Indigenous Vegetables Worldwide: their Importance and Future Development

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Abstract

Indigenous (traditional) vegetables are best defined as species that are locally important for the sustainability of economies, human nutrition and health, and social systems—but which have yet to attain global recognition to the same extent as major vegetable commodities such as tomato or cabbage. Given the hundreds of indigenous vegetables consumed worldwide, their accumulated value for mankind is considerable. These species deserve much greater recognition and investment in agricultural research and development than they have presently.

Indigenous vegetables are primary candidates for greater use of crop biodiversity in horticulture as they are already consumed and enjoyed locally and can be produced profitably in both rural and urban environments. Yet many such species have received little scientific attention to date. More effort in research and development would likely produce rewarding results, as productivity increases in these neglected crops are much easier to realize than for intensively researched staple cereals.

Questions therefore are:
1) How can we rescue, conserve and utilize the genetic diversity of cultivated and wild forms of indigenous vegetables under threat of genetic erosion?
2) How can the lack of quality seed be overcome?
3) Given the increased levels of biotic and abiotic stresses driven by climate change, as well as existing rural-urban migration trends, how can these indigenous vegetables help produce sufficient quantities of quality food?
4) Can postharvest management be improved to make market chains more effective and profitable?
5) Can greater consumption of such diverse and nutritious indigenous vegetables be encouraged, knowing that changing dietary habits is a difficult exercise?

INTRODUCTION

Whereas 800-900 million people do not get enough food to meet their energy needs, roughly half of the world's population has some kind of micronutrient deficiency (Mason et al., 2001). In developing countries, nearly 20% of the population suffers from iodine deficiency. Subclinical vitamin A deficiency affects about 25% of children, and more than 40% of women are anemic (Mason et al., 2001). Increasing dietary diversity and the intake of vegetables and fruits is widely recognized as a key strategy to address this problem (Hughes and Keatinge, 2013). Global public spending on agricultural research and development reached US$ 31.7 billion in 2008 and has increased at an average annual rate of 2.4% since 2000, mostly driven by China, India and the United States (Beintema et al., 2012). Although data are not disaggregated by crop, it would be safe to say that very little of this money is spent on research for fruit and vegetables, and virtually none of it goes into the improvement of indigenous vegetables.

Indigenous or traditional vegetables show very substantive biodiversity, are adapted to specific marginal soil and climatic conditions, and often can be grown with minimal external inputs (de la Peña et al., 2011; Hughes and Ebert, 2013). Diversifying current production systems with traditional vegetables will increase their heterogeneity and will subsequently lead to better resilience to abiotic and biotic stresses (Newton et al., 2011). Lin (2011) provides several examples of successful pest and disease suppression and buffering against climate variability in more diverse agroecosystems. This should be of great relevance to rural, poor smallholders with limited land resources and agronomic inputs, but sufficient labor. The generally shorter production cycles of traditional vegetables compared to most other field crops would be an added advantage. Yet, lack of market access, substantive production risks and lack of knowledge constrain smallholders from better exploiting the opportunities represented by these crops. Research is needed to understand the potential opportunities and perceived constraints faced by poor smallholder farmers in cultivating indigenous vegetables to be able to devise adoption and dissemination strategies to best meet their needs. The production of indigenous vegetables is to a large extent constrained by limited demand. Previous studies have shown that interventions designed to increase vegetable consumption among adults and children can be effective (Knai et al., 2006; Nicklas et al., 1998; Pomerleau et al., 2005). Obel-Lawson (2006) showed that consumers in Nairobi have a negative perception about African leafy vegetables as they are considered "low status" food. This view is also held in the South and Central Pacific regarding local indigenous vegetables. However, Obel-Lawson's study also showed that consumers can easily adopt positive perceptions after being exposed to simple media messages on the value of African leafy vegetables for health and nutrition. Research is therefore needed on cost-effective ways to increase the consumption of indigenous vegetables by promoting their nutritional, cultural and culinary properties.

Traders and consumers tend to over-value vegetable attributes such as aesthetics, color, keeping quality, firmness and texture and seemingly under-value their nutritional contribution to diets. This leads to a general underinvestment in crop breeding to enhance plant nutrient density (Unnevehr et al., 2007). Yet awareness of the importance of nutrition recently has increased in many countries, which should create new opportunities for indigenous vegetables. For global vegetables in temperate zones, Davis and Riordan (2004) have reported falling nutrient quality in a wide range of temperate vegetables bred and produced in the USA since 1950. Evidently, seed companies and public sector vegetable breeders have been mainly breeding for higher yield and other more rewarding aesthetic and postharvest characteristics. This trend needs to be rapidly reversed if world malnutrition issues are to be addressed through balanced diets. Relatively nutrient-dense indigenous vegetables thus have a potentially key role to play in improving human nutrition. Amongst other indigenous vegetables, this applies, for example, to cucurbits, specifically bitter gourd

(*Momordica charantia*) and tropical pumpkin (*Cucurbita moschata*), which are important indigenous vegetables in the tropics and possess good nutrient density. Bitter gourd fruits are a rich source of β-carotene, vitamin C, folic acid, magnesium, phosphorus and potassium (Yuwai et al., 1991). The fruits are often used in folk medicine to treat type II diabetes, a rapidly spreading non-communicable disease that afflicts millions of people living in low- and middle-income countries and is most prevalent in proportional terms in many countries in the South and Central Pacific (WHO, 2012; IDF, 2013). In addition to the fruits, which are eaten stir-fried, in soups, pickled or raw, the young tender shoots of bitter gourd also can be consumed. Tropical pumpkins abound in α- and β-carotenes and lutein, and are a rich source of dietary fiber. As a precursor of vitamin A, β-carotene is required for the proper development and functioning of the eyes, while lutein has an important photo-protective function in the macular region of the retina (Azevedo-Meleiro and Rodriguez-Amaya, 2007). Almost all parts of pumpkin—fruit, leaves, flowers, and seeds—are edible and can be prepared in a variety of dishes, using the fruit in soup, baked, stuffed, stir-fried or as a sweet dessert. Tender leaves and shoots are also good sources of micronutrients including provitamin A and minerals such as calcium, iron, and zinc. Growing vegetables, in particular leafy nutrient-dense species, in home gardens is important for families to obtain daily access to safe and nutritious food (Keatinge et al., 2012). This is very important for reducing vitamin A and iron deficiency in vulnerable groups such as elderly people and pregnant women, and in improving maternal health and the health of children under five (Lyimo et. al., 2003). Poor nutrition results in morbidity, mortality and poor growth in children, which eventually affects their ability to learn (Ghana Demographic Health Survey GDHS, 2003).

