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AVRDC
The World Vegetable Center

Annual Report 2015
AVRDC - The World Vegetable Center



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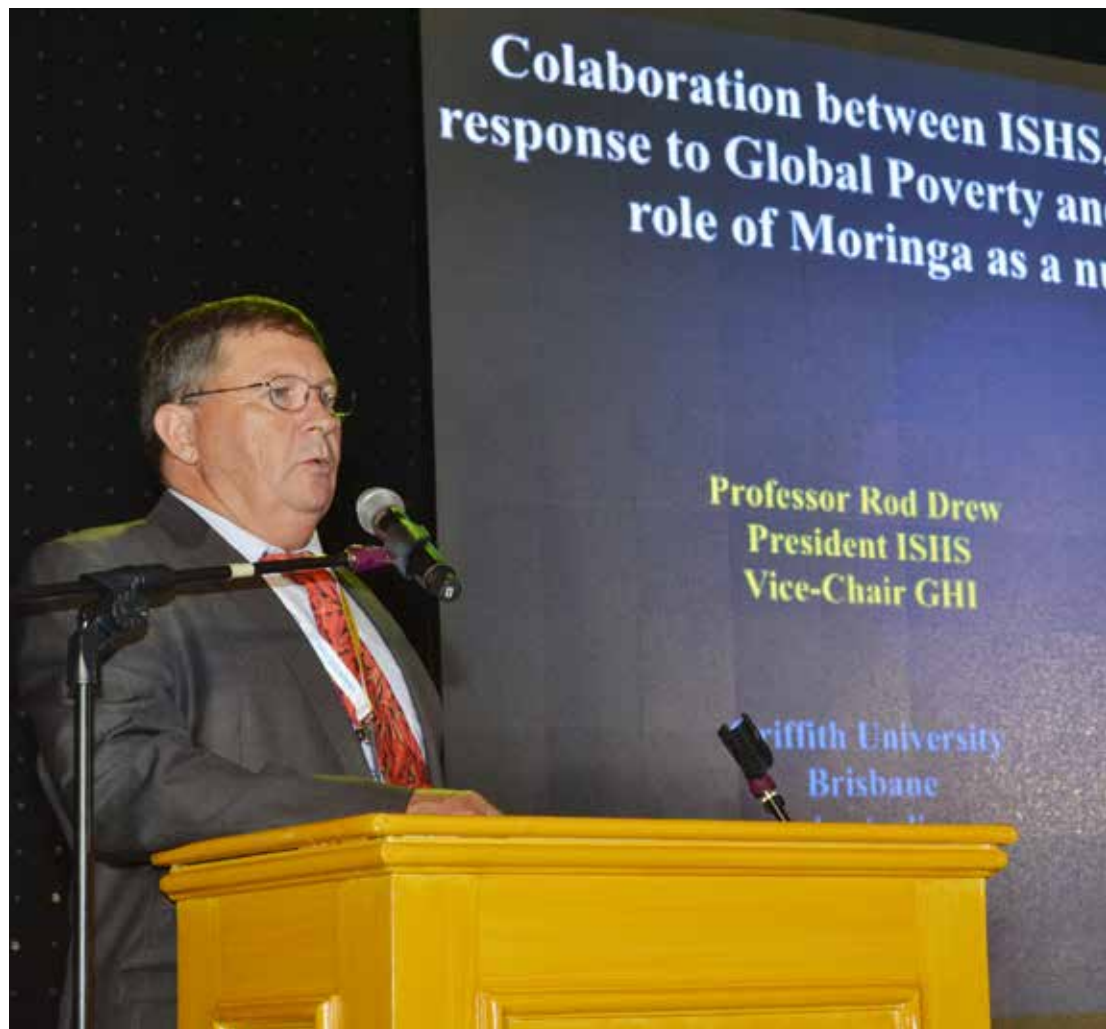
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Foreword

With Sustainable Development Goal 2 (“End hunger, achieve food security and improved nutrition and promote sustainable agriculture”) the United Nations seeks to abolish both hunger and malnutrition by ensuring the continuous supply of sufficient, wholesome food to enable people to adopt healthier, well-balanced diets. This goal calls for new ways to reduce food waste, and for farming in a manner that conserves biodiversity and environmental services, increases enterprise profitability through new business models, and empowers women. It urges governments to create coherent policies at all levels, to allow positive changes in farming systems to take place in every country.

From 15-17 November 2015, the Center, the International Society for Horticultural Science (ISHS) and the Moringaling Foundation of the Philippines conducted the First International Symposium on Moringa in Manila. Key scientists from around the globe attended this important workshop to present advances in the research and development of this vital and supremely versatile traditional tree vegetable species. AVRDC believes that moringa (*Moringa oleifera*) will play an essential role in helping attain SGD 2. Moringa is a unique species; both its fresh leaves and pods are edible and have high levels of vital micronutrients. The dried leaves are a good source of micronutrients to fortify food for chronically underfed and malnourished children. This fast growing, productive tree adapts well to a range of environments, especially in hot, semi-arid regions, and is thus a climate-resilient crop. It grows well in a range of production systems, from a densely planted green vegetable crop that can sustain repeated harvests, to a fully grown tree crop that can be harvested periodically when needed. Use of this diversity of production systems in specialized environments can

Professor Rod Drew explained the malnutrition-alleviating benefits of moringa during the First International Symposium on Moringa in November 2015.



promote in-situ germplasm conservation, soil conservation, sustainable production systems, enhanced profitability, a continuous source of vitamins and minerals for smallholder farm families—and often, all of these attributes together. This species is thus a boon to women smallholders, as it enables them to provide their families with highly nutritious food direct from the home garden or purchased at the local market. Moringa's good productivity and range of adaptability helps to develop resilience in farm enterprises and ensure profitability and sustainability.

The potential for indigenous and traditional vegetables such as moringa to become key levers to address serious micronutrient malnutrition has been made manifest globally in a seminal paper prepared and presented at the ISHS International Congress at Brisbane, Australia in 2014 by 22 AVRDC authors, and published in *Acta Horticulturae* Vol. 1102 (Keatinge et al., 2015). This paper sets the path for indigenous/traditional vegetable research for at least the next decade and has generated considerable attention among researchers worldwide. Yet traditional crops, which are now receiving somewhat greater research attention, must not follow the same trends of declining nutrient density from breeding, as has been the fate of many global fruit and vegetables selected principally for yield, shelf life, and appearance in the USA and Europe.

Moringa has substantial potential to become a globally important vegetable, not only for its value as a key component of well-balanced, nutritious diets for humans and livestock in the developing world, but also for its likely profitability, highly diverse markets, and possibilities for pharmaceutical use. There has been insufficient investment to ensure the agronomy of moringa is well understood; its relative resistance to pests and diseases compared to many other vegetables in open field cultivation is a major advantage that has not yet been fully exploited. More rigorous research is needed on the economics of production, postharvest and marketing, as well as on ways to make the nutrients in this nutritionally dense crop as bioavailable as possible. Given such investment, the likelihood of moringa contributing substantially to the rapid attainment of Sustainable Development Goal 2 is very sure.

It is critical that governments concerned with eliminating malnutrition promulgate appropriate policies to encourage the adoption of healthy diets with adequate diversity to counteract unhealthy trends in global food consumption resulting from increased urbanization, changing socio-demographic factors, trade liberalization, and food industry marketing. This must include better policy harmony between agriculture, health, education, and trade ministries within governments. Failure in either of these areas may lead to chronic human ill-health through attempts to alleviate hunger with an excess of high energy staples and oils and an insufficiency of fruit and vegetables. This insidious combination is presently feeding a growing world epidemic of obesity, type II diabetes and other noncommunicable diseases; it needs to be halted immediately if real progress is to be made in the attainment of SDG 2.

AVRDC – The World Vegetable Center is proud to be at the forefront of the fight against malnutrition and I am convinced the Center will play an increasingly important role in this effort in the coming decade. After two terms as Director General, I can now confidently pass the baton to Dr. Marco Wopereis, who has the qualities, energy, determination and drive to take the Center to a new level. I wish him and the Center every success in the future.



J.D.H. Keatinge
Director General



Office Map





1. **AVRDC - The World Vegetable Center Headquarters - Shanhua, Taiwan**
2. **East and Southeast Asia - Bangkok, Thailand**
3. Research and Training Station - Kamphaeng Saen, Thailand
4. Project Office - Hanoi, Vietnam
5. Project Office - Siem Reap, Cambodia
6. Project Office - Sigatoka, Fiji
7. Project Office - Honiara, Solomon Islands
8. **Korean Sub-Center - Jeonju, Republic of Korea**
9. **South Asia - Hyderabad, India**
10. Project Office - Ranchi, India
11. Project Office - Bhubaneswar, India
12. Project Office - Raichur, India
13. Project Office - Dhaka, Bangladesh
14. Project Office - Jessore, Bangladesh
15. Project Office - Barisal, Bangladesh
16. Project Office - Islamabad, Pakistan
17. Project Office - Sargodha, Pakistan
18. Project Office - Faisalabad, Pakistan
19. Project Office - Mingora-Swat, Pakistan
20. **Central Asia and the Caucasus Sub-Office - Tashkent, Uzbekistan**
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22. **Eastern and Southern Africa - Arusha, Tanzania**
23. Project Office - Kampala, Uganda
24. Project Office - Nairobi, Kenya
25. **West and Central Africa - Bamako, Mali**
26. Project Office - Sikasso, Mali
27. Project Office - Mopti, Mali
28. Liaison Office - Yaoundé, Cameroon
29. Project Office - Maroua, Cameroon

Dr. Lucy Sun Hwang (*second from left*) and Dr. Douglas Pachico (*third from left*) met with AVRDC staff in South Asia and other regional offices to review progress and provide guidelines for future program development and policies.



IN FOCUS

8th External Program and Management Review

AVRDC – The World Vegetable Center's 8th External Program and Management Review (EPMR) took place in the latter half of 2014 under the chairmanship of Dr. Douglas Pachico. The three-member panel submitted its report to the Board of Directors in early 2015. The purpose of the 8th EPMR was to assist the Center's board and management in providing the research base for promoting increased and sustained vegetable production, safe and effective postharvest management of vegetables, and greater vegetable consumption for dietary diversity, nutrition and health. This forward-looking review took into account a rapidly changing global environment for food and agriculture (including a greater recognition of the importance of dietary diversity, nutrition, and linkages between agriculture and health) and thus will help guide the Center's program development, policy, communication strategies and management approaches for the next five to seven years. The report, its recommendations, and the initial responses by the Center's management were approved by the board in April 2015.

The panel highlighted what it believed to be notable achievements at the Center and formulated several recommendations for strategic and operational adjustments and changes that, if properly implemented, should enhance AVRDC's performance. The panel recognized that vegetable production presents small-scale farmers with exceptional opportunities for increasing their incomes. Vegetables generate higher values of production per unit area than grain or legume field crops. They create more employment for rural laborers, and present market opportunities with faster growing demand. For example, the global market value of tomatoes alone exceeds that of any crops researched by all international centers except rice and wheat. The panel endorsed AVRDC's critically important and unique mission to conduct research that increases production of an array of vegetables to improve nutrition, and commended AVRDC for its determination that its research results yield real development outcomes and impact.

The panel significantly recommended that AVRDC reorient its strategy around a long-term vision of its contribution to the Sustainable Development Goals



(SDG) and undertake regionally based planning to construct global priorities for crops, production systems and constraints. These recommendations have been accepted enthusiastically, as the Center contributed to the formulation of SDG 2 (“Zero Hunger”), which strives to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture—issues that can be addressed by the Center’s research and development activities. In addition, the Center believes it can contribute to SDG 12 (“Responsible Production and Consumption”) through its postharvest activities that are better addressed under this SDG than in SDG 2.

Several of the EPMR recommendations already have been adopted and implemented. The others are in the process of execution or awaiting the arrival of new Director General Dr. Marco Wopereis in April 2016. The 8th EPMR was a constructive and productive review of considerable benefit to the Center and we offer our sincere thanks to the panel members. The full report is available at avrdc.org.



EASTERN and SOUTHERN AFRICA

About 340 million people live in the 22 countries that make up Eastern and Southern Africa, of whom 70% live in rural areas. The area encompasses several of the fastest growing economies in the world, including Tanzania, where the Center's regional office is located. Population densities and urbanization rates are very high in some countries, with a large proportion of youth. Women play an important role in vegetable production for home consumption and local trade, safeguarding the nutrition of their families, which is one of the main pillars of AVRDC's work in Africa. Traditional African vegetables are key in this pursuit, and will become more important with climate change. Vegetables are also increasingly chosen as income-generating agribusiness opportunities, a focus of the Center's activities in the region.

During the year, AVRDC Eastern and Southern Africa increased its staff to 36, of which 11 are internationally recruited scientists providing leadership in the region. Staff increased at the office in Kampala, Uganda, housed by the International Institute of Tropical Agriculture, while a new project office was opened in Nairobi, Kenya at *icipe*. Other countries with research activities include Ethiopia, Malawi, Mozambique and, since late 2015, Zambia. The regional office continues to build capacity through informal and formal training. More than 25 students were trained at AVRDC Eastern and Southern Africa during 2015, while more than 400 participants, including many farmers, joined informal training courses on vegetable seed kits for home gardening, postharvest technologies, value chain thinking, and several other topics.

The year saw the launch of VegOneX in Tanzania, an online ordering system developed by AVRDC for foundation seed transactions between the Agricultural Seed Agency and the private sector. The system also incorporates dissemination of vegetable prices to farmers, both at wholesale and retail level, using radio and text and voice messages.

The regional USAID project "Deploying vegetable seed kits to tackle malnutrition in Uganda, Kenya, Tanzania" started field activities in 2015. The project aims to implement home, school and community garden interventions for enhanced access to and consumption of vegetables by poor households, especially women and children. Partnership agreements were developed with three national agricultural research organizations and two nongovernmental organizations. After extensive

training, 1,840 seed kits were distributed to farmers in Uganda and in Tanzania, most of which were women, and 29 demonstration gardens were established to create awareness in the villages. Training topics covered human nutrition, increased crop productivity, water management, and postharvest handling.

Selection and breeding efforts continue to focus on traditional African vegetables, with amaranth (*Amaranthus* spp.) and African eggplant (*Solanum aethiopicum*) as the flagship crops. Through selection, parental lines are identified for use in breeding programs. The breeding program at the regional office continues to work with national agricultural research systems and seed companies to promote advanced lines for release and commercialization. Activities focus on gender-disaggregated participatory cultivar selection to ensure developed cultivars fit not only to different environmental conditions but also to the end user. While most efforts are geared towards selection within germplasm collections, creation of genetic variability started in 2015 and will continue in 2016 with selection within segregating populations for improvement of these two strategic crops. Other traditional African vegetables are addressed through smaller projects, and selection of African nightshade (*S. scabrum*), Ethiopian mustard (*Brassica carinata*), spider plant (*Cleome gynandra*) and vegetable cowpea (*Vigna unguiculata*) is ongoing. Breeding research on global vegetables continues, especially for tomato, a very important crop in Eastern and Southern Africa. An in-depth study conducted by AVRDC in 2015 showed that in Tanzania alone, 50% of tomato and 98% of African eggplant commercial seed production used varieties developed by AVRDC, generating economic gains of US\$ 254 million for tomato and US\$ 5 million for African eggplant up to 2014.

At the regional office, research on the invasive tomato pest *Tuta absoluta* started in 2015. The incidence and extent of damage by this destructive moth in Solanaceous crops and weeds in four major tomato growing regions of Tanzania was assessed, and trials are underway to test the efficacy of commercially available pheromone lures and biopesticides.

The regional office houses a large USAID-funded postharvest program and takes a three-pronged approach to tackle postharvest issues. First, through

value chain analyses, problems and opportunities in vegetable handling and marketing are assessed. This is followed by adaptive research activities to identify new technologies and interventions, and provide solutions. Finally, improved technologies are promoted through awareness creation and capacity building. In 2015, 685 beneficiaries, mostly farmers, were trained in improved postharvest technologies in Kenya and Tanzania. Also during 2015, focus group discussions were conducted to understand opportunities and constraints in the marketing of dried and processed traditional vegetables in Malawi and Tanzania. Research into novel solar dryer designs, improving the nutritional quality of solar-dried vegetables, including moringa and vegetable cowpea, and better dehydration methods is ongoing in collaboration with the Nelson Mandela Institute of Science and Technology, the Amsterdam Initiative Against Malnutrition, and the Irish Aid-funded Good Seed Initiative. Cool storage remains a critical component for vegetables, and in collaboration with Jomo Kenyatta University of Agriculture and Technology, experiments showed that ice packs and insulated bags are able to keep leafy vegetables cooler by 4-5 °C and prevent weight loss by 11%. A simple hydro-cooler suitable for a range of vegetable crops was found to reduce respiration and improve shelf life. In 2015, AVRDC embarked on a comparison of different vegetable marketing arrangements in Tanzania. This initiative is funded under the USAID Postharvest Program, and is developing guidelines for governments and donor organizations to facilitate vegetable marketing and postharvest processing initiatives.

The project “Improving Income and Nutrition in Eastern and Southern Africa by Enhancing Vegetable-Based Farming and Food Systems in Peri-Urban Corridors” (VINESA), funded by the Australian Centre for International Agricultural Research, uses a value chain approach to train unemployed youth by immersing them in best practice hubs for several months. So far, 185 young farmers have been equipped in four East African countries with skills such as identifying consumer needs to become their preferred suppliers, reducing postharvest waste, and identifying and nurturing relationships with key value chain players. For example, in Malawi and Mozambique, VINESA partners engaged value chain players to target new markets using a seven-step guide based on a farmer SWOT analysis. In 2015, the project delivered seed production and conservation training to youth

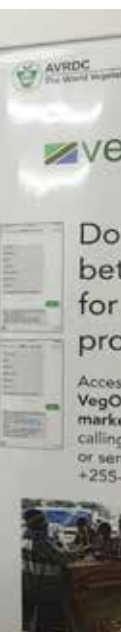
and women groups in Ethiopia and Tanzania. Using quality declared seed (QDS) protocols, farmers are equipped with skills to produce and market quality seeds and seedlings. Currently, best practice hubs are strengthened by soliciting support for trainees after graduation to help scale out practices to produce healthy seedlings, get crop nutrition right, grow safe vegetables, and reduce postharvest losses. Project partners are developing strategies for the takeover of these hubs by returning graduates, communities, and other stakeholders as a project exit strategy.

Vegetables in Eastern and Southern Africa are almost exclusively grown by smallholder farmers, along with other crops and commodities. Several projects at the regional office study vegetables using a systems approach. In the USAID-funded project Africa RISING, led by the International Institute of Tropical Agriculture, farmer-managed field demonstrations were implemented in four villages in Babati in Tanzania, a vegetable hotspot. The demonstrations contrasted controls against treatments with increased farmer resources and better technologies, so that farmers can see the differences and learn from them, and scientists can measure the effect of the new technologies using cost-benefit analyses. In Africa RISING, AVRDC is promoting mobile garden technology and integration of vegetables with poultry. New vegetable species such as African nightshade and Ethiopian mustard have been introduced. USAID recently started a sister project in Tanzania that fast-tracks delivery and scaling of agricultural technologies developed in Africa RISING. In 2015, AVRDC, in collaboration with the Horticulture Research and Training Institute Tengeru, successfully implemented its first season of training in nine pilot villages located in three districts in Tanzania (Babati, Kiteto, and Kongwa). Nursery management, soil preparation and soil enhancement practices, good agronomic practices, postharvest handling, and food safety and food preparation training sessions were conducted for 158 farmers, who subsequently became trainers themselves. Almost 800 seed kits were handed out to the farmer trainees and secondary recipients to get them started, and nine additional villages have been selected to scale out activities.



AMAZING AMARANTH: Amaranth is a versatile food plant: There are leafy vegetable types, dual types for leaf and grain, and grain types. Although AVRDC – The World Vegetable Center breeders work on all three types, developing a nutrient-dense, high leaf-yielding line is a major breeding objective. Including checks, 16 amaranth lines were evaluated in three locations (AVRDC Eastern and Southern Africa in Arusha, Moshi, and Mbuguni) in northern Tanzania in 2015. Line Ug-AM-9-ES13-2 developed in 2013 by single plant selection from germplasm collections consistently gave the highest marketable vegetative yield across the three locations, ranging from 21 t/ha in Moshi to 30 t/ha in AVRDC Eastern and Southern Africa—considerably higher compared to the control cultivar ‘Madiira 1,’ which yielded 5 t/ha in Moshi and 19 t/ha at AVRDC Eastern and Southern Africa. The line also received the highest score in gender disaggregated farmers’ participatory cultivar selection across the locations. Farmers liked its green to dark green leaf color and succulent stems, as they consider dark green leaves a sign of high nutrient content. **Fekadu Dinssa**, Vegetable Breeder at AVRDC Eastern and Southern Africa, said that Ug-AM-9-ES13-2 definitely has potential to be adopted by farmers and favored by consumers if it is released for commercial production. AVRDC will work with national programs to facilitate the release of the line, which also will be used as a parent in future breeding programs.





VegOneX FOR TANZANIA: The VegOneX for Tanzania project funded by AVRDC's 2014-15 Innovations Fund has made remarkable progress in understanding and addressing critical bottlenecks while improving the efficiency of the seed supply and distribution system. Module 1 bridged information gaps between government agencies and private seed companies. Module 2 is improving market information systems and competitiveness of farmers' produce via SMS messaging and a voice dialing market information system to provide weekly produce prices of selected vegetables elicited from representative wholesale and retail markets in the Arusha region.

The online platform (<http://asa.worldveg.org/>) developed in Module 1 is active and is being used by stakeholders to order foundation seeds from Tanzania's Agricultural Seed Agency (ASA) for the 2016-2017 growing season. This seed distribution system enables timely communication among key players in the seed industry: Seed companies place orders for foundation seeds; ASA

plans for delivery against orders placed before a new season commences; and finally, the seed quality-control agency monitors these transactions—an essential step in the last mile of the supply chain. What previously took days and weeks is now done in minutes.

In Module 2, the project team collaborated with Farm Radio International and Radio 5 to collect price data for specific vegetables on alternate days each week at wholesale and retail markets located within Arusha. The raw data is then condensed, aggregated, statistically tested and cleaned before being broadcast to farmers and the general public via Radio 5. Hundreds of farmers in Arusha use their mobile phones to send SMS text messages of a vegetable crop name (in Swahili) to a local telephone number (short code) or use the voice call-back facility; to date, thousands of requests for market prices have been received and responded to through these mobile services.



HIGH RETURNS ON INVESTMENT IN VEGETABLE BREEDING: Improved lines of tomato and African eggplant developed by AVRDC – The World Vegetable Center and introduced to Tanzania in collaboration with national partners have made much impact in Tanzania, but just how much had never been quantified. A study was conducted to assess the adoption, economic impact and returns to vegetable improvement for Tanzania. **Teresa Sequeros**, an independent consultant hired by AVRDC, visited all vegetable seed producers of Tanzania to collect data on seed sales of all current varieties of tomato and African eggplant and their origin. She found that 87% of tomato and 100% of African eggplant seed sales by private companies were unmodified open-pollinated AVRDC lines. Together with AVRDC researchers she then estimated the difference in yields and input costs as compared to alternative varieties.

Using the economic surplus method, they estimated AVRDC research had generated US\$ 255 million in economic returns to farmers and consumers for tomato through 2014, and US\$ 5 million for African eggplant, which was introduced more recently. Factoring in the research investment, there was an internal rate of return of 29% for tomato and 12% for African eggplant, though the latter was projected to increase to 26% by 2024. International vegetable breeding research thus shows very attractive returns on investment. However, with the substantial time gap between initial investment and returns, vegetable breeding research requires long-term commitment from breeders and donors.



LEAFY VEGETABLES FIND FANS IN TANZANIA: When Omary Poputo tasted the African nightshade for the first time, he said: “I have neither seen nor tasted this vegetable before, but for sure it is definitely one of the best leafy vegetables I have ever tried.”

