World Vegetable Center

ANNUAL REPORT
2016

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Published by
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WorldVeg Publication: 17-814
ISBN: 92-9058-221-9

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On the cover: In Tanzania, improved screenhouse designs based on the Center's research in protected cultivation help Maria Elias and her family keep their pepper crop safe from pests.

Suggested citation
World Vegetable Center. 2017. Annual Report 2016. World Vegetable Center, Shanhua, Taiwan. Publication 17-814. 64 p.

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Foreword from the Chair

2016 was a year of transition for the World Vegetable Center. The retirement of Dyno Keatinge after eight years as Director General presented the WorldVeg Board with the difficult challenge of finding a new leader to build on the organization's strengths.

I am pleased to report our Board members responded with enthusiasm throughout the candidate selection process, ably led by our Vice-Chair David Sammons. David engaged the Board and staff in the process, encouraging them to share their views on the attributes of a desirable candidate, offer nominations for the position, and contribute their thoughts on the candidates' suitability. Based on this extensive input, the Board made its selection and in April, Marco Wopereis from the Netherlands took up the position as DG. His dynamic, forward-thinking approach is leading the Center in new and exciting directions.

Marco's first, and perhaps most important, task was listening—to staff, to partners, and to donors. He traveled to all the Center's regional offices, getting out into the field to meet the people who interact with the Center, and finding out how those interactions could become even more positive and fruitful. These global consultations culminated in a week of intensive strategy planning in November at WorldVeg headquarters. The result of that effort is a new outcome-oriented operational plan distinguishing iterative and connected discovery, piloting/proof of concept, and scaling activities. The plan aims to ensure the Center's research can deliver the necessary impact to improve the lives and livelihoods of small-scale farmers and their families and other actors involved in vegetable processing and marketing in developing countries.

To succeed, a plan needs a champion. After a rigorous search, Marco and his team selected David Johnson from the USA to serve as Deputy Director General – Research. David came on board in January 2017 to help execute the plan and involve staff in its day-to-day implementation, and his collaborative, inclusive approach has been well received.

During the year we said farewell to two Board members. Always lively and thoughtful, Jim Phelan from Ireland contributed a practical perspective to Board discussions throughout his six-year appointment. Paz J. Benavidez II from the Philippines also provided valuable guidance for the Center's management. We thank them for their service to the Center and their dedication to horticulture and health. Chongrak Wachrinrat from Thailand joined the Board in 2016, and we look forward to his contributions.

It was also a year of transition for me. I stepped down as Board Chair, a role I had gladly filled since 2013. The three years I spent as Chair brought me into contact with an extraordinary group of talented, committed individuals willing to devote their time and expertise to make the Center more effective as it strives to alleviate poverty and malnutrition with vegetables. I commend the Center's donors and partners for their support of this important mission. I have every confidence that our incoming Chair will continue to capably guide the board in its vital advisory role.

With Marco, David, and the next Chair, I leave the Center in good hands.

Yutsai Huang

Yutsai Huang

Foreword from the Director General

This is my first foreword for an annual report since being appointed as the Director General of the World Vegetable Center. It is a true honor and privilege to be part of such a wonderful organization. Throughout the year I have interacted with staff and partners at our headquarters in Taiwan and regional centers in Africa and Asia to get firsthand information about the exciting work that is ongoing. It is a blessing to join hands with such committed staff and to be connected with so many partners all around the world.

Marco Wopereis sets the keystone for the Center's new two-storey office and lab building at Samanko Station, Bamako, Mali.

The year 2016 marked the beginning of the Decade of Action on Nutrition, and with good reason. More than 2 billion people are forced to rely on monotonous imbalanced diets leading to a chronic lack of vitamins and minerals. Paradoxically, 1.4 billion people are now overweight or obese. Nutrition security was very high on the agenda in discussions we held with partners in Africa and Asia in 2016 to develop the contours of a new strategic plan for 2017-2025. The results of those discussions can be found in this annual report. Our nutrition work has moved to the forefront and now occupies a very prominent place in the new organizational structure of our science work.

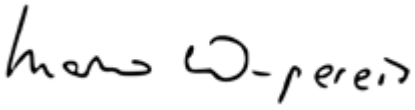
Some of the stories in this report give voice to the people in the regions we work in. That includes Mrs. Upasi Devi from Bhubhui village, northeastern India who has become a role model for other farmers in growing pointed gourd; Mr. Mwinyijuma Bakari Kimweri from Kaloleni village, Manyara region, Tanzania who has become an expert in growing tomatoes, earning on half an acre of land cultivated with vegetables about the same amount of money as from seven acres of land cultivated with maize; and Mr. Ngoura Adamou, now able to sell certified onion seed produced in Cameroon to local onion growers.