How can we rescue, conserve and utilize the Genetic Diversity of Cultivated and Wild Forms of Indigenous Vegetables under Threat of Genetic Erosion?

Competition for the ever-shrinking land area available and suitable for horticultural crop cultivation is increasing worldwide due to rapid human population growth. Indigenous vegetables and other neglected and underutilized plant species compete for land, water and labor resources with other crops and with many other human activities, especially in peri-urban areas. Genetic biodiversity in all cropping systems and in home gardens is under constant threat from habitat loss, overexploitation of land for commercial or subsistence reasons, the introduction of exotic species, and rapid urbanization (Kahane et al., 2013). These factors discount the importance of many indigenous vegetables as mainstays of a number of local communities for food, nutrition, income and for their medicinal value (Abukutsa-Onyango, 2010). For example, while still holding only a niche market in Africa, indigenous vegetables are regularly produced and gathered for home use and also sold fresh or in semi-processed form at both local open markets and urban supermarkets (Afari-Sefa et al., 2012). The market share of indigenous vegetables in Nairobi, Kenya has been going up recently, accounting for about 30% of overall vegetable sales(Vorley et al., 2007). Likewise, the consumption of African leafy indigenous vegetables has been increasing in several countries in Eastern Africa (Mwangi and Kimathi, 2006; Smith and Eyzaguirre, 2007; Chelang'a et al., 2013). Similarly, in India many indigenous vegetables are either collected from the wild or are cultivated. The products are sold fresh in the harvesting season, dried and used in home consumption during "hungry months", or sold in markets for income generation. Regional demand for vegetable crops of underutilized species needs to be better identified, particularly for the collection of those species showing traits of high yield, good quality, resistance to diseases and pests, or tolerance to abiotic factors (Rai et al., 2004).

Nevertheless, research and development funding for indigenous fruit and vegetable crops is chronically deficient—a situation that demands urgent attention (Keatinge et al., 2010). The factors likely to predetermine support for research and development funding for these crops are first, an enhancement of descriptors of the socioeconomic and cultural value of indigenous vegetables; second, actions to counteract their perceived stigma as "famine foods" among the general public, and third, better provision of the evidence of their potential for wide use in overcoming malnutrition through effective, balanced diets.

Indigenous vegetables often are the principal sources of essential micronutrients especially for the poorest people, as shown from surveys of people across a wide range of incomes in Tanzania (Weinberger and Msuya, 2004). More research is needed to strengthen the case of the value to society of indigenous vegetables, such as provided by Yang et al. (2013), who report that in addition to the beneficial nutrient density of many indigenous vegetables in sub-Saharan Africa, species such as moringa (*Moringa oleifera*), amaranth (*Amaranthus* spp.), sweet potato (*Ipomoea batatas*) leaves and spider plant (*Cleome gynandra*) also have high levels of anti-inflammatory phytochemicals such as flavonoids and other antioxidants that are of value to human health.

African indigenous vegetables play a significant role in addressing increasing incomes, reducing malnutrition and maintaining biodiversity (Habwe et al., 2009). Traditional leafy vegetable diversity is an important part of Tanzania's biocultural heritage, particularly with regard to food security, nutrition and health. In many African countries locally adapted landraces are known as "farmer varieties" and these still contribute significantly to sustainable food production, household nutrition and increased incomes. Typically, landraces are mainly grown for family use or for the local market. Indigenous leafy vegetables can provide a substantial contribution not only to poverty reduction but also to increasing food security and maintaining health in vulnerable communities, as indigenous leafy vegetable production can often be done with little capital investment (Abukutsa-Onyango, 2003).

These indigenous vegetable crops have been neglected by researchers, policy makers and funding agencies and are currently threatened with extinction, which would mean a substantive reduction in biodiversity (Adebooye and Opabode, 2004). African indigenous vegetables have yet to be fully integrated into the mainstream of agricultural production. Production is generally on a small-scale, employing traditional technologies and knowledge (Ojiewo et al., 2010). The introduction of new vegetable varieties into traditional agroecosystems is one of the major factors driving genetic erosion, can lead to loss of landraces and associated local knowledge (Rhoades and Nazarea, 1999).

AVRDC's Eastern and Southern Africa seed repository currently conserves about 2500 accessions of 20 indigenous crops plus some older ("traditional") varieties of global crops. The number of accessions of indigenous African vegetables represents the largest part of this collection (76%). AVRDC's seed repository is thus the largest collection of indigenous African vegetable germplasm on the continent; this collection is well categorized and fully available in the public domain (http://avgris.worldveg.org). The main objective is to conserve vegetable germplasm and to provide seeds of the crops that are vital to meet the nutritional needs of the African population and to determine whether such crops have opportunities for expansion at a global level. Among the crops the biggest collections in the seed repository are of African eggplant (*Solanum* spp. 359 accessions) followed by okra (*Abelmoschus* spp. 334 accessions) and roselle (*Hibiscus sabdariffa* 298 accessions). The origin of the plant material is from 35 countries mostly from Africa and a small part of this collection came from genebanks in France, the USA, Laos, Thailand and Australia.

Opportunities remain in African environments for in-situ strategies for vegetable species to conserve crop evolutionary processes and provide scope for ongoing evolution, particularly in response to environmental changes, and pathogen and pest pressures which fluctuate in numbers and genetic composition (Brown, 2000). The preservation and utilization of crop genetic diversity is of particular importance in the more marginal, diverse agricultural environments where modern plant breeding has had much less success (Tripp and van den Weineke, 1996).

Moringa (*Moringa* spp.) is a well-known, very versatile, high-nutrient density vegetable crop in most tropical countries, and is most commonly produced in home gardens rather than in cultivated field situations. The few existing breeding programs have yet to produce consistent success. In India, where moringa breeding is in progress, there are different species and types available but these are neither well-documented nor used as parental material.

National genebanks need support and encouragement to increase and fully categorize their collections of local indigenous vegetable germplasm now and into the future. The complex taxonomy of many of these species and the need for precise identification are areas where capacity building is likely to be required for staff of national and international genebanks. For example, in the case of the African nightshades and eggplants *(Solanum scabrum, S. nigrum, S. villosum, S. aethiopicum, S. macrocarpon, S. anguivi*, etc.) effective taxonomic characterization is mandatory given that their near relative found in Europe and North America (*Atropa belladonna*) is toxic to humans (Yang and Ojiewo, 2013). The Global Action Plan for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture, adopted at Leipzig (Germany) in June, 1996 gave clear priority to the conservation and use of minor and underutilized crop species (FAO, 1996). Since then, nothing has been done to remove this continuing research need from the Global Priority List.

