cambodia)

The HARVEST program funded by USAID/Cambodia is a major Feed the Future value chain project implemented by Fintrac Inc. Of the three agriculture programs that HARVEST is working with, two are horticulture related: household gardens and semi-commercial horticulture production, the third being rice. All three are focused on the planting of diversified crops, increasing household incomes through product sales, and implementing sustainable adaptation measures that reduce the risk to climatic change. The two horticulture programs also focus heavily on nutrition, working both with existing locally-grown crops and new crops that are introduced by the project for their high nutritional value (recommended vegetable types based on the highest content of vitamin A and C, including iron). In addition to the 40 different types of crops being recommended, new growing technology is being introduced along with Good Agricultural Practices and continuous technical assistance in the areas of production, postharvest handling and marketing as well as training on nutrition related topics. HARVEST also co-invests with all clients in the purchase of farm infrastructure for demonstrative purposes comparing the results of traditional growing techniques to introduced growing methods and equipment.

The *Household Gardens Program* targets direct technical assistance to 6,000 households. All receive basic equipment and technical assistance in the following areas – selection of varieties for dry vs. rainy seasons; set-up of seedling nurseries; low-cost gravity fed drip irrigation; plastic mulching; trellis netting; composting; pest and disease diagnosis; IPM practices; agro-chemical safety awareness training; and basic postharvest handling techniques. The *Semi-Commercial Horticulture Program* targets work with 1,000 small size farms (half hectare and below) grouped together to plant the same crops for marketing advantages. Rather than focusing on export markets, this approach aims to place more locally grown produce in local markets. All farmers receive basic equipment and implement the same growing practices according to the crops selected. Technical assistance is provided in the following areas: selection of varieties with high market demand; set-up of semi-commercial size seedling nurseries; design of drip irrigation systems under pressure and their maintenance; use of raised beds and reflective plastic mulch; soil pH adjustments based on probe meter testing; crop specific fertilizer programs; pest and disease diagnosis; IPM practices; agro-chemical safety awareness training; basic postharvest handling techniques; and marketing assistance.

CONCLUSION

Integration of horticultural production into food security programs can be highly advantageous since vegetables provide more income per hectare than most other crops, are vital ingredients of a diversified diet which can help to provide micronutrients and combat hidden hunger, and are often cropped preferentially by women farmers whose household resource allocation decisions are vital to the health of vulnerable infants and young children. For all these reasons, combined with the fact that return on horticultural research investment is so high compared to other crops, it makes sense for Feed the Future to make major investments in horticultural production and research. As BFS/ARP is making a major push to promote "sustainable intensification" in four high priority agro-ecosystems, it must prioritize efforts to integrate horticulture into these systems where appropriate, and to fully realize the potential long term economic, social, and environmental benefits of horticulture as a component of cereal-based production systems. Horticultural inputs and technologies which are being promoted by Feed the Future may have certain short term benefits which clearly improve hunger and poverty in key Feed the Future farming systems, however, the horticultural research and production teams funded by USAID (many of which are described in this paper), and the farmers they serve, must also strive to better understand to what extent these interventions may either inhibit or stimulate preservation of the eco-systems. Such an understanding of sustainable intensification is one of the next big challenges which horticultural researchers and production specialists funded by USAID must face in the coming years.

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References

Bruinsma J. 2009. The resource outlook to 2050: By how much do land, water and crop yields need to increase by 2050? Expert Meeting on How to Feed the World in 2050. FAO. Rome.

DFID (Department for International Development, United Kingdom). 2005. Rates of return to research: A literature review and critique, final report. London. 29pp.

Pretty J. 2008. Agricultural sustainability: concepts, principles and evidence. Philosophical Transactions of the Royal Society of London, Series B 363 (1491): 447-466.

USAID/Feed the Future. 2011. Feed the Future: global Food Security Research Strategy. Washington DC. 47pp.

World Bank. 2007. From Agriculture to Nutrition: Pathways, Synergies and Outcomes. Agriculture and Rural Development Department. The International Bank for Reconstruction and Development. Washington D.C.

Figure 1. HortCRSP and IPM CRSP assist tomato farmers in Kirinyaga Kenya with establishment of simple high tunnels and seedling production. (*Photo:* J. Bowman).

Figure 2. KHCP, HortCRSP, and AVRDC are working together in Eldoret Kenya to improve production, marketing, and consumption of African indigenous vegetables. (*Photo:* J. Bowman)

The Water, Energy, Food and Nutrition Security Nexus: UNSGAB's: Message to the UN Conference on Sustainable Development (Rio+20)

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INTRODUCTION

The United Nations Secretary General Advisory Board (UNSGAB) on Water and Sanitation is an independent body established in March 2004 by United Nations Secretary-General, Mr. Kofi Annan, to give the Secretary-General advice as well as to galvanize action on water and sanitation issues.

Chaired by His Royal Highness the Prince of the Netherlands, the Board is composed of 22 dignitaries, technical experts, and individuals with proven experience in providing inspiration, moving the machinery of government, regional development banks as well as working with the media, the private sector and civil society.