Other stories provide insight into our research, such as on salinity tolerance in mungbean; development of virus-resistant pumpkins; IPM work in Cambodia, Vietnam and India; and how we are helping farmers to diversify maize farming in Tanzania by introducing traditional vegetables such as amaranth, African nightshade and jute mallow.

But this annual report can only provide a glimpse of the work done. An excellent way to stay connected and get the latest news and updates on our activities is by reading our monthly Fresh newsletter available online (https://avrdc.org/fresh) or by following us on Twitter or Facebook. Or take a look at our videos available on YouTube. I particular recommend the video on our work with students at Baraa Primary School in Arusha, Tanzania. Watch how they learned to produce their own vegetables and discovered why it is important to eat some vegetables every day. The video was produced by Rhiannon O'Sullivan, a videographer from Australian Volunteers International. See: https://avrdc.org/seed-kits-baraa-primary-school-garden/.

A big thank you to our financial partners who made our work possible in 2016 and to all of you who joined us in reflecting on a new strategic plan, which will see the light early next year.

Happy reading!



Marco Wopereis

Timeline

01 JANUARY

A workshop to raise awareness about the South American **tomato leaf miner** (*Tuta absoluta*) in Tanzania attracted farmers, researchers and policymakers to WorldVeg Eastern and Southern Africa

02 FEBRUARY

Official launch of the **International Mungbean Improvement Network**, in Kanpur, India

03 MARCH

WorldVeg joined **G2P-SOL** and **TomGEM**, two projects to track and use tomato, pepper, and eggplant genetic resources, and to ensure crop resilience as the climate changes

07 JULY

WorldVeg varieties were on display at the **First International Fruit and Vegetable Fair** in Tashkent, Uzbekistan.

Seed company representatives from the **Asia & Pacific Seed Association** met at WorldVeg HQ.

08 AUGUST

Children's Day: Children and grandchildren of Headquarters staff spent a full day at the Center learning about vegetables, how to grow them, and how to eat them for a nutritious diet.

Regional Strategy Meeting: WorldVeg Eastern and Southern Africa, Arusha, Tanzania.

09 SEPTEMBER

Bitter Gourd Open Field Days at WorldVeg East and Southeast Asia introduced more than 400 bitter gourd breeding lines to seed companies.

Regional Strategy Meeting: WorldVeg West and Central Africa, Bamako, Mali.

WorldVeg participates in **USAID Horticulture Review and Strategy Meeting** in Malaysia.

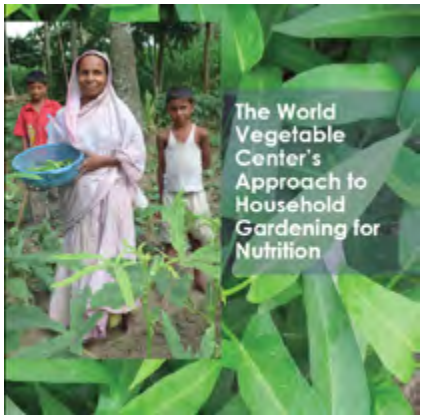
Representatives from 38 regional seed companies attend a **Field Day for virus-resistant tomato** at WorldVeg South Asia, Hyderabad, India.

04 APRIL

New Director General **Marco Wopereis** joined WorldVeg

05 MAY

The World Vegetable Center's Approach to Household Gardening for Nutrition was published



06 JUNE

The **Asian Food and Agriculture Initiative** training course welcomed participants from 11 countries.

Brainstorming meetings held at HQ to plan a **new research structure.**

10 OCTOBER

Across WorldVeg, 158 staff members were trained to **develop skills** in language (English, French, Thai), project management, gender research, experimental design & data analysis, leadership, computing and graphics, etc.

Regional Strategy Meeting: WorldVeg East and Southeast Asia, Bangkok, Thailand.

Regional Strategy Meeting: WorldVeg South Asia, Hyderabad, India.

Taiwan Seed Industry Development Forum: Representatives from 10 Taiwan seed companies, the Council of Agriculture and other Taiwan institutions meet with HQ staff to plan collaborative activities.

11 NOVEMBER

More than 70 WorldVeg staff and several board members participated in an intensive week of **strategy planning** at HQ to guide future action for impact at scale.

WorldVeg participated in the **20th Seed and Seedling Festival** at the Tainan District Agricultural Research and Extension Station, Xinhua, Taiwan.

12 DECEMBER

An agreement to form a **vegetable breeding consortium** between the Asia & Pacific Seed Association and WorldVeg was signed.

More than a million visitors to **Kaset Fair** at Kasetsart University in Kamphaeng Saen, Thailand toured the WorldVeg exhibit.

GLOBAL STRATEGY PLANNING

Since its founding in 1971, the World Vegetable Center has continued to evolve, to better realize the immense potential of vegetables for improving nutrition and incomes in developing countries. This evolution is necessary to effectively address changing global and regional development priorities and to continuously modernize the Center's thinking along the research to development continuum.