2) How can the lack of quality seed be overcome?

Lack of a sustainable supply of quality seeds is the main bottleneck in the development of indigenous vegetables, with more than 75% of seeds being supplied through informal sources (AVRDC, 2008). Until very recently farmers were the sole sources of such seeds (Weinberger and Msuya, 2004). Prior to the advent of the Economy Recovery Program initiated by the World Bank in several sub-Saharan Africa countries in the mid-1980s, seed supply systems in most countries were largely dominated by the public sector, but these often have become non-functional due to resource constraints, with informal supply systems remaining important, particularly for indigenous crops. More recently private seed companies have been encouraged to help in the role of public organizations as a formal approach to seed systems, but with varying levels of success in the indigenous vegetables sector, as most countries have no clear guidelines for formal variety releases of vegetables in general. Thus, despite recent modest improvements in seed supply by the private sector, informal sources comprising different community seed production system models, farmer owned and recycled seeds, gifts or exchange with other farmers, are still by far the most important sources of seed for smallholders. Smallholders face many constraints such as lack of information about production methods, no or outdated price information, and lack of credit to purchase inputs, while volatile prices discourage commercialization and poor infrastructure raises the cost of inputs and lowers revenue from crop sales (Minot, 2011). For development of a more effective seed supply system, all actors, including individual farmers, farmer groups, public seed enterprises, research and development organizations and local and multinational seed companies now have key roles to play in harmony with each other.

Smallholder farmers and home gardeners of indigenous vegetables need open or self-pollinated varieties, as few hybrids are available and seed of those that do exist cannot be saved by farmers for planting in the subsequent season. There is a general reluctance among seed companies, for example in India, to sell seeds packed in the small volumes required by smallholder farmers, which they perceive to increase their sales costs.

Seed moisture levels during storage are the biggest hurdle to seed longevity and good germination. Community seed production and storage systems must be set up in villages, where growers can be trained to produce reasonably genetically pure seed to store in low-relative humidity conditions after drying (Manzanilla et al., 2011; Ebert et al., 2013). The availability of quality seed for indigenous vegetables can be increased through the development of primary and elite seed production facilities in research institutes and by the private sector. Training farmers to develop specialized skills for seed multiplication and encouraging them to become contract seed growers for the private sector would be a major factor in overcoming the present poor and irregular seed supply. Farmer training to improve efficiency in pesticide use, harvesting, seed extraction, and seed marketing has shown that seed yields can be increased substantially (http://avrdc.org). A range of formal private and public sector models can be employed; all can work well in specific situations and can substantially improve farmer incomes (ASARECA, 2012; Afari-Sefa et al., 2013). Seed exchange among farmers and farm families can be an important cultural force in some societies that should not be ignored in the creation of new seed systems (Manzanilla et al., 2011).

Public seed enterprises in many countries largely focus on strategic staples and export crops and thus underplay the need for investment in vegetables in general and indigenous vegetables in particular; this includes seed certification and other regulatory bodies. Many countries, for example many countries in sub-Saharan Africa, do not have separate variety release systems for vegetable crops (Afari-Sefa et al., 2012), and apply inappropriate valuation criteria to vegetable species such as “Value for Cultivation and Use” (VCU) developed specifically for use in cereal crops. In most cases their main contributions are in the area of quality control and foundation seed provision. The mounting interest in consumption and use of indigenous vegetables in many countries demands that this situation now be addressed effectively (ASARECA, 2012; Karanja et al., 2012).

Since the mid-1980s, seed programs have turned away from supporting state seed enterprises and toward the development of a more diverse and competitive private seed sector. The number of private firms involved in seed production has increased, although not as much as would be desired as private firms are reluctant to provide seed for currently relatively unprofitable and underutilized crops such as indigenous vegetables (Minot, 2008). In general, private sector seed companies are more efficient in the generation and distribution of seed than the public sector. There is a growing interest in vegetable seeds among private seed companies in eastern Africa that market both global and indigenous vegetable varieties, and have an interest in variety development and expanding and diversifying their crop range. They wish to expand their seed production to a greater volume and across an increasing geographical range (Dinssa et al., 2013). However, the majority of private companies—especially multinational companies—with sufficient capacity for variety release, seed production, processing and commercialization will invest only if they are sure they have full control over their marketable product. This objective is achievable only by breeding their own hybrids used for specific release only in those areas where plant breeders’ rights are enforced. Also, most private companies, especially multinationals, are mainly interested in a single variety grown over large geographical areas to simplify seed production, packaging and distribution (Dinssa et al., 2013) and therefore increasing profitability. The breeding program for indigenous vegetables in sub-Saharan Africa is in its infancy; selections are made from within existing natural populations (landraces) and genebank accessions. This is in contrast to the situation in India, where indigenous vegetable seed is sold by small private seed companies that produce and package local landraces of crops such as Malabar spinach

(*Basella* spp.), kangkong (*Ipomoea aquatica*), and amaranth. The public sector has released a few improved varieties of these crops, but may not produce enough seed for wide distribution. Some exceptions exist, such as the Indian Institute for Horticultural Research in Bangalore, which has its own seed production and distribution agency.

Other actors in the seed production sector can include nongovernmental organizations (NGOs) involved in agricultural development, disaster relief and rehabilitation (Weinberger and Msuya, 2004). In 2012, AVRDC, in collaboration with a local NGO in the eastern part of India, started producing superior home garden seed for year-round production of vegetables, including indigenous vegetables such as green leafy types (Malabar spinach and kangkong) and gourd species (bitter, bottle, ridge, etc.) (AVRDC, 2014). In Bangladesh AVRDC has an extensive home garden program (funded by USAID) that is implemented through two local NGOs.

A range of indigenous local vegetables are being tested for year-round cultivation such as stem amaranth, red amaranth, kangkong, Indian spinach, bottle gourd, bitter gourd, ridge gourd, snake gourd, okra, and eggplants (AVRDC, 2014). Ensuring the availability of quality seed is a key issue to assure the sustainability of home gardens with indigenous vegetables. Private sector seed companies and large NGOs have expressed keen interest in this new market and seed packs for small-scale home gardens can now be purchased widely in the country.