The Board's Hashimoto Second (2^{nd}) action plan, formulated in 2010 has five (5) focus areas:

- Sanitation
- Financing
- Monitoring
- Integrated water resource management (IWRM)
- Water and disaster

Each focus area has working groups that galvanize, advocate, and catalyze action plans which move governments, industries, academe, NGOs, communities, media, and other stakeholders. UNSGAB also adheres to the UN Millennium Development Goals, but its focus is on water and sanitation, preferably for the post-MDGs.

UNSGAB contribution to UNCSD 2012: underpinning the pillars of sustainable development in the context of a green economy

Good management of water and sanitation is a precondition for sustainable development. It underpins the three pillars of sustainable development and also contributes to a green economy and to poverty eradication. These are compelling reasons to address water and sanitation challenges in UNCSD2012.

UNSGAB believes that the global community must make progress on three major water and sanitation challenges during UNCSD2012. It makes the case for a strong focus and decisions on:

- access to sanitation and drinking water
- wastewater management
- more productive water use in agriculture

It suggests objectives on these issues to be decided in UNCSD2012 and describes potential targets related to them. The following objectives are:

Objective 1: Access to safe drinking water and sanitation. Ensure universal access to sanitation and safe drinking water through the adoption of plans for accelerated implementation of all dimensions of the human right to water and sanitation: safety, availability, accessibility, acceptability, affordability, non-discrimination, participation and accountability.

Objective 2: Common vision of wastewater management. Governments together decide to strengthen their respective actions on pollution of freshwater by adopting a shared vision of urban, industrial and agricultural wastewater management including collection, treatment and water reuse.

Objective 3: More food with the water available. Adoption of an internationally agreed political objective linking food production and water use through increasing global water productivity of agriculture.

Below are UNSGAB's recommendations for UNCSD 2012

- UNSGAB makes the case for a strong focus and concrete decisions on access to sanitation & drinking water, wastewater management and more productive water use in agriculture.
- UNSGAB proposes related objectives to be decided in UNCSD2012 and describes potential targets to support them.
- Currently, 70% of all freshwater withdrawals are used by the agricultural sector for irrigation
- In OECD countries, freshwater use in irrigation is already decreasing.

Water use in agriculture (UNSGAB's recommendation for Objective #3)

- Economic progress, notably in the emerging countries, translates into increased demand for diversified diets. World food demand will surge both because of this phenomenon and from sheer population growth.
- Food production will need to increase by 70% globally and by 100% in developing countries by 2050 Yet, both land and water resources, the basis of our food production, are finite and already under heavy stress.
- Future agricultural production will need to have higher and more sustainable yields if people are to be fed adequately. Given the growing competition for water from agriculture, power generation, people > new sources of water will have to be identified especially if ecosystems are to be maintained restored. In this context it does not seem possible that irrigated agriculture uses much more water than today.
- Economic progress, notably in the emerging countries, translates into increased demand for diversified diets. World food demand will surge both because of this phenomenon and from sheer population growth.
- Food production will need to increase by 70% globally and by 100% in developing countries by 2050 Yet, both land and water resources, the basis of our food production, are finite and already under heavy stress.
- Future agricultural production will need to have higher and more sustainable yields if people are to be fed adequately. Given the growing competition for water from agriculture, power generation, people > new sources of water will have to be identified especially if ecosystems are to be maintained restored. In this context it does not seem possible that irrigated agriculture uses much more water than today.
- It is therefore not only desirable but imperative that water systems for agricultural purposes, irrigation in particular but also for livestock care, be more efficient, thereby raising the productivity of farmland.
- Gaining more yield and value from less water has many benefits: it can reduce the need for "new" water; it can limit and even reverse environmental degradation and ultimately contain the competition for water.

- Such progress should not be limited to irrigated agriculture through technological improvement but should encompass the selection of appropriate crops while not loosing effective methods of traditional farming.
- The global community needs to take action to grow more food with less water in order to mitigate current and potential difficulties in the future.
- Objectives and relevant indicators recognizing the fundamental relationship between agricultural output and water use could energize stakeholders to take a fresh look.

According to UNSGAB, these three Water Objectives need to have possible actions such as those noted below. These three objectives are offered to the UNCSD2012 to help sharpen the substantive discussion on water and sanitation. It is possible that countries will negotiate precise targets against which to quantify progress: in this case, potential targets are hereafter proposed. Making improvements as suggested below will contribute to sustainable development and poverty alleviation as well as to a green economy.

Objective 1: Access to safe drinking water and sanitation

Examples of targets

- Universal access to basic sanitation and improved water sources by (year)
- Universal access to safe drinking water by (year)
- Development of good quality services in cities at a rate that exceeds the rate of urban growth
- Drinking water networks to supply water continuously (24/7) in order to ensure safety and availability of water

Possible actions

Such targets would need to be supported by the establishment of feasible sets of global, regional and national targets and the adoption of meaningful and measurable indicators to keep track of progress on the basis of five-year rolling milestones. An integrated monitoring programme of the indicators linked to the criteria established for the human right to water and sanitation and the factors determining the enabling environment is to become effective after 2015.