In 2016 WorldVeg embarked on defining a new strategy. It started in June with a brainstorming session among the Center's scientists about a new science structure for the Center. This was followed by regional strategy meetings in Arusha, Tanzania (25-26 August), Bamako, Mali (19-20 September), Bangkok, Thailand (12 October) and Hyderabad, India (17-19 October). Key research and development partners and donors participated in these meetings. The Center was instrumental in organizing the United States Agency for International Development (USAID) Horticulture Review and Strategy meeting in Malaysia (8-9 September), which contributed to refining USAID's priorities for horticulture in phase two of the Feed the Future program.

These meetings culminated in a week-long Global Strategy Planning event at headquarters in Taiwan (14-18 November) in which 70 global staff participated. A meeting of the executive committee of the board preceded the meeting and

some of the board members stayed on to take part in the planning meeting. An agreement was reached to organize the Center's science in four mutually supportive flagship programs that address the priorities identified by the regions:

- **Seeds that Perform** will collect, conserve, characterize and use genetic diversity to improve vegetable crops in close partnership with seed companies and national seed systems. This flagship comprises the Center's unique competence in vegetable breeding and vegetable genetic diversity.

- **Safe and Sustainable Value Chains** will use improved seed and combine it with good agricultural and postharvest practices to improve vegetable production systems and value chains, with an emphasis on creating income and employment opportunities for women and youth.

- **Healthy Diets** will use improved seed and combine it with good agricultural practices and behavioral change communication in the areas of nutrition and water, health and sanitation, with an emphasis on increasing vegetable production and consumption among population segments vulnerable to malnutrition.

- **Enabling Impact** will develop scaling strategies for the Center's technologies and interventions and conduct impact evaluation and policy-oriented research. It will also provide services such as monitoring and evaluation systems, knowledge management systems, biometrics support and the international vegetable training course.

Each flagship is divided into 2-4 innovation clusters, which are teams of WorldVeg staff and partners working towards a clear and measurable set of outcomes through discovery, piloting and scaling activities and continuous improvement of a coherent set of product lines (e.g. high performance vegetable lines) or product packages (e.g. household gardens or off-season vegetable production methods).

The anticipated improvement over the previous arrangement, which was structured around projects grouped under global themes, is that research and development will be more continuous and focused on a well-defined set of longer-term goals and less driven by short-term project cycles (Table 1). Flagship Program Leaders will gain more authority over the directions of their programs, while Regional Directors will gain more authority over projects in their regions.

Old: Global Themes

- The innovation process tends to be project-bound and is not continuous. Some projects tend to "reinvent the wheel" by not building on past experience and results.
- Global Theme Leaders have little influence on the research within their Theme, with their main task being the review of project reports and coordination of annual reporting.
- Themes have a goal but not a well-defined strategy for how to achieve this goal.
- Each project is categorized under one Global Theme even if it contributes to several other Themes.

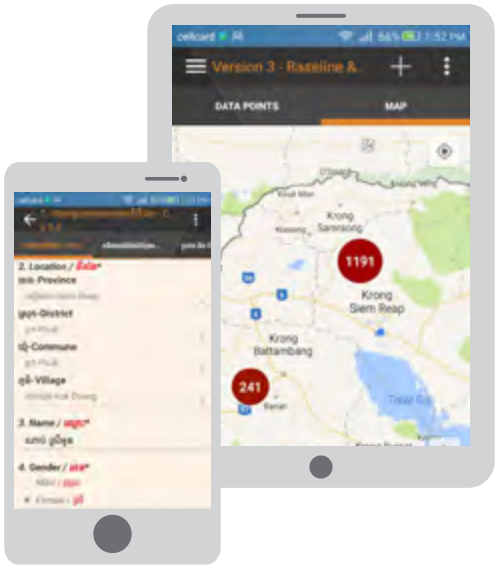
Addressing the need for change while building on the Center's strengths and the priorities identified in the regions was an important accomplishment for 2016. It also laid the foundation for a new strategy and operational plan to be drafted in 2017.

New: Flagship Programs

- Continuous innovation process that explicitly recognizes the need for discovery research, piloting research, scaling activities and impact evaluation. An effective knowledge management system keeps track of past and ongoing research.
- Regional Directors take over project supervision in the regions with Flagship Program Leaders focusing on research excellence and flagship development.
- Each product line/package has a vision and long-term goals. Detailed scaling strategies will be defined for key product lines/packages.
- Projects can contribute to one or more Flagship Programs and Innovation Clusters.