Omary hails from Sunya village in Kiteto District, central Tanzania and is among the 227 lead farmers supported by the Africa RISING – NAFKA scaling project funded by the United States Agency for International Development (USAID). Through the project, farmers in 12 villages located in Manyara, Dodoma and Morogoro regions of Tanzania have been introduced to African nightshade and amaranth farming. The project has had a multiplier effect: those 227 lead farmers attracted nearly four times their number, and now 800 farmers are engaged in growing these two nutritious vegetables.

Why African nightshade and amaranth? The two vegetables are much richer in vitamin A and micronutrients such as iron than most leafy vegetables grown in Tanzanian villages. Deficiencies of vitamin A can cause night blindness for adults and may reduce bone growth for children. According to the United Nations Children’s Emergency Fund (UNICEF), one-third of children under the age of 5 are vitamin A deficient in Tanzania. Increasing the intake of vitamin A is therefore an important objective to improve health and well-being in the country.

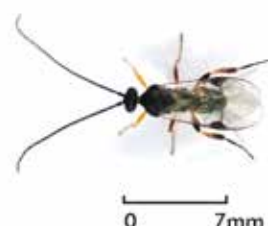
The sweet taste of the nightshade cultivar ‘Nduruma’ convinced Omary that this was a good vegetable everyone in the family could enjoy. Farmers also appreciated the cultivar’s drought tolerance. Observed Omary: “With these great qualities, ‘Nduruma’ might soon replace other more popular, but less nutritious vegetable varieties.”

PROMISING FUTURE FOR A FAVORITE CROP: African nightshade (*Solanum scabrum*) is a popular traditional leafy vegetable in many African countries, and leaf yield is one of the major traits farmers look for in an ideal cultivar. Fifteen promising lines, including checks, were evaluated in three locations (AVRDC Eastern and Southern Africa in Arusha, Moshi, and Mbuguni) in northern Tanzania in 2015. Lines RC10-ES13-3 and BG22-ES13-3 gave high marketable vegetative yield across the three locations. Farmers involved in participatory cultivar selection said they liked the lines for their leaf color and size. The lines were developed by single plant selection in 2013 from

germplasm collections available at AVRDC Eastern and Southern Africa. “Farmers prefer dark green leaves and narrow leaf size in addition to vegetative biomass yield,” said **Fekadu Dinssa**, Vegetable Breeder at AVRDC Eastern and Southern Africa. These promising lines are available for further evaluation by national agricultural research systems and seed companies.



NEW NATURAL ENEMY TO PROTECT AMARANTH: The leaf webber (*Spoladea recurvalis*) is the most important biotic constraint limiting the production of amaranth; infestations have caused 100% yield loss in parts of Eastern Africa. Amaranth typically is harvested several times throughout a growing season, and with such short harvest intervals, pesticide residues may remain on the harvested leaves, posing serious safety concerns to consumers. Alternative management strategies such as biological controls can help reduce pesticide misuse on amaranth. A systematic survey was initiated to identify species-specific as well as the most effective parasitoids of *S. recurvalis*. A solitary endoparasitoid, *Apanteles opacus* (Hymenoptera: Braconidae) was found to be the major parasitoid of *S. recurvalis* in Taiwan. It was present in the field throughout the year, except in March and September, with field parasitism ranging from 14% to 44%. *A. opacus* is a larval parasitoid, and the females prefer to attack the first three larval instars of *S. recurvalis*. Because it prefers to infest the early larval stages, this parasitoid could significantly limit leaf webber damage in amaranth. A female parasitoid parasitized a maximum of 65% of *S. recurvalis* larvae exposed to the parasitoid under laboratory conditions. The optimum temperature for mass production of *S. recurvalis* is 25 – 35 °C. It is likely this parasitoid will adapt well to the tropics and subtropics, where amaranth is mostly grown.



NEW PERSPECTIVE ON TRADITIONAL CROPS: The USAID-funded Home Garden Scaling project was initiated in Uganda to increase the availability of quality seeds of tested nutritious vegetables, including a range of traditional leafy vegetables. AVRDC, together with Voluntary Efforts for Development Concerns (VEDCO), sensitized farm households about the dangers of micronutrient deficiencies and the benefits of balancing diets by consuming more vegetables. Interested farmers, particularly young mothers, were then trained to raise vegetable seedlings for their home gardens and to produce vegetables throughout the year; they also learned how to prepare nutritious recipes, and earn income from selling surplus vegetables from their home gardens. Extension workers and other influential people in the villages were trained to amplify the message of growing vegetables for healthy diets. Still, it wasn't easy to convince the trainees to grow traditional vegetables like amaranth and nightshade, as these crops are considered to be weeds and are usually fed to pigs, goats and other livestock.

Nalongo Sekinkuse, a 67-year-old widow in Nakisunga Sub County, Katente village, Mukono district used to think vegetables were a poor man's food, the traditional types in particular. After participating in the training, Nalongo's opinion of vegetables improved—especially when she realized how these foods can provide nutrients for her seven dependents (four of them under the age of 5). This attitudinal change is not only apparent with Nalongo, but also among her grandchildren, who have started to consider vegetables a delicacy. "My 3-year-old granddaughter enjoys eating amaranth more than banana or cassava and she cries if we do not prepare it," said Nalongo. "I am very sure that I will not have challenges of nutritional deficiency diseases among my grandchildren." Nalongo's enthusiasm for gardening prompted her group members to select her to become a Community Trainer. She received three days of training on nutrition and agronomy from the National Agricultural Research Organisation, and then she started training other group members and fellow farmers.



SCHOOL LUNCHES GO GREEN: AVRDC Eastern and Southern Africa provided vegetable seed kits to 155 pre-primary and primary schools serving 97,322 students in Bunda, Musoma, and Butiama districts of Mara region, Tanzania in 2015. The kits contained five different vegetables: African eggplant, amaranth, Ethiopian mustard, okra, and vegetable cowpea. These vegetables were carefully selected to provide the best possible nutrition for the schoolchildren: vegetable cowpea as a source of protein, and leafy and fruit vegetables to provide vitamins (vitamin A, E, C), minerals (Ca, Fe, Zn) and other nutritional compounds such as fiber and antioxidants. Project Concern International (PCI), a nongovernmental organization working with the Government of Tanzania and funded by the United States Department of Agriculture, distributed the kits; PCI's goal is to support establishing school gardens at every school as a learning tool and as a source of fresh vegetables for daily school meals. Leafy vegetables supplemented school meals at all schools where the seeds were sown during the rainy season. Students from Masaba Primary School enjoyed vegetable cowpea leaves as part of their lunch, while at Sarakwa Primary School, students held a taste test and gave their preference for amaranth 'Madiira 1' as more palatable compared to amaranth 'Madiira 2.'





WEST and CENTRAL AFRICA

The regional situation: West and Central Africa is home to about 300 million people, many of whom are smallholder farmers growing a variety of staple food crops within complex farming systems where livestock, tree crops, and vegetables exist in various spatial and temporal configurations.

Besides recurrent episodes of severe hunger caused by climate or conflict emergencies, the region faces chronic malnutrition and this poses a silent and relentless obstacle to economic development. Nutrition interventions aimed at mothers and children together with programs to boost agriculture have a great impact on household nutrition and health. Evidence-based awareness creation and strong multi-stakeholder advocacy for consumption of nutrient-dense vegetables as cereal accompaniments would have a very strong impact, especially in rural areas. This comes with the challenge of demand exceeding the supply of these nutritious foods.

Rising food and nutritional insecurity threatens the livelihoods of millions of poor people as well as the region's social cohesion and stability. As a growing population demands more and higher quality foods, and as environmental problems such as soil degradation, water scarcity, biodiversity loss, and climate change become more acute, the need for innovative vegetable solutions to improve food and nutritional security cannot be overemphasized.

Vegetables dominate production during the cool dry season and are grown with field crops during the warm rainy season. They are mainly grown on small plots and traded by women as fresh produce or dried products that account for a significant share of the market sales of agricultural products in the region. There are many opportunities, interventions and technologies that can support vegetable production and consumption, thus contributing to nutritional security. In particular, capacity building and policy interventions are critical to ensure mechanisms are in place to support both the production and the market, thus contributing to availability of affordable and health-promoting vegetables.

Vegetables hold great promise for alleviating poverty and improving the health and well-being of people in the region, despite constraints in production and supply chains including limited availability of quality seeds, inappropriate varieties, lack of water and inputs, pests and diseases, limited information and knowledge and inadequate marketing systems.



FROM CLEANING ROOMS TO CLEANING SEED:

When she's done cleaning rooms at the Institute of Agricultural Research for Development (IRAD) in Ekona, Cameroon, **Bessem Ayuk Florence** (right) sets aside her broom and mop to multiply seed of traditional African vegetables. Bessem Ayuk Florence and **Ojong Agbor**, a research assistant at IRAD, attended a seed multiplication training workshop organized by AVRDC in March 2015, where they learned how to produce and market quality seed of traditional African vegetables. "Our way of producing seed is completely different from the traditional ways, because we nurse and cultivate seeds using the best practices we learned," she said. "We also test our seed to measure the germination rate before we pack it plastic bags." After showing samples of their packed seed to some farmers, the overwhelming positive response left the women wondering if they will be able to meet the demand. Undaunted by the challenge, the women are preparing to expand their seed production business.

WHITE DIAMONDS: A new jewel of the field has farmers talking in the Ntem Valley division of southern Cameroon. African eggplant variety Oforiwa—nicknamed "white diamond" by local growers for the high income it generates—was introduced in the area by the Center for Assistance to Sustainable Development (CASD) through the project "Enhancing productivity, competitiveness and marketing of traditional African vegetables for improved income and nutrition in West and Central Africa" funded by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD). CASD organized a training workshop in the Ntem Valley to strengthen vegetable farmers' skills in improved nursery techniques and farm management. After the training, the farmers received improved vegetable seeds of African eggplant, amaranth, African nightshade, jute mallow, and okra from AVRDC – The World Vegetable Center. Vegetable grower **Patrick Ancho** of Meyo-Nyaka was reluctant to accept the African eggplant seed, as he felt the variety he already was producing was the best. With some persuasion from his wife, he finally decided to grow the new variety.

After their first harvest of Oforiwa, Mr. and Mrs. Ancho were so impressed by the performance of the variety that they decided to abandon the one they previously cultivated. "Oforiwa is high yielding and produced fruits for a long period," said Mr. Ancho. "With sufficient moisture, it can produce many times a year, and it is disease resistant." He especially appreciated the attractive milk-white color of the fruit, and the taste, which is good both raw and cooked; these are strong selling points for consumers. "The demand is becoming high as well as the market value compared to other varieties," he said. Mrs. Ancho calls Oforiwa the "white diamond" because it has proven to be incredibly valuable for her family: the crop brings in at least 140,000 CFA (about US\$ 234) weekly.





LINING UP FOR IMPROVEMENTS: To support local onion farmers, 20 lead onion farmers in the Far North Region of Cameroon received training in 2015 to update their knowledge and skills for onion bulb and seed production, marketing and preservation. Nine out of eleven monitored farmer groups trained in the improved production techniques reported an average production increase of 60% with the local onion landrace. **Sadou Nouhou**, an onion producer in Mesquine, said “sowing seed in lines (rows) in a nursery seems like a lot of labor because we are not used to it,” but acknowledged that the method allows for vigorous uniform seedling growth, facilitates weeding, minimizes losses, and allows for better airflow among the onion tops. “I have also used the technique on cabbage and the result was splendid compared to what I used to do,” he added. “Seedlings in the nursery grow faster,” said **Aladji Foamed Habiba**, an onion grower in Gazawa. “Transplanting in lines make uses of all the space, and it is easier to count the exact number of seedlings planted and reduce losses during weeding.” By following improved management practices, she doubled her production from 25 bags to 50 bags on a quarter-hectare of land. “Previously producers did not know the quantity of seedlings they were growing per square meter,” said AVRDC research assistant **Ronal Chendjou**. “By planting in lines, they can now estimate their yield.”



Souleymane Koné is spearheading change in his community. Souleymane is a vegetable farmer in Fienso, a village of about 1200 inhabitants located in the commune of Zangasso, Koutiala district, in the Sikasso Region of Mali. This small village is in a well-known shallot production zone—an activity in which Souleymane was involved. He was already producing vegetable seed using traditional methods when he heard about the USAID-funded project “Deploying Improved Vegetable Technologies to Overcome Malnutrition and Poverty in Mali” through interaction with beneficiaries of the Sokourani Best Practice Hub (BPH) and the Vegetable Technology Immersion Cluster (VTIC) of Kouoro Barrage. Souleymane made sure to participate in the training provided by AVRDC field technician, **Yaya Togola**, on vegetable production, postharvest handling, and seed production techniques. He visited other project-trained vegetable seed producers. Not only was Souleymane interested in vegetable seed production, he also wanted others in his locality to learn the same. Together with his neighbors, he lobbied the project intensively to install a VTIC in Fienso—and in June 2015, his dream was realized when AVRDC set up a training cluster in the village. “I am happy with the project intervention, not only for the cash I am earning but also for the birth of a network of vegetable producers in the surrounding communities,” said Souleymane. “I am now sharing my knowledge with other farmers because I benefited from others.”

Impact evaluation studies in Bangladesh showed home gardens are a cost-effective approach for alleviating iron, vitamin A and zinc deficiencies.



IN FOCUS

Impact Evaluation

The goal of impact evaluation is to assess change in the well-being of AVRDC's targeted populations that can be attributed to the Center's technologies and interventions. The central question is how people's well-being would have changed if AVRDC projects had not taken place, which requires the careful identification of a comparison group. Impact evaluation is important for an organization to learn what has worked and what has not worked, and to understand the reasons why.

Impact studies are time-consuming and costly and cannot be done for every project. In 2015, the following guiding principles were adopted for selecting technologies and interventions to be evaluated:

- (1) *Innovative*: The intervention or technology is testing a new approach with potential for impact.
- (2) *Replicable*: It is replicable in other countries or scalable to a large population of beneficiaries.
- (3) *Strategic*: It is strategically relevant to AVRDC; it relates closely to AVRDC's mission and strategic plan.
- (4) *Need for evidence*: Little is known about the impact, positive or negative, of the intervention or technology.
- (5) *Policy relevance*: The results of an impact study have potential to influence policy debate.

Two key impact studies were completed in 2015. The first study quantified the impact and cost-effectiveness of training poor rural women in Bangladesh in home gardening and nutrition. Using baseline and follow-up data for 646 intervention and control households, it found significant improvements in vegetable production, vegetable consumption, and micronutrient supply from the garden and provided the first evidence that home gardens are a cost-effective approach for abating iron, vitamin A and zinc deficiencies. Further baseline data were collected for home gardens in Tanzania.

The second completed study analyzed the adoption of tomato and African eggplant

varieties developed by AVRDC, released by national partners and supplied to farmers by private seed companies in East and Southern Africa. It found that 50% of tomato and 98% of African eggplant commercial seed production in 2014 were varieties developed by AVRDC. The study showed very attractive internal rates of return to research in these crops for Tanzania. In 2015, the study was expanded to South Asia and Southeast Asia.

Data collection continued for an impact evaluation of school gardens linked to complementary interventions in nutrition and health on nutritional indicators for primary schoolchildren in Bhutan, Burkina Faso, Indonesia and Nepal. Preliminary results for Nepal showed a significant increase in children's awareness about fruit and vegetables, their knowledge about agriculture and human nutrition, and their stated preferences for eating fruit and vegetables.

Integrated pest management (IPM) is another strategic area for impact evaluation. Baseline studies were conducted in Cambodia, Laos and Vietnam among 900 farm households growing leafy brassicas and vegetable legumes. Post-intervention data were collected in Bangladesh from 300 vegetable growers who had been trained in IPM and an equal number of control households.

The Impact Evaluation group now has a clear pipeline of studies in key areas of AVRDC's work, covering all research and development themes and regions. The results will contribute to learning and strategy development and will enable AVRDC to be more effective and efficient in fulfilling its mission.

EAST and SOUTHEAST ASIA

Elite varieties: Dissemination of improved and adapted varieties has been a key thrust of initiatives to invigorate the vegetable sector across East and Southeast Asia (ESEA). The Cucurbit breeding program, operating from its base in Thailand, developed genetically improved lines of bitter melon to meet specific market segments that had improved yields and quality with inbuilt resistance to fungal and viral diseases. These were showcased to breeders and pathologists from public and private institutes in Asia during Bitter Melon Open Field Days at AVRDC East and Southeast Asia's Research and Training Station, Kasetsart University (KU), Kamphaeng Saen, Thailand, 9-23 August 2015. Results from this concerted breeding effort have led to the creation of a Cucurbit support group among seed companies so that breeders and farmers across the region can benefit from the Center's improved lines. AVRDC researched bitter melon breeding lines with high yield potential and resistance to biotic stresses with preferred consumer traits (fruit shape, color and taste); these were tested in Myanmar and Vietnam in collaboration with Department of Agricultural Research (DAR) and the Fruit and Vegetable Research Institute, respectively, thanks to financial support from the Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan. To develop multiple virus resistant tropical pumpkin lines, the Cucurbit breeding program has established a close research collaboration with KU virologists to undertake controlled environment inoculations to assess resistance to specific viral species and lines selected with resistance are in advanced stage of development. In 2015 the USAID-funded project "Mobilizing Vegetable Genetic Resources and Technologies to Enhance Household Nutrition, Income and Livelihoods in Indonesia" was successfully completed. The legacy was the selection of elite vegetable lines with resistance to prevalent pests and diseases, invigoration of the vegetable sector, and increased technical capacity of agricultural research and development partners.

High value vegetables: Recognition of poor diets and associated noncommunicable diseases in Oceania was addressed by the Australian Centre for International Agricultural Research (ACIAR)-funded project "Strengthening integrated crop management research in the Pacific Islands in support of sustainable intensification of high-value crop production." This created necessary capacity to develop integrated crop management strategies for the sustainable intensification of high-value vegetable production for export and domestic markets.

Activities included the introduction, evaluation and registration of improved Solanaceous varieties, and the testing and promotion of integrated technologies to sustain production across seasons and to stimulate market demand. ‘Melrose’ (formerly CLN3150A-5, sourced from the AVRDC genebank in Taiwan) was officially released by the Ministry of Agriculture in Fiji on 30 September 2015. ‘Melrose’ was selected because it performed very well under Fiji’s growing conditions; it is high yielding and produces well-shaped fruit with a taste preferred by the local market. This variety also has good tolerance to diseases—it is homozygous for the *Ty-2* and *Ty-5* genes for resistance to begomoviruses, and for the *Tm²²* allele for resistance to *Tomato mosaic virus*. For Fijian farmers this new open-pollinated variety provided the opportunity to produce for the local market and to save seeds. This was a milestone achievement for the Secretariat of the Pacific Community, whose technical officers gained capacity during the registration and variety promotion process, along with MOA and the project lead, the University of Queensland. For capsicum, three lines with outstanding performance and acceptable taste (AVPP 1114, AVPP 0701 and AVPP 1113) were selected for further testing in 2016. For the Solomon Islands, results from the regular season tomato promotion trial led to the selection of the orange-fleshed AVRDC cherry line CLN 2071D for official recommendation by the Ministry of Agriculture in 2016 based on superior yield, taste and suitability for the local market. These characteristics were evaluated by collecting yield data over three cropping seasons and conducting of organoleptic tests to determine acceptability as judged by local tasters. A seed production plot was established to produce foundation seed and expert training in seed multiplication and storage of open-pollinated varieties in Papua New Guinea, again funded by ACIAR and other countries in the Pacific, was successfully implemented to catalyze vegetable value webs. To overcome off-season tomato production constraints such as flood and bacterial wilt, grafting was demonstrated using eggplant rootstocks. Local farmers received high quality seeds of improved lines of eggplant, tomato, yard-long and dwarf beans from AVRDC and training to initiate quality seed supply mechanisms.

Seed collection and availability: Activities were undertaken in collaboration with DAR, Myanmar to increase capacity for seed collection, characterization, storage and multiplication to

ensure purity and disease-free status. Similarly in Lao PDR, the Horticulture Research Center (HRC) of the National Agriculture and Forestry Research Institute (NAFRI), received training to build capacity in germplasm and genebank management; to safeguard, characterize and make accessible vegetable germplasm collected from across Lao PDR; and to upgrade and improve the HRC genebank and germplasm management system for medium-term conservation. Partnership with the East-West Seed Company was strengthened in 2015 through supply of high quality seed of traditional and global vegetable varieties that are hardy and nutrient dense for home gardens and commercial production in Cambodia.

Traditional vegetables: Promotion of consumption and production of traditional but recently ignored hardy vegetables in Oceania was facilitated by an ACIAR-funded project to promote nutrient dense and hardy vegetables in Papua New Guinea (PNG) led by Charles Darwin University in Australia in collaboration with AVRDC, the National Agricultural Research Institute, PNG Women in Agriculture for Development, World Vision and International and Fresh Produce Development Agency. To address the constraint of supply of high quality seed (worsened by adverse weather conditions in 2015 that killed existing and limited stocks) AVRDC implemented training-of-trainer programs on “Producing and Saving your Own Vegetable Seeds” to enhance the knowledge and skills on producing, processing and storing high quality vegetable seeds and community mediated seedbank management.

Ecological based pest management: Persistent problems in the production of solanaceous crops and grain legumes are caused by begomoviruses. These concerns were addressed through a project funded by Federal Ministry for Economic Cooperation and Development (BMZ), “Better livelihoods for farmers in tropical Asia with Begomovirus-resistant tomato, hot pepper and mungbean and integrated disease management,” in Thailand and Vietnam (plus India). Population diversity of begomoviruses and their whitefly vectors were mapped and transmission rates determined, and crop varieties selected with corresponding resistance. A consortium of 24 seed companies under the auspices of the Asia & Pacific Seed Association (APSA) took great interest in the multilocation trials of tomato lines with different combinations of

resistance genes, and started a separate project in cooperation with AVRDC to replicate these trials on their own research farms across India, Indonesia, Philippines and Thailand. Tomato lines carrying *Ty-2*, *Ty-3* and *Ty-5* genes were the most tolerant to ranges of begomovirus species. For pepper, the best putative resistance was due to genes conferring resistance/repellence to aphids and whiteflies, and was a quantitative and multigenic trait. For mungbean, markers for resistance were developed for use by breeders to increase selection efficiencies. The integrated disease management options demonstrated that bright yellow traps were effective for whiteflies and the organic salt biopesticide “Lastraw” reduced whitefly populations when applied as seedlings were transplanted. BMZ also funded the “Attraction in Action” project to train national agricultural research staff from Cambodia, Lao PDR and Vietnam to diagnose and control the major pests and diseases of yard-long bean and leafy brassicas. Increasing capacity for diagnosis was a key component as the first and critical step for the deployment of appropriate control interventions. Research components included pest/pathogen characterization, evaluation/validation of IPM technologies, and their promotion and commercialization through public and private sector partnerships. Technologies tested include pheromone traps, biopesticides, natural enemies, and host plant resistance. A similar IPM strategy was deployed for the Swiss Agency for Development and Cooperation funded project “Cambodian Horticulture Project for Advancing Income and Nutrition.” Training activities were undertaken in partnership with Crop Life Asia to promote judicious pesticide use to mitigate pesticide contamination from use of the wrong product, dose, timing, application, storage, and disposal.

Capacity building: AVRDC in Bangkok continued to disseminate technologies for sustainable agricultural production developed by AVRDC and partner organizations. 2015 witnessed the completion of SATNET, the “Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia” funded by the European Union and coordinated by the United Nations Economic and Social Commission for Asia and the Pacific. There were 13 residential in-country technical training programs that met identified demands in Cambodia, Indonesia, Lao PDR and Myanmar. A total of 256 participants were exposed to genebank management

and seed multiplication systems, production and agronomy, IPM, postharvest technologies, extension and project development. The international and academically recognized International Vegetable Training Course (IVTC) was in its 34th year, and AVRDC in partnership with KU and several other lead research and development organizations empowered 40 participants from 21 countries from Asia, Africa, the Middle East and the Pacific Islands. Each of the three month-long modules culminated with every participant preparing a Development Action Plan that harnessed their newly acquired knowledge and adapted it to the specific demands and opportunities found in their respective countries to increase production and consumption of nutritious and health-promoting vegetables. Fifteen lead extension officers from Nepal’s Ministry of Agriculture gained capacity in postharvest technologies provided by AVRDC in collaboration with KU, Asian Institute of Technology (AIT) and King Mongkut’s University of Technology (KMUTT); the initiative was funded by IFAD through the “High Value Agriculture Project in Nepal.” There was a second training focusing on postharvest technologies facilitated by Asian Food and Agriculture Cooperation initiative (AFACI) funded by Rural Development Administration (RDA) of Korea with two participants selected from each of 11 countries. This was conducted in close collaboration with the Department of Agriculture, Thailand, KU, KMUTT and RDA Korea and resulted in the formation of the Asia Postharvest Working Group and in the production of a postharvest reference manual. The success of these trainings is reflected by the fact that AFACI, Nepalese and IVTC trainings will be repeated in 2016.