The nutrient-dense nature of many indigenous vegetables and their adaptation to local environments makes them most appropriate for NGOs that address problems of hunger and malnutrition. Collaboration between the research system, extension, seed (formal and informal seed systems) and NGOs is very important if the potential of indigenous vegetables is to be adequately exploited to improve nutrition, food security and income generation. Community seed production projects that can be classified as a semi-formal system have become quite common in several developing countries to address the widely known spatial, time, information and value gaps which inhibit development of the seed sector, provision of emergency seed relief, or simply the generation of income, but they often require external support (Minot, 2008) with corresponding challenges regarding their sustainability. Whereas early programs ignored the informal seed sector, there is now greater interest in understanding and learning from it, including attempts to combine the strengths of the formal and informal seed sectors in various semi-formal farmer-led seed enterprises and/or community seed production and distribution system models such as the quality declared seed system (see for example, Afari-Sefa et al., 2013) and the integrated seed systems development concept (see for example, Louwaars et al., 2013) among others.

3) Given the increased levels of biotic and abiotic stresses driven by climate change, as well as existing rural-urban migration trends, how can indigenous vegetable species help produce sufficient quantities of quality food?

Pests and diseases of indigenous vegetables worldwide are seriously under-researched and poorly understood. If indigenous vegetables are to gain in prominence, cover greater production areas than at present and possibly be monocropped it is likely that biotic stresses will increasingly pose serious threats to their sustainable production throughout tropical Asia and Africa (Gohole et al., 2013). Furthermore, Keatinge et al. (2013) and Keatinge et al. (2014) suggested that plant breeders should be ready for increases in average air temperature that might exceed 1 ^{o}C in the next 25 years at some locations worldwide. Severe weather induced by global warming such as high winds and flooding will also need to be addressed. Some indigenous vegetable species such as Malabar spinach have shown good tolerance and recovery after severe natural flooding at AVRDC in Taiwan (Ruby Hsiao, pers. comm. 2013). Global warming will also influence biotic stresses by allowing more generations of insects to reproduce in a given time period, it may alter the aggressiveness and epidemiology of pests and pathogens, it will also cause some bacterial and fungal diseases to be favored over others in a given location, thus requiring farmers to change their agronomic practices. Luoh et al. (2014) studied the effect of water stress on the nutritional yield of African indigenous vegetables grown in glasshouses at AVRDC Taiwan. Nutritional yield, defined as edible yield x nutritional content, was reduced in amaranth, nightshade, and most particularly Ethiopian kale (*Brassica carinata*). This included significant decreases in carotenoids, tocopherols, calcium and zinc. Of the six species tested, *A. hypochondriacus* and *S. scabrum* had the lowest nutrient losses under drought conditions.

Greater crop diversity, including more indigenous vegetable species, is thus a sensible tactic to be employed by farmers as the climate changes. This additional diversity should strengthen the overall resilience of farming systems (Keatinge et al., 2013; Keatinge et al., 2014). For example, the wild crop species of northeastern India are reservoirs of genetic diversity that have yet to be exploited for traits to counter biotic and abiotic stresses (Singh et al., 2012). In Bangladesh such crops are closely linked to cultural traditions and have an important role to play in supporting social inclusiveness. Traditionally these vegetables have made an important contribution to subsistence farming to support the well-being of rural people (Rahim et al., 2013).

1. Plant Insect Interactions. Information on the major insect and mite pests constraining indigenous vegetable production is scanty. Monitoring the incidence and infestation of various insect and mite pests on selected indigenous vegetables is being carried out by entomologists at AVRDC – The World Vegetable Center's regional locations. Examples follow:

Indigenous leafy vegetables are grown throughout sub-Saharan Africa and in South and Southeast Asia. In the case of the amaranth group, amaranth leaf webber (*Hymenia recurvalis*) is a cosmopolitan pest, and can cause severe yield losses. Stem weevils (*Hypolixus* spp.) also cause occasional damage to growing shoots and stems, especially in India, when winter amaranth is grown in summer. Striped flea beetle (*Phyllotreta striolata*) is the major insect pest on leafy brassicas such as Chinese cabbage, pak-choi, choi sum and Chinese kale (*Brassica* spp.) in Southeast Asia. Occurrence of these beetles at the seedling stage can kill plants. However, aphids (*Brevicoryne brassicae* and *Lipaphis erysimi*) are the predominant pests on Ethiopian mustard (*B. carinata*), a popular indigenous vegetable in eastern Africa. Besides causing direct feeding damage, aphids (*Aphis* spp.) also can transmit severe virus diseases to Ethiopian mustard. Aphids are also common in nightshade (*Solanum nigrum*) and on mint (*Mentha* spp.), reducing the quality of the produce. *Solanum torvum* fruits are readily infected by the eggplant fruit and shoot borer (*Leucinodes orbonalis*) and act as reservoir for the pest in India.

Cucurbits are also damaged by aphids (*Aphis gossypii*) in both tropical Asia and Africa. Pumpkin beetles (*Aulacophora* spp.) and spotted beetles (*Epilachna* spp.) are serious defoliators of bottle gourd and bitter gourd in Asia. Cucumber moth (*Diaphania indica*) is a major pest feeding on the leaves, flowers and young fruits of various gourds in South and Southeast Asia, whereas melon fly (*Bactrocera cucurbitae*) and melon thrips (*Thrips palmi*) are cosmopolitan pests on various cucurbit species.

Legume vegetables such as leafy cowpea (*Vigna unguiculata*), yard-long bean (*V. unguiculata* subsp. *sesquipedalis*) and lablab bean (*Lablab purpureus*) are highly susceptible to bean aphids (*A. craccivora*). Bean thrips (*Megalurothrips* spp.) are also a major pest feeding on the flowers of cowpea, yard-long bean and soybean (*Glycine max*), especially during cold and rainy periods, significantly reducing the harvestable grain yield. Reproductive organs of legume vegetables such as cowpea, yard-long bean, lablab bean, winged bean (*Psophocarpus tetragonolobus*), soybean, *Sesbania grandiflora* and *Canavalia* spp. are damaged by pod borers (*Maruca vitrata*, *Etiella zinckenella* and *Helicoverpa armigera*) and pod bugs (*Clavigralla* spp. and *Nezara viridula*). Most of these pests are highly prevalent in sub-Saharan Africa, and South and Southeast Asia. In the South Pacific *A. craccivora*, *M. vitrata* and *N. viridula* are pests found on yard-long bean, for example, in the Solomon Islands. *Riptortus pedestris* is also a pest on yard-long bean and the achiote tree (*Bixa orellana*) is used by subsistence farmers on Malaita, one of the Solomon Islands as a trap crop for this pest.