The Center charts a new course to deliver impact at scale

GROWING WITH BIG DATA



A household garden project in Cambodia benefits from a fully digital approach to data collection

The World Vegetable Center-managed USAID Household Garden Scaling Project in Cambodia partnered with **Akvo**, a not-for-profit foundation that creates open source, internet and mobile software and sensors, to use Akvo Flow, a mobile application for data collection in April 2016. This application has allowed the project to capture an enormous amount of data cheaply, accurately and securely. To date more than 15,000 records have been collected and a further 50,000 diverse data records are expected to be available by 2018.

"I've been involved in traditional paper based surveys before and they are costly, time consuming and slow in regard to data analysis and on-the-ground action," said Project Manager Stuart Brown. "Data capture, database entry and the multiple handling of data prior to analysis was extremely inefficient."

The use of a fully digital approach combined with cloud services, powerful data analytics, and visualizations has opened many possibilities to use data science within the project.

Although Akvo Flow initially was used to capture data to measure indicators for reporting purposes, the project also has used the tool to capture and analyze specific technical requests from project clients to understand the major home garden challenges encountered by households. This data-driven approach has allowed the project to be more informed and act on these challenges. In addition, the GPS data captured through surveys of input supply stores within the region of the project has opened enormous possibilities to improve the seed distribution network within the region. This is an important step toward true scaling of home gardens in Cambodia.

In 2017 the project will pilot the use of Akvo Caddisfly to test and measure soil fertility parameters and soil pH. A mobile device equipped with Caddisfly and a camera calibrated to commercially available soil strip tests interprets the soil data using color charts.

EAST AND SOUTHEAST ASIA

OCEANIA

- A Memorandum of Understanding with **Kasetsart University** was signed to host the WorldVeg regional center for another 25 years in Thailand at Bangkhen and Kamphaeng Saen campuses.
- ***SEAVEG 2016 Symposium - Vegetables for Improved Nutrition and Livelihoods*** was coordinated by WorldVeg and the Malaysian Agricultural Research and Development Institute (MARDI) from 6-8 September 2016 in Malaysia. In attendance: 145 registered participants, 45 chairpersons and speakers (107 from Malaysia and 83 international, representing eight ASEAN countries; East, Central and South Asia; Oceania; Australasia; Europe; and America).
- The **USAID Horticulture Review and Strategy Meeting** produced a white paper to inform Phase 2 of Feed the Future. Coordinated by WorldVeg and held 8-9 September 2016 in Malaysia, the meeting included USAID-funded mission, development and research partners.
- **AARNET** (ASEAN-AVRDC Regional Network for Vegetable Research and Development) held its 11th annual meeting in Malaysia, coordinated by WorldVeg and MARDI on 22-24 March 2016, including an Expert Consultation on Vegetables for Health.
- A scaling strategy was implemented for **home garden seed kits** to tackle malnutrition in Cambodia in partnership with an NGO network, East West Seeds, Stockholm Environment Institute (for gender assessment), Tufts University (health and nutrition assessment), Akvo for data management, corporate responsibility arms of hotels and philanthropists, plus local development and research projects.
- Improved **WorldVeg tomato and pepper varieties** were registered by Ministries of Agriculture in the Solomon Islands and Fiji.
- **Pathogen diagnostics** and appropriate control options including grafting, protected cultivation, biological control and registration of Bt toxin were carried out in partnership with University of Queensland, Secretariat of the Pacific Community (SPC) and Ministries of Agriculture in Fiji, Papua New Guinea (PNG), Samoa, Solomon Islands, Tonga.
- WorldVeg promoted utilization and production of **traditional vegetables** in PNG in partnership with the National Agriculture Research Institute (NARI) and Charles Darwin University.
- An **innovation platform** was established to provide incentives for farmers and value chain actors to increase profits in northwest Vietnam.

- The influence of season and ethnic minorities on **home gardens** was assessed in Vietnam's central highlands and northwest region.
- Improved **bitter gourd, chili and pepper** were evaluated in Vietnam and Myanmar.
- **Biological based IPM solutions** were promoted in Cambodia, Laos and Vietnam for vegetable legumes and leafy brassicas.
- **Technologies promoted** to advance income and nutrition in Cambodian horticulture included varietal selection, targeted IPM, nutrition awareness, diet diversity, and postharvest methods.
- Seed companies invested in the Center's **cucurbit breeding program** for improved bitter gourd pre-breeding lines that harness genetic diversity from the WorldVeg genebank.
- The **35th International Vegetable Training Course** held in Thailand from 5 September to 25 November 2016 increased capacity and networking for 42 participants from Burkina Faso, Cambodia, Egypt, India, Laos, Lebanon, Malaysia, Marshall Islands, Mauritius, Myanmar, Nigeria, Oman, Sri Lanka, Sudan, Swaziland, Tajikistan, Taiwan, Thailand, Tuvalu, Vietnam.
- **Training on Postharvest Management for Horticultural Crops** held in Thailand from 15-27 June 2016 for 44 participants from Asian Food and Agriculture Cooperation Initiative (AFACI) member states (Bangladesh, Cambodia, Indonesia, Kyrgyzstan, Laos, Mongolia, Nepal, Philippines, Sri Lanka, Thailand, and Vietnam) was coordinated by WorldVeg with support from Thailand's Department of Agriculture.
- The regional office participated in **Kaset Fair** (1 million visitors) and **Bitter Gourd Field Days** to promote WorldVeg technologies.
- Regional Director Fenton Beed promoted WorldVeg to national research partners, universities, seed companies and CIAT, CropLife, World Fish, IWMI, ICRAF, ILRI, IFPRI, OECD, APAARI and APSA through an invited Presidential Address to **British Society of Plant Pathology**.