Objective 2: Common vision of wastewater management

Examples of targets

- Reduce the percentage of wastewater that is not collected safely from households
- Reduce the percentage of wastewater that is discharged into the natural environment without treatment
- Increase the percentage of urban wastewater that is treated for safe reuse in agriculture and industrial processes
- Reduce the amount of water pollution arising from agriculture
- Reduce the amount of water pollution released by industry

Possible actions

- Establish or strengthen national policies and regulations for wastewater collection, treatment and discharge in order to ensure that individual and collective practices and systems are sufficient to protect health of individuals against potential contamination by others and by economic activities and to protect natural ecosystems against harmful pollution
- Get organized to monitor and stimulate at national level progress of wastewater collection and treatment by collective systems and individual facilities
- Get organized to monitor and control potential contamination of drinking water sources by man-made pollution

- Introduce or strengthen laws and other forms of regulation to support the reduction of pollutants and make water reuse possible, including the recovery of positive substances

Objective 3: More food with the water available

Adoption of an internationally agreed political objective linking food production and water use through increasing global water productivity of agriculture

Examples of targets

- Irrigated agriculture to grow more food with the same amount of freshwater and without over-abstracting water tables
- 70% of irrigated land using technology that increases crop per drop by (year)
- Organizing urban use of water to allow its reuse in agriculture in all water scarce areas

MAIN PROBLEMS/ CONSTRAINTS

- Government policies
- Lack of funds
- Capital intensive
- Raising awareness
- Capacity-building
- Integrated programs
- Transfer of technologies
- Lack of incentives
- Implementation gaps

Challenges

- Good Governance and Transparency needs to become top priority for business
- Governments, be it local, national or regional need to include agricultural issues in their agenda/ platform
- All stakeholders have to work together to monitor that it happens

CONCLUSIONS AND RECOMMENDATIONS

- Align with the Millennium Development Goals (MDGs)
- Countries to have an enabling framework (legislation, institutions, authorities and enforcement) for sustainable agricultural programs
- Countries create a national platform to promote sound sustainable agricultural programs
- bringing together the main actors of the sector

For All

- Develop capacities of national policymakers, technical experts, and staff of financing institutions for promoting sustainable agriculture
- Support policy, regulatory, and institutional reforms
- Facilitate access to private sector financing for water & sanitation (on agriculture)

Tools to reach the targets

- Awareness-raising at different levels and scales (communications campaigns, making the business case, demonstration projects, best practices)

- Capacity building adapted to regional and local needs
- Mechanisms for coordination and enforcement of policies
- Locally developed national evaluation systems for sustainable agriculture performance
- Monitoring tools such as country benchmarks
- Introduction of sustainability criteria in agricultural policies

Related events to give further support to agriculture and the world vegetable sector

Important Milestones: Bonn Conference on Water, Energy, and Food Security leading to Rio+20 last November 2011, 2nd Asia Pacific Water Forum in March 2012, World Water Forum6 in Marseille, France this March 2012 and the UN Rio+20 Conference in June 2012.

- Recognize the importance of wastewater management and set policy targets that have relevance to agriculture
- Share knowhow and good practices in the food sector such as in agriculture
- Governments to agree on a shared vision for food sector/agriculture
- Encourage governments to improve monitoring of food sector/agriculture
- Agriculture/food sector to be part of a strategic financial planning process

ANNEX

Water and sanitation: Underpinning the pillars of sustainable development in the context of a green economy. UNSGAB contribution to UNCSD 2012.

ANNEX

Water and sanitation: Underpinning the pillars of sustainable development in the context of a green economy

UNSGAB contribution to UNCSD 2012
26 September 2011

The UN SG's Advisory Board on Water and Sanitation (UNSGAB) is an independent body established in March 2004 to give advice to the UN Secretary-General as well as to galvanize action on water and sanitation issues. Chaired by His Royal Highness the Prince of Orange, the Board is composed of a wide range of dignitaries, technical experts, and individuals with proven experience in providing inspiration, moving the machinery of government, as well as working with the media, the private sector and civil society.

www.unsgab.org

EXECUTIVE SUMMARY

Good management of water and sanitation is a precondition for sustainable development. It underpins the three pillars of sustainable development and also contributes to a green economy and to poverty eradication. These are compelling reasons to address water and sanitation challenges in UNCSD2012.

UNSGAB believes that the global community must make progress on three major water and sanitation challenges during UNCSD2012.

This paper makes the case for a strong focus and decisions on (i) access to sanitation & drinking water, (ii) wastewater management and (iii) more productive water use in agriculture. It suggests objectives on these issues to be decided in UNCSD2012 and describes potential targets related to them.

Objective 1: Access to safe drinking water and sanitation. Ensure universal access to sanitation and safe drinking water and sanitation through the adoption of plans for accelerated implementation of all dimensions of the human right to water and sanitation: safety, availability, accessibility, acceptability, affordability, non-discrimination, participation and accountability.

Objective 2: Common vision of wastewater management. Governments together decide to strengthen their respective actions on pollution of freshwater by adopting a shared vision of urban, industrial and agricultural wastewater management including collection, treatment and / or water reuse.