Vegetables of the *Malvaceae* family such as okra (*Abelmoschus* spp.), slippery cabbage (*A. manihot*), roselle (*Hibiscus sabdariffa*) and false roselle (*H. acetosella*) are highly prone to the damage by leafhopper (*Amrasca devastans*) and aphids. Severe infestations can lead to complete yield loss as the leaves become unsuitable for marketing and consumption. Both okra and jute mallow (*Corchurus olitorious*) leaves are severely damaged by flea beetles *(Podagrica* spp.) in sub-Saharan Africa. In addition, okra is also heavily damaged by pod borers (*Earias* spp. and *H. armigera*). *Okra yellow vein mosaic virus*, transmitted by whitefly (*Bemisia tabaci*) is a major threat to the crop in South Asia. The major pest on solanaceous vegetables, especially African eggplants and African nightshades (*Solanum* spp.) is the spider mite (*Tetranychus evansi*) in sub-Saharan Africa. Infested plants, if the mites are not controlled, are killed rapidly. The infestation is more severe during the dry season. In the Pacific, specifically in Papua New Guinea and the Solomon Islands, the flea beetle (*Nisotra basselae*) and the stem borer (*Earias vitella*) are major pests of slippery cabbage.

2. Climate Change and the Dynamics of Pests and Natural Enemies. Changing climate, especially increased carbon dioxide (CO_2) concentration and rising temperatures, may substantially alter the status of a pest species. For example, *Spodoptera litura* showed increased feeding on mungbean (*Vigna radiata*), when the plants were grown under elevated CO_2 concentrations due to an increase in mungbean plant sugar levels (Srivastava et al., 2002). Reproduction of cabbage aphid (*B. brassicae*) was significantly reduced, whereas it was substantially increased for green peach aphid (*Myzus persicae*) on *B. oleracea* plants (Bezemer et al., 1999). Besides CO_2, temperature also impacts insect pest species. For example, the winter mortality of the green stink bug (*Acrosternum hilare*) is predicted to be reduced by 16.5% by every additional 1 °C in air temperature (Kiritani, 2006). Increases in temperature also increase the number of generations in *B. tabaci* biotypes (Muniz and Nombela, 2001; Keatinge et al., 2014).

Climate change may also modify the performance of natural enemies under field conditions. For example, the natural enemies *Podisus maculiventris* (a generalist predator) and *Cotesia plutellae* (a specialist parasitoid) of the diamondback moth (*Plutella xylostella*), the principal insect pest of vegetable brassicas, discriminated only between the odors of intact and *P. xylostella*-damaged plants grown at ambient CO_2 concentration, preferring the odor of the damaged plants. The predators did not detect damaged plants grown under an elevated atmospheric CO_2 (720 μmol mol^{-1}) concentration, indicating a disturbance in the orientation behavior of the natural enemies (Vuorinen et al., 2004). Understanding the population dynamics of different phytophagous insects and their natural enemies in indigenous vegetable production systems will become a major scientific issue as the world warms rapidly.

3. Developing Integrated Pest Management Strategies. (i) Host plant resistance offers great scope for avoiding pest damage on indigenous vegetables. For instance, earlier work at AVRDC has confirmed the existence of tolerance in four non-heading Chinese cabbage (*B. juncea*) accessions (VI010611, VI010634, VI010635, and VI010637) to aphids

(*Rhopalosiphum pseudobrassicae* and *M. persicae*). Recent screening experiments using okra accessions from AVRDC germplasm have identified aphid (*A. gossypii*)-resistant okra accessions such as VI033805, VI036213, and VI051114, and leafhopper-resistant accessions such as VI041230 and VI033809. However, insect resistance screening has not been carried out for most of the other indigenous vegetable species that are available in AVRDC's collection. Further screening might identify valuable accessions with desirable horticultural traits for farmer use.

(ii) Sticky traps have been widely used in the management of sucking insects such as thrips, whiteflies and leafhoppers in global vegetables. However, recent findings have shown that use of kairomones (volatile chemicals from host plants) increased trapping of some thrips species up to six-fold (Nielsen et al., 2010). This strategy can be combined with the use of entomopathogens such as *Metarhizium anisopliae*. A semiochemical-baited autoinoculation device treated with *M. anisopliae* has effectively controlled thrips on French bean (*Phaseolus vulgaris*) in East Africa (Niassy et al., 2012). These novel strategies could be validated for use against the sucking insects on different indigenous vegetables in Asia and Africa.

(iii) Pheromones are widely used as monitoring and/or mass-trapping tools in integrated pest management programs. Effective pheromone lures are commercially available for pests such as *H. armigera*, *S. litura* and *P. xylostella*, and are being used in pest monitoring. Although sex pheromones have been identified in *M. vitrata* and *D. indica*, they are not highly effective in field conditions (Schläger et al., 2012). Similarly, the male-derived aggregation pheromone compound of *P. striolata* attracted a significantly higher number of beetles either alone or in combination with the host plant volatiles in laboratory conditions (Beran et al., 2011), although it is not apparently highly attractive in field conditions. These sex and aggregation pheromones are currently being refined at AVRDC, with the objective of using them in indigenous vegetable production systems.

(iv) Natural enemies play a significant role in regulating pest populations, including on indigenous vegetables. For example, parasitism rates of *H. recurvalis* of up to 60% by *Apanteles* spp. were recorded in India (Manoharan et al., 2010). In South Africa, Louw et al. (1995) found that the amaranth stem weevil (*H. haerens*) was predominantly attacked by *Entedon* spp. Three natural enemies of *M. vitrata* (*Phanerotoma syleptae*, *Therophilus javanus* and *T. marucae*) with high host specificity were identified in Southeast Asia (Srinivasan et al., 2013). However, a dearth of information about the natural enemies of major insect pests on different indigenous vegetables in Asia and Africa calls for an exploratory agroecosystem study to identify efficient and pest specific indigenous natural enemies, and in case of their absence, assess the possibilities for introducing exotic natural enemies.

(v) Given the short harvest intervals of most indigenous vegetables, biopesticides are highly suitable for pest management as they leave no residues and thus have no requirements for pre-harvest intervals. For instance, Nigerian isolates of *M. anisopliae* and *Beauveria bassiana* were highly pathogenic against adults of *A. craccivora* and leaf beetle (*Ootheca mutabilis*) on cowpea (Ekesi et al., 2000; Ekesi, 2001). *Bacillus thuringiensis*-based biopesticides are highly effective in controlling *M. vitrata* on yard-long bean in Thailand (Yule and Srinivasan, 2013). Several commercial *B. thuringiensis*, nuclear polyhedrosis virus (NPV), *M. anisopliae*, *B. bassiana* and neem (*Azadirachta indica*) products have been registered for the control of *S. litura*, *H. armigera*, *P. xylostella*, etc. in different countries in South and Southeast Asia as well as sub-Saharan Africa. These biocontrol agents may have a much greater role in the future for defending indigenous vegetables against key pests globally. In the Pacific, formulated essential oils from the neem and tea trees (*Melaleuca alternifolia*) were tested for their toxicity against *A. gossypii* on slippery cabbage. They were found to be toxic to the pest but not its natural enemies (Iramu, 2012).