AARNET: ASEAN-AVRDC Regional Network on Vegetable Research and Development:

In 2015, NAFRI, Lao PDR, hosted the 10th annual AARNET Steering Committee Meeting and Expert Consultation, which focused on climate change adaptation strategies for vegetables in Southeast Asia. Respective country policy frameworks for research and development programs and strategies to mitigate and adapt to climate change were shared and discussed. The AARNET Steering Committee identified common challenges and approaches pertinent to all ASEAN countries and prioritized the need for capacity building on mechanisms to harness the diversity of vegetable genetic resources. In response to this demand, AVRDC facilitated training at headquarters for ASEAN member

scientists that encapsulated germplasm collection, characterization, conservation, and screening for resistance to abiotic and biotic stresses, as well as the sharing of standard protocols for wider use and adoption by ASEAN countries.

1st International Symposium on Moringa, 15-18 November 2015, Manila, Philippines:

The four-day symposium and congress co-organized by AVRDC and hosted by Moringaling Philippines Foundation, Inc. brought together 300 global scientists to share and discuss the latest advances in research and development for moringa, the multipurpose tree. Thematic areas included sustainable production, processing, utilization, marketing and trade as well as consumption for health and vitality, industry profitability, and global competitiveness. The program featured invited speakers, poster sessions, student/fellow presentations, and discussion sessions.

Integrated agricultural systems: Diversification of agricultural production systems to enhance environmental sustainability, market revenues, diet diversity and nutrition through projects that integrate nutritious vegetables with other crops and food sources offers potential to provide options to farmers and value web actors. The CGIAR CRPs offered this opportunity: in the Aquatic Agricultural Systems (AAS) CRP, AVRDC collaborated with WorldFish on sustainable farming for income generation and crop diversification contributing to nutrition security for communities in Malaita Hub, and for the Humidtropics program in the central Mekong action site. For AAS, rural participatory appraisals of smallholder vegetable farmers in Alea, Malaita demonstrated that soil fertility was a major limitation (deficiencies in phosphorus, potassium, calcium, zinc, copper, iron and boron) and that production was further worsened by monocropping, poor seeds, losses due to pests and diseases and off-season climatic effects and marketing problems. To overcome these constraints, interventions were recommended to improve soil fertility (such as fallow cultivation of *Mucuna*), availability of quality seeds, pest management (including grafting) and promotion of crop diversification. Improved varieties for each of tomato, eggplant, and yard-long and dwarf bean were introduced and training was undertaken on taro mini sett technique, seed multiplication and saving for open-pollinated varieties and good agronomic practices. For the Humidtropics program, AVRDC led a situation

analysis to identify opportunities and constraints to agricultural diversification in Northeast Thailand. Based on these results, AVRDC introduced high quality seeds, provided capacity in home garden management, and investigated options for vegetable intercropping with trees.

For Northwest Vietnam, AVRDC led activities to integrate vegetables into agricultural systems, including home gardens and commercial plots, to improve livelihoods of ethnic minorities through increased nutrition and incomes. Vegetable species and varieties were tested and selected based on their seasonal suitability, nutritional content, taste and marketability; linkages between producers and markets were facilitated through an innovation platform. Ecological pest management technologies were demonstrated and adopted and water management technologies tested to enable off-season production. Results from food and nutrition assessments enabled AVRDC and partners to target training initiatives through partnership with the National Institute of Nutrition and the Fruits and Vegetables Research Institute.



MAINTAINING THE DIVERSITY OF BITTER GOURD: Bitter melon is an important cucurbit crop for Asia with economic potential and nutritional importance. However, the repeated use of a comparatively small number of genetically closely related bitter melon lines for commercial breeding has narrowed the genetic diversity of the crop. “With less diversity to work with, it is more difficult to make gains in breeding,” said **Narinder Dhillon**, Cucurbit Breeder, AVRDC East and Southeast Asia. This has been confirmed through simple sequence repeat (SSR) marker analysis of commercial cultivars of bitter melon completed at AVRDC. The Center’s bitter melon breeding approach was to inbreed genetically diverse AVRDC genebank accessions, followed by selection for desirable traits, which led to the identification of 400 advanced breeding lines. These lines belong to different market segments popular with growers and consumers in Asia that have been bred for enhanced fruit quality, improved yield, and resistance to powdery mildew and downy mildew. Some of these lines have been observed to be resistant to viruses during three seasons of field trials in Kamphaeng Saen, Thailand.

Breeders from the private seed sector established a cucurbit support group with AVRDC to benefit from these breeding lines, which were displayed during Bitter Melon Open Field Days at AVRDC East and Southeast Asia’s Research and Training Station on the Kasetsart University campus in Kamphaeng Saen, Thailand. These lines will be subjected to multi-country evaluation with the cooperation of breeders from the private and public seed sector. “AVRDC has made available to us a collection of different valuable traits in bitter melon for our breeding program, especially for powdery mildew and virus resistance,” said **S. Thippeswamy**, Cucurbit Breeder, Bayer Crop Science Vegetable Seeds India. “There is an enormous good effort in AVRDC on breeding multiple disease resistant bitter melon lines.” Other seed company representatives concur: **Gopalkrishna Hegde**, Director of Research, Noble Seeds, India, said “We feel AVRDC’s Global Cucurbit Breeding Program will enable us to develop new bitter melon products for farmers by using AVRDC-bred lines of different pedigrees.”

FARMERS FAVOR FIELD SCHOOLS: As part of the AVRDC-led Vegetables for Indonesia project funded by USAID, Farmer Field Schools (FFS) were conducted to train 3,280 farmers (35% women) on tomato and chili production technologies drawn from the project's adaptive research results. Technologies shared with the farmers included tomato grafting for soil-borne disease management, AVRDC-improved tomato and chili pepper lines, rain shelters, phosphoric acid for tomato late blight management, and starter solution to increase fertilizer efficiency.

An independently conducted outcome assessment indicated that knowledge transfer through FFS was effective. Materials and knowledge disseminated through FFS were perceived by farmers to be useful, and have been implemented, at least partially, by a majority of FFS participants. FFS had a positive impact on the crop yield produced by FFS farmers compared to their counterfactual.

"Farmer Field Schools utilize a participatory approach to increase learning and knowledge retention among the farmers who take part," said **Greg Luther**, the project's principal investigator. "Farmers are in general quite enthusiastic about FFS due to the discovery-based learning and community participation aspects. They usually find the experience to be very worthwhile." Farmers felt that FFS have given them valuable knowledge they can apply to a greater diversity of crops. "Before joining FFS I only planted cassava," said **Mr. Mistohir**, a farmer in Kediri. "But now I plant so many vegetables on my land, and by doing this, I'm able to have more income."



VIRUSES IDENTIFIED: The incidence and severity of virus-like symptoms in vegetable crops, particularly tomato, chili pepper and eggplant, are increasing across many tropical and subtropical growing regions. Knowledge of which viruses are causing the symptoms and how they are spread is key to managing the diseases, but identification of the viruses by observation of the symptoms alone is not possible; more sophisticated diagnostic tools are required.

As part of ongoing projects in South and Southeast Asia, field surveys were conducted and samples from plants with virus-like symptoms were collected and sent to AVRDC headquarters in Taiwan or project partner laboratories for virus diagnosis. Each set of samples was first tested by enzyme-linked immunosorbent assay (ELISA) with antisera specific to the viruses or virus groups most likely to be present. Molecular biology procedures such as polymerase chain reaction and sequencing were used for more specific virus identification.

Comparing the recent results with those from earlier surveys showed that whitefly-transmitted begomoviruses remain the most prevalent group of viruses affecting tomato, peppers and eggplant, though there is high incidence of aphid-transmitted potyviruses in peppers in some locations.

Analysis of partial begomovirus genome sequences indicated the presence of *Tomato yellow leaf curl Kanchanaburi virus* (TYLCKaV) in most samples from eggplant showing virus-like symptoms collected in Indonesia, Lao, Thailand, and Vietnam. However, the sequences from some samples shared greater sequence identity with *Pepper leaf curl virus* (PepLCV). Full-length genome sequences are required to determine if these represent a new begomovirus species, or strains of PepLCV with eggplant as a new host.





AN EFFECTIVE STORAGE SOLUTION IN CAMBODIA AND TANZANIA: Many farmers and traders lack suitable storage facilities for their harvested vegetable crops, resulting in some produce being discarded, reduced marketing opportunities, and reduced income. To keep harvested vegetables fresh, AVRDC has been testing the **zero energy cool chamber (ZECC)**, a brick double-walled chamber filled with moist sand that works by evaporative cooling. Trials in Arusha, Tanzania with traditional leafy vegetables found the ZECC had only a minor effect on temperature, but kept a higher level of humidity in the storage chamber, which reduced water loss from stored produce. Demonstration sites were established in Lushoto and Morogoro regions to evaluate the ZECC technology under farmer-managed conditions. Eighty-five participants (27 women and 58 men) learned how to build and use ZECCs. Farmers can now keep leafy vegetables such as amaranth for up to three days instead of one, while fruit vegetables can be kept up to seven days. Traders with access to ZECCs use them for temporary storage while they bulk up their produce prior to delivery to market. Members of the Kilimo Farmers' Group in the Nduruma area of Tanzania reported that they were previously earning US\$ 7 per sale of about 100 kg of leafy vegetables, but since they started using the ZECC, they are now getting US\$ 9-11 per sale.

Farmers growing leafy vegetables in Svay Rieng province, Cambodia incur losses if produce is not marketed on the day of harvest. Leafy produce such as amaranth, morning glory, and leaf mustard wilts within hours of harvest and must be sold quickly to obtain the best price. Leafy vegetables often are stored in the farmer's house before they are sold in the market the following day, and losses of more than 20% are common due to weight loss, wilting, and loss of visual quality. AVRDC's postharvest project at the Royal University of Agriculture, Phnom Penh introduced simple evaporative coolers through several training-of-trainers workshops and technology forums. A Japanese nongovernmental organization, International Volunteer Center of Yamagata (IVY), working on agriculture and community development programs at the grassroots level in Svay Rieng, learned about the technology and disseminated it among about 90 farmer beneficiaries. These farmers were able to keep their leafy vegetables fresh for marketing the following day, had no more worries about losing income, and were truly able to enjoy the fruits of their labor.

SOUTH ASIA

With more than 60 staff, AVRDC South Asia now has the largest staff complement ever, supported by eight projects and core funding. Several large USAID-funded projects account for the bulk of our regional work. Existing AVRDC operations in Central Asia and the Caucasus were combined with those of South Asia during the year, creating greater linkages between staff and projects. A new mungbean project spans Pakistan and Uzbekistan, and there has been extensive sharing of expertise between staff in India and Pakistan through reciprocal visits and joint workshops. Several study tours of Indian staff to Bangladesh have boosted the sharing of innovative practices.

Staff scientific capacities: Regional staff skills were expanded with new appointments in training, communications, agricultural engineering, postharvest management, protected cultivation, and extension. Training activities in India, Pakistan and Bhutan were expanded in addition to those already ongoing in Bangladesh and Nepal, new agricultural engineering work in protected cultivation and mungbean harvesting was done in Pakistan, and new protected cultivation work started in Tajikistan. The extension of improved vegetable production technologies was expanded in Pakistan and India. At the end of the year, the long-running USAID-funded project in Bangladesh closed with most staff leaving, but good progress has been made in home and school gardening, and in promoting improved varieties and better marketing methods.

New lines and their impact: Improved lines continue to be the most important source of AVRDC's impact. An evaluation of the impact of AVRDC tomato and chili lines in South Asia was conducted through interviews with 27 commercial seed companies and 9 public institutions. Despite the privatization of vegetable seed supplies and the shift to hybrids, 14% of hybrid tomatoes and 13% of hybrid chilies sold in India contain AVRDC germplasm, and this directly benefited over half a million farmers. With the growing use of hybrids, AVRDC germplasm has become more important as a source of specific traits rather than ready varieties. However, such open-pollinated varieties are still important in other locations—for instance, in Central Asia and the Caucasus, where the longest running AVRDC regional network has officially released 52 varieties of 15 different vegetables in six countries over the last decade.

Protected cultivation: There is huge scope to expand protected cultivation in South and Central Asia. It is a key part of the USAID-funded Agricultural Innovations Program (AIP) in Pakistan, the largest AVRDC project in the region, and a component of projects in India, Bangladesh, and Tajikistan. Good progress was made in identifying better varieties, developing and promoting improved structures and management, and in evaluating the economics of particular structures.

The Pakistan team identified top performing varieties of tomato, capsicum, cucumber, chili, bitter gourd and vegetable marrow for winter production under protected cultivation, and top-performing spinach and coriander varieties for summer production under shade net. More than 30 demonstration sites of new protected cultivation technologies have been set up across the country and Punjab Agricultural University in India has produced a new 100 m² sturdy poly net house kit for promotion in Pakistan. Pesticide misuse is widespread, but training of farmers and extension agents has begun to promote alternative practices, and trickle irrigation demonstrations have shown up to 50% savings of water compared to conventional practices.

Protected cultivation is actively promoted in the rest of the region. In India, demonstration net houses were built in Karnataka as part of the Bhoo Samruddhi project to promote capsicum production and the use of grafting for overcoming soil diseases in tomato and chili. These technologies are now being taken up by government extension workers for wider promotion. In Tajikistan, a new USAID project to promote small backyard protected cultivation structures to improve local vegetable supplies has shown major yield improvements with the use of better varieties, staking and improved pest and disease management.

Mungbean: AVRDC's global legume breeding program is based at the South Asia regional office, focusing on mungbean, vegetable soybean, vegetable cowpea, and yard-long bean. Most breeding and project work was done with mungbean. Research and extension work is producing new improved varieties and also expanding the adoption of these and new practices by thousands of farmers.

In Pakistan, improved varieties and management practices have increased yields by up to 80% in

traditional mungbean growing districts. Mungbean is being promoted as an additional source of income in rice-wheat rotations, in double-cropped situations, and as an intercrop in sugarcane and in citrus orchards. Useful herbicides for post-emergence weed control have been researched and methods for effective desiccation and mechanical harvesting of mungbean have been developed and promoted to farmers. Both are increasingly important as rural labor shortages change how the crop is managed. More than 350 farmers were trained in improved pest management. There was good success in expanding seed production of improved varieties; more than 1,300 t of mungbean seed were produced, which will have a major impact on improving production in the 2016 season.

The new BMZ-funded "Beans with Benefits" project links work on mungbean in Pakistan and Uzbekistan. The AVRDC global mini-core collection has been sent to both countries and is being evaluated by national partners to help select better adapted local varieties suited to extremes of heat and salinity.

In India, AVRDC's legume physiologist and national partners have identified six mungbean lines with superior tolerance to high temperatures at flowering and six with good salinity tolerance. Lines have been identified with rapid canopy development and higher yields under elevated CO₂ levels. The global legume program made good progress in the selection of mungbean lines with good resistance to mungbean yellow mosaic disease, the most important viral disease in the region, and good resistance to bruchids, the most important storage pest. Both problems can lead to complete crop losses.

Postharvest management: AVRDC's work on postharvest management of vegetables in the region was strengthened with the appointment of a postharvest specialist to support work in Pakistan and India. The USAID-funded Postharvest Project continued to expand its work in Bangladesh and Nepal. The regional focus is on improving value chains for fresh vegetables, but in Pakistan there also has been a strong emphasis on improving value chains for vegetable seed.

Baseline studies of postharvest losses for tomato and eggplant in Bangladesh and for tomato and cauliflower in Nepal were completed. A baseline

review of vegetable value chains in Pakistan found many areas of need to reduce losses and to improve training. Varietal trials identified tomato varieties with a shelf life up to 8 days longer than local controls in Nepal, and 8-10 days longer in Bangladesh.

New technologies have been tested for their effect in reducing postharvest losses. Coolbots doubled the shelf life of tomato and eggplant in Bangladesh, and this was further extended with modified atmosphere packaging. Brick evaporative coolers improved shelf life by reducing moisture loss, and postharvest laboratories are under development in Bangladesh, Nepal, India, and Pakistan. Non-invasive methods of quality evaluation of tomato were developed and a range of fungicidal treatments were successfully tested as alternatives to chlorine, including calcinated calcium from scallop powder and 0.5% chitosan dip. Solar dryers were developed for rapid production of more hygienic tomato, eggplant, chili and leafy vegetable products. Successful trials of tomato sauce production in Bangladesh and Nepal and the production of eggplant pickles in Bangladesh were conducted. However, some farmer practices such as cauliflower packing methods in Nepal were found to cause lower losses than best practices from the lab. Many of these technologies were showcased in an international postharvest conference in Cambodia in late 2015.

Extensive training programs for trainers and farmers have been conducted to promote improved postharvest management and the use of the best identified technologies, with five workshops in Bangladesh, four in Nepal, and one in Pakistan. Seed quality is a major problem across the region, but in Pakistan more than 8 t of basic seed of improved varieties of onion, peas, okra, tomato and chili was produced for bulking up by farmer-cooperators. Workshops were held with farmers to help develop seed grower cooperatives and to link these to commercial buyers. There has been very strong demand for the seed produced.

Home and school gardens: Home gardens are important components of projects in India and Bangladesh. Improved practices for home gardens have been promoted in Karnataka in India and in flood-ravaged parts of Odisha state under the COFRA-funded project to provide improved diets following disasters. Five training programs were developed for Odisha and promoted with both

printed and video materials. Almost 19,000 disaster response home garden seed packs were distributed to flood victims, and the benefits assessed. In Bangladesh more than 1,200 women were trained in home gardening, with production pamphlets and seed packs provided; data collected shows that gardens lead to a significant increase in home vegetable consumption.

School gardens are being actively developed and promoted in Nepal, Bhutan, and Bangladesh. Vegetables Go to School, the Swiss Development Corporation-funded project to promote school gardening, has completed baseline and year-end studies of the nutritional value of school gardens in Nepal and Bhutan showing that they make a significant difference to students' nutritional knowledge and attitudes. The project is strongly supported by governments; extensive data are being collected and training programs have been developed for teachers and students. The school garden work is integrated with improving water supply and sanitation programs. An evaluation of the first phase of the project was positive and recommended its continuation. In Bangladesh more than 3,400 students were trained in school gardening and seven gardens established in four districts.

THE SIGN OF PROSPERITY: Forty-five-year-old **Khadrayya** (*second from left*) of Raichur district in Karnataka, India only has a 0.4-hectare farm, but he was quick to realize the potential of vegetable cowpea as a lucrative commercial crop as well as a remedy for his tired soil. Instead of leaving his land fallow after rice, he planted vegetable cowpea on residual moisture, and last year earned an additional Rs.11,500 (US\$ 170), which was enough cash to get out of his annual cycle of debt. “My farm is green all throughout the year,” he said. “Friends and neighbors see it as a sign of prosperity. I too started to experience the same. At this time of the year we are usually on the hunt for loans to buy inputs for paddy cultivation in the rainy *kharif* season. But for once, I can put my worries to rest.” In India, cowpea is consumed as green pods, and Khadrayya harvested 985 kg of pods from his field and sold it at Rs.16/kg (US\$ 00.24). The new crop also benefits the paddy rice that is the mainstay of their lives. “When fellow farmers come to me, I also tell them how this crop will improve our nitrogen-starved soil,” he says. AVRDC is promoting vegetable cowpea as a pure crop, and as an intercrop with sugarcane and in coconut/areca nut gardens. Over the last two years the introduction of improved high-yielding varieties has changed perceptions of the crop. In 2015, 43 farmers in the project areas joined Khadrayya in growing vegetable cowpea for the first time.



PROFITING FROM KNOWLEDGE: Through October 2015, AVRDC conducted 38 training sessions, 20 field days and 16 workshops for farmers in Pakistan—and **Muhammad Saleem Gujjar** is one farmer among many that benefited from the knowledge he gained by participating in the sessions. Mr. Saleem, a progressive farmer from Bhikhi, Sheikhpura, Pakistan has been growing capsicum, chilies, cucumber, bitter gourd and tomato in tunnels on 5.6 hectares since January 2014. Mr. Saleem attended a series of AVRDC training classes on healthy vegetable seedling production, tunnel management, vegetable production technology, integrated pest management, postharvest management, and value addition for vegetables. He also took part in a five-day training of trainers workshop on “Understanding the opportunities of protected cultivation of vegetables in

Pakistan” conducted by AVRDC staff and experts from Punjab Agriculture University, Ludhiana, India. Through the Agriculture Innovation Program (AIP) for Pakistan funded by USAID, AVRDC provided Mr. Saleem with two net houses and a drip irrigation system, and one flume for calculating water in flood irrigation. “Being a beneficiary of AVRDC is a good experience for me, as I have learned new methods and technologies for protected cultivation of vegetables,” said Mr. Saleem. “By applying these methods in the field I have reduced input costs and have increased profit from the bumper crops in the last two years.” In 2014-2015, Mr. Saleem’s per-hectare net profit from cucumber was US\$ 7,219; from capsicum, US\$ 11,506; and from tomato, US\$ 19,911—evidence that acquiring knowledge can be a profitable exercise.





COOLBOTS ARE HOT IN NEPAL: Prem Lama is an enterprising entrepreneur who has been engaged in vegetable production and marketing for the past 14 years in Nepal. A member of several farmers' cooperatives, Mr. Lama operates a 10-hectare organic horticulture farm at Aashapuri, Kavre at a high altitude 30 km northeast from Kathmandu, and a 10-hectare farm in Nabalparasi at a lower altitude in the Terai region 175 km southwest of Kathmandu. Mr. Lama sells most of his produce to high-value direct markets: high star-rated hotels, 25 foreign embassies and diplomatic missions, and many foreigners working in international organizations. Mr. Lama also exports some organic vegetables to New Delhi, India and Singapore through agents. Vegetables bring in about 2 billion Nepalese rupees (US\$ 18,868) annually for Mr. Lama.

However, finding ways to preserve the quality of his fresh produce after harvest and during distribution remains a challenge. He purchased two large refrigerators to temporarily store vegetables before distribution, but the volume of produce the refrigerators could accommodate was limited.

Coolbot to the rescue! The Coolbot, a device developed at the University of California (UC) - Davis and adapted by AVRDC and the USAID-funded Postharvest Project, can turn any room into a low-cost cold storage space. A standard air-conditioning unit is installed in the room, and a Coolbot is attached to the unit. The lowest setting on most air-conditioners is 16 °C—but with a Coolbot, the temperature can be set as low as 0 °C. About 5 °C is suitable for semi-temperate or sub-tropical vegetables, and 13 °C is best for tropical produce. The project provided a Coolbot to Mr. Lama, who installed it in the packhouse preparation area in his house in August 2015. He was able to store his vegetables at least 3 times longer than at room temperature. He plans to add four more Coolbots at his own expense so that he can expand and improve his business. Three other farmers and entrepreneurs that have seen the device in action also want to install Coolbots. The project is working with the UC Davis Horticulture Innovation Lab Regional Center for Asia, based at Kasetsart University, Bangkok, Thailand, to obtain the Coolbot devices.