NEVER GIVE UP

Although cold weather constricted pointed gourd production, Upasi Devi knew the crop had potential. Her patience was rewarded.

It takes great patience and courage to stick to a crop when others have tried and failed, particularly when it takes much longer than other crops to produce a return. One woman from Bhubhui village in Gola of Ramgarh district, Jharkhand who had that patience is now reaping big rewards for her whole village and the neighboring district.

It all started when five nominees came forward as research farmers under the project "Improving livelihoods through innovative cropping systems on East India Plateau" (ACIAREIP) in 2013, funded by the Australian Centre for International Agricultural Research (ACIAR). The farmers had been selected by their villages to introduce new cropping ideas, and the project introduced them to pointed gourd—a long-term crop grown on trellises.

Despite being experienced vegetable farmers, they'd never cultivated this strange crop or tasted it. Practical training on pointed gourd production was provided by the World Vegetable Center and PRADAN, the project's NGO partner. The economics of pointed gourd cultivation was new for them, but they were excited to see what would happen when they took up the challenge of planting the cuttings they'd been given.

Days passed and neighbors' crops were flourishing, but the pointed gourd wasn't growing due to low temperatures. Early hopes of getting more income than other farmers were quickly fading. Four out of the five farmers gave up, saying that the land and climate were just not suited to the crop. **Mrs. Upasi Devi** also considered pulling out the pointed gourd in her 260 m^2 field. But her younger daughter, Ms. Savita Devi, encouraged her mother to keep going.

After a couple of weeks, the weather warmed up and the pointed gourd began to sprout, but Mrs. Upasi still had to be patient before fruits would come. The village research farmers decided to cultivate other crops in the field as intercrops to better utilize the land, and to get some additional income. Mrs. Upasi planted red amaranth between the trellised rows of pointed gourd. Her family, friends and relatives consumed most of it and the surplus was sold in the market. The amaranth added nutrition to their diet, but didn't bring in much money.

When the vines of pointed gourd grew bigger and it was difficult to grow another crop under the trellis, the group of research farmers came up with a new idea—shade-loving ginger. So she planted it and harvested about 90 kg, earning an additional income of 3575 Indian Rupees (INR). She kept 20 kg for seed, and the 5 kg she kept for home use reduced her food bills.

At long last her patience was rewarded when she was able to sell 517 kg of pointed gourd, earning an income of 13,000 INR (US$ 200) from her small field. This income made a big difference in her household expenditures and also helped her at a crucial time when her eldest daughter needed medical treatment.

Mrs. Upasi is now a role model for other farmers in her village who have adopted the crop, and her progress encouraged farmers in ten nearby villages to give pointed gourd a try.

"Success is only possible when we encounter challenges and difficulties," said Mrs. Upasi. Demand for locally produced pointed gourd cuttings is growing, and the youth of Bhubhui built a village nursery to meet the need. So far they have sold almost 1000 seedlings to neighboring villages at 10 INR each.

SOUTH ASIA

CENTRAL ASIA

Vegetable legumes

- WorldVeg established the **International Mungbean Network** with partners from India, Bangladesh, Myanmar and Australia to strengthen national research and breeding pzrograms and to share elite germplasm between partners. The distribution of the mungbean mini-core collection to members and to Pakistan and Uzbekistan is now generating interest from additional partners.
- **Improved mungbean lines** have been developed from the world's most popular variety 'NM94' that incorporate early maturity and excellent resistance to Mungbean yellow mosaic disease (MYMD), the most devastating disease of the crop—and for the first time also include resistance to powdery mildew and complete resistance to bruchids, which ruin stored seed.
- Twelve mungbean lines have been identified with excellent **tolerance to salinity** in Uzbekistan and Pakistan and three show good tolerance to high temperatures; the latter will cope with temperatures over 40° C during the flowering period and have been tested in India and Pakistan.
- WorldVeg project activities over the last three years have i**ncreased mungbean production** by 60% in traditional growing areas of Pakistan and in the new rainfed double cropping areas in Pothwar district.
- Over the last three years, 744 t of high quality **mungbean seed** has been produced in Pakistan. When sown to produce more seed, this will be enough to replant more than 400,000 ha across the country.
- Hand harvesting is the single biggest expense in mungbean production, and successful demonstrations of **low cost mechanical harvesting** in Pakistan led to more than 7400 ha being harvested by machine last season, opening up new economic opportunities for the crop.
- Two pre-emergent **herbicide**s (pendimethalin and imazethapyr) for effective and economic weed control in mungbean have been identified to replace hand weeding, one of the highest costs in production.
- Successful introgression of improved seed viability has lifted **on-farm seed survival of vegetable soybean** from 50% to 80% in the year after harvest. Glabrous pods also have been incorporated for the lucrative snack food market.