4. The Importance of Plant Diseases on Sustainable Production of Indigenous Vegetables. Information about yield losses of indigenous vegetables caused by plant diseases is very limited. This is largely due to the meager research efforts devoted to such neglected crops. Nevertheless, potential yield losses have been indicated from the results of surveys conducted by AVRDC. For example, a considerable incidence (40-100%) of late blight (*Phytophthora infestans*) on nightshade was found in Cameroon, while a serious outbreak of southern blight (*Sclerotiorum rolfsii*) on African eggplant was found in Ghana during the rainy season of 2009.

Farmer knowledge of plant diseases of indigenous vegetables is insufficient. AVRDC 2009 survey results from Cameroon provide some insights. The number of farmers unable to identify diseases of amaranth was 96%, compared to 83% of the farmers being unable to identify insect pests. Damage caused by less conspicuous problems, such as viruses, nematodes, and wilting were not regarded by farmers as diseases but as issues caused primarily by climatic factors. Their knowledge of diseases affecting global crops was better than that for indigenous vegetables. The number of farmers being unable to identify a specific disease as a constraint was much lower for tomatoes (69%) than for amaranth (96%) or jute mallow (98%). Most respondent farmers (75%) in Cameroon were unaware of methods, other than the use of synthetic pesticides, for pest and disease management. This situation is not unique to Cameroon. The need to enhance the capacity of both scientists and farmers at the national level on disease diagnosis and management, as well as the different management options, is urgent.

5. Indigenous Vegetables Serving as a Reservoir for Diseases Infecting Global Vegetables. Common pathogens can infect closely related or even distantly related global and indigenous vegetables. For example, begomoviruses are important pathogens of tomato, pepper, and other crops. They were detected in sweet leaf bush (*Sauropus androgynous*) in Thailand recently (Shih et al., 2013). Three species of begomoviruses were identified, including a novel species. Frequency of co-infection of two different begomovirus species was high. This indicated that sweet leaf, a perennial shrub, acts as a potential nursery for genetic recombination between begomoviruses species and strains. Diseases of nightshade are similar to early blight, late blight and other diseases that affect crops in the economically important Solanaceae family. However, it is not clear whether the pathogen population infecting nightshade differs from those infecting other solanaceous crops. When managing vegetable diseases, the role of potential alternative host plants in the landscape needs to be considered.

6. Principles of Managing Diseases of Indigenous Vegetables. Disease profiles and their severity on indigenous vegetables may change in production systems with different levels of inputs and intensification. Correct diagnosis is a prerequisite for making decisions on effective disease management. For example, the foliar symptoms of web blight caused by *Rhizoctonia solani* on pak choi looks like the damage caused by leaf-feeding insects. Farmers may then resort to the use of insecticides to control the problem without a positive outcome. Misdiagnosis can lead to faulty decisions on control methods, and may result in a waste of resources.

After correct identification of the pathogen, plant diseases can generally be managed by integrating control practices using a “four principles” approach (Wang, 2010). The first aim should be to exclude pathogens from outside the country or active production areas through quarantine means. Pathogen-free planting materials (seeds, seedlings or other propagating materials) should be used as much as possible. Viral pathogens, such as *Bean* *common mosaic virus* (BCMV), were found to be present in 0.8% to 12.4% of seed samples of catjang bean and yard-long bean (both *Vigna unguiculata* ssp.) collected in Northern Vietnam (Ngo, 2003). Plots that are pathogen-free or without a disease history should be selected where possible. Covering seedlings with nets to exclude insect vectors of viral pathogens is an important means of producing healthy seedlings.

When diseases become endemic and regularly appear seasonally on specific crops, control practices for reducing the pathogen population size present in an area, a plot, a plant, or plant parts (such as seeds) must be used to reduce disease severity in current and future crops. These practices can be cultural (rotation, sanitation, and creating conditions unfavorable to pathogens); physical (soil solarization, heat treatment of planting materials); chemical (soil fumigation, seed treatments with chemicals, and soil amendments); or biological (use of biocontrol agents). For example, application of lime or calcium cyanamide (nitrolime) to the soil can suppress the pathogen density and incidence of clubroot (caused by *Plasmodiophore brassicae*) on leafy brassicas (McDonald et al., 2004).

The use of resistant varieties is the least expensive, easiest, and safest control method for use by farmers. Moreover, many diseases such as those caused by vascular pathogens and viruses often cannot be controlled adequately by any other means. Some accessions and breeding lines resistant to important diseases of indigenous vegetables have been identified or developed. For example, accessions of Ethiopian mustard resistant to *Turnip mosaic virus* (TuMV) and downy mildew (*Erysiphe cruciferarum*) have been identified in Tanzania (AVRDC, 2005). White rust caused by *Albugo bliti* is a major disease on leafy amaranth under hot and wet conditions. AVRDC accession VI033488 was found to be a durable resistance source, and the resistance has been transferred to commercial cultivars with various preferred leaf colors (Wang and Ebert, 2012). Performance of resistant varieties can be location-specific due to pathogenic variability. Therefore, varieties should always be evaluated onsite before making specific recommendations to farmers.

Crops must be protected from infection by endemic fungal pathogens during the production season. Direct protection can be achieved with the application of synthetic fungicides. Choice of pesticide and their application method must follow local recommendations and safety regulations for good agricultural practices. Field scouting of disease symptoms and the appropriate application of protective agents when the symptoms first appear is always more effective than later applications when severe symptoms or higher incidence has occurred. The use of biopesticides in managing diseases of indigenous vegetables is limited at present. Yet results of field evaluations show seedling and foliar application of amino acid-based organic and calcium-based fertilizers could reduce the incidence of TuMV and its vector aphid, as well as powdery mildew on Ethiopian mustard (AVRDC, 2005). Much more research in this area needs to be conducted if the potential for disease control is to be fully exploited.