GROWING UP: The use of nets and vertical structures to support bottle gourd is helping farmers in DI Khan, Pakistan harvest better quality fruit, which fetches higher prices in markets. Known as *lauki* in the local language, the local varieties of bottle gourd were low yielding and produced poor quality fruit. To improve farmers' livelihoods and enhance the sustainability of local agriculture, AVRDC – The World Vegetable Center introduced vertical gardening methods with the support of the USAID-funded Agriculture Innovation Program (AIP) in collaboration with Pakistan's Agriculture Research Institute at DI Khan. Field demonstrations were carried out during October-December 2015; farmers received seed of two bottle gourd hybrids ('Long' and 'Super hybrid F₁'), nets, and technical assistance. Vertical nets were installed on bamboo stakes in the farmers' fields, and the crop was trained to grow up the nets. Farmers using the vertical method have reported improved fruit quality and yield. "Using nets and amending planting geometry has enhanced the quality of our fruit," said **Malik Ramzan**, a farmer from Hissam village—who also noted pest infestations were less severe after he began using vertical structures.



IMPACT AND COST-EFFECTIVENESS OF HOME GARDEN TRAINING:

There is growing interest in the potential of household-based food production to address micronutrient undernutrition in developing countries. Home gardens in particular have been recognized as potentially effective in reaching nutritional outcomes, but evidence that **home gardens** are a cost-effective method to combat micronutrient deficiency is lacking. AVRDC conducted a study to quantify the impact and cost-effectiveness of training poor rural women in Bangladesh in home gardening and nutrition. AVRDC and local partner BRAC trained more than 8,000 Bangladeshi women in vegetable gardening methods and nutrition between 2012 and 2013. The researchers collected data from 646 women in 2013 and again in 2014, after 408 of them had been trained. Using a double-difference method, the researchers were able to show that the intervention significantly ($p < 0.01$) increased vegetable production and vegetable consumption. Most of the increase was due to leafy vegetable production, which led to a significant increase ($p < 0.01$) in the micronutrient supply. The disability adjusted life years (DALYs) approach was then used to quantify the potential health benefits of increased micronutrient availability. Comparing the cost per DALY saved in abating iron, vitamin A and zinc deficiencies to the per capita income of Bangladesh, as suggested by the World Health Organization, shows that the intervention was cost-effective. Home gardens are therefore a useful strategy to promote better balanced diets among poor rural households, and may complement other health interventions.



MUNGBEAN SEED MULTIPLIES IN UZBEKISTAN AND PAKISTAN: In Uzbekistan's hot and dry summers, a lack of water limits cultivation of vegetable crops and intensive winter wheat production has caused overall soil fertility to decline. AVRDC works with the International Center for Agricultural Research in the Dry Areas (ICARDA) to develop **cereal-mungbean crop rotation systems** for Uzbekistan's Fergana valley. Large quantities of mungbean seed are required to support this effort, and in 2014 local farmers from Akmal Matmusaev district began producing seed of mungbean cultivars 'Durdona,' 'Zilola,' 'Marjon' and 'Turon' developed from AVRDC germplasm and released in Uzbekistan. The farmers produced about 800 kilograms of super elite seed, which was distributed to farmers in the valley. An additional four mungbean seed production farms were established in Kuva district in 2015, and these farms produced about 15 t of elite seed, which will support the enlargement of Uzbekistan's mungbean production area to 1000 hectares in 2016. Farmers in Uzbekistan are beginning to appreciate mungbean as a catch crop: they are realizing more profit from mungbean production compared to crops that require more water; consumer demand is developing; mungbean contributes to gradual improvements in soil fertility; and it also can be used as livestock fodder.

In Pakistan, AVRDC introduced mungbean into various cropping systems, as well as an intercrop in sugarcane and citrus plantations. Demonstration plots of high yielding mungbean cultivars 'NM-11' and 'AZRI-6' were planted in six clusters involving 58 farmers in Bhakkar and Layyah districts of Punjab. The use of improved production practices including line sowing, use of *Rhizobium* + PSB (Phosphorus Solubilizing Bacteria), post-emergence chemical weed control, and integrated pest management methods led to a significant increase in yield and farmers' incomes. According to the Agricultural Statistics of Pakistan, the average mungbean yield of the area is 600 – 700 kilograms per hectare (kg/ha). With AVRDC improved lines and practices, the mean yield was 1143 kg/ha with a net profit of US\$ 540 – 945. When mungbean was introduced as a catch crop in the rice-wheat system, the yield ranged from 594 – 1297 kg/ha, and 40 farmers realized a net revenue gain from US\$ 186 – 688 per hectare. This is additional income for this cropping system and indicates the value of the innovation. Introducing mungbean in the rain-fed wheat-fallow system in medium to high rainfall (up to 350 mm) areas (Attock, Rawalpindi/Islamabad, Chakwal and Jhelum districts, Pothwar) proved valuable for 80 farmers; their mean yields ranged from 600 – 1300 kg/ha, with net profits of US\$ 124 – 624 per hectare. Bhakkar district is in the center of Pakistan's traditional mungbean production area and is a suitable location for seed production. The Arid Zone Research Institute (AZRI)-Bhakkar, an AVRDC partner, produced 28 t of quality seed of the two main high yielding mungbean cultivars, 'AZRI-06' and 'NM-11,' with a total seed value of about PKR 2.8 million (US\$ 26,697). Outreach to Mumtaz Seed Company Ltd. led to the production of 500 t of seed of three cultivars ('AZRI-06,' 'NM-11' and 'NM-15'). This means more than 1300 t of quality mungbean seed will enter the market during the 2015-16 cropping season.



SALT-TOLERANT MUNGBEAN A STEP CLOSER: Soil salinity affects more than 800 million hectares of land globally. Saline soils impair plant growth in two ways: through osmotic stress and through ion toxicity. Plants can adapt to osmotic stress through accumulation of solutes that lower the water potential in the plant tissue and facilitate water uptake from moderately saline soils. Tolerance to toxic ion concentrations can be achieved through reducing ion uptake or by allocating excess ions to specific plant cell compartments.

Salt stress reduces crop yields, and legume crops are particularly sensitive to salinity. "Salt stress affects establishment of the mungbean crop in the field resulting in low plant density and reduced yields," said Legume Breeder **Ram Nair**. "Soil salinity is becoming a major limiting factor for mungbean growth in parts of South and Central Asia. At the same time, we lack information on salt tolerant mungbean germplasm for breeding improved lines."

To identify salt-tolerant accessions, AVRDC researchers selected 296 accessions for a mini-core collection that represents a large portion of the diversity available in the whole AVRDC mungbean collection (about 8,000 accessions). This germplasm panel was challenged with salt (sodium chloride) during seed germination and seedling growth. Several highly tolerant accessions were detected: Two accessions of the mini-core had a 100% germination rate under salt stress, and for eight accessions the germination rate exceeded 90%. At the seedling stage, seven highly tolerant accessions were found. Tolerance during the seedling stage apparently relied on different mechanisms than seed germination, as different accessions were tolerant at each of the stages. The next steps: investigate the traits underlying tolerance at the different growth stages, and combine seed germination and seedling tolerance in mungbean lines to improve salt tolerance.

PACIFIC ISLANDS PREFER AVRDC OPEN-POLLINATED TOMATOES: Regular season tomato variety evaluation field trials conducted over three cropping seasons in the Solomon Islands and Fiji concluded with the official launch of a fresh market line for each country. In the Solomon Islands, '**Rose's Choice**' (CLN 2585D), selected for its high yield and excellent taste, is now widely promoted. The initial distribution of

seed was limited to farmers in Honiara and farmers from rural areas who enquired at the AVRDC Solomon Islands office. An opportunity for wider introduction to farmers in Malaita came about during the Aquatic Agricultural Systems Project Field Day on 26 August 2015. During the event, 91 recipients received more than 100 seed packets and seedlings of 'Rose's Choice.' The AVRDC team visits farmers in the three communities of North Malaita to provide technical advice on improved crop management practices to achieve optimum yield and crop quality for the local market.



'**Melrose**' (CLN3150A-5) was selected because it performed very well under Fiji's growing conditions. This high-yielding tomato produces tasty, well-shaped fruits, and has excellent disease resistance, being homozygous for *Ty-2* and *Ty-5* genes for resistance to tomato yellow leaf curl disease caused by begomoviruses, and for the *Tm²²* allele for resistance to *Tomato mosaic virus*. The cultivar was officially launched at Sigatoka Research Station on 30 September 2015 by Fiji's Assistant Minister for Agriculture, Joeli Cawaki, and the event was attended by farmers and Ministry of Agriculture staff from different parts of the main island of Viti Levu. Shalendra Prasad, the Principal Research Officer of Sigatoka Research Station, said 'Melrose' is now the best tomato in the country.

PICKLE PRODUCTS A POSITIVE PROMOTION: In March 2015, the USAID Horticulture Project in Bangladesh implemented by AVRDC and the International Potato Center (CIP), together with the USAID Postharvest Project and the Bangladesh Department of Agriculture Marketing (DAM), started promoting vegetable processing for microentrepreneurs to improve household incomes and nutritional status. The effort quickly got into a pickle, which proved to be a positive outcome for a young farmer named **Mr. Shoeb**.

Mr. Shoeb attended a training program on postharvest handling, vegetable processing, and market development in Faridpur from 22-23 March 2015, where he learned how to prepare different types of pickles. After the training, he produced sample pickle products of brinjal (eggplant), mixed vegetables and garlic, which were then supplied to four supermarkets in Faridpur to test demand for homemade products. Consumers especially liked his garlic pickles, but the stores insisted the product be registered with the Bangladesh Standards and Testing Institution (BSTI). The project arranged the BSTI registration of garlic pickle on December 2015—a challenging process that required six types of certificates from different organizations. USAID covered the cost of BSTI registration and worked with DAM to facilitate the paperwork. The projects initially paid for Mr. Shoeb's bottles and labels.

Mr. Shoeb began selling his pickled products in July 2015 in Faridpur. He sold 297 bottles of garlic pickle and 49 bottles of brinjal pickles in different malls and department stores, which netted about US\$ 200. He used the money to purchase small-scale processing equipment. Now he is purchasing bottles and other packaging materials on his own, and he is marketing his pickled products nationwide.



SAVING SEED SAVES PAPUA NEW GUINEA: In August 2015, El Nino-driven drought and frost in the normally tropical highlands of Papua New Guinea (PNG) brought cold Tasmania-like weather to Enga province. It was the worst frost to hit the province in 40 years, and directly affected 300,000 people. Hundreds of villages faced months without food after their gardens were destroyed by the dry, cold weather. With the lost crops and the ongoing drought, people lost not only their food and water sources, but also their source of seed for the next cropping season. To enhance seed security in PNG and to ensure availability of good quality seed of traditional vegetable crops, AVRDC conducted a training-of-trainers course on “Producing and Saving your Own Vegetable Seeds” in September 2015 at the Laloki Southern Regional Center near Port Moresby. Participants learned how to produce, maintain and store high quality vegetable seed, and also how to manage community seedbanks. Twenty key staff from the Fresh Produce Development Agency (FPDA), World Vision International (WVI), PNG Women in Agriculture for Development (PNGWiAD), the National Volunteer Service, the City Mission, Childfund, the Correction Institute Service, the National Agricultural Research Institute (NARI), and the Department of Agriculture from the Central Province were trained in seed-saving methods.

The training had a special focus on traditional vegetable crops. Historically, crops such as aibika (*Abelmoschus manihot*), pumpkin tips (*Cucurbita* spp.), sweet potato leaves (*Ipomoea batatas*), and rungia (*Rungia klossii*) provided a large proportion of the daily protein, vitamin and mineral intake in village diets. But food consumption patterns in urban areas have changed in recent decades, with an increasing consumer preference for imported food such as tinned meats, rice and flour. Increasing availability and access to traditional vegetables can improve food and nutrition security, particularly for communities that are remote and isolated, and for poor urban communities. “I work with an organization that mostly deals with imported seed, chemical pesticides, herbicides and fertilizers, so this workshop changed my perspective,” said **Brigitta Kindiwa**, Extension Advisor for the Fresh Produce Development Agency. “As an extension advisor, I will start to teach farmers how to preserve traditional seeds, and put more emphasis on biological and cultural control of insect pests, diseases, and weeds.”

VEGETABLES GO TO SCHOOL IN NEPAL: Many children in low income countries are affected by poor quality diets with long-term and largely irreversible effects on their physical and intellectual development. In an attempt to promote balanced diets, school garden programs try to influence eating habits and food attitudes of younger children, as evidence suggests that these can persist through to adulthood. “There is little to no evidence for the impact of school gardens on younger children’s nutritional outcomes for low income countries,” says **Pepijn Schreinemachers**, Lead Specialist – Impact Evaluation. “All existing evidence comes from studies in high income countries, which might not apply to a low income country.” With funding from the Swiss Agency for Development and Cooperation, AVRDC researchers in collaboration with national partners in the target countries, the University of Freiburg, and the Swiss Tropical and Public Health Institute conducted an experiment in Nepal. Using a cluster randomized controlled trial design, the team established school gardens linked to complementary lessons and promotional activities about gardening, nutrition, and health in 10 randomly selected schools and compared the outcomes to 20 randomly selected control schools. Data were collected at the start and at the end of the school year for a sample of 1,275 school children. Preliminary results show that the school garden intervention led to a significant ($p < 0.01$) increase in children’s nutritional awareness about fruit and vegetables, their knowledge about agriculture, nutrition and health linkages, and their stated preferences for eating fruits and vegetables. However, these improvements did not, or have not yet, translated into increased fruit and vegetable consumption or improved nutritional status. Such improvements might take longer to materialize, and thus the experiment will continue for another year.



SHARING IS THE KEY TO SUCCESS: “Sharing a handful of seeds with our near and dear could mean securing our future during troubled times,” said 38-year-old **Sarawati Baralo** from Lombilo village in the Eastern Indian state of Odisha. “After harvest, I invest my excess seeds with my neighbors, helping them have their own home garden; they in turn help others and through this chain my profits will increase manyfold.” Ms. Baralo was one of almost 19,000 beneficiaries who received disaster response seed kits provided by AVRDC following disastrous flooding in Odisha in August 2014. Her village, along with several others in Nimapada and Kanas blocks of Puri

district, regularly experience severe flooding and prolonged waterlogging of their fields, making cultivation impossible. Crops and property are destroyed and the prices of vegetables and other commodities shoot up following the floods. This makes life particularly hard on women and children as the quality of their diets suffer for months at a time.

Working as a part of a development project with AVRDC, the Society for Women’s Action and Development (SWAD) organized a training program on seed extraction and storage in March 2015. Sarawati and others learned how to save their own seeds of basella, spinach, tomato and amaranth. Nearly one-third of the trainees are estimated to have produced seed from their home gardens and to have shared them widely within their communities. While the disaster response kits met immediate needs, new vegetables and management techniques are improving the quality of diets in the long term. The activities were part of the three-year project ‘Strengthening the capacity of vulnerable communities to prepare for the recovery from floods in India’ funded by the COFRA Foundation and led by Catholic Relief Services.





SEEDS OF REVOLUTION: A group of onion farmers in Pakistan fed up with the exorbitant prices and poor quality of onion seed decided to completely reform their seed supply system. It takes two seasons to produce onion seed, but only one to produce a saleable onion bulb. Seed production is also more complex, and strong demand for fresh onions meant that professional seed growers disappeared over the last 20 years. Farmers might let a crop to go to seed if onion prices were low, but the seed they sold was not true to type and most farmers bought seed from seed companies. Most seed companies in Pakistan import seed rather than source it locally. Mixed seed, the sale of untested varieties and poor storage meant that the quality of seed sold to farmers is often very poor. With little bargaining power, farmers who did produce seed got low prices from traders.

The interventions of AVRDC – The World Vegetable Center under the Agricultural Innovation Program (AIP) for Pakistan eased the situation as farmers were provided with onion mother bulbs and other inputs through Agriculture Research Institutes (ARIs) across the country. These institutes are authentic sources of certified seed and mother bulbs. In Sindh, Punjab, Balochistan and Khyber Pakhtunkhwa, 20 farmers were selected to produce onion seed on a total of 4.9 hectares in 2014-15. AVRDC provided the growers with true-to-type onion bulbs of the popular open-pollinated varieties Sariab Red, Chiltan-89, Phulkara, Swat 1 and Nasar Puri and gave training in certified seed production. ARIs helped them with harvesting, threshing, grading, certification and attractive and durable packaging. The crops were constantly monitored for insect infestation and disease. A total of 1.73 t of quality seed was produced, which fetched Rs. 2500 – 4000/kg (US\$ 36-58) in the market.

“It’s very profitable compared to fresh produce, and as the temperatures drop it is easy to keep the seed for up to six months for sale next season,” said **Arbab Mir Ahmad**, a seed grower from Balochistan. Fresh onions sell for Rs. 400-800 per 100 kg bag (US\$ 5-11) and the gross income per hectare is around Rs. 200,000 to 400,000 (US\$ 3,000-6,000). But seed production is a much more profitable endeavor, said AVRDC Vegetable Seed Specialist **Mazullah Khan**: “A farmer can produce about 450-500 kilos of seed per hectare and sell it for 2500-4000 rupees per kilo (US\$ 36-58) easily. Growing onion seed can return a gross income about three to four times that of fresh produce.”

A different strategy was adopted for marketing seed. As the plantations were started, meetings were organized between farmers and seed dealers, and the dealers were invited to see the standing crop at the flowering stage. Seed was sold at premium prices, mostly owing to this unique strategy of AVRDC.



QUALITY PUT TO THE TEST: Vegetable varieties with quality traits (e.g. high yield, good quality fruit, long shelf life, and desirable processing traits) that require fewer inputs need to be identified and promoted for adoption by farmers, traders and consumers. Several postharvest value chain assessments carried out under the USAID-funded Postharvest Project revealed stakeholders had a strong interest in **new vegetable varieties** with improved quality characteristics to replace the varieties they currently produce and handle.

Field trials were conducted in Bangladesh, Nepal and Cambodia to evaluate crop growth, fruit yield, harvest quality, shelf life and processing quality of elite AVRDC tomato lines, with one set of trials for fresh market lines and the other for processing lines. Nine advanced tomato lines with long shelf-life attributes from the AVRDC breeding program were compared with local varieties Mongal in Cambodia, BARI Tomato-14 in Bangladesh, and Pusa Ruby in Nepal. In Ghana, a variety trial was conducted to evaluate yield of amaranth and jute mallow lines. AVRDC's 'Madiira 2' (4.64 t/ha) performed better than the local indigenous landrace Alefu (1.49 t/ha). AVRDC jute mallow selection HS (1.38 t/ha) out-yielded the local variety Ayoyo (0.96 t/ha).

Yield data from the trials show several of the AVRDC lines out-yielded the local check. In Bangladesh, CLN3948 (84 t/ha) performed better than BARI Tomato-14 (73 t/ha). In Nepal CLN3940 (113 t/ha) outperformed Pusa Ruby (33 t/ha). In Cambodia CLN3940 (99 t/ha) performed better than Mongal (77 t/ha). Some lines consistently performed better than the local check in all three locations, especially CLN3948 and CLN3940 in terms of yield.

In Bangladesh, shelf-life tests produced some interesting results, with the local landraces keeping for 10 days after harvest while lines CLN3948 and CLN3949 remained in good condition for 20 days at ambient conditions. In Nepal, all promising lines with high yields kept for 30 days—at least 10 days longer than the local check. In Cambodia, the local check had very good shelf-life and stayed in good condition for 23 days with CLN3948 being the only closely comparable line, remaining in good condition for 18 days.





IN FOCUS

Research and Development

The Center's research and development portfolio is led by the Deputy Director General for Research who also chairs the Institutional Research and Development Committee. This Committee reviewed and monitored the Center's research and development agenda to assure consistency with the Center's *Strategic Plan 2010 - 2025*, and the *Medium-Term Plan 2014 - 2016*. The Center's strategic vision with respect to its research and development portfolio was also developed to attract funding in coordination with the Center's resource mobilization efforts to keep an appropriate balance between research and development. To strengthen the innovative environment within the Center for research and development, the management continued to stimulate research initiatives among staff members by providing support from the Innovations Fund to implement short-term research activities that would otherwise not be supported by external funding until "proof-of-concept" had been obtained. The research supported by the Innovations Fund is intended to test new ideas, assess novel approaches, and create new opportunities for which external project funding might then be a possibility.

The Center had strong support from many donors in 2015. In particular, the Center appreciated the core funding support from Taiwan's Ministry of Foreign Affairs and Council of Agriculture, the United Kingdom's Department for International Development (DFID), the United States Agency for International Development (USAID), the Federal Republic of Germany, the Royal Government of Thailand, Korea, the Philippines, Japan and Australia (through the Australian Centre for International Agricultural Research). The funding from Taiwan remained a critical funding base for the Center through the Council of Agriculture (COA), and special funding from the Ministry of Foreign Affairs (MOFA) supported AVRDC's global activities that span several regions including South Asia, Southeast Asia, Oceania, and Central America. A research project funded by COA helped the Center strengthen linkages with Taiwanese institutions and scientists, provided outputs of interest to Taiwan and, building on the technical expertise within Taiwan, strengthened the Center's research portfolio. As in previous years, the Center successfully presented the year's work to COA to help them justify the proposed 2016 core funding allocation. Twenty-five donors supported AVRDC through restricted project funding in 2015, with the top ten restricted project donors being USAID, the Federal Republic of Germany through the Ministry for Economic



Cooperation and Development (BMZ), the Swiss Agency for Development and Cooperation (SDC), ACIAR, the CGIAR Consortium of International Agricultural Research Centers, *Conseil ouest et centre africain pour la recherche et le développement agricoles* / West and Central African Council for Agricultural Research and Development (CORAF/WECARD), MOFA (Taiwan), COA (Taiwan), EuropeAid (European Commission) and the Rural Development Administration, Korea. The management ensured linkages with the donor community were sustained and strengthened. In 2015, this consisted of significant time focused on the USAID-funded portfolio to ensure quality outputs that are in line with the United States Feed the Future vision. Collaboration with the Federal Republic of Germany through BMZ and the Advisory Service on Agricultural Research for Development (BEAF) remains strong, supporting Master's students from Germany and the provision of agricultural experts through the Centre for International Migration and Development.

Innovations Fund

The Center set up an Innovations Fund—an internal competitive fund for innovative research—to support research ideas that otherwise are not ready through proof-of-concept to solicit financial support from external donors. These research ideas can include preliminary testing of research concepts, preliminary studies on newly emerged vegetable pests or diseases, exploratory use of biotechnological tools to characterize germplasm and facilitate gene mining for improved conventional breeding, or research that may seem mundane but is nevertheless necessary and for which external donor support is difficult to attain.

The Innovations Fund provides up to US\$ 75,000 per project with a maximum implementation duration of 12 consecutive months. Members of the Center's Institutional Research and Development Committee form a review panel to identify proposals with potential—the main criteria are innovativeness and how the outputs will contribute to the Center's mission. If necessary, AVRDC staff members with relevant background expertise are requested to review the proposals further before a final decision is made by the Deputy Director General – Research.

Two calls for proposals were made in 2015, which resulted in 38 research ideas, ranging from upstream basic research such as genome-editing via site-directed mutagenesis in tomato, to more adaptive research on understanding the inheritance of resistance to powdery mildew in bitter melon, to more downstream research such as improving seed storage techniques and management, and testing a scheme for empowering women in the vegetable value chain. Sixteen research ideas were approved with a total funding support of US\$ 497,905 (see table below). One additional proposal for \$121,000 was approved to provide vital support to facilitate the distribution of AVRDC's Solanaceous germplasm.

Results from Innovations Fund projects will be presented during the bi-weekly research and development seminar series at the Center, and the project managers are strongly encouraged to publish research papers from the Innovations Fund projects in peer-reviewed journals. The Innovations Fund will strengthen the ideas so that they can be presented in a coherent manner supported by quality data to bring in external donor funding for further development.