Objective 3: More food with the water available. Adoption of an internationally agreed political objective linking food production and water use through increasing global water productivity of agriculture

INTRODUCTION

The global community is aiming to secure renewed political commitment for sustainable development at the United Nations Conference on Sustainable Development in Rio de Janeiro in June 2012 (UNCSD2012) with a specific focus on poverty eradication in the context of green economy. Good management of water and sanitation underpins sustainable development's social, economic and environmental pillars. Furthermore, water and sanitation also contribute to a green economy and to poverty eradication. Another objective of the UNCSD2012 is to assess the remaining gaps in implementation of previously agreed goals. Two major gaps are the insufficient progress made for basic sanitation and on the management of water, including provision of drinking water and management of water resources.

These are among the many compelling reasons to take on water and sanitation challenges in Rio. Clear, articulate objectives for sanitation and water must inform the renewed vision for the future that emerges from UNCSD2012. UNSGAB believes that the global community should make real progress on three major water and sanitation challenges, while also making sure that water-related disasters do not reverse any progress made.

This paper makes the case for a strong focus and concrete decisions on access to sanitation & drinking water, wastewater management and more productive water use in agriculture. The paper proposes related objectives to be decided in UNCSD2012 and describes potential targets to support them.

THE CHALLENGES

Access to Sanitation and Drinking Water

Since the first Rio Summit in 1992, the global landscape has evolved with the emergence of dominating issues such as urbanization, climate change, financial and food crises, and devastating natural disasters. While global politics, economics and social priorities are in constant flux, one thing has stayed stubbornly constant for the last 20 years: the 2.6 billion people who lack access to improved sanitation facilities, now roughly one third of the global population. The trends are better for access to improved water sources. However, (i) an estimated 884 million people still have no access to improved water sources for their basic needs, (ii) access to improved water sources is decreasing in the urban half of the world and (iii) many more than 884 million people may have access to improved water sources, however, it is not safe for consumption [i]. In fact, it is estimated that between 2 and 3 billion people might not have access to safe drinking water [ii]. This sets up a vicious cycle of ill health and further impoverishment with severe personal, financial and health costs. In addition, water sources might not be close enough to households so that many people, mostly girls and women, continue to endure the time-consuming task of water collection. This hinders their opportunities for education and formal paid employment. Access to safe drinking water and sanitation is recognized by the UN General Assembly as a human right essential to the full enjoyment of life and all other human rights. The creation of any future global development framework must build on this growing international consensus by incorporating the centrality of these two basic services in the three pillars of sustainable development:

1) Social: When feces are not properly contained and treated, they often pollute the water sources, thus leading to illness and death. According to UNICEF, 1.9 million deaths per year, 90% being children under 5, can be attributed to unsafe water, poor sanitation, and the lack of hygiene [iii]. It is estimated that at any given time, approximately half the people in developing countries suffer from chronic diseases associated with inadequate provision of sanitation and safe drinking water [iv] Open defecation is the daily routine for 1.2 billion people globally [v]. A healthy living environment, one that supports human dignity and is free of disease-transmitting agents and conditions, is impossible if open defecation is widely practiced. Access to safe, clean toilets brings dignity, equity and safety, particularly for women and girls. Toilets and safe water in schools increase attendance, particularly for adolescent girls. Without sanitation and clean water, sustainable development’s social objectives remain unmet.

2) Economic: A growing body of empirical evidence shows that poor sanitation and a lack of clean water curbs economic growth. The World Bank assessed in 2010 the annual economic impact of poor sanitation in a range of countries. It found, for example, that the annual cost of poor sanitation in India was US$54 billion, translating to around 6.4% of GDP [vi]. The economic objectives of sustainable development will be greatly advanced by the expansion of basic sanitation services. In addition, providing basic sanitation services such as toilets, operation and

maintenance services and reuse of human waste, on a regular basis, creates a market for entrepreneurs, in particular for local and small-scale businesses.

3) Environmental: Clearly, a healthy environment depends on sanitation. When human wastes pollute water sources through open defecation, dumping from buckets or unsafe disposal of latrine effluents, or when wastewater is not collected after use to be diverted from local surroundings, ecosystems and people suffer, and ecosystem services are at risk.

The global community has adopted two Millennium Development Goal (MDG) targets to improve access to basic sanitation and access to safe drinking water.vii While the world is globally on track to meet the drinking water target, it is clear that many who are considered to have access to improved water sources, still do not enjoy water that is safe for human consumption. The MDG sanitation target is arguably the most behind of all the MDGs. This target was endorsed at UNCSD2002 in Johannesburg, thereby putting this neglected issue onto the international development agenda. In 2012 in Rio, countries can honor the legacy of the Johannesburg basic sanitation target, while creating the context for the next logical step, by agreeing on a goal for universal access to basic sanitation. In addition, countries should reinvigorate and upscale efforts by adopting a universal access to safe drinking water goal, as well as setting forth the means to ensure success.

Management of wastewater: collection, treatment and reuse

Although many countries have national policies with respect to management of wastewater [viii], the global community does not share any common vision on wastewater management. UNCSD2012 is an opportunity to fill this gap.

The MDG sanitation target monitors access to decent toilets, which does not encompass sanitation in all its components. Humans and the planet need more than basic sanitation. We need the pollution resulting from domestic, urban, industrial or agricultural discharge of wastewater to be controlled to protect our health, our economies and our ecosystems.