7. Design and Evaluation of Locally Adapted Integrated Disease Management Packages. Control practices to be applied before, during, and after the crop has been selected follow the four principles—pathogen exclusion, pathogen reduction, host plant resistance and direct protection—which, when combined, form an integrated disease management package. For example, TuMV is a major pathogen of Ethiopian kale and other cruciferous crops. The major virus source is mustard-type weeds like penny-crest (*Thlaspi* spp.) and shepherd's purse (*Capsella bursa-pastoris*) that are able to overwinter from the previous growth season. Weed hosts that harbor both virus and aphids should be destroyed before the crop is planted. Although insecticides cannot act quickly enough to kill aphids before viral transmission has occurred, insecticides do help to reduce aphid populations and reduce the rate of virus spread. Sources of resistance for TuMV have been found for some crucifers; seed catalogs should be checked for the most disease-resistant lines. Farmer participation in the evaluation of disease management practices is important to ensure that recommendations for control are economically and culturally viable and acceptable. A stable supply of the inputs required for managing diseases, such as seed of resistant varieties and biopesticides, needs to be ensured to allow for large-scale adoption of sustainable and environmentally safe disease management practices.

Can postharvest management be improved, thus making market chains more effective and profitable?

Like other horticultural crops, indigenous vegetables are very often perishable and are easily damaged by poor handling. Careful attention must be given to handling at harvest, during transportation, during value addition, transport to market, and in storage. In most cases this requires considerable investment in ensuring good grower/packer knowledge of suitable postharvest handling techniques, the availability of appropriate on-site or nearby cooling facilities, suitable good quality packaging, and effective transport and storage infrastructure.

Postharvest problems that occur during handling and storage include loss of moisture, which leads to weight loss and thus value of the product at market. Many indigenous vegetables are leafy types, such as amaranth and African nightshade, and are very susceptible to wilting and weight loss. Quantitative information on the extent of postharvest losses of indigenous vegetables is limited, but some studies indicate that up to 23% of African eggplant is lost on farm (Barry et al., 2009). In a survey conducted in Benin, 18% of amaranth was discarded at both the farmer level and then a further 18% at the retailer level. In Rwanda, the percentage of amaranth that was sorted out for discard was 8% on farm, 2% during wholesale, and 25% at the retail level (Kitinoja, 2010).

Crops such as okra will be easily damaged if not handled well. In Ghana, 17% of okra is lost on farm, 2% during wholesale and 6% at the retail end. In India postharvest losses for okra were 19% at farmer level, 8% at the wholesale stage and 10% during retail (Kitinoja, 2010).

Research into the postharvest biology of these crops is generally limited and recommendations on optimum handling are still being developed. Optimum storage temperature regimes have been elaborated for most crops; information on oxygen and carbon dioxide levels for modified atmosphere storage require further development. Optimum temperature for amaranth leaves has been worked out to be 0-2 ^{o}C and bitter gourd 12-13 ^{o}C (McGregor, 1987). Modified atmosphere packaging was used to store *Perilla frutescens* for 13 days at 4 ^{o}C, producing CO_2 levels of 6% and O_2 levels of 14% (Thompson et al., 2001). These results show the potential for modified atmosphere packaging, which can be effectively used by smallholder farmers and consolidators as long as the correct material for packaging is available.

Postharvest methods suitable for resource poor farmers are being developed to prolong the shelf life of indigenous vegetables, such as the use of ice in bottles packed with leafy vegetables—a modification of the top icing treatment used in the USA for greens for many years. Low cost treatments such as the use of 2% bicarbonate wash to reduce microbial contamination have been developed and tested (Acedo et al., 2009) and are being promoted by AVRDC for suitable indigenous vegetables.

It is generally recommended to place vegetable crops in a cool environment to prolong their shelf life. The use of cold rooms and cooling equipment that are mechanically powered is now widespread and very effective, but many smallholder producers do not have access to such equipment and the necessary infrastructure such as a regular electricity supply may not be available. Evaporative cooling principles can be employed using various materials such as using shade and covering vegetables with moist hessian sacks or using charcoal/moist brick walled structures to provide lower cost cooling options. Effectiveness will depend on the ambient humidity but results from trials in Asia show temperatures can be reduced by about 4 ^{o}C and can thus help provide a longer useful storage period even in high humidity environments (Acedo et al., 2009). The use of these methods will allow smallholders to deliver a higher quality product.

Attempts to link small-scale producers with high value markets have been tried in several development projects with the aim of improving farmer income in Africa through a value chain approach. However, many of these projects have had only limited success (Temu and Marwa, 2007) mainly due to the relatively small size of this particular market in the region. Linkages with export markets have been more successful (Graffham and Macgregor, 2006) but these markets can presently only carry limited volumes of indigenous vegetables. These value chain linkages have used the methods highlighted above, including evaporative coolers and improved packaging such as plastic crates for transporting the crop, and have enabled growers to deliver a higher quality product to market.

Improvements in knowledge of postharvest handling requirements for vegetable crops and use of the opportunities for better market linkages mean that growers and traders should be able to increase their income from the production and marketing of indigenous vegetables as demand for these crops increases among consumers.

5) Can greater consumption of such diverse and nutritious indigenous vegetables be encouraged, knowing that changing dietary habits is a difficult exercise?

A growing number of people, including those in the medical profession are now conscious of the need for healthy diets (Oyobode et al., 2013). This enhanced awareness may increase the consumption of indigenous vegetables, as seems to be the case in many parts of Eastern and Central Africa (Karanja et al., 2012). Sharing and disseminating information about the different indigenous vegetable types and species, their nutritional value for health, and how they can be sources of income generation can be done through extension events (farmer days, women's groups and youth training, recipe formulation, preparation and testing) and exposure in the mass media are ways in which indigenous vegetables can be further popularized. Dietary preferences in a population can be changed; in Central Asia, for instance, non-traditional species such as vegetable soybean and Chinese cabbage have been introduced successfully. Consumption of an important, health-promoting indigenous vegetable such as bitter gourd can be encouraged by breeding non-bitter or less bitter cultivars that may be more palatable to different consumers and developing bitter gourd recipes that increase phytonutrient retention but moderate the bitter taste. However, this must not compromise the antidiabetic and deworming qualities of the vegetable which may be associated with its bitter chemistry. Promoting bitter gourd as a vegetable in school gardens so that children adjust to the taste at an early age can be a sensible introduction strategy. Policy makers should support the generation of persuasive research-based information, and initiate suitable national legislation and information campaigns. At present, only scattered information is available. Although scientists aim to produce such data, its generation requires immediate and consistent donor support over at least the next two decades if the UN's proposed Sustainable Development Goal 6 ("Improve Agriculture Systems and Raise Rural Prosperity") is to be fully realized (Sustainable Development Solutions Network, 2013).