<i>Approved Innovations Fund Projects in 2015</i>	<i>Budget (US\$)</i>
CRISPR/Cas9 site-directed mutagenesis in tomato	33,000
Understanding the inheritance of resistance to powdery mildew in bitter melon and identify the molecular markers linked to resistance gene	36,000

<i>Approved Innovations Fund Projects in 2015</i>	<i>Budget (US\$)</i>
To harness and enrich germplasm held by Department of Agricultural Research in Myanmar through enhanced collection, conservation, characterization and linkages	16,000
An expedited response to the invasion of the tomato pest <i>Tuta absoluta</i> in Tanzania	31,200
Foliar application of boron to suppress anthracnose disease in chili peppers	28,000
To find a proper alternative to peat moss for agricultural use in the Center	16,000
<i>Maruca vitrata</i> : a complex species or species complex? Unlocking the identification mystery to unravel pheromone polymorphism	22,750
Development of efficient hybrid onion production method using "in-vitro" regeneration of cytoplasmic male sterile (CMS) lines	52,500
SNP genotyping platform	25,000
Improving quality traits in amaranth through polyploidization	25,000
An association mapping study in <i>Capsicum baccatum</i> germplasm to identify novel resistant accessions and markers linked with anthracnose resistance against <i>Colletotrichum acutatum</i> and <i>C. truncatum</i>	48,000
Developing an amaranth selection strategy: Performance of diverse sources of amaranth germplasm in diverse target production environments	30,600
Can our recently identified whitefly and spider mite-resistant wild tomato accessions offer a future solution to the <i>Tuta absoluta</i> crisis?	35,000
Stable isotope signatures: A novel tool to identify genotypes with improved biomass and water use efficiency among vegetable species	43,500
International Vegetable Training Course's web portal for assessing training needs, student registration, networking and evaluation	23,000
Empowering women to be village distributors of high quality vegetable seeds	32,355
Seed health quality control	121,000

MARKER MULTIPLICATION: Molecular markers are in high demand for assessing the genetic diversity among organisms, for trait mapping, and for marker-assisted selection. In the past, obtaining a sufficient amount of high quality molecular markers exceeded the resources available for most vegetable species. The advent of genotyping by sequencing was a game changer, making available molecular markers for virtually any crop at low cost. The method combines marker detection and genotyping in one working step and can yield thousands of markers for mapping populations or germplasm panels in only a few weeks. The standard protocol for preparing sequencing libraries easily can be modified for use with different crop genome sizes and complexity. Freely available bioinformatics software that operates with modest computing power facilitates the extraction of high quality markers from large raw sequence data sets.

AVRDC has adopted genotyping by sequencing to develop markers for vegetable crops including wild and cultivated tomato, pepper, mungbean, pumpkin, spider plant and polyploidy okra. For pepper, a high density genetic map resolving all 12 linkage groups was produced after optimizing the genotyping by sequencing protocol for a crop with large genome size. The map is available for tracking virus and insect resistance genes. In mungbean, the method served to map bruchid and virus resistance loci and markers linked to resistance genes were forwarded to breeders. Genotyping by sequencing on spider plant was applied to monitor line purification in the breeding program, and in okra we showed that genotyping by sequencing also can be successfully applied on a polyploid vegetable crop. “Lack of molecular markers is definitively a thing of the past,” said **Roland Schafleitner**, AVRDC Molecular Breeder. “Now we have the tools required to tackle complex traits of vegetables such as plant growth and yield under drought, heat and salt stress on the molecular level.”



BANK ON IT: AVRDC – The World Vegetable Center’s genebank is the world’s largest public repository of vegetable seed. To date, the genebank at AVRDC headquarters holds in trust 61,835 accessions of 440 vegetable species from 156 countries. Another 2,736 accessions from 50 species are conserved in the seed repository at AVRDC Eastern and Southern Africa in Arusha, Tanzania. The seeds are kept in long-term storage at -18 °C. To maintain viability, seed needs to be regenerated periodically by planting the accessions in the field and harvesting new seed. “Most genebanks experience backlogs in seed regeneration, as this process is laborious and logistically demanding,” said Genebank Manager **Svein Solberg**. “Bad weather also affects seed regeneration.”

In 2015 the genebank significantly reduced the seed regeneration backlog: almost 2,000 accessions of different species from amaranth to yard-long bean, including global vegetables such as tomato and pepper as well as less-known crops such as senna (*Cassia* spp.) and jute mallow (*Corchorus olitorius*) were regenerated in Taiwan and Tanzania. The overall regeneration success rate was exceptionally high (99%). Genebank staff also characterized the morphology of the plants growing in the regeneration fields. These data are available online in the AVGRIS database (<http://203.64.245.49/AVGRIS/>).

The genebank maintains backups of the collection in different locations to protect this precious resource of biodiversity from loss or disaster. In 2015, 649 accessions were sent for safety duplication to the National Plant Genetic Resources Center in Taichung, Taiwan, increasing the total number of duplicated accessions at this institution to 28,079. Other important backup locations are the genebank of the Rural Development Administration in South Korea and the Svalbard Global Seed Vault.



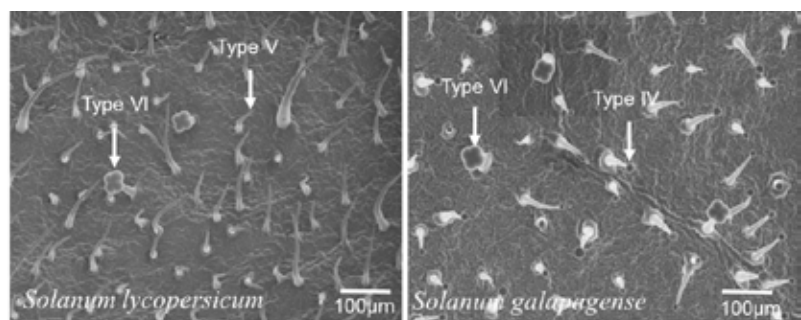
REJUVENATING AND DISTRIBUTING DIVERSITY:

Adding new entries to keep the genebank up-to-date and filling seed requests from users are key tasks of the AVRDC genebank. In 2015, the AVRDC genebank at headquarters acquired 634 new vegetable accessions, and AVRDC Eastern and Southern Africa in Arusha, Tanzania added 144 accessions its seed repository. “Many of the new entries are traditional vegetable species that are extremely important for food security and nutrition,” said Traditional Vegetable Breeder **Fekadu Dinssa**. “Maintaining the biodiversity of these crops in the genebank is essential for future development of improved vegetable varieties. We must protect this diversity for the generations to come.”

The importance of a genebank can be estimated from the number of seed lots distributed to users. In 2015, the AVRDC genebank sent seed of 6,455 vegetable accessions and breeding lines to public and private institutions in 41 countries in compliance with international agreements. This seed is mostly used for research and for breeding new vegetable cultivars or hybrids. New varieties based on AVRDC germplasm are continuously developed. For example, in Kazakhstan alone, five new vegetable varieties produced from AVRDC germplasm were released in 2015.

HAIR A KEY TO RESISTANCE INHERITANCE? Tomato is the world's most popular fruit and the second most important vegetable crop. Unfortunately, cultivated tomato is equally popular among insect pests. More than 50 years ago, tomato breeders began programs to develop insect-resistant tomato to reduce pesticide use and increase grower profit. They crossed thousands upon thousands of different tomato lines—including some wild relatives of tomato—in an effort to breed tomato with resistance to pests and diseases as well as good fruit characteristics, high yield, and tolerance to heat and drought. Yet no resistant cultivars are available to date. Genetically, resistance from distant wild tomato relatives is associated with horticulturally detrimental traits, an effect known as linkage drag. “We have to look for new sources of insect resistance among the species closely related to cultivated tomato,” said **Peter Hanson**, AVRDC Tomato Breeder.

In search of a faster way to screen, or evaluate, tomato plants for resistance traits, AVRDC researchers began taking a closer look at trichomes, the very fine hairs on tomato stems and leaves. There are different types of trichomes, and by checking the trichome type on more than 255 accessions of *Solanum galapagense*, *S. cheesmaniae* and *S. pimpinellifolium* (wild relatives of tomato) and conducting assays with whitefly and spider mites, breeders were able to rapidly identify tomato accessions resistant to these pests.

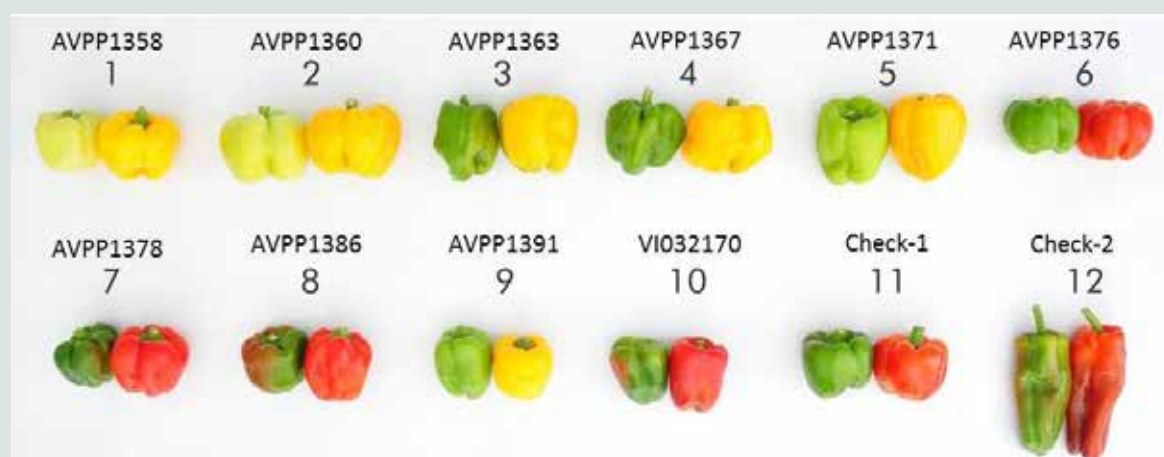


Interestingly, high levels of whitefly and spider mite resistance were found in accessions of all three species. “Insect resistance in these accessions is noteworthy because these species are closely related to cultivated tomato, so introgression of whitefly resistance should be relatively straightforward,” said **Mohamed Rakha**, Postdoctoral Fellow in Tomato Breeding. The selected accessions also will be screened for resistance to Western flower thrips (*Frankliniella occidentalis*), tomato thrips (*Ceratothripoides brunneus*), onion thrips (*Thrips tabaci*), red spider mite (*Tetranychus urticae*), and South American tomato leafminer (*Tuta absoluta*), which are serious production constraints in sub-Saharan Africa and many other regions of the world.



RICE ROTATION KEEPS TOMATO PATHOGEN IN CHECK: *Ralstonia solanacearum* causes the lethal disease, bacterial wilt, on a wide range of crops. Tomato can be infected by strains of all phylotypes of this pathogen. Phylotype IIB-1 strains are mostly present in temperate regions and tropical highland areas. The strain was first identified in Taiwan in 1999 in the central western lowlands. A severe epidemic of potato brown rot occurred in 2006 in Yunlin, Taiwan, where potato is grown during the cool season in rotation with rice. Since then, the disease has occurred sporadically in this area. The influences of temperature, paddy rice rotation, and presence of bacteriophages (viruses that infect bacteria) on the survival capacity of phylotype IIB-1 strains were studied. Results showed pathogen density declined to an undetectable level during a 60-day incubation at 35 °C in Yunlin soil, and a 30-day incubation in AVRDC farm soil. High temperature conditions are unfavorable for the pathogen's survival in soil, regardless of strain. Results of a pot trial showed that paddy rice rotation could effectively reduce the soil pathogen density. The pathogen density rapidly declined from 10^8 colony-forming units (CFU) per gram of dry soil to an undetectable level within 60 to 90 days of rice planting. Bacteriophages capable of infecting phylotype IIB-1 strains were isolated from Yunlin soil, although the density and distribution was limited. Thirty unknown bacteriophages were isolated and all infected the phylotype I and IIB-1 strains tested. Based on the results, AVRDC researchers concluded that the agroecosystem of Yunlin is not a favorable environment for the survival of phylotype IIB-1 strains.

SWEET PEPPERS FOR THE HOT SEASON: AVRDC's pepper breeding program aims to breed heat tolerant sweet peppers adapted to open field conditions in the tropics to provide income-generating opportunities for small-scale farmers. After continuous selection and generation advancement, 10 sweet pepper lines were selected for international distribution (as International Sweet Pepper Nurseries, ISPN-1 to ISPN-10) based on data from replicated trials of two seasons. More than two dozen public and private sector plant breeders selected these lines based on yield performance, nutritional content, and reaction to pests and disease. Besides varying in pod size, shape, color, and heat tolerance, these lines are resistant to *Chili veinal mottle virus* (i.e. AVPP1367, AVPP1371) and *Tomato mosaic virus* (i.e. AVPP1378, AVPP1386). Pepper Breeder Sanjeet Kumar works with the Center's Genetic Resources and Seed Unit to distribute seed samples of these improved nutritious lines along with checks for testing by farmers, researchers, and breeders worldwide.



TRACKING PHYTONUTRIENTS: In 2015, the **AVRDC Nutrition Laboratory** generated 3,664 nutrition data points including contents of essential nutrients (such as protein, beta-carotene, vitamin C, vitamin E and minerals) and phytochemicals (such as carotenoids, flavonoids, anthocyanins, isoflavones) from 629 vegetable samples of tomato, chili pepper, sweet pepper, pumpkin and other vegetable species. Data were shared with collaborators for analysis and reporting. The phytochemical data contributed to the study on “Vegetable, fruit, and phytonutrient consumption patterns in Taiwan in comparison with Korea and the United States.”

Phytonutrients play important roles in human health. Studies describing phytonutrient consumption patterns at the national level and their associations with public health were few due to limited availability of food phytochemical databases. The AVRDC Nutrition Laboratory has been generating nutritional and phytochemical data for a range of vegetable species including more than 150 types of traditional vegetables in tropical Asia and Africa. In 2015, AVRDC collaborated with Academia Sinica in Taiwan to develop a food phytonutrient database with 933 plant-based foods, based on the Taiwanese diet. Values of ten selected phytonutrients from major phytochemical groups (carotenoids, flavonoids, isoflavones and anthocyanins) were collected by integrating selected databases (including the AVRDC nutrient database), a literature search by Academia Sinica, and chemical analyses by the AVRDC Nutrition Laboratory for those plant foods without phytonutrient data.

Phytonutrient consumption patterns and their association with health-related parameters in Taiwan were studied by Dr. Pan Wen-Han's research team from Academia Sinica. Preliminary results suggest that (i) food sources of the ten phytonutrients were diverse, mostly from the food groups of fruit and vegetables; (ii) phytonutrient intakes were higher in populations that consumed recommended intakes of fruit and vegetables (5 portions a day) than in those that did not, and (iii) phytochemical intakes are higher among Taiwanese populations compared to the US and Korea. Taiwanese diets are particularly rich in lutein/zeaxanthin (carotenoids) from green leafy vegetables such as sweet potato leaf, mustard leaf and kangkong, which may confer varied health effects on target populations. Future research is urgently needed to increase the numbers of phytonutrients in the database and to understand the relationship between phytonutrient consumption patterns and long-term health.



List of projects in 2015

Project	Donor	Duration	Budget (in USD)
Multi-location evaluation of tomato lines carrying different combinations of <i>Ty</i> genes for resistance against begomovirus infection	Asia & Pacific Seed Association	2014 - 2016	278,263
International training workshop on postharvest management technology for horticultural crops	Asian Food and Agricultural Cooperation Initiative	2015 - 2017	68,579
Increasing productivity of allium and solanaceous vegetable crops in Indonesia and sub-tropical Australia	Australian Centre for International Research and Development	2013 - 2016	48,710
Multiplication and Distribution of Mungbean Mini-Core Germplasm	Australian Centre for International Research and Development	2015 - 2015	11,272
Improving livelihoods with innovative cropping systems on the East India plateau	Australian Centre for International Research and Development	2012 - 2016	89,454
Strengthening integrated crop management research in the Pacific Islands in support of sustainable intensification of high-value crop production	Australian Centre for International Research and Development	2011 - 2016	831,024
Promoting traditional vegetable production and consumption for improved livelihoods in Papua New Guinea and Northern Australia	Australian Centre for International Research and Development	2014 - 2018	126,031
Improving income and nutrition in Eastern and Southern Africa by enhancing vegetable-based farming and food systems in peri-urban corridors	Australian Centre for International Research and Development	2013 - 2016	1,968,407
Operations of the Humidtropics Innovation Platform in Cameroon	CGIAR	2015 - 2016	41,300
Humidtropics: CGIAR Research Program on Integrated Systems for the Humid Tropics	CGIAR	2012 - 2016	2,143,212
Case study on enhanced nutritional outcomes of a population through nutrition-sensitive agricultural promotion by a vegetable seed company in Bangladesh	CGIAR	2013 - 2015	100,000
CGIAR Research Program for Aquatic Agricultural Systems	CGIAR	2014 - 2015	30,000

Project	Donor	Duration	Budget (in USD)
Strengthening the capacity of vulnerable communities to prepare for the recovery from floods in India	COFRA Foundation, India	2013 - 2015	108,634
Strengthening the cooperation between AVRDC - The World Vegetable Center and Taiwan research institutes on vegetable research and development	Council of Agriculture, Taiwan	2015 - 2015	448,296
Network for knowledge transfer on sustainable agricultural technologies and improved market linkages in South and Southeast Asia	European Commission	2012 - 2015	388,991
Attraction in Action: Using pheromones and other safe and sustainable management strategies to reduce losses from insect pests and plant diseases on vegetable legumes and leafy brassicas in Southeast Asia	Federal Ministry for Economic Cooperation and Development, Germany	2014 - 2017	1,332,001
Vegetable cucurbits for nutrition-sensitive home and school gardens in Southeast Asia	Federal Ministry for Economic Cooperation and Development, Germany	2014 - 2015	66,600
Beating Begomoviruses: Better livelihoods for farmers in tropical Asia with begomovirus resistant tomato, hot pepper and mungbean and integrated disease management	Federal Ministry for Economic Cooperation and Development, Germany	2012 - 2015	1,332,001
GlobE UrbanFoodPlus: Controlled central factorial experiments for participatory development, evaluation and demonstration of improved nutrient and water management strategies	Federal Ministry for Economic Cooperation and Development, Germany	2013 - 2016	124,209
Implementation of integrated thrips and tospovirus management strategies in smallholder vegetable cropping systems of eastern Africa	Federal Ministry for Economic Cooperation and Development, Germany	2012 - 2015	84,470
Enhancing the livelihood opportunities of smallholder African indigenous vegetable producers through the development and implementation of IPM measures for arthropod and nematode pests	Federal Ministry for Economic Cooperation and Development, Germany	2014 - 2016	185,632
Horticultural innovations and learning for improved nutrition and livelihoods in East Africa	Federal Ministry for Economic Cooperation and Development, Germany	2013 - 2016	222,000
Wild Relatives to Fight Blight: Using wild tomato to enhance the resistance of tropical tomato cultivars against late blight	Federal Ministry for Economic Cooperation and Development, Germany	2015 - 2017	88,800
Beans with Benefits: Integrating improved mungbean as a catch crop into the dryland systems of South and Central Asia for increased smallholder farmer income and more sustainable production systems	Federal Ministry for Economic Cooperation and Development, Germany	2015 - 2018	1,332,001
Local Focus: Safe and effective pest and crop management strategies to strengthen the vegetable value chain in the humid tropics	Federal Ministry for Economic Cooperation and Development, Germany	2012 - 2015	120,990

Project	Donor	Duration	Budget (in USD)
RegenIntro: Introduction of accessions from the regeneration initiative into the international collections held by AVRDC	Global Crop Diversity Trust	2013 - 2015	59,451
Improving rural livelihoods through innovative scaling-up of science-led participatory research for development in Karnataka	Government of Karnataka, India	2013 - 2017	231,000
Good Seed Initiative	Irish Aid	2013 - 2016	135,854
Screening for development of begomovirus-resistant processing tomato hybrid	Kagome Co. Ltd., Taiwan	2010 - 2015	88,253
Sustainable Action for Edible Gardens	Milan Municipality, Italy	2014 - 2015	11,100
Selection of tropically adapted lines of vegetables to improve productivity of the vegetable value chain in Southeast Asia	Ministry of Agriculture, Forestry and Fisheries, Japan	2015 - 2016	147,058
Networking to enhance international cooperation in vegetable research and development	Ministry of Foreign Affairs, Taiwan	2015 - 2016	600,000
Mobilize resistance genes from wild tomato for breeding salt tolerant tomato cultivars	Ministry of Science and Technology, Taiwan	2014 - 2016	79,334
Identification and introgression of whitefly (<i>Bemisia tabaci</i>) resistance genes from <i>Solanum pimpinellifolium</i> to tomato	Ministry of Science and Technology, Taiwan	2015 - 2016	18,911
Local adaptation of <i>Ralstonia solanacearum</i> phylotype IIB sequevar 1 strains in Taiwan and identification of their resistance sources in tomato	National Science Council, Taiwan	2013 - 2015	59,855
Utilizing the genome of the vegetable <i>Cleome gynandra</i> for the development of improved cultivars for the West and East African markets	Netherlands Organization for Scientific Research	2015 - 2017	6,105
Support for the implementation of PADFA's onion seed programme	PADFA (Commodity Value-Chain Development Support Project), Cameroon	2012 - 2015	178,673
The supply of services pursuant to request of supplying seed kits and training	Project Concern International	2015 - 2015	9,584
Development of breeding techniques and selection of disease-resistant germplasm in cucurbits	Rural Development Administration, Korea	2014 - 2016	120,000
Development of breeding techniques and selection of virus-resistant germplasm in pepper and tomato	Rural Development Administration, Korea	2013 - 2015	120,000
Postharvest program for RDA seconded scientist	Rural Development Administration, Korea	2014 - 2015	120,000
Cambodian Horticulture Project for Advancing Income and Nutrition	Swiss Agency for Development and Cooperation	2015 - 2017	539,345

Project	Donor	Duration	Budget (in USD)
Vegetables Go to School: Improving nutrition through agricultural diversification	Swiss Agency for Development and Cooperation	2013 - 2016	3,633,169
Evaluation and screening of Syngenta maize and vegetable hybrids for adaptation in Nigeria and skills development program for Syngenta staff	Syngenta Crop Protection AG	2014 - 2017	42,000
Improving incomes, nutrition and health in Bangladesh through potato, sweet potato and vegetables	United States Agency for International Development	2011 - 2015	3,094,421
Mobilizing vegetable genetic resources and technologies to enhance household nutrition, income and livelihoods in Indonesia	United States Agency for International Development	2010 - 2015	1,439,784
Cereal-based Systems of West Africa: Vegetables and associated best management practices in cereal-based crop production systems to improve income and diets of rural and urban households in Northern Ghana and Southern Mali	United States Agency for International Development	2012 - 2016	871,544.00
Deploying Improved Vegetable Technologies to Overcome Malnutrition and Poverty in Mali	United States Agency for International Development	2014 - 2017	7,200,000
Africa RISING: Enhancing vegetable value chains in rice-based and sole crop production systems to improve farm household income and consumer access to safer vegetables in Morogoro, Tanzania (IITA)	United States Agency for International Development	2012 - 2016	418,037
Enhancing partnership among Africa RISING, NAFKA and TUBORESHE CHAKULA Programs for fast-tracking delivery and scaling of agricultural technologies in Tanzania	United States Agency for International Development	2014 - 2016	370,678
Improving nutrition and income of smallholder farmers in Eastern Africa using a market-driven approach to enhance value chain production of African indigenous vegetables	United States Agency for International Development	2015 - 2015	30,000
Africa RISING: Enhancing vegetable value chains in rice-based and sole crop production systems to improve farm household income and consumer access to safer vegetables in Morogoro, Tanzania	United States Agency for International Development	2014 - 2016	591,147
Agricultural Innovation Program: Promoting science and innovation in agriculture in Pakistan	United States Agency for International Development	2013 - 2017	3,164,273
AVRDC Postharvest Program	United States Agency for International Development	2012 - 2017	5,000,000
Deploying vegetable seed kits to tackle malnutrition in Cambodia, Kenya, Uganda, Tanzania and Liberia	United States Agency for International Development	2014 - 2017	6,000,421
Urbanisation and its Impacts on the Use of Natural Resources in Africa	Volkswagen Stiftung, Germany	2014 - 2015	62,826

Project	Donor	Duration	Budget (in USD)
Enhancing productivity, competitiveness and marketing of traditional African (leafy) vegetables for improved income and nutrition in West and Central Africa	West and Central African Council for Agricultural Research and Development	2013 - 2016	658,018

MANAGEMENT

AVRDC – The World Vegetable Center's Management Team in 2015 comprised the Director General, the Deputy Director General - Research, the Deputy Director General - Administration and Services, the Director of Human Resources and the Director of Finance. The management, supported by the Institutional Management Committee and Institutional Research and Development Committee, continued to lead the Center toward achieving its goal of alleviating poverty and malnutrition in the developing world through the production and consumption of health-promoting vegetables. The Institutional Management Committee provided guidance for the Center in line with the strategies, policies, and plans of the Center that were agreed by the Board of Directors. The Institutional Research and Development Committee reviewed, monitored and guided the Center's research and development programs consistent with the Center's 15-year Strategic Plan, Medium-Term Plan and Annual Workplan. The management team therefore set the strategic direction of the Center, guided progress, and assured accountability. The management was involved in the recruitment by AVRDC's Board of Directors of the Center's next Director General who will take up the position in April 2016, and is committed to a seamless handover of the Center's leadership.