Seed production and marketing

- A **new vegetable seed industry** has been created in Pakistan. In 2016 more than 21 t of certified seed of five vegetables was produced and farmers in three provinces linked with seven seed companies to market their produce. This new income stream for seed growers is reducing costs and improving vegetable seed quality.
- A pilot study in Bangladesh has shown that training women experienced in vegetable production to become **village seed distributors** by linking them with private seed companies can expand the supply of high quality seeds to isolated villages to improve yields.

Protected cultivation and IPM

- In Pakistan 62 varietal trials on-station and on-farm, and 36 on-farm adaptation trials identified the nation's **best performing tomatoes and cucumbers** under cover, as well as the two best sweet pepper, bitter gourd, vegetable marrow and chili varieties.
- In Tajikistan, 1100 farmers were trained in **protected cultivation** of tomato, pepper and cucumber, while 12 demonstrations of 100 m^2 backyard polyhouses produced more than 20 t of cucumber.
- Training provided to 96 farmers in **tunnel production and IPM technologies** across three provinces in Pakistan produced a 10-15% drop in pesticide use.
- Field trials of **pheromone traps** to control the tomato leaf miner (*Tuta absoluta*) in Karnataka, India have cut sprays from 12-15 per season to 2-3 and increased yields by 30%.
- In Pakistan, the promotion of **off-season spinach and coriander** under green shade nets in summer was very profitable, with an average spinach yield of 43.9 t/ha worth US$ 14,647, and an average coriander yield of 14.6 t/ha worth US$ 15,979.
- 23 demonstration **drip irrigation systems** across Pakistan showed water and fertilizer savings of 30-40% in cucumber, bitter gourd, vegetable marrow and tomato, with 30-40% yield increases for tomato and cucumber, and 20-30% increases for other cucurbits.
- Field trials in Odisha have proven the viability of producing **onions in the wet summer season** by raising seedlings under plastic covers. This has doubled prices received by farmers and provoked great interest across the state.

SMALL IS PROFITABLE

How a half-acre of vegetables became a business asset

Mwinyijuma Bakari Kimweri is 51 years old and has been a vegetable farmer in Kaloleni village, Kiteto district, Manyara region in Tanzania for more than 14 years. He is among the 3,000 vegetable farmers who benefited from the partnership of the USAID-funded Africa RISING, NAFAKA and TUBORESHE CHAKULA programs for fast-tracking delivery and scaling of agricultural technologies in Tanzania.

Although Mr. Mwinyijuma had been generating a small amount of additional income from growing vegetables, he did not pay much attention to proper planning and production practices. However, the training provided by WorldVeg and HORTI-Tengeru, which focused on nursery management, good agricultural practices and postharvest handling of vegetable crops, changed his view of vegetable production.

"The training opened my eyes," he said. "I am now using proper crop rotation, I use improved vegetable varieties given to me by the project, and I certainly take care to apply good management practices."

During the last agricultural season, due to changing his vegetable production approach, Mr. Mwinyijuma was able to cover all pesticide, fertilizer and labor costs for his tomato plot (0.5 acres) from a weekly sale of leafy vegetables (Ethiopian mustard), which brought in TSH 60,000 (US$ 30).

Despite the dry weather in August 2016, Mr. Mwinyijuma harvested 60 crates of tomatoes from a half-acre of land and sold 50 crates for TSH 40,000 (US$ 20) each, generating a total revenue of TSH 2 million (US$ 1,000). During the same season, he harvested 86 bags of maize from 7 acres of land, of which he sold 60 bags at the farm gate for TSH 45,000 (US$ 22.5) per bag, generating a total revenue of TSH 2.7 million (US$ 1,350). A little over a half-acre of land cultivated with vegetables provided Mr. Mwinyijuma with almost the same revenue he made from seven acres of land cultivated with maize.

"From the agribusiness training I learned to invest part of my revenues," Mr. Mwinyijuma said. "I have already invested TSH 560,000 (US$ 280) from my vegetable sales to buy a 2-inch water pump, which simplifies irrigating and will enable me to grow more vegetables in the next season." He smiled and continued: "And I also bought a motorbike with that money."