Worldwide, it is estimated that up to 90% of wastewater is dumped untreated into water bodies [ix] polluting usable water resources; this exacerbates the impact of water-related disaster such as floods, when invading low-level settlements. These challenges are compounded not only by climate change, but also by the loss of half of the world's wetlands, which severely cripples natural cleaning systems.

While currently there is no absolute shortage of clean water in the world, availability and access to clean affordable water varies widely, with some regions and countries under significant stress. Furthermore, demand is increasing. Water demand has been growing at more than twice the rate of population increase in the last century due to economic growth and changes in consumption patterns. Given this reality, it is imperative to treat water after use. Water reuse is one of the solutions for the future.

Recent publications have confirmed the high economic rate of return of investments in wastewater management. There are many linkages with other green growth activities since wastewater management creates opportunities such as:

- source of energy through burning sludge extracted from wastewater, using calories transported by the wastewater or using wastewater flows to produce hydroelectricity
- source of water and nutrients for agriculture, both of which can contribute to solving the food crisis
- source of water to mitigate increasing water scarcity
- improve people’s health and nutrition and to protect ecosystem integrity
- improve otherwise polluted lands to benefit economic activities including tourism
- develop peri-urban agricultural activities to increase employment and provide urban centers with food, while reducing transportation and other costs

Currently, there is no internationally agreed target for wastewater collection and treatment, and water reuse; and no system to effectively monitor how much wastewater countries and the global community is treating. UNCSD2012 is an opportunity for the global community to recognize the linkages among wastewater, food and energy by rallying around a common vision of wastewater management, in recognition of wastewater as a vital resource for development.

Water use in agriculture

It is impossible to address management of water resources and growing water scarcity without addressing water use in agriculture. Currently, 70% of all freshwater withdrawals are used by the agricultural sector for irrigation [xi].

Economic progress, notably in the emerging countries, translates into increased demand for diversified diets. World food demand will surge both because of this phenomenon and from sheer population growth. Food production will need to increase by 70% globally and by 100% in developing countries by 2050[xii] . Yet, both land and water resources, the basis of our food production, are finite and already under heavy stress. Future agricultural production will need to have higher and more sustainable yields if people are to be fed adequately. Given the growing competition for water from industry, agriculture, power generation and people, new sources of water will have to be identified especially if ecosystems are to be maintained and restored. In this context it does not seem possible that irrigated agriculture uses much more water than today. In OECD countries, freshwater use in irrigation is already decreasing.

It is therefore not only desirable but imperative that water systems for agricultural purposes, irrigation in particular but also for livestock care, be more efficient, thereby raising the productivity of farmland. Gaining more yield and value from less water has many benefits: it can reduce the need for "new" water; it can limit and even reverse environmental degradation and ultimately contain the competition for water. Such progresses should not be limited to irrigated agriculture through technological improvement but should encompass the selection of appropriate crops while not loosing effective methods of traditional farming [xiii].

While the water constraint is still underestimated and undervalued by many food scenarios, the linkage between water and food is increasingly understood. The global community needs to take action to grow more food with less water in order to mitigate current and potential difficulties in the future. Objectives and relevant indicators recognizing the fundamental relationship between agricultural output and water use could energize stakeholders to take a fresh look.

THE THREE WATER OBJECTIVES

These three water Objectives are offered to the UNCSD2012 to help sharpen the substantive discussion on water and sanitation. It is possible that countries will negotiate precise targets against which to quantify progress: in this case, potential targets are hereafter proposed. Making improvements as suggested below will contribute to sustainable development and poverty alleviation as well as to a green economy.

Objective 1: Access to safe drinking water and sanitation

Examples of targets

- Universal access to basic sanitation and improved water sources by (year)
- Universal access to safe drinking water by (year)
- Development of good quality services in cities at a rate that exceeds the rate of urban growth
- Drinking water networks to supply water continuously (24/7) in order to ensure safety and availability of water

Possible actions

Such targets would need to be supported by the establishment of feasible sets of global, regional and national targets and the adoption of meaningful and measurable indicators to keep track of progress on the basis of five-year rolling milestones. An integrated monitoring programme of the indicators linked to the criteria established for the human right to water and sanitation and the factors determining the enabling environment is to become effective after 2015.

Objective 2: Common vision of wastewater management

Governments together decide to strengthen their respective actions on pollution of freshwater by adopting a shared vision of urban, industrial and agricultural wastewater management including collection, treatment and / or water reuse

Examples of targets

- Reduce the percentage of wastewater that is not collected safely from households
- Reduce the percentage of wastewater that is discharged into the natural environment without treatment
- Increase the percentage of urban wastewater that is treated for safe reuse in agriculture and industrial processes
- Reduce the amount of water pollution arising from agriculture
- Reduce the amount of water pollution released by industry

Possible actions

- Establish or strengthen national policies and regulations for wastewater collection, treatment and discharge in order to ensure that individual and collective practices and systems are sufficient to protect health of individuals against potential contamination by others and by economic activities and to protect natural ecosystems against harmful pollution;
- Get organized to monitor and stimulate at national level progress of wastewater collection and treatment by collective systems and individual facilities;
- Get organized to monitor and control potential contamination of drinking water sources by man-made pollution;
- Introduce or strengthen laws and other forms of regulation to support the reduction of pollutants and make water reuse possible, including the recovery of positive substances;
- Request the United Nations Environmental Program (UNEP) or another UN agency to collect national statistics on wastewater management and report on its global progress.