The launch of the United Nations Sustainable Development Goals and the proposed targets for international development allowed the Center to consider its future focus and how it will articulate its vision of success. With the participation of AVRDC's Deputy Director General - Research in the formulation of the proposed goals relating to food and nutrition security, nutrition and dietary diversity were clearly visible at a global level. This will enable the Center to develop an informed and globally aligned strategy for the future.

AVRDC held the Chairmanship of the Association of International Research and Development Centers for Agriculture (AIRCA) in 2015, which will rotate in

Developing and nurturing partnerships: Director General of Mali's L'Institut d'Economie Rurale (IER) Bourema Dembele (*second from left*) signed a memorandum of understanding with AVRDC Director General Dyno Keatinge and Regional Director for West and Central Africa, Abdou Tenkounao.



2016 to the Director General of *icipe*. Similarly, the Chairmanship of the Global Horticultural Initiative has passed after two years from AVRDC to the president of the International Society of Horticultural Science (ISHS). The Director General of AVRDC has retained membership on the Executive Committees of both organizations; this will allow AVRDC's global experience along the vegetable value chain to continue to help guide these initiatives and contribute to international policy through their strategies for the attainment of Sustainable Development Goal 2 (SDG2).

AVRDC – The World Vegetable Center has built upon the recommendations of the External Program and Management Review (EPMR), which assessed the Center's performance for the period from 2008 to 2014. While some of the recommendations are on hold pending the arrival of the incoming Director General, as these recommendations will affect the strategic alignment of the Center in the future, much progress has been made to address the other recommendations and suggestions. The Center has decentralized additional responsibility and authority to the Regional Directors, with an additional focus on regional planning to feed into the Center's global planning mechanisms. There has been continued investment in the research and support facilities, both in terms of capital items and infrastructure, as well as funding being made available to complete minor repairs and purchases that could not be funded through restricted project funding. Partnerships were strengthened at headquarters in Taiwan and in the regions where AVRDC has, or wishes to have, a presence. Partnerships with academia were a focus, both in terms of academic excellence, but also as a mechanism to bring in additional project resources from diverse donors. While longer-term partnerships help the Center identify fundraising opportunities, time and trust are needed to build and strengthen new partnerships.

Human Resources continued to develop and improve the Center's organizational structure, strengthen its policy framework, acquire and develop talent, and enhance the engagement of staff in the Center's mission. The recruitment of both international and national staff was done efficiently and in a timely manner to meet competency requirements and project needs.

The Center's policy framework was reviewed and updated. Some of the new policies that were developed are the Child Protection Policy, Anti-Fraud Policy, and Whistleblowing Policy. Compensation benchmarking was undertaken at headquarters and in two regions where the Center has a strong presence for the Nationally Recruited Staff (NRS) category; salary and benefits adjustments were done based on the review. Staff Performance Management was further strengthened and an online appraisal system was implemented for most of the national staff at headquarters. As part of staff capacity building, various staff members were trained in leadership, science communication, media relations, gender and project management skills.

The Center continues to maintain a good gender balance compared with other international agriculture research organizations, with its international staff comprising 30% women, and about 53% women in its overall staff membership. Diversity-positive measures at various stages of the Center's recruitment process ensures and helps to improve the gender balance.

Financial Services provides support to the Center's operational activities and assurances to its stakeholders that AVRDC works efficiently and effectively. Finance is responsible for financial planning, funds management, recording of financial transactions, and financial reporting. Finance maintains Maconomy, the enterprise

resource planning system, which covers accounting needs and offers Human Resources, administration, and project management functions. The Center started using a new report generator in 2015.

At headquarters eight staff work in the Finance unit. In addition, each regional office has finance officers to assist the regional directors and project managers. In 2015 Finance trained the newly appointed finance officer for West and Central Africa. Finance officers from the other regional offices gathered last year at headquarters for training and to exchange experiences with colleagues.

AVRDC rotates the auditors of its financial statements every five years. In 2015, after a competitive tender, AVRDC appointed new auditors for 2015-2019.

The Center has strengthened its financial reserves in recent years. Part of the reserve fund has been set aside to provide a cushion against unexpected financial setbacks. Other reserves are being used to replace and update AVRDC's equipment and infrastructure and to pursue innovative research ideas through the Innovations Fund.

The Deputy Director General for Administration and Services is the Center's main contact with the government authorities of the headquarters host country, the Republic of China (Taiwan), and provides insight and guidance on matters of security, and on diplomatic, environmental and biosafety concerns related to Taiwan to enable the Center to comply with Taiwan's laws and regulations. AVRDC was also able to give appropriate responses to government agencies on institutional issues and was able to address the host country's concerns, interests or expectations, and to assure that fundraising efforts with various host country governmental agencies were coordinated.

Efforts were made to promote AVRDC's reputation and visibility in Taiwan to strengthen government and public support, as well as AVRDC's international reputation through the host country's diplomatic connections. Enhancement of scientific cooperation with the host country's academic and research institutions, and facilitation of linkages with the international agricultural community for Taiwanese scientists were also coordinated.

Administrative and service offices under the Deputy Director General - Administration and Services ensured efficient and effective services to support the implementation of research and development programs, and support the Director General in host country relations. The offices of Purchasing, Travel, General Affairs, Food and Dormitory Services, and Technical Services ensured up-to-date standard operating procedures, assured essential infrastructure for safety and better efficiency, and provided high quality services to institutional functions, including the purchase and import of research materials.

Internal Audit helped the Center maintain good governance to safeguard donors' interests, and reinforced compliance with the Center's policies as well as national and international regulations. In 2015, Internal Audit audited the operations of the Genetic Resources and Seed Unit (which houses AVRDC's genebank), property management at headquarters, operations at the Pakistan sub-regional office, and operations at the regional offices in Eastern and Southern Africa and East and Southeast Asia. Except for some minor errors in maintaining financial and property records at regional and sub-regional offices, there were no material issues found during Internal Audit's routine audit assignments.

Appointed institutional committees functioned to address particular aspects of the Center's research and development activities. The Global Risk Management Committee formulated and recommended strategies to manage risks, ranging from regular checks of potential hazards at the workplace and deployment of fire-fighting equipment and first aid kits, to responding to public health issues (e.g. the Ebola outbreak in Mali and dengue fever in Taiwan), and safety monitoring and contingency plans to evacuate staff in regions where social unrest and insurgency may occur.

The Agricultural Chemicals Control, Campus Environment, and Health and Safety Committee ensured all custodians of toxic chemicals were informed about new regulations from Taiwan's Environmental Protection Administration (EPA), and understood how to manage laboratory waste and keep records of toxic chemicals. At headquarters, the Center joined an organization consisting of 41 local institutions that manufacture, use, store or transport toxic chemical substances and has taken appropriate action with respect to protective equipment for safe handling and disposal of toxic chemicals.

The Institutional Biosafety and Ethics Committee provided oversight of AVRDC's research and development activities to ensure compliance with biosafety regulations, requirements and restrictions. The committee has oversight at headquarters in Taiwan, and in other countries where AVRDC has activities that need to comply with biosafety guidelines and regulations. The committee is the only conduit for obtaining approval for AVRDC activities covered by biosafety regulations and for those experiments using animals.

The Green@AVRDC Committee continues to review the use of utility resources and other activities that have an impact on the environment. The committee recommended improvements and developed procedures for utility resource efficiency and to reduce the carbon footprint of the Center's activities. The headquarters-based Laboratory and Greenhouse Space Allocation Committee assured the optimal use of the Center's greenhouse, screenhouse and glasshouse facilities, as well as laboratories and their associated offices. This committee was vital during the urgent need to establish a Quarantine Laboratory and facilitated the movement of staff and research equipment to free up the needed space. Similarly, the Assets Committee ensured equitable allocation of resources for the Center's global capital requirements, infrastructure and farm improvement to assure greater efficiency and uninterrupted operations. Although the Center's budget and activity levels have increased from previous years, the trend in electricity, fuel and water use, and generation of solid waste, continue to decline due to awareness, monitoring and actions to optimize their use. Peat moss usage was reduced to a negligible quantity, and its purchase stopped. Coconut-based material was tested and substituted as potting material to replace peat moss. All street lights on the headquarters campus were replaced with LED lamps, saving considerable fossil fuel-based energy. Lower electricity consumption reduced the carbon footprint by about 40 metric tonnes of CO₂. The Center now analyses utility usage data trends to detect early water leakages and take remedial action.

BIOMETRICS

Sound biometric methods and access to statistical information and techniques are important for achieving scientifically reliable and high quality research output. AVRDC's biometrics resource covers all biometrics-related aspects of experimentation, from experimental design, field plotting techniques, plot sampling methods, remedial measures for problem data, and statistical analysis of data to presentation and interpretation of results. The quality of all scientific manuscripts is ensured through comprehensive statistical review of reports to ensure and maintain the Center's credibility among donors, clients, and the scientific community.

Biometrics provides the following services to the Center's research scientists and staff: 1) advisory support – provide consulting services or assistance in designing experiments, dealing with data, or other statistical issues; 2) training – in-country and in-house, aimed at improving the skills and understanding of researchers and NARS collaborators who may be infrequent users of statistics; 3) assurance of high quality data – evaluate experimental plans in detail before experiments begin to help ensure proper recording and archiving of procedures and data; and 4) manuscript review – check reports, proposals, and scientific manuscripts for statistical accuracy before submission to international peer-reviewed journals. Specific outputs are analyses of agricultural and meteorological data to highlight the effects of climate on rural smallholder agricultural systems to minimize risk and maximize productivity.

The screenshot displays the homepage of 'The Journal of Agricultural Science'. The header features the journal's title in a green banner, accompanied by images of crops and a cow. Below the header, a navigation bar includes links to 'Home', 'The Journal of Agricultural Science', 'Volume 152', 'Issue 01', and the article title 'Projecting annual air temperature changes to 2025 and beyond: implications for vegetable production worldwide'. The main content area highlights the article 'Projecting annual air temperature changes to 2025 and beyond: implications for vegetable production worldwide' by J. D. H. KEATINGE^{#1}, D. R. LEDESMA^{#1}, F. J. D. KEATINGE^{#2}, and J. D'A. HUGHES^{#1}. The article is from Volume 152, Issue 01, February 2014, pages 38-47. It is published by Cambridge University Press. The page also includes a 'Table of Contents' for February 2014, Volume 152, Issue 01, and a 'Buy This Article' section with pricing options. On the left side, there is a sidebar with social media links (Facebook, Twitter, YouTube, LinkedIn, RSS) and a 'Register for an Account' button. The footer of the page mentions 'Options' and 'Export Citation'.

COMMUNICATIONS AND INFORMATION

Creating media strategies and promotions to inform and influence the public engages the eight members of the Communications and Information group (secretary, graphic designer/photographer, visitor services coordinator, assistant, three librarians, and a group head/editor).

To foster public awareness, the group contacts local and international media, handles press queries, and develops success stories for donors. Communications and Information published 12 issues of *Fresh*, the AVRDC newsletter, distributed to more than 4,000 subscribers; prepared promotional and scientific brochures and posters, videos, and PowerPoint presentations; and produced extension publications on various aspects of vegetable production. International press coverage about the Center in 2015 included television programs aired on stations in Burkina Faso, Laos, Nepal, Taiwan, Tanzania, Thailand and Vietnam; reports on global aggregator websites Food Tank, SciDevNet, and Seed Quest; articles published in the *Guardian*, *Nature*, *International Innovation*, *Appropriate Technology*, *Rural 21*, and *Taiwan Business Topics*; and radio broadcasts on Farm Radio International in Africa.

The Center's website (avrdc.org), developed and managed by Communications, receives approximately 13,000 unique visitors each month. The site offers news, publications, video access, online ordering for seed, and other services. The team coordinates social media outreach through Facebook pages in English and Chinese: www.facebook.com/WorldVegetableCenter), Twitter (@go_vegetables), and a YouTube channel (www.youtube.com/WorldVegetableCenter), and also maintains the Greenhouse, the Center's intranet. Communications opened the AVRDC PhotoBank, an online collection of more than 23,000 photos accessible to staff and partners worldwide.

Visitors view the latest improved tomato and pepper lines during the annual Seed and Seedling Festival and Exhibition of Agricultural Achievements at the Tainan District Agricultural Research and Extension Station in Taiwan.





The Center's editor reviewed more than 200 articles, abstracts, books, proposals, newsletters and other documents in 2015 for grammar, style and coherence. Major publications produced during the year included the *Annual Report 2014*, *Year in Review 2014*, *2015 Annual Workplan*, and *SEAVEG2014 Proceedings*. The AVRDC Library's Library News, a regular e-newsletter, keeps staff up-to-date on recent acquisitions and the latest articles published by colleagues.

The Communications Head gave a seminar on altmetrics to headquarters staff, guided Vegetables Go to School partners in promotional activities, organized a screening of the film *Seeds of Time*, and conducted a day-long development communications session for the 34th International Vegetable Training Course.

Communications coordinated the Center's booth at the Seed & Seedling Festival, an annual event hosted by the Tainan District Agricultural Research and Extension Station in Taiwan that attracted 20,000 visitors in 2015. In line with the event theme—tomato—the Center showcased aspects of its local and global research work on this important crop. The Communications team prepared posters for the festival and Science Day 2015.

Center headquarters welcomed 552 visitors in 2015 from 42 countries; all visitors received briefings and tours tailored to their specific interests. Nested canvas tote bags were added to the Center's corporate gifts.

GLOBAL TECHNOLOGY DISSEMINATION

The Global Technology Dissemination (GTD) group conducted a range of activities in 2015 in the areas of capacity building, technology dissemination and agricultural development innovation.

GTD participated in many activities in AVRDC projects in Asia and Africa. In the Vegetables Go to School project, GTD was part of the rapid assessment team, surveying Bhutan, Nepal and Indonesia, and supported the project by preparing educational materials and providing technical advice. In Thailand, GTD led a home garden training-of-trainers workshop for 23 men and 10 women farmers under the CGIAR's Humidtropics program; research on an innovation platform in Thailand also was completed. GTD participated in a gender R&D project in Bangladesh, which facilitated more than 15 women nursery operators' training in business skills and raising winter vegetable seedlings; field days were attended by 300 farmers to strengthen women's capacity for year-round business operation. GTD concluded a research and development project in Indonesia in which it served as the lead partner; an independently conducted outcome assessment indicated knowledge transfer through Farmer Field Schools was effective. A fertigation research project also was concluded in 2015; the results indicate a computerized fertigation system from Taiwan was more cost-effective than a similar one from Israel.

GTD published four issues of *Feedback from the Field*, a bulletin that communicates technology applications from the field to its readers. This publication is disseminated via the AVRDC website, email and Facebook, where the page has garnered 621 Likes. Other publications on procedures for raising healthy tomato seedlings and tomato grafting also were produced. GTD contributed to development of AVRDC's global household garden strategy and training manual. The group also coordinated the Center's Disaster Response Program to distribute seed of hardy, fast-growing and nutritious vegetable crops to disaster survivors. Approximately 30 kg of seeds were multiplied to replenish stocks. Data on seed kit distribution in 2005-2014 for nutrition and disaster response seed kits from 12 countries were collected and compiled; this information is now available in an internal database. A total of 25,000





seed kits (6 crops/kit) are available at HQ for future requests. In collaboration with the breeding groups and Communications, GTD maintained a web-based seed catalog which greatly facilitates germplasm transfer; onion (6 lines), cucumber (6 lines), pumpkin (7 lines) and rootstocks (9 lines) were added and tomato was updated in the catalog.

GTD managed the headquarters Demonstration Garden, which showcases the Center's technologies and serves as an educational platform for visitors and trainees. A total of 39 families, 156 species, and 224 accessions of vegetables were planted in the garden, including 31 AVRDC improved lines. Nutritional and other information about each crop can be found on signs that are regularly updated. This year, 344 visitors from 34 countries in 2015 visited the garden, guided by GTD staff and others. GTD also supported promotion of the Center's achievements at Taiwan's annual "Seed and Seedling Festival and Exhibition of Agricultural Achievements". Seeds of two accessions of recommended AVRDC eggplant and chili pepper rootstocks were multiplied and processed; more than 700 g of quality seed was produced for future distribution. Seeds of cluster bean and fig-leaf gourd were contributed to the Genetic Resources and Seed Unit after multiplication in the garden. Staff from the Entomology and Pathology groups collect insect and disease samples in the garden.

GTD wrote a capacity development strategy for AVRDC, facilitated administrative issues and logistics for 55 trainees (30 women and 25 men) from 19 countries for training activities at headquarters, and provided guidance for capacity building in the regions.

The group managed a Google Group called "INNOVEG" to link AVRDC scientists working on knowledge-sharing, technology innovation and scaling up/out; 44 AVRDC scientists in Africa, Asia and the Pacific have joined the group. Four concept notes were written in 2015 and submitted for internally funded Innovation Fund grants. GTD managed the Center's mature technologies database and training documents on the intranet to facilitate use by AVRDC staff.

INFORMATION TECHNOLOGY

Information Technology works closely with the Center's research and administration groups at headquarters and in the regional offices.

At headquarters, storage devices have been installed to facilitate network-based services and file discovery and sharing. To provide better security, storage devices have been introduced as pilot installations for the Purchasing and Breeding groups. Network-based services have been implemented at the Bangkhen and Kamphaeng Sean offices in Thailand. IT is working to install and support essential internet infrastructure in the regional offices, and investigating the possibility of having access to high-speed internet via satellite-based services.

To enhance safety of data, IT upgraded key servers running Windows Server 2003 (no longer supported by Microsoft) to Windows Server 2012 R2. Windows 10 was critically evaluated prior to installation on computers running Windows 7, 8 or 8.1. Scheduled updates to VegOne were delivered and quarterly reminders were sent to all users in the first and last months of each quarter. VegOne is a database for accomplishment indicators for the Center's research and development activities. VegOneX for Tanzania was launched to support the Agricultural Seed Agency in Tanzania in maintaining the seed distribution system developed by the Center. A service to disseminate vegetable price information over radio and through text and voice messages also was established. These initiatives were made possible with a grant from the AVRDC Innovations Fund.

Continuing our work with Bioinformatics and the Head of the Biotechnology/Molecular Breeding group, IT has supported genotyping by sequencing software and hardware for scientists, stakeholders and visiting students.

An online form for appraisals of Taiwan-based nationally recruited staff was set up with support from the Human Resources Director; this form saves time in the approval and appraisal process.

GRANTS & PARTNERSHIP DEVELOPMENT

Grants & Partnership Development strives to provide effective and efficient institutional support for the research and development agenda of AVRDC. This is realized mainly through donor intelligence, quality review (proposals, technical reports, contracts), drafting of contracts, facilitation and coordination, and acting as a focal point for resource mobilization and project administration. Grants & Partnership Development participates in Global Theme Meetings.

Grants & Partnership Development consists of two staff and its work in 2015 was mainly in three areas:

- (i) Facilitate, coordinate and support resource mobilization efforts: donor intelligence and priorities; review, edit and submit concept notes and proposals; develop partnerships.
- (ii) Monitor and support project administration: negotiate, draft, review and edit contracts; review, edit and submit technical reports; solve a multitude of other project-specific issues.
- (iii) Develop and manage tools for resource mobilization and project administration.

The Office of the Deputy Director General for Research is the oversight office for the Center's research and development agenda and so it is crucial that it receives relevant information in a systematic manner. Grants & Partnership Development continued to manage this process in 2015.

During the year, 55 concept notes and proposals were reviewed, edited and submitted to donors. As of February 2015, 23 were funded, 9 rejected, 6 dropped and 17 are pending.

Thirty-two technical project reports were reviewed and edited, and 112 technical project reports were submitted to donors and partners.

The Center collaborates with more than 170 partners across the globe, and all agreements signed with project donors and partners pass through Grants & Partnership Development. In 2015 the office supported negotiations and prepared, reviewed and edited numerous agreements.

LEGAL SUPPORT

In 2015, AVRDC maintained the same resources for legal and intellectual asset management by having an external consultant based in Kuala Lumpur who is a qualified intellectual property legal practitioner. The main legal and intellectual property activities in 2015 were:

1. Providing support as a panel member and speaker on intellectual property issues in public-private partnerships at the 15th African Seed Trade Association (AFSTA) congress.
2. Reviewing intellectual property provisions in donor-related and research-related agreements to ensure consistency with AVRDC's position on management of its intellectual assets.
3. Reviewing collaboration agreements between research partners and AVRDC.
4. Participating as a member in the AVRDC Institutional Biosafety Committee and providing feedback and approval to applications on biosafety-related experiments.
5. Drafting a template agreement for sponsored research by seed companies to AVRDC.
6. Drafting and reviewing host country agreements between AVRDC and the governments of Myanmar and Thailand.

The legal and intellectual property consultant together with the Deputy Director General for Research co-supervised an intern who was based at AVRDC headquarters for three months. The intern produced a report on the legal status of AVRDC that will be submitted as a background paper to the incoming Director General.