EASTERN AND SOUTHERN AFRICA

- **Research activities** were conducted in six countries: Ethiopia, Kenya, Mozambique, Tanzania, Uganda and Zambia.
- WorldVeg Eastern and Southern Africa **hosts** the International Institute of Tropical Agriculture (IITA) and is in advanced talks to host other international organizations and private companies on its campus to create synergy.
- A high-level sensitization workshop on ***Tuta absoluta***, a major tomato pest, held in conjunction with USAID and the Tanzania Horticultural Association (TAHA) included an insect resistance workshop.
- WorldVeg hosted a **regional training workshop** on *T. absoluta* and other emerging pests in collaboration with the Food and Agriculture Organization of the United Nations (FAO).
- *Tuta absoluta* research in the region is focusing on the use of **biopesticides** against this invasive pest as well as a search for resistance in wild tomato accessions among our genebank accessions.
- WorldVeg Eastern and Southern Africa researchers published **peer-reviewed articles** on topics including the regional office's women-oriented improvement and development strategy for traditional African vegetables; molecular markers for genetic diversity studies in African leafy vegetables; effects of climate variability and change for smallholder farmers in Kenya; commercialization of food crops and farm productivity in Central Africa; and reducing tomato postharvest losses using wooden crates.
- Capacity building through formal training was a high priority. In 2016, **30 students** (3 PhD students, 11 MSc students, 6 BSc students, 10 interns) conducted their research at the regional office.
- A state-of-the-art facility was built to house the **Eastern and Southern Africa genebank**, a treasure trove for the Center's many partners in the region. Seeds are now stored at 10-12° C, vastly increasing the period of storage, maintaining seed viability, and reducing seed regeneration costs. A new advanced seed dryer will be installed in 2017.
- A **new drip irrigation system** was installed for most of the fields at the regional office, paving the way for studies on modelling greenhouses with CIRAD and other partners.
- The **auditorium** was completely refurbished, further enhancing the regional office as a venue for events, training, and conferences related to vegetables and horticulture.

- The regional office organized two week-long **international training workshops** for its staff and partners, including a gender workshop and statistics training, while partner organizations used the venue for other training courses.
- A regional coordination meeting of the **Homegarden Scaling Project** was held at the regional office from 15-17 March 2016, hosting 39 participants from research and development organizations and the private sector in Tanzania, Kenya, Uganda, Taiwan and Liberia.
- Over 60 **delegations** visited the regional office during 2016 from all over the world, contributing to enhanced visibility and partnerships in vegetable research.
- Together with HORTI-Tengeru and TAHA, the regional office organized a **vegetable fair** to showcase its products as well as those from private sector partners to thousands of farmers and agriculture professionals.
- Through the **Global Action Plan for Agricultural Diversification** (GAPAD), WorldVeg and CABI co-organized a webinar and a high-level roundtable forum in Nairobi, Kenya highlighting the importance of agricultural biodiversity for Sustainable Development Goal 2: Zero Hunger.
- Using a "seven step guide," the Australian Centre for International Agricultural Research (ACIAR)-funded **VINESA project** connected 120 farmers to new vegetable markets in Malawi, Mozambique and Tanzania, and taught skills to identify specific niche markets. Three marketing models have been identified and are being pursued through partnerships with a private company (Mozambique), a farmers' cooperative (Malawi) and a farmers' association (Tanzania).

CERTIFIABLY GOOD

A major problem in onion production is the challenge of producing good quality seed and making it available to farmers. Onion needs two seasons to produce seed, and technical know-how is required to manage onion seed production in Cameroon's dry northern region.

A partnership between the World Vegetable Center and the Commodity Value-Chain Development Support Project (PADFA) funded by the International Fund for Agricultural Development (IFAD) through the Cameroon Ministry of Agriculture provided the needed impetus to improve the onion seed supply and distribution system in the northern region by strengthening the capacity of several Common Initiative Groups (CIGs) to produce seed in Baila-Bachira, a target community.

An onion seed multiplication plot was established for the production of certified onion seed with 20 farmers (10 women, 10 men) from 8 CIGs. One hundred and ninety-two onion farmers from 19 CIGs received training on how to produce good quality seed.

Farmers producing onion seed in Cameroon find a ready market

"We had never produced onion seed on more than 1,000 m^2 of land," said **Ngoura Adamou**, the 42-year-old president of one of the CIGs, who has been cultivating onion for about 25 years. "Prior to the PADFA onion project, our seed was not certified as we didn't know we had to involve seed inspectors for quality control."

Yields were extremely low—less than 10 kg per hectare, and had a very low germination rate.