Objective 3: More food with the water available

Adoption of an internationally agreed political objective linking food production and water use through increasing global water productivity of agriculture

Examples of targets

- Irrigated agriculture to grow more food with the same amount of freshwater and without over-abstracting water tables
- 70% of irrigated land using technology that increases crop per drop by 20%
- Organizing urban use of water to allow its reuse in agriculture in all water scarce areas

ENDNOTES

i. UNICEF and WHO – Joint Monitoring Programme (JMP) Progress on Sanitation and Drinking-Water, 2010 Update 2010. The JMP defines “improved” access to water as use of the following sources: piped water into

dwelling, yard or plot; public tap or standpipe; tubewell or borehole; protected dug well; protected dug well; protected spring; rainwater collection.

ii. C. de Albuquerque, Special UN Rapporteur on the human right to safe drinking water and sanitation, UN-HRC,2010 page number to be confirmed
iii. UNICEF International Year of Sanitation Fact Sheet 2008.
iv. UN Millennium Project Task Force on Water and Sanitation Water and Sanitation: Health, dignity and development: what will it take? 2005, pg. 20.
v. Progress on Sanitation and Drinking-Water 2010 Update pg. 12.
vi. Water and Sanitation Programme, World Bank Economic Impacts of Inadequate Sanitation in India 2010.
vii. The official MDG targets for water is to half, by 2015 the number of people lacking access to safe drinking water, and for sanitation to half by 2015 the number of people lacking access to basic sanitation.
viii. Some countries have reflected national policies regarding wastewater in Integreated Water Resource Management and Water Efficiency Plans. These Plans were called for in 2002 in Johannesburg in Article 26 of the World Summit on Sustainable Development Action Plan.
ix. Corcoran, E., C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli (eds). 2010. Sick Water? The central role of wastewater management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal, pg. 9.
x. OECD (2011), Benefits of Investing in Water and Sanitation: An OECD Perspective, OECD Publishing.
xi. World Water Assessment Programme The United Nations World Water Development Report 3: Water in a Changing World 2009.
xii. FAO High-level Expert Panel How to Feed the World 2050 Oct. 2009.
xiii. Comprehensive Assessment of Water Management in Agriculture. 2007. Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London: Earthscan, and Colombo: International Water Management Institute.

Posters

1. **Alternative approaches in managing insect pests of lowland vegetables**
Roxas, A. C., Pagaduan, R. V., Aquino, C. D.
Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines

2. **An economic analysis of production and marketing of tomato (*Lycopersicon esculentum*) in Nadia district of West Bengal province of India and identification of relevant constraints**
Saha, P., Ali, Md. H., Akhtar, S., Pal, A. K., Chudali, H. D.
Department of Agricultural Economics, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, P.O. Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

3. **Assessment on cooperation pattern between the farmers and exporter in marketing of red chili (Case study in Poncokusumo district, East Java)**
Pudji, S., Yuniarti
Assessment Institute for Agricultural Technology East Java, Indonesia

4. **Breeding of sweet potato (*Ipomoea batatas* L.) for fresh consumption**
Kurubungerdjit, R., Suthanukool, P., Poolperm, N., Dangpium, N., Tayamanont, P., Buara, P.
Sukhothai Horticultural Research, Center Srisatchanarai, Sukhothai, Thailand

5. **Control of brown color in minimally processed eggplant (*Solanum xanthocarpum Schrad.* and *Wendl)***
Somboonkaew, N., Wanasirakul, S., Wanich, M., Chinaputhi, A.
Postharvest and Processing Research and Development Office, Department of Agriculture, Bangkok 0900, Thailand

6. **Cucurbit breeding at AVRDC – The World Vegetable Center**
Dhillon, N.P.S., Phethin, S., Chung-cheng, L.
AVRDC – The World Vegetable Center, East and Southeast Asia, Kamphaeng Saen, Nakhon Pathom 73140, Thailand

7. **Development of gynoecism in ridge gourd (*Luffa acutangula* L.): Novel approach**
Jadhav, B. P., Deshmukh, N. D., Nilakh, S. B., Halakude, I. S., Rajput, J. C.
Nirmal Agricultural Research and Development Foundation, Pachora Dist. Jalgaon, India

8. **Diversity analysis in sweet gourd (*Momordica subangulata* ssp. renigera [(G.Don) W.J.de Wilde)] accessions collected from eastern India**
Chakraborty, L., Acharyya, P.
Department of Horticulture, Institute of Agricultural Science, University of Calcutta, Kolkata, India

9. **DNA marker based genetic diversity in oriental pickling melon (*Cucumis melo* var. conomon)**
Mukunda Lakshmi, L., Lingaiah, H.B., Mohan Rao, A., Ramesh, A., Narayana Swamy, P., Putta Raju, T.B., Pitchaimuthu, M.
University of Horticultural Sciences, Bagalkot- 587 102, Karntataka State, India