**FINANCIAL
HEALTH**

	AVRDC	CGIAR** recommended range
Cash management on restricted operations*	0.32	less than 1
Adequacy of reserves	137 days	75-90 days
Short-term solvency	165 days	90-120 days

2015 Revenues (in '000 USD)		
Unrestricted grants	9,306	45%
Restricted grants	11,234	54%
Other revenues	243	1%
Total	20,782	100%

Unrestricted Grants

Republic of China (ROC)	4,516
UK Department for International Development (UK/DFID)	2,954
United States Agency for International Development (USAID)	1,000
Australian Centre for International Agricultural Research (ACIAR)	323
Germany	278
Thailand	124
The Philippines	50
Korea	50
Japan	11
Sub-total	9,306
Other revenues	243
Total	9,549

Restricted Grants

United States Agency for International Development (USAID)	5,170
* Republic of Germany (BMZ)	1,103
Swiss Agency for Development and Cooperation (SDC)	1,055
Republic of China / Ministry of Foreign Affairs (MOFA)	866
Australia / Australian Centre for International Agricultural Research (ACIAR)	838
Consultative Group on International Agricultural Research (CGIAR)	534
Republic of China / Council of Agriculture (COA)	456
West and Central African Council for Agricultural Research and Development (CORAF/WE CARD)	263
Korea / Rural Development Administration (RDA)	161
COFRA Foundation	131
Government of Karnataka	116
Others (projects with expenses less than 100K USD)	539

Sub-total **11,234**

Total Revenues **20,782**

* BMZ = Federal Ministry for Economic Cooperation and Development



**DIVERSE
AND
STRONG**



In 2015
AVRDC – The World Vegetable Center staff members
came from 34 countries, including Taiwan

Women occupy 28%
of the 67 professional staff positions

Staff Name	Position Title	Location	Nationality
Acedo, Jun	Postharvest Specialist	Hyderabad, India	Philippines
Afari-Sefa, Victor	Scientist - Socioeconomics and Global Theme Leader - Consumption	Arusha, Tanzania	Ghana
Ahmed, Mohammed Razu	Deputy Sector Leader - Vegetables	Dhaka, Bangladesh	Bangladesh
Ali, Mansab	Horticulture Project Leader (AIP Pakistan Project)	Islamabad, Pakistan	Pakistan
Beed, Fenton	Regional Director, East and Southeast Asia	Bangkok, Thailand	United Kingdom
Bidogeza, Jean-Claude ³	Socioeconomist and Liaison Officer for Cameroon (Humidtropics Project)	Yaoundé, Cameroon	Burundi
Brown, Stuart ²	Project Manager (Home Garden Scaling Project, Cambodia)	Siem Reap, Cambodia	Australia
Caltagirone, Cristina ¹	Training Specialist	Shanhua, Taiwan	USA
Chang, Jan ¹	Scientist - Biotechnology	Shanhua, Taiwan	Taiwan
Chang, Rollen	Manager - Technical Services	Shanhua, Taiwan	Taiwan
Chang, Yin-Fu	Deputy Director General - Administration & Services	Shanhua, Taiwan	Taiwan
Chen, Willie	Postdoctoral Fellow – Agronomist/Plant Protection Specialist	Shanhua, Taiwan	Taiwan
Dhillon, Narinder	Vegetable Breeder - Cucurbits	Bangkok, Thailand	India
Dinssa, Fekadu Fufa	Vegetable Breeder	Arusha, Tanzania	Ethiopia
Diwani, Thuweba ¹	Project Manager (Home Garden Scaling Project, Mali)	Bamako, Mali	Kenya
Dubois, Thomas	Regional Director, Eastern and Southern Africa	Arusha, Tanzania	Belgium
Easdown, Warwick	Regional Director, South Asia	Hyderabad, India	Australia
Ebert, Andreas ¹	Genebank Manager and Global Theme Leader - Germplasm	Shanhua, Taiwan	Germany
Fleissner, Klaus ¹	Agronomist/Breeder - Vegetable Cropping Systems	Yaoundé, Cameroon	Namibia

Staff Name	Position Title	Location	Nationality
Gautam, Shriniwas	Postdoctoral Scientist - Monitoring and Evaluation	Bangkok, Thailand	Nepal
Gramzow, Andreas ²	Agribusiness/Marketing Specialist	Arusha, Tanzania	Germany
Ha, To Thi Thu	Horticulturist and Project Coordinator (Humidtropics Project)	Hanoi, Vietnam	Vietnam
Hanson, Peter	Plant Breeder (Tomato and Indigenous Vegetables Research) and Global Theme Leader - Breeding	Shanhua, Taiwan	USA
Hong, Yoonpyo	Postharvest Specialist (seconded scientist from RDA/Korea)	Shanhua, Taiwan	Korea
Hsu, Sylvia	Manager - Food and Dormitory Services	Shanhua, Taiwan	Taiwan
Hughes, Jacqueline d'Arros	Deputy Director General - Research	Shanhua, Taiwan	United Kingdom
Inukonda, Nagaraj	Director of Human Resources and Senior Management Advisor to the Director General	Shanhua, Taiwan	India
Iramu, Ellen	Project Coordinator - Pacific Islands	Honiara, Solomon Islands	Solomon Islands
Keatinge, J.D.H.	Director General	Shanhua, Taiwan	Ireland
Kenyon, Lawrence	Plant Virologist	Shanhua, Taiwan	United Kingdom
Krishnan, Bharath	Manager - Information Technology Services	Shanhua, Taiwan	India
Kumar, Sanjeet	Scientist - Pepper Breeding	Shanhua, Taiwan	India
Kumar, Senthil ²	Postdoctoral Fellow - Entomology	Shanhua, Taiwan	India
Kwazi, Nadine ³	Manager – Administration	Arusha, Tanzania	Zambia
Ledesma, Dolores	Board Secretary and Biometrician	Shanhua, Taiwan	Philippines
Li, Jiu-Kai ²	Program Officer, Office of the Deputy Director General - Research	Shanhua, Taiwan	Taiwan
Lu, Vincent	Internal Auditor	Shanhua, Taiwan	Taiwan
Luther, Greg	Technology Dissemination Specialist	Shanhua, Taiwan	USA
Luther, Kartini	Assistant to Deputy Director General - Research	Shanhua, Taiwan	USA
Macharia, John	Project Manager (Income and Nutrition through Vegetables Project)	Arusha, Tanzania	Kenya
Mak, Adrienne	Manager - Management Support & HR Services	Shanhua, Taiwan	Taiwan
Manickam, Ravishankar	Research Site Coordinator	Jharkhand, India	India
Mariyono, Joko ¹	Project Site Coordinator (Indonesia)	Jawa Timur, Indonesia	Indonesia
Mavlyanova, Ravza	Regional Coordinator for Central Asia and the Caucasus	Tashkent, Uzbekistan	Uzbekistan
Mecozzi, Maureen	Head - Communications and Information	Shanhua, Taiwan	USA

Staff Name	Position Title	Location	Nationality
Nair, Ramakrishnan	Vegetable Breeder - Legumes	Hyderabad, India	India
Nenguwo, Ngoni	Postharvest Specialist	Arusha, Tanzania	Zimbabwe
Öberg, Annelie	Manager - Grants and Partnership Development	Shanhua, Taiwan	Sweden
Overweg, Dirk	Director of Finance	Shanhua, Taiwan	The Netherlands
Palaniswamy, Usha ¹	Project Manager (Vegetables Go to School Project)	Shanhua, Taiwan	USA
Pottorff, Marti	Postdoctoral Fellow - Plant Pathology	Shanhua, Taiwan	USA
Rajendran, Srinivasulu	Postdoctoral Scientist - Agricultural Economics	Arusha, Tanzania	India
Rakha, Mohamed	Postdoctoral Fellow - Tomato Breeding	Shanhua, Taiwan	Egypt
Ramasamy, Srinivasan	Entomologist	Shanhua, Taiwan	India
Roothaert, Ralph ²	Project Manager (Home Garden Scaling Project, East Africa)	Arusha, Tanzania	The Netherlands
Rouamba, Albert ^{1,3}	Outreach and Capacity Building Coordinator	Bamako, Mali	Burkina Faso
Schafleitner, Roland	Head - Molecular Genetics	Shanhua, Taiwan	Austria
Schreinemachers, Pepijn	Agricultural Economist and Lead Specialist – Monitoring & Evaluation	Shanhua, Taiwan	The Netherlands
Sobgui, Caroline Makamto ²	Nutrition & WASH Specialist (Home Garden Scaling Project, Mali)	Bamako, Mali	Cameroon
Solberg, Svein ²	Genebank Manager	Shanhua, Taiwan	Norway
Stoilova, Tsvetelina	Scientist - Genetic Resources	Arusha, Tanzania	Bulgaria
Tenkouano, Abdou	Regional Director, West and Central Africa	Bamako, Mali	Burkina Faso
Tignegre, Jean-Baptiste	Vegetable Breeder	Bamako, Mali	Burkina Faso
Toure, Sheikh Hamid	Project Manager (BFS Scaling Project, Liberia)	Bamako, Mali	Mali
Wang, Jaw-fen	Plant Pathologist and Global Theme Leader - Production	Shanhua, Taiwan	Taiwan
Yang, Ray-yu	Nutritionist	Shanhua, Taiwan	Taiwan
Yeboah, Martin ¹	Scientist (Vegetable Breeder & Horticulturist), Liaison Officer for Cameroon	Yaoundé, Cameroon	Ghana

¹ Left in 2015

² Arrived in 2015

³ Position title change in 2015

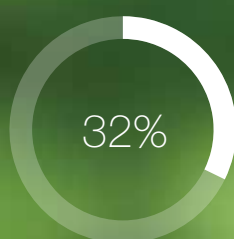
RESEARCH FOR DEVELOPMENT

In 2015, Center researchers shared their knowledge and results in international peer-reviewed journals, at conferences, and in partnership with scientists from developing countries.

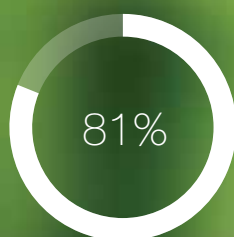


38.5 Number of scientists

*Each internationally hired scientist counts as 1; the Director General, Deputy Director General – Research, Regional Directors, and Biometrician each count as 0.5. Scientists who leave the Center before the end of July are counted in the year's calculation. Newly recruited scientists are counted only if they joined the Center before the end of July.



Percentage of scientific papers in refereed journals and books published with female authors from developing countries



Percentage of scientific papers in refereed journals and books published with partners (male and female) from developing countries

2.36

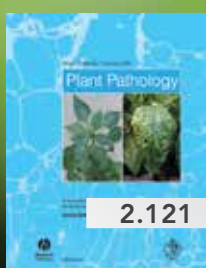
Total externally reviewed publications per scientist (journal articles, books, book chapters)

1.15

Publications per scientist in journals listed with Thomson Reuters

TOP 10 Journals

The top 10 journals (rated by Thomson Reuters impact factors) in which Center researchers published in 2015



Thomson/ISI Journal Articles (36)

1. **Afari-Sefa V, Rajendran S,** Karanja KD, Musebe R, Saami S, Makaranga MA, **Kessy, RF.** 2015. Impact of nutritional awareness of traditional African vegetables on farm household production decisions: A case study of smallholders in Tanzania. *Experimental Agriculture*. 20 May 2015; p 1-14. DOI: <http://dx.doi.org/10.1017/S0014479715000101>.
2. Bendera M, Ekesi S, Ndung'u M, **Srinivasan R,** Torto B. 2015. A major host plant volatile, 1-octen-3-ol, contributes to coupling in the legume pod borer, *Maruca vitrata* Fabricius (Lepidoptera: Crambidae). *Science of Nature* 102:47.
3. Chen H-M, **Lin C-Y,** Tsai W-S, **Kenyon L,** Chan M-T, **Yen J-Y** et al. 2015. Resistance to tomato yellow leaf curl viruses through RNAi targeting of two begomovirus species. *Journal of Plant Biochemistry and Biotechnology*. DOI: <http://dx.doi.org/10.1007/s13562-015-0325-7>.
4. Dwivedi N, Kumar R, Paliwal R, Kumar U, **Kumar S,** Singh M, Singh RK. 2015. QTL mapping for important horticultural traits in pepper (*Capsicum annuum* L.). *Journal of Plant Biochemistry and Biotechnology*. 24(2): 154-160.
5. Hodgetts J, Karamura G, Johnson G, Hall J, Perkins K, **Beed F,** Nakato V, Grant M, Studholme DJ, Boonham N, Smith J. 2015. Development of a lateral flow device for in-field detection and evaluation of PCR based diagnostic methods for *Xanthomonas campestris* pathovar *musacearum*, the causal agent of banana Xanthomonas wilt. *Plant Pathology* 64: 559-567. DOI: <http://dx.doi.org/10.1111/ppa.12289>.
6. Jibrin M, Timilsina S, Potnis N, Minsavage J, Shenge KC, Akpa A, Alegbejo M, **Beed F,** Vallad GE, Jones J. 2015. First Report of Atypical *Xanthomonas euvesicatoria* Strains Causing Bacterial Spot of Tomato in Nigeria. *Plant Disease* 99(3): 415 <http://apsjournals.apsnet.org/doi/pdfplus/10.1094/PDIS-09-14-0952-PDN>.
7. Kim SK, **Nair RM,** Lee J, Lee S-H. 2015. Genomic resources in mungbean for future breeding programs. *Frontiers in Plant Science* 6:626. <http://dx.doi.org/10.3389/fpls.2015.00626>.
8. Knierim D, Maiss E, **Kenyon L,** Winter S, Menzel W. 2015. First full-length genome sequence of the polerovirus luffa aphid-borne yellows virus (LABYV) reveals the presence of at least two consensus sequences in an isolate from Thailand. *Archives of Virology* 160(10): 2633-2636. DOI: <http://dx.doi.org/10.1007/s00705-015-2529-5>.
9. Knierim D, Maiss E, Menzel W, Winter S, **Kenyon L.** 2015. Characterization of the complete genome of a novel polerovirus infecting *Sauropus androgynus* in Thailand. *Journal of Phytopathology* 163(9): 695-702. DOI: <http://dx.doi.org/10.1111/jph.12365>.
10. **Lin C-H, Chuang M-H, Wang J-F.** 2015. First report of bacterial wilt caused by *Ralstonia solanacearum* on chard in Taiwan. *Plant Disease* 99: 282.
11. Lin C-P, Ko C-Y, Kuo C-I, Liu M-S, **Schafleitner R,** Chen L-F. 2015. Transcriptional slippage and RNA editing increase the diversity of transcripts in chloroplasts: insight from deep sequencing of the *Vigna radiata* genome and transcriptome. *PLoS ONE* 10(6): e0129396. DOI: <http://dx.doi.org/10.1371/journal.pone.0129396>.
12. **Lin S-W, Shieh H-C, Wang Y-W,** Gniffke P, Tan C-W, **Schafleitner R,** Yang W-J, **Kumar S.** 2015. Restorer breeding in sweet pepper: Introgressing Rf allele from hot pepper through marker-assisted backcrossing. *Scientia Horticulturae* 197: 170-175. DOI: <http://dx.doi.org/10.1016/j.scienta.2015.09.036>.
13. **Malini P, Schafleitner R,** Krishnan M, **Srinivasan R.** 2015. Phylogeographical structure in mitochondrial DNA of legume pod borer (*Maruca vitrata*) population in tropical Asia and sub-Saharan Africa. *PLoS ONE* 10(4): e0124057.
14. Metwally EI, **Rakha MT.** 2015. Evaluation of selected *Cucumis sativus* accessions for resistance to *Pseudoperonospora cubensis* in Egypt. *Czech Journal of Genetics and Plant Breeding*. 51:68-74.
15. Murithi HM, **Beed FD,** Soko MM, Haudenschild JS and Hartman GL. 2015. First Report of *Phakopsora pachyrhizi* on Soybean Causing Rust in Malawi. *Plant Disease* 99(3): 420. <http://dx.doi.org/10.1094/PDIS-09-14-0924-PDN>.
16. Murithi HM, **Beed F,** Tukamuhabwa P, Thomma BPHJ, Joosten MHJ. 2015. Soybean production in eastern and southern Africa and threat of yield loss due to soybean rust caused by *Phakopsora pachyrhizi*. *Plant Pathology* 98(11): 1586. DOI: <http://dx.doi.org/10.1111/ppa.12457>.
17. Murithi M, Owati A, Madata CS, Joosten M, **Beed F,** Kumar L. 2015. First Report of 16SrII-C Subgroup Phytoplasma Causing Phyllody and Witches' broom Disease in Soybean in Tanzania. *Plant Disease* 99(6): 886 DOI: <http://dx.doi.org/10.1094/PDIS-11-14-1225-PDN>.
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19. **Nair RM,** Thavarajah D, Thavarajah P, Giri, RR, **Ledesma D, Yang R-Y, Hanson P, Easdown, W, Hughes, J. d'A., Keatinge JDH.** 2015. Mineral and phenolic concentrations of mungbean (*Vigna radiata* (L.) R. Wilczek var. *radiata*) grown in semi-arid tropical India. *Journal of Food Composition and Analysis* 39: 23-32. DOI: <http://dx.doi.org/10.1016/j.jfca.2014.10.009-1575/>.
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15. **Karimov B**, Lyan E, **Mavlyanova R**. 2015. Selection of promising rootstocks for grafting greenhouse tomato varieties for growing in greenhouses of Uzbekistan. International Conference on the Role of Seed Breeding in Ensuring Food Security, 24 August 2015, Dushanbe, Tajikistan. p. 84-88. (in Russian).
16. **Kim V**. 2015. Vegetable soybean cultivation in Uzbekistan. International Conference on the Role of Seed Breeding in Ensuring Food Security, 24 August 2015, Dushanbe, Tajikistan. p. 147-149. (in Russian).
17. Latifah E, Andri KB, **Mariyono J**. 2015. An agronomic and economic study of plastic shelter application for tomato production during hot season in Kediri, East Java, Indonesia. Regional Symposium on Sustaining Small-Scale Vegetable Production and Marketing Systems for Food and Nutrition Security (SEAVEG2014), 25-27 February 2014, Bangkok, Thailand.
18. Lohmann J, Ziebul JJ, Akello J, Atehnkeng J, Mukanga M, Njapau H, **Dubois T**, Cotty PJ, Bandyopadhyay R. 2015. Aflasafe technology in Zambia: upscaling and dissemination through on-farm trials for wide uptake and utilization. Tropentag, 16-18 September 2015, Berlin, Germany.
19. **Mavlyanova R**. 2015. Diversification and seed production development in Central Asia and the Caucasus. International Conference on the Role of Seed Breeding in Ensuring Food Security, 24 August 2015, Dushanbe, Tajikistan. p. 120-124. (in Russian).
20. **Mavlyanova R**. 2015. Strategic approaches for research and development of vegetable production in Central Asia and the Caucasus. Regional Symposium on Sustaining Small-Scale Vegetable Production and Marketing Systems for Food and Nutrition Security (SEAVEG2014), 25-27 February 2014, Bangkok, Thailand.

21. **Mavlyanova R.** 2015. Strategic approaches for research and development of vegetable production in Central Asia and the Caucasus. Regional Symposium on Sustaining Small-Scale Vegetable Production and Marketing Systems for Food and Nutrition Security (SEAVEG2014), 25-27 February 2014, Bangkok, Thailand.
22. **Nair RM, Yan M-R, Srinivasan R, Schafleitner R.** 2015. Developing bruchid resistant mungbean varieties. SABRAO 13th Congress and International Conference, 14-16 September 2015, Bogor, Indonesia. p. 52.
23. **Srinivasan R, Chang JC, Malini P.** 2015. Know your enemies better: changes and challenges in molecular characterization of insect pests on vegetable crops. In: Srinivasan G, Premalatha K, Nalini R, Chandramani P, Jayaraj J, Baby Rani W, Muthiah C, Chinniah C, Manisegaran S, Kalyanasundaram M, Chinnusamy C (eds). Proceedings of the International Conference on Innovative Insect Management Approaches for Sustainable Agro Ecosystem (IIMASAE), 27-30 January 2015, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India. p. 3-10.
24. **Srinivasan R, Thanh Hien NT, Thuy Trang VT, Khánh L, Hai VM, Chansamone P, Phimchai V, Soukhavong K.** 2015. Integrating bio-pesticides with chemical pesticides to manage legume pod borer (*Maruca vitrata*) on yard-long bean in Lao PDR and Vietnam. In: Hughes J d'A, Kasemsap P, Dasgupta S, Dutta OP, Ketsa S, Chaikiattiyos S, Linwattana G, Kosiyachinda S, Chantrasmi V (eds). Proceedings of the Regional Symposium on Sustaining Small-scale Vegetable Production and Marketing Systems for Food and Nutrition Security (SEAVEG2014), 25-27 February 2014, Bangkok, Thailand. AVRDC – The World Vegetable Center, Publication No. 15-785. Shanhu, Taiwan. p. 174-182.

Abstracts (7)

1. **Chen L-H, Shen T-C, Chen W-Y, Chen J-Y, Chen C-C, Hughes J d'A.** 2015. Evaluation of Summer Light Intensity Between the East and West Sides of a Twin-span Glasshouse. In: Book of Abstracts, GreenSys2015, International Symposium on New Technologies and Management for Greenhouses, 19-23 July 2015, Évora, Portugal.
2. **Dhillon NPS, Sanguansil P, Yang R-Y, Hanson P.** 2015. Status of bitter melon breeding at AVRDC-The World Vegetable Center. In: Book of Abstracts, Fifth ISHS International Symposium on Cucurbits, 22-26 June 2015, Cartagena, Spain.
3. **Ebert AW, Huang Y-K.** 2015. Are *Momordica charantia* (bitter melon) seeds truly orthodox? In: Lohwasser U, Börner A (eds). Book of Abstracts, Seed Longevity Workshop of the International Society for Seed Science (ISSS), 5-8 July 2015, Wernigerode, Germany. p. 58.
4. **Ha TTT, Schreinemachers P, Wang J-F, Nguyen TTL, Le TT, Le NT, Beed F, Ebert AW, Dhillon N, Srinivasan R, Hanson P, Kenyon L, Yang R-Y, Afari-Sefa V.** 2015. Sustainable Intensification of Smallholder Agriculture in Northwest Vietnam: Exploring the Potential of Integrating Vegetables. In: Book of Abstracts, International Conference on Integrated Systems Research for Sustainable Intensification in Smallholder Agriculture, 3-6 March 2015, Ibadan, Nigeria.
5. **Shen T-C, Tai C-Y, Hughes J d'A, Kuo L-T, Chen W-Y.** 2015. Nutrient solutions for protected vegetable production in tropical and subtropical Taiwan. In: Book of Abstracts, GreenSys2015, International Symposium on New Technologies and Management for Greenhouses, 19-23 July 2015, Évora, Portugal.
6. **Stoilova T, Dubois T, Ebert AW, Dinssa FF.** 2015. Vegetable and legume germplasm collections to address food and nutritional security challenges in sub-Saharan Africa. In: Book of Abstracts, International Conference on Biodiversity for Food and Nutrition, 23-24 November 2015, Nairobi, Kenya.
7. **Tsai WS, Kenyon L.** 2015. Molecular identification of eggplant-infecting begomoviruses in Southeast Asia. In: Phytopathology 105 (Suppl. 4): S4.139. APS Annual Meeting, 1-5 August 2015, Pasadena, California, U.S.A.

Presentations (79)

1. **Acedo AL Jr, Nenguwo N, Easdown W, Hughes J d'A.** 2015. AVRDC - The World Vegetable Center's postharvest initiatives on food safety in Asia. Asian Food Safety and Security Association (AFSA) Conference on Food Safety and Food Security, 15-18 August 2014, Dong Nai University of Technology, Vietnam.
2. **Afari-Sefa V, Rajendran S, Lukumay PJ, Nega M, Kachokammanja C, Mudema J.** 2015. Invited Oral Presentation at Second Annual Project Review and Planning Meeting, 6-8 October 2015, Lilongwe, Malawi.
3. **Afari-Sefa V.** 2015. Improving the quality of informal vegetable seed supply and distribution systems. Invited USAID Agrilinks Webinar, 12 November 2015, Washington, DC., USA.
4. **Beed F.** 2015. AVRDC's Program on Food Safety in East and Southeast Asia. SEAsia2015 3rd ISHS Southeast Asia Symposium on Quality Management in Postharvest Systems. Technical Program and Book of Abstracts. 13-15 August 2015, Siem Reap, Cambodia.
5. **Beed F.** 2015. Principles to sustain crop productivity and quality. Australasian Plant Pathology Society Conference Handbook, 14-16 September 2015, Freemantle, Australia.
6. **Beed F.** 2015. Vegetable Value Chains (2015) International Study Course on Agro-Business and Quality Inputs for Agro-Inputs Retailer Network for USAID, 18 May 2015, Kamphaeng Saen, Kasetsart University, Thailand.