In addition to policy makers, the public needs to be well-informed about accessible and affordable sources of micronutrients and antioxidants. A strong promotional campaign is required at the global level to enhance consumption and better understanding of the benefits of nutrient-dense indigenous vegetable crops. This need for popularization should go beyond traditional dissemination activities (Kiiza et al., 2012) to reach the largest number of people as quickly as possible, especially the two billion people who are presently malnourished worldwide (Keatinge et al., 2011).

Studies that can provide more in-depth information and knowledge about the nutritional value of indigenous vegetables will also help to enhance their use. For example, tef (*Eragrostis tef*) is a cereal crop previously only used in Ethiopia and Eritrea and is grossly under-researched at a global level, but now there is interest in the crop in more countries (Netherlands, USA, Australia) because of its good quality essential amino acid content with no gluten (Gamboa and van Ekris, 2008). This principle can apply to other indigenous vegetables, such as slippery cabbage grown extensively in Oceania and contains extremely high levels of folate, a nutrient required by women in pregnancy.

Many factors have limited greater consumption of indigenous vegetables, including (1) loss of traditional knowledge and skills in their utilization, especially following large-scale urban migration; (2) low priority given to research on improvement of local indigenous vegetable landraces to meet production and market requirements; (3) the highly perishable nature of leafy indigenous vegetables compared to cabbage, onions and eggplants; (4) altered or changing consumption patterns and food habits; (5) food systems characterized by easier (physical and economic) access to foods of low nutritional quality. The international community has only recently articulated its awareness of this problem, although the situation has been developing over a long time due to the growing neglect of suitable dietary diversity and concentration on the production of carbohydrate- and fat-based food items in the so-called "developing process" of countries (Grivetti and Ogle, 2000).

Nutrition and health outcomes result from the entire food system: from agricultural and food production to marketing and consumption. The lack of interaction among the agricultural, food and nutrition/health sectors has shaped current food systems, which are inappropriate to meet the nutritional requirements of many populations (Keatinge et al., 2010; Hughes and Keatinge, 2013). It is a challenging, urgently needed task to bring local nutritious food, including indigenous vegetables, back into rural and urban food systems. Active advocacy by donor agencies and international agricultural research centers has resulted in the creation of encouraging linkages and synergies among the agriculture, food, and nutrition/health communities, resulting in revived interest in indigenous vegetables, as evidenced in Kenya (Bioversity International, 2010)

To enhance food diversity and quality diets with local nutritious food including vegetables, a two-pronged approach of increasing nutrition awareness and consumer demand along with interventions to increase agricultural production and year-round supplies is required. Factors influencing food systems (from agricultural inputs to market and consumption factors) and nutritional outcomes need to be taken into consideration in problem analysis, research and design of possible interventions. Strategies can be incorporated into programs to enhance public awareness and increase consumer knowledge about the benefits of healthy, balanced diets, eventually leading to sustainable behavior changes that will increase demand for more local nutritious food, which will include indigenous vegetables. Changing diets is difficult but can occur, as has been observed over the last decade with the success of moringa as a vegetable in Bangladesh and the Philippines, where this little-known seasonal crop is sold throughout the year in principal markets and is recognized as a highly nutritious and valued vegetable (Rahim et al. 2013; M. Palada, pers.comm., 2014).

CONCLUSIONS

In this paper AVRDC – The World Vegetable Center's global scientific team has articulated the growing importance and potential research and development directions of indigenous and traditional vegetables worldwide. This report complements the many, diverse and effective efforts in research and development of fruit and vegetables promulgated by the

International Society of Horticultural Science and specifically the recent paper by Grubben et al. (2014) in the society's *Chronica Horticulturae* (vol. 54) highlighting the need to use vegetables to combat hidden hunger (malnutrition) in Africa. There remains a very large amount of biodiversity that has yet to be adequately exploited for the benefit of humanity. During the Global Forum for Food and Agriculture in Berlin in 2014, agriculture ministers from 65 countries pledged to promote the diversity of agricultural production to enhance dietary diversity to meet nutritional needs. If this promise is to be put into action then the biodiversity of the indigenous vegetables is a prime candidate for further global development.

Two actions can launch this worthy endeavor: 1) halt the severe genetic erosion of these crops due to rapid urbanization trends and their substitution by global vegetable varieties into human diets, and 2) collect, preserve, and effectively characterize traits of those indigenous and traditional species in genebanks using modern molecular characterization.

Characterization is the first step in new breeding programs for indigenous vegetable crops, and should be initiated now in many countries. It is likely to be a myth that these crops are more permanently "resistant to pests and diseases" than conventional field crops or global vegetable crops. Once indigenous crops enter mainstream production, the wide range of pests and diseases described in this paper will surely and quickly compromise farm productivity. Thus, defensive strategies through breeding, grafting, integrated pest management and good agronomic practices will be required for a sufficient quantity and quality of crops to be produced on-farm in a profitable and efficient manner.

Many of these crops are highly sensitive to inadequate postharvest handling, and postharvest infrastructure is a significant weakness in most developing world vegetable value chains. Better regimes for shading, cooling, packaging, transporting and storing will be required along the value chain from field to kitchen, particularly in the case of nutrient-dense leafy green vegetables with an apparently short shelf life, such as African nightshade, slippery cabbage, and Malabar spinach.

Many of these indigenous vegetables are preferred by consumers for their taste, appearance and vitamin and mineral content. Packaging and marketing to ensure food wholesomeness, cooking to ensure taste and nutrient bioavailability, and attractive meal presentation are all crucial aspects for acceptance of these food products by consumers. Efforts to encourage people, especially young people, to adopt the World Health Organisation (WHO)-recommended lifelong habit of consuming more than 400 g of fruit and vegetables a day, and to consume a sufficient diversity of foods for a balanced and healthy diet need to be made—and made with all the vegetables we have available, not solely the current, narrow range of species that are presently globally important. Failure in this regard will unnecessarily entrench malnutrition worldwide for future generations. The vegetables described in this paper are often more nutrient-dense than global vegetables such as white cabbage and red tomatoes (in terms of vitamins A, C, folic acid, iron, zinc, etc.) and thus need to play an immediate and crucial role in the continuing struggle to abolish micronutrient malnutrition. Practitioners seeking new ways to reduce infant mortality, stunting and reduced IQ, and to gain other highly significant economic health benefits, such as reduced incidence of cancer and cardiovascular disease, as described for the UK by Oyebode et al. (2013), would do well to direct their attention and efforts toward indigenous vegetables.

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