10. **Effect of Bt Cry1Fa1 gene on target insect, non-target insect and economic benefit of brinjal**
Mazumdar, B., Naphade, P., Mali, A., Kunchge, N., Agrawal, S.S.
Bejo Sheetal Seeds Pvt. Ltd.P.O Box 77, Jalna 431 203, India

11. **Effect of phosphorus and micronutrients on production potential of French bean (*Phaseolus vulgaris* L.)**
Mandal, J. Ghosh, C.
Department of Crop Improvement, Horticulture and Agricultural Botany, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal 731236, India

12. **Effect of organic and inorganic fertilizer on growth and yield of Sprouting Broccoli (*Brassica oleracea* L.var. *italic* cv. Aishwarya)**
Biswas, M.R, Prasad, V.M.
Department of Spices & Plantation Crops, Bidhan Chandra Krishi Viswavidyalaya (B.C.K.V), Mohampur, W.B, India

13. **Effects of bio-extracts on growth and yield of vegetable soybean under substrate culture**
Phosri, P.
Department of Agricultural Technology, Faculty of Science and Technology, Thammasat University, Pathum Thani 12121, Thailand

14. **Evaluation of chili (*Capsicum annum* L.) genotypes for Heat tolerance**
Jadhav, B. P. , Deshmukh, N. D., Nilakh, S. B., Halakude, I. S., Rajput, J. C.
Nirmal Agricultural Research and Development Foundation, Pachora Dist. Jalgaon, India

15. **Framing of fruit ideotype through correlation and path coefficient analyses utilizing morphological and quality characters of fruits in tomato (*Solanum lycopersicum*)**
Akhtar, S., Chattopadhyay, A., Hazra, P
Department of Vegetable Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, India

16. **Genetic improvement of adopted okra cultivars for YVMV disease resistance involving wild relatives in genus *Abelmoschus***
Dhankhar, S. K.
Department of Vegetable Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125004, Haryana, India

17. **Growth and yield of Okra (*Abelmoschus esculentus*) as influenced by seed weight**
Thapa, U., Rai A. K.
Department of Vegetable Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, Nadia 741252, India

18. **Horticultural characterization and propagation of moringa germplasm at AVRDC – The World Vegetable Center**
Palada, M.C., Wu, D.L., Ebert, A.W.
College of Agriculture, Resources and Environmental Sciences, Central Philippine University, Iloilo City, Philippines

19. **Identification of new TLCV resistance sources of Tomato (*Lycopersicon esculantum* L.)**
Jadhav, B. P., Deshmukh, N. D., Nilakh, S. B., Halakude, I. S., Rajput, J. C.
Nirmal Agricultural Research and Development Foundation, Pachora Dist. Jalgaon, India

20. **Integrated crop management for vegetables grown under protected culture in the Philippines**
Aganon, T.M. Aganon, C.P., Manipon, A.O, Nicolas, R.R.
Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines

21. **Integrated nutrient management to improve yield and quality of onion bulb**
Dudi, B.S., Chohan, P.K., Dhankhar, S.K., Khayaliya, J.
Department of Vegetable Science, Haryan Agricultural University, Hisar, Haryana, India

22. **Nutrient management in organic vegetable production and its relevance to productivity, quality and soil health**
Prabhakar, M., Hebbar, S.S., Nair, A.K., Panneerselvam, P., Shivashankara, K.S., Chinnu. J.K.
Division of Vegetable Crops, Indian Institute of Horticultural Research, Hessaraghatta Lake P.O., Bangalore 560 089, India

23. **Performance of F1 hybrid involving male sterile line in ridge gourd (*Luffa acutangula* L. (Roxb))**
Kannan, D., Pradeepkumar,T ., Hegade, V.C.
Department of Olericulture, College of Horticulture, Vellanikkara, P.O. Kau, Trichur, Kerala, India

24. **Performance of advanced lettuce lines at different locations**
Quamruzzaman, A.K.M., Ahmad, S.
Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute
Joydebpur, Gazipur-1701, Bangladesh

25. **Performance of bacterial wilt resistant hybrids of tomato (*Solanum lycopersicum* L.) under polyhouse**
Sharma, P, Bilashini, M., Bhardwaj, N.
Department of Vegetable Science and Floriculture, Himachal Pradesh Agricultural University, Palampur 176062, India

26. **Performance of gynoecious hybrids of cucumber under plastic greenhouse**
Bhatia, A.K. Batra,V.K., Singh, Vijay Pal
Department of Vegetable Science CCS Haryana Agricultural University, Hisar, Haryana, India

27. **PGPR inoculation of open-pollinated and hybrid tomatoes under field condition**
Delfin, E. F., Rodriguez, F. M., Paterno, E.S.
Institute of Plant Breeding-Crop Science Cluster, College of Agriculture, UP Los Baños, College, Laguna, Philippines

28. **Population correlates and critical pest level (CPL) of the leafhopper, *Amrasca biguttula* and associated insect pests attacking** o**kra, *Hibiscus esculentus* (L.)**
Agsaoay, M. V., Briones, R. C.
Institute of Agriculture and Forestry, Tarlac College of Agriculture, Tarlac, Philippines