7. **Beed F.** 2015. Vegetables in a Changing Climate and Cross Cutting Issues, Assumptions and Reflections. Expert Group Meeting on the Impact of Climate Change on Food Security in Association of Southeast Asian Nations (ASEAN), 14-15 May 2015, Centre for Non-Traditional Security Studies (CNTS), S. Rajaratnam School of International Studies (RSIS), Nanyang Technological University, Singapore.
8. **Chen WY.** 2015. Vegetable Grafting in Tropical and Subtropical Areas. Vegetable Grafting Workshop, 23-24 November 2015, Zamorano, Tegucigalpa, Honduras.
9. Chepnego J, Kinyuru J, **Nenguwo N**, Owino W. 2015. Combined Effects of Hydrocooling, Calcium Treatment and Low Temperature Storage on Postharvest Quality of Selected Vegetables. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
10. Chepnego J, Kinyuru J, **Nenguwo N**, Owino W. 2015. Effects of Low Cost Hydrocooling System on Postharvest Quality of Selected Tropical Vegetables. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
11. **Dinssa FF, Mbwapo O.** 2015. Effect of leaf defoliation and genotype on grain yield of amaranth: Developing dual-purpose cultivars for food and nutrition security from local germplasm collections. Second International Conference on Biodiversity for Food and Nutrition, 23 November 2015, Nairobi, Kenya.
12. **Dinssa FF, Mndiga H**, Kitudu J, Wang J-F. 2015. Status of tomato and pepper grafting exercise at AVRDC in Eastern Africa. Local Focus Project Closing Workshop, 22-24 June 2015, Malindi, Kenya.
13. **Dinssa FF, Tenkouano A.** 2015. Harnessing the potential of the vegetable seed industry in Africa. AFSTA Congress 2015, 2-6 March 2015, Victoria Falls, Zimbabwe.
14. **Dinssa FF.** 2015. AVRDC's amaranth breeding strategy. Theme Breeding annual meeting, 1-2 October 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
15. **Dinssa FF.** 2015. Experimental protocols for best practice hubs. Visit Malawi and Mozambique VINESA Project Partners, 8-14 February 2015, Lilongwe, Malawi, and Maputo, Mozambique.
16. **Dominick I, Afari-Sefa V**, Lukumay PJ, Coyne D, Lukuyu B, Marwa L. 2015. Integrating Vegetables into Maize Based-Farming Systems in Babati District, Tanzania, Invited Presentation Fourth Annual Project Review & Planning Meeting, 14-16 July 2015, Magochi, Malawi.
17. **Dubois T, Stoilova T.** 2015. Some traditional African vegetables and the challenges involving for popularizing them. Workshop to develop a Curriculum on Neglected and Underutilized Species (NUS), 22-24 September 2015, Biodiversity, World Agroforestry Centre, ANAFE.
18. **Ebert AW, Chou Y-Y.** 2015. Development of Breeding Techniques and Selection of Virus Resistant Germplasm in Pepper and Tomato. Technical Progress Report for Period 1 April 2013 to 31 December 2014, 10-11 February 2015, Suwon & Jeonju, Republic of Korea.
19. **Ebert AW.** 2015. Collecting and handling seed in the field. AARNET Vegetable Germplasm Training Course for ASEAN countries, 18 May 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
20. **Ebert AW.** 2015. How can germplasm be used to mitigate and adapt to climate change? Expert Consultation on Climate Change Mitigation and Adaptation Strategies for Vegetables in Southeast Asia. ASEAN - AVRDC Regional Network for Vegetable Research and Development (AARNET), 26 March 2015, Pakse, Champasak Province, Lao PDR.
21. **Ebert AW.** 2015. In situ conservation: nature reserves, on-farm, home and school gardens, community seed banks. AARNET Vegetable Germplasm Training Course for ASEAN countries; 28 May 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
22. **Ebert AW.** 2015. Seed Quality, Seed Storage and Seed Priming for High Yield and Quality of Produce. International Training-Workshop funded by AFACI (Asian Food & Agriculture Cooperation Initiative) on Postharvest Management Technology for Horticultural Crops, Postharvest Training Program in Asia, 8 June 2015, Bangkok, Thailand.
23. **Ebert AW.** 2015. The role of germplasm for adaptation to climate change. AARNET Vegetable Germplasm Training Course for ASEAN countries, 18 May 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
24. **Ebert AW.** 2015. Vegetable seed regeneration and quality preservation. AARNET Vegetable Germplasm Training Course for ASEAN countries, 19 May 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
25. Gautam DM, Adhikari RK, Mishra BP, Tripathi KM, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH.** 2015. Modified atmosphere packaging of cauliflower in ambient and evaporative cooling conditions in Nepal. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
26. Gautam DM, Joshi S, Tripathi KM, Devkotha A, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH.** 2015. Effects of modified atmosphere packaging on quality and shelf-life of tomatoes in Nepal. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.

27. Gautam DM, Naupaney R, Tripathi KM, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH**. 2015. Tomato sauce processing and acceptability of spicy and non-spicy products. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
28. Gautam DM, Tripathi KM, Dakota A, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH**. 2015. Fermentation study using different salt solutions for cauliflower preservation in Nepal. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
29. Gautam DM, Tripathi KM, Dakota A, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH**. 2015. Evaluation of anti-browning treatments on the quality of solar dried cauliflower (*Brassica oleracea* var. *botrytis*). 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
30. Gautam DM, Tripathi KM, Paudel S, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH**. 2015. Cauliflower handling trials integrating best practice and developed technologies to reduce postharvest losses in Nepal. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
31. **Gautam S, Acedo AL Jr, Hong Y, Schreinemachers P, Nenguwo N, Beed F, Hughes J d'A**. 2015. Postharvest Losses in Vegetable Value Chain in Bangladesh, Cambodia and Nepal. The First International Congress on Postharvest Loss Prevention: Developing Measurement Approaches and Intervention Strategies for Smallholders, 4-7 October 2015, Rome, Italy.
32. **Ha TTT, Schreinemachers P, Beed F, Wang J-F, Loc NTT, Thuy LT, Van DT, Srinivasan R, Hanson P, Afari-Sefa V**. 2015. Sustainable intensification of smallholder agriculture in Northwest Vietnam: Realizing the potential of integrating vegetables. Selected Presentation at First International Conference on Integrated Research Systems of the Humid Tropics, 3-6 March, 2015, IITA Campus, Ibadan, Nigeria.
33. **Hughes J d'A**. 2015. Southeast Asian vegetable production - a vision for the future (Inaugural Address), Regional Symposium on Sustaining Small-Scale Vegetable Production and Marketing Systems for Food and Nutrition Security (SEAVEG2014), 25-27 February 2014, Bangkok, Thailand.
34. **Kitundu J**. 2015. Evaluation of performance of some commercial tomato cultivars grafted on tomato and eggplant rootstock genotypes. Local Focus Project Closing Workshop, 22-24 June 2015, Malindi, Kenya. (MSc student).
35. **Krishnan B**. 2015. Launch VegOneX for Tanzania. AVRDC - The World Vegetable Center Eastern and Southern Africa, 3 February 2015, Arusha, Tanzania.
36. **Krishnan B**. 2015. Linux, Hardware and the Cloud for Bioinformatics. Plant Research Center, 12 May 2015, Hanoi, Vietnam.
37. **Krishnan B**. 2015. VegOneX for Tanzania - Seed supply system. AVRDC - The World Vegetable Center Eastern and Southern Africa, 4 February 2015, Arusha, Tanzania.
38. **Kumar S**. 2015. AVRDCs pepper breeding: an overview. 11 March 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
39. **Kumar S**. 2015. Evaluation of chili pepper varieties for horticultural traits, and disease resistance. MAFF (JAPAN) Project Inception Workshop, 21-22 July 2015, AVRDC – The World Vegetable Center Research and Training Center, Kamphaeng Saen, Thailand.
40. **Lin LJ**. 2015. Healthy seedling preparation for home garden. Home Garden Training of Trainers Workshop, 26-29 March 2015, Nan, Thailand.
41. **Lin LJ**. 2015. Planning your planting schedule for home garden. Home Garden Training of Trainers Workshop, 26-29 March 2015, Nan, Thailand.
42. **Lin LJ**. 2015. Site and vegetable crop selection for home garden. Home Garden Training of Trainers Workshop, 26-29 March 2015, Nan, Thailand.
43. **Luther GC, Lin L-J, Chen W-Y**. 2015. An Introduction to Integrated Pest Management. Home Garden Training of Trainers Workshop, 26-29 March 2015, Nan, Thailand.
44. **Luther GC, Lin L-J, Yang R-Y**. 2015. AVRDC Recommended Practices: Sustainable Technologies for School Gardens. Consultative Meeting with Royal Government of Bhutan, 2 July 2015, Conference Hall of RNR RDC Bajo, Wangduephodrang, Bhutan.
45. **Luther GC, Lin L-J, Yang R-Y**. 2015. AVRDC Recommended Practices: Sustainable Technologies for School Gardens. Nepal Agricultural Research Council workshop, 5 July 2015, Khumaltar, Lalitpur, Nepal.
46. **Luther GC, Lin L-J**. 2015. AVRDC's global disaster response efforts in 2009-2014. Science Day, AVRDC Board Meeting, 22 April 2015, Hyderabad, India.
47. **Luther GC**. 2015. Biological Control with Natural Enemies. Home Garden Training of Trainers Workshop, 26-29 March 2015, Nan, Thailand.
48. **Mavlyanova R, Saidov N**. 2015. Tajikistan Nutrition Sensitive Vegetable Technologies Project plans for implementation in Khatlon region. Meeting in the Ministry of Agriculture of Tajikistan, 28 January 2015, Dushanbe, Tajikistan.

49. **Mavlyanova R.** 2015. Central Asia and the Caucasus Regional Network for Vegetable Systems Research & Development Strategies 8 SCM CACVEG. VIIIth Steering Committee Meeting of Regional Network for Vegetable Research and Development in Central Asia and the Caucasus (CACVEG), 10-12 November 2015, Tashkent, Uzbekistan.
50. **Mavlyanova R.** 2015. Characterization and evaluation of AVRDC vegetable germplasm introduced to Central Asia and the Caucasus. Theme Germplasm meeting 5-6 October 2015, AVRDC – The World Vegetable Center, Shanhua, Tainan, Taiwan.
51. **Mavlyanova R.** 2015. Collaboration on vegetable production in Uzbekistan within CGIAR Collaborative Research Program (CRP 1.1.). VIIIth Steering Committee Meeting of Regional Network for Vegetable Research and Development in Central Asia and the Caucasus (CACVEG), 10-12 November 2015, Tashkent, Uzbekistan.
52. **Mavlyanova R.** 2015. Documentation and rules for mungbean elite seed production. Training on production of high quality mungbean seed, 11 December 2015, Kuva district, Fergana region, Uzbekistan.
53. **Mavlyanova R.** 2015. Legumes new varieties for cultivation in Karakalpakstan. Workshop on analysis of seed systems for improving food security in Karaozak district, 30-31 March 2015, Karaozak district, Nukus region, Karakalpakstan.
54. **Mavlyanova R.** 2015. Mungbean: new varieties and cultivation technology. Training on production of high quality mungbean seed, 11 December 2015, Kuva district, Fergana region, Uzbekistan.
55. **Mavlyanova R.** 2015. Mungbean: new varieties for cultivation in dry and hot conditions of Uzbekistan. Farmers Day, 15 October 2015, Bukhara region, Uzbekistan.
56. **Mavlyanova R.** 2015. New varieties and recipes from non-traditional vegetables. Training on crop diversification for improve incomes and nutrition of rural communities in Aral Sea Basin, 19 August 2015, Karauzyak, Karakalpakstan.
57. **Mavlyanova R.** 2015. Twelve presentations in a training course on breeding vegetable crops, 3-7 August 2015, Tashkent, Uzbekistan.
58. **Mavlyanova R.** 2015. Using new vegetable varieties in the diet. Training on strengthening of the role of home gardens in improving food security in the Fergana Valley, 6 April 2015, Kuva district, Fergana region, Uzbekistan.
59. **Mavlyanova R.** 2015. Vegetables for a healthy diet. Presentation in School #279, 23 January 2015, Tashkent, Uzbekistan.
60. Nagaraju K, Amaresh S, Dattawade B, Subramanian R, **Nair RM.** 2015. Bhoochetana Plus for Improving Rural Livelihoods through Innovative Scaling-up of Science-led Participatory Research for Development in Karnataka, Annual project review meeting, February 2015, India.
61. **Nair RM.** 2015. Climate Change Adaptation Research Strategies in Mungbean Improvement at AVRDC - The World Vegetable Center, CLAN meeting, December 2015, Seoul, Korea.
62. **Nair RM.** 2015. Progress in Mungbean (green gram) Improvement at AVRDC - The World Vegetable Center, 24 November 2015, University of Hyderabad, Hyderabad, India.
63. **Nenguwo N, Afari-Sefa V, Marealle R.** 2015. Evaluation of Low Cost Cooling Options for Leafy Vegetables Grown by Smallholder Farmers in Tanzania. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
64. Okolle JN, **Afari-Sefa V, Bidogeza J-C, Tata PI, Ngome FA.** 2015. Assessing smallholder farmers' knowledge and perception on vegetable pests and diseases and their management practices within coffee and cocoa-based farming systems in the humid tropics of Cameroon. Selected Oral Presentation at the First International Conference on Integrated Research Systems of the Humidtropics, 3-6 March, 2015, IITA Campus, Ibadan, Nigeria.
65. Owino W, **Afari-Sefa V, Nenguwo N.** 2015. Postharvest loss assessment of vegetables in Kenya: a case study of tomato and Amaranth. Oral Presentation at First International Congress for Postharvest Loss Prevention, 4-7 October 2015, Antonianum, Rome, Italy.
66. **Schreinemachers, P.** 2015. Too much to handle? Pesticide exposure in commercialized upland agriculture in Southeast Asia. 1st International Conference on Asian Highland Natural Resources Management (AsiaHiLand) & 2nd IDRC-SEARCA Upland Fellowship and Conference, 7-9 January 2015, Chiang Mai, Thailand.
67. **Shieh HC.** 2015. Breeding for heat tolerance in sweet pepper. 16 April 2015, Taiwan Agricultural Research Institute (TARI), Taichung, Taiwan.
68. Soeung R, Phen V, Buntong B, Chrun R and **Acedo AL Jr.** 2015. Detection of Coliform, *Enterococcus* spp. and *Staphylococcus* spp. on fermented vegetables in major markets in Cambodia. 3rd ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
69. **Srinivasan R, Luther GC.** 2015. Major insect and mite pests of some common vegetables. Home Garden Training of Trainers Workshop, 26-29 March 2015, Nan, Thailand.
70. **Srinivasan R.** 2015. Contribution of Integrated Pest Management in enhancing biodiversity in tropical vegetable production. International Conference on Life Sciences and Biotechnology (ICOLIB), 28-29 September 2015, Biology Department, Faculty of Mathematics and Natural Sciences, University of Jember, Jember, East Java Province, Indonesia.

71. **Srinivasan R.** 2015. Developing a sustainable pest management strategy for lowland brassica production systems in Asia. International Plant Protection Congress (IPPC) 2015, 24-27 August 2015. Berlin, Germany.
72. **Srinivasan R.** 2015. Insect pests of Vegetable Brassicas (Cambodia, Lao PDR, Vietnam), Attraction in Action Workshop, 30 November-7 December 2015.
73. **Srinivasan R.** 2015. Insect pests of Vegetable Legumes (Cambodia, Lao PDR, Vietnam), Attraction in Action Workshop, 30 November-7 December 2015.
74. **Srinivasan R.** 2015. Know your enemies better: changes and challenges in molecular characterization of insect pests on vegetable crops. International Conference on Innovative Insect Management Approaches for Sustainable Agro Ecosystem (IIMASAE), 27-30 January 2015, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India.
75. **Srinivasan R.** 2015. Sustainable Pest Management techniques for safer vegetable production. University Students from South Korea, 10 December 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
76. **Srinivasan R.** 2015. Towards developing an integrated pest management strategy for striped flea beetle on Radish. Seventh International Workshop on Management of the Diamondback Moth and Other Crucifer Insect Pests, 23-27 March 2015, University of Agricultural Sciences, Bengaluru, India.
77. **Srinivasan R.** 2015. Towards developing an integrated pest management strategy for cabbage production systems in lowlands of Taiwan. Seventh International Workshop on Management of the Diamondback Moth and Other Crucifer Insect Pests, 23-27 March 2015, University of Agricultural Sciences, Bengaluru, India.
78. **Srinivasan R.** 2015. Why are we so scared of a new invader? The threat of South American tomato leaf miner, *Tuta absoluta*. R&D Seminar, 15 October 2015, AVRDC headquarters, Shanhua, Tainan, Taiwan.
79. **Stoilova T, Dubois T, Ebert AW, Dinssa FF.** 2015. Vegetable and Legume germplasm collection to address food and nutritional security challenges in sub-Saharan Africa, 2nd International Conference on Biodiversity for Food, 23 November 2015, Nairobi, Kenya.

Posters (28)

1. **Acedo A Jr.** 2015. Simple solar dryers for rapid and hygienic drying of vegetables. Science Day 2015, 22 April 2015, AVRDC – The World Vegetable Center South Asia, Hyderabad, India.
2. Ahmed S, Bari ML, Rahman MA, Goffar MA, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH.** 2015. Development of novel sanitizers for fresh vegetables. Third ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
3. Buntong B, Vanna S, Maulyin C, **Acedo AL Jr, Hughes J d'A, Keatinge JDH.** 2015. Evaluation of AVRDC advanced tomato lines with long shelf-life and processing ability in Cambodia. Third ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
4. **Chen L-H, Shen T-C, Chen W-Y, Chen J-Y, Chen C-C, Hughes J d'A.** 2015. Evaluation of Summer Light Intensity Between the East and West Sides of a Twin-span Glasshouse. GreenSys2015, International Symposium on New Technologies and Management for Greenhouses, 19-23 July 2015, University of Évora, Évora, Portugal.
5. Chhengla L, Laikong S, Buntong B, **Acedo AL Jr, Hughes J d'A, Keatinge JDH.** 2015. Effects of chitosan coating on quality and shelf-life of tomato during coolbot cold storage. Third ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
6. Douglas C, **Nair RM, Schafleitner R, Huttner E.** 2015. Establishing the International Mungbean Improvement Network. <http://tropagconference.com.au/>.
7. **Ebert AW, Huang Y-K.** 2015. Are Momordica charantia (bitter melon) seeds truly orthodox? Seed Longevity Workshop of the International Society for Seed Science (ISSS), 5-8 July 2015, Wernigerode, Germany.
8. **Ebert AW.** 2015. Traditional leafy vegetables for poverty alleviation and improved household nutrition. Science Day 2015, 22 April 2015, AVRDC – The World Vegetable Center South Asia, Hyderabad, India.
9. Emanu B, **Afari-Sefa V, Ayana A, Dinssa FF, Balemi T, Temesgen M.** 2015. The Potential for integrating vegetables into staple crop production systems in the humid tropics of Ethiopia. First International Conference on Integrated Research Systems of the Humidtropics, 3-6 March 2015, IITA Campus, Ibadan, Nigeria.
10. Goffar MA, Rahman MA, **Hanson P, Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH.** 2015. Evaluation of AVRDC Tomato Advanced Lines for Processing and Fresh Marketing in Bangladesh. Third ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.
11. Goffar MA, Rahman MA, Nasrin TAA, **Acedo AL Jr, Easdown W, Hughes J d'A, Keatinge JDH.** 2015. Integrating non-chlorine sanitizing and modified atmosphere packaging in low cost cooling systems for brinjal (*Solanum melongena*). Third ISHS South East Asia Symposium on Quality Management in Postharvest Systems (SEAsia 2015), 13-15 August 2015, Siem Reap, Cambodia.

12. **Hong YP.** 2015. Chlorine dioxide gas treatment for quality maintenance of oriental melon during storage and transportation. Annual Spring Conference, Korean Society for Horticultural Science, 20-23 May 2015, Junju, Korea.
13. **Hong YP.** 2015. Postharvest loss by quality evaluation of tomato and cauliflower in Nepal and Cambodia. Annual Spring Conference, Korean Society for Horticultural Science, 20-23 May 2015, Junju, Korea.
14. Kotu B, Kimaro A, Swamila M, Lyimo, S., Lukuman YP, **Afari-Sefa V**, Ngulu F, Kihara J, Abass A., Bachwenkizi B, Bekunda M, Hoeschle-Zeledon I. 2015. Cost-benefit analysis of Africa RISING Project Technologies in Tanzania. International Conference on Management of Land Use Systems for Enhanced Food Security: Conflicts, Controversies and Resolutions, Tropentag, 16-18 September 2015, Humboldt University of Berlin, Berlin, Germany.
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Acronyms & Abbreviations

AARNET	ASEAN-AVRDC Regional Network
AAS	Aquatic Agricultural Systems
ACIAR	Australian Centre for International Agricultural Research
AFACI	Asian Food and Agriculture Cooperation Initiative
AGRA	Alliance for a Green Revolution in Africa
AIFSRC	Australian International Food Security Research Centre
AIP	Agricultural Innovations Program
AIRCA	Association of International Research and Development Centers for Agriculture
AIT	Asian Institute of Technology
APSA	Asia and Pacific Seed Association
ARI	Agricultural Research Institutes, Pakistan
ASEAN	Association of Southeast Asian Nations
AVGRIS	AVRDC Vegetable Genetic Resources Information System
AZRI	Arid Zone Research Institute, Bhakkar, Pakistan
BARI	Bangladesh Agricultural Research Institute
BEAF	Advisory Service on Agricultural Research for Development
BMZ	Federal Ministry for Economic Cooperation and Development
BPH	Best Practice Hub
BSTI	Bangladesh Standards and Testing Institution
CASD	Center for Assistance to Sustainable Agriculture
CATIE	Tropical Agriculture Research and Higher Education Center
CFU	Colony forming units
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIM	Center for International Migration and Development
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CMS	Cytoplasmic male sterility
COA	Taiwan Council of Agriculture
CORAF/WE CARD	Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles / West and Central Africa Council for Agricultural Research and Development
CRP	Collaborative research program
DALY	Disability adjusted life years
DAM	Department of Agriculture Marketing, Bangladesh
DAR	Department of Agricultural Research
DFID	UK Department for International Development
ELISA	Enzyme-linked immunosorbent assay
EPA	Environmental Protection Administration, Taiwan
EPMR	External Program and Management Review
ERP	Enterprise resource planning system
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field Schools
FPDA	Fresh Produce Development Agency, Papua New Guinea
GRSU	Genetic Resources and Seed Unit

GTD	Global Technology Dissemination
HKI	Helen Keller International
HortCRSP	USAID Horticulture Collaborative Research Support Program
HQ	Headquarters
HRC-NAFRI	Horticulture Research Center, National Agriculture and Forestry Research Institute, Lao PDR
ICARDA	International Center for Agricultural Research in the Dry Areas
icipe	International Centre of Insect Physiology and Ecology
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institut d'Economie Rurale
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IITA	International Institute for Tropical Agriculture
ILRI	International Livestock Research Institute
IP	Intellectual property
IPM	Integrated pest management
IRAD	Institute of Agricultural Research for Development
IRRI	International Rice Research Institute
ISHS	International Society for Horticultural Science
ISPN	International Sweet Pepper Nursery
IVTC	International Vegetable Training Course
IVY	International Volunteer Center, Yamagata, Japan
KMUTT	King Mongkut's University of Technology
KU	Kasetsart University, Thailand
KWH	Kilowatt hours
MAFF	Ministry of Agriculture, Forestry and Fisheries, Japan
MOA	Ministry of Agriculture, Fiji
MOFA	Taiwan Ministry of Foreign Affairs
NAC	National Agrobiodiversity Center
NARES	National agricultural research and extension systems
NARI	National Agricultural Research Institute, Papua New Guinea
NGO	Nongovernmental organization
NPS	Neutralized phosphorous acid salt
NRS	Nationally recruited staff
NSC	National Science Council
PADFA	Projet D'Appui au Développement des Filières Agricoles
PARC	Pakistan Agricultural Research Council
PCI	Project Concern International
PepLCV	Pepper leaf curl virus
PGS	Participatory guarantee systems
PNG	Papua New Guinea
PNGWiAD	Papua New Guinea Women in Agricultural Development
PSB	Phosphorus solubilizing bacteria
RDA	Rural Development Administration, Korea
SATNET	Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia
SDC	Swiss Agency for Development and Cooperation
SGD	Sustainable Development Goals

SMS	Short message service
SPC	Secretariat of the Pacific Community
SSR	Simple sequence repeat
SWAD	Society for Women's Action and Development
SWOT	Strength - Weakness - Opportunity - Threat
t/ha	Tons per hectare
TYLCKaV	Tomato yellow leaf curl Kanchanaburi virus
UC	University of California
UN-ESCAP	Economic and Social Commission for Asia and the Pacific of the United Nations
UNICEF	United Nations Children's Emergency Fund
USAID	United States Agency for International Development
VINESA	Improving Income and Nutrition in Eastern and Southern Africa by Enhancing Vegetable-Based Farming and Food Systems in Peri-Urban Corridors
VTIC	Vegetable Technology Immersion Cluster
WACCI	West Africa Centre for Crop Improvement
WVI	World Vision International
ZECC	Zero energy cool chamber

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