29. **Potentialities of growing Kharif onion as high value crop in the plains of West Bengal**
Thapa, U., Das, R., Chattopadhyay, N.
Department of Vegetable Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, Nadia -741252, India

30. **Standardization of agro-techniques for capsicum production under greenhouse**
Bhatia, A. K. Batra, V.K. Singh, V. P.
Department of Vegetable Science CCS Haryana Agricultural University, Hisar, India

31. **Studies on genetic variability in cherry tomato (*Solanum lycopersicum* var. cerasiforme)**
Prema, G., Lindiresh, K. M., Santhosha, H. M.
P.G. Centre, UHS Campus, GKVK, Bangalore, India

32. **Study collection and conservation of sweet potato (*Ipomoea batatas* L.) in Thailand**
Poolperm, N., Tayamanon, P., Dangpium, N., Kurubungerdjit, R., Jamjumroon, S., Linwattana, G.
Office of Agricultural Research and Development Region 2, Wangthong, Phitsanulok, Thailand

33. **Study collection and conservation of taro (*Colocasia esculenta* L.) in Thailand**
Poolperm, N., Tayamanon, P., Dangpium, N., Loungkraw, T., Jamjumroon, S., Linwattana, G.
Office of Agricultural Research and Development Region 2 , Wangthong, Phitsanulok , 65130 , Thailand

34. **Substitution of chemical fertilizer with vermicompost and its influence on production potential of cabbage (*Brassica oleracea* L. var. *capitata*)**
Ghosh, C., Mandal, J., Chatttopadhyay, G.N.
Department of Crop Improvement, Horticulture and Agricultural Botany, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India

35. **Sulabha - A high yielding variety of ivy gourd (*Coccinia grandis* Voigt)**
Sadhankumar, P. G., Raju, V.K., Nirmaladevi, S., Gopalakrishnan, T.R. Peter, K.V.
Department of Olericulture, Kerala Agricultural University, Kau P.O, Thrissur, Kerala, India

36. **Surveillance and identification of *Xanthomonas campestris* pv. *campestris* races in Taiwan**
Hseu, S. H., Wang, S.T.
Department of Plant Protection, Fengshan Tropical Horticultural Experiment Branch, Kaohsiung City 83052, Taiwan

37. **Trichoderma-based management against major soil-borne pathogens of selected crops in the northern highlands of the Philippines**
Mangili, T.K., Oloan, R.M., Lorezco, T.M., Perez, J.C.
Bureau of Plant Industry, Guisad, Baguio City, Philippines

38. **Varietal improvement of Jinda Chili (*Capsicum annuum* L.)**
Chokpachuen, J., Nimkingrat, T., Kumcha, U., Kurubunjerdjit, R., Praporm, S., Poolperm, N., Kraikruan, W.
Si Sa Ket Horticultural Research Centre, Horticultural Research Institute, Thailand

39. **Varietal improvement of Loei Chili (*Capsicum annuum* L.)**
Austin, J., Ketsakul, S., Kumlee, C., Praporm. S., Somnuke, S. Kumcha, U.
Si Sa Ket Horticultural Research Centre, Si Sa Ket, Thailand

40. **Varietal trial of sweet potato (*Ipomoea batatas* L.) for processing**
Tayamanon, P., Dangpium, N., Kurubungerdjit, R., Jamjumroon, S., Poolperm, N., Sittinam, T., Sompak, S., Puttaeong, S.
Phichit Agricultural Research and Development Center, Muang, Phichit, Thailand

41. **Variety improvement of Yod Son Chili (*Capsicum annuum* L.)**
Austin, J., Ketsakul, S., Kumlee, C., Praporm. S., Somnuke, S., Kumcha, U.
Si Sa Ket Horticultural Research Centre, Si Sa Ket, Thailand

42. **Yield comparison of taro (*Colocasia esculenta* L.)**
Longkraw, T. Tayamanon, P., Dangpium, N., Vinotchana, N., Jamjumroon, S., Poolperm, N., Linwattana, G.
Phichit Agricultural Research and Development Center, Muang, Phichit, Thailand

Awards

Best Oral Presentation

Developing a vegetable E-trading: Characterization from the vegetable marketing practices in Northern Mindanao, Philippines
Allan P. Bacho
Agribusiness and Marketing Assistance Division, Department of Agriculture-Regional Office 10, Cagayan de Oro City, Philippines

Special Mention (Oral Presentations):

Can public GAP standards reduce agricultural pesticide use? The case of fruit and vegetable farming in Northern Thailand
Pepijn Schreinemachers
The Uplands Program, Faculty of Agriculture, Chiang Mai University, Thailand

The control of root knot nematode of tomato by "Jeevatu" based organic liquid manure
B. K. Poudyal
Senior Vegetable Development Officer,
Central Vegetable Seed Production Centre, Khumaltar, Lalitpur, Nepal

Best Poster Presentation

Effect of Bt Cry1Fa1 gene on target insect, non-target insect and economic benefit of brinjal
Mazumdar, B., Naphade, P., Mali, A., Kunchge, N. and Agrawal, S. S.

Participants

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