"Following WorldVeg's advice, in the 2015-2016 cropping season we produced more than 300 kg of certified onion seed per hectare," he said. "I have never seen so much onion seed in my life!"

Ronal Chendjou, WorldVeg research assistant, noted that only imported onion seeds were sold as certified seed in Cameroon prior to the WorldVeg intervention. The first certified onion seed produced by local farmers has several advantages, in particular a higher germination rate (98%), which is much higher than for imported seeds (85%) due to their better adaptation to the agro-climate. "Plants are more vigorous and our onion seeds are more affordable," said Ronal.

Mr. Souley, a farmer who bought and tried the seed, was grateful for the opportunity to have quality onion seed at a good price with an excellent germination rate. "I will not use other onion seeds anymore except that from farmers who received training from WorldVeg," he said. "In fact, I bought one pack of 500 g and this can sow more space than ever before. We have established 4000 m^2 for the production of mother bulbs for the next cropping season with our own seed."

Many onion farmers have started placing requests in advance to buy the onion seed for the next season. "It's so popular that some of them are anticipating we will increase the seed price for next year," said Mr. Adamou. "With that kind of demand, you know you have a good product."

WEST AND CENTRAL AFRICA

- Operations were mainly undertaken in **Mali, Cameroon** and **Liberia**. Specific project activities were also implemented in **Burkina Faso** (Swiss Agency for Development and Cooperation (SDC)-funded Vegetables Go to School project) and **Ghana** (Africa RISING West Africa project, USAID-funded Postharvest Program, and CORAF/WECARD-funded traditional African vegetables project) via partners.
- Construction began on a **new 2-storey office and lab building** at Samanko Station to provide adequate space for the growing number of staff; the new space will be ready in 2017.
- Four **Best Practice Hubs** in Sikasso and 15 **Vegetable Technology Immersion Clusters** in Mopti were upgraded to become WASH (Water, Sanitation, Hygiene) compliant with the construction of latrines and access to water.
- The **Mali Horticulture Scaling Project** was showcased as one of the best projects funded by USAID that integrates agriculture with nutrition and health outcomes and gender mainstreaming. A video documentary about the project's approach to training, behavior change communication, and community mobilization was developed and shared with project partners and USAID.
- An **impact assessment** of the Mali Horticulture Scaling Project on key nutritional and gender outcome indicators via the "Gender, Agriculture, and Assets Project – Phase 2" managed by the International Food Policy Research Institute (IFPRI) and funded by USAID and the Bill & Melinda Gates Foundation (BMGF) was undertaken. Analysis and results will be made available in 2017.
- Under the Urban Food Plus project being implemented in Burkina Faso, Cameroon and Ghana, options for **sustainable intensification of year-round vegetable production** in urban and peri-urban settings, focusing on soil fertility and suitably adapted varieties, were tested in northern Cameroon. Vegetable production techniques including the use of biochar and compost were evaluated via studentships.
- Three MSc. **students** completed their theses at the University of Bamenda, Cameroon. The thesis of one PhD student (a former WorldVeg employee) from Cameroon is in progress and is expected to be completed in mid-2019.
- Under the CORAF/WECARD-funded **traditional African vegetables** project, an increased supply of traditional African vegetables was observed in local Cameroon markets as people shift from gathering forest produce to cultivating vegetables. Seed production and processing is becoming an income-generating activity.

- Based on WorldVeg advice and examples, **Peace Corps Cameroon** integrated traditional African vegetables into their home garden programs in seven regions.
- WorldVeg produced about 200 kg of **seed** of improved traditional vegetables and distributed the seed to project partners. The WorldVeg Cameroon team trained 100 (36 women, 64 men) participants in Cameroon, Ghana and Burkina Faso to produce quality seed; now partners no longer need to rely on WorldVeg for their seed supply. The Institute of Agricultural Research for Development (IRAD), for example, produced, packed and distributed about 330 kg of seed.
- Two traditional African **vegetable value chain innovation platforms** were set up to link value chain actors and stakeholders.
- Under the International Fund for Agricultural Development (IFAD)-funded PADFA onion project, 192 onion farmers from 19 community groups were trained in **certified seed production**. A total of 533 kg of certified onion seed was produced compared to the initial target of 300 kg. This was the first time certified onion seeds were produced with better quality, higher yields and a higher germination percentage than the imported seeds farmers usually use. The seed was handed over to PADFA, who in turn donated the seeds to farmers' groups and individual farmers to be planted on 133 ha of land.
- In Liberia, the USAID-funded Home Garden Scaling Project signed **memoranda of understanding** with the Agricultural Extension and Technical Services of the Ministry of Agriculture (MoA) and the Central Agricultural Research Institute (CARI). Five hundred and thirty-five vegetable producers, mostly vulnerable households, participated in short-term agricultural training; all trainees received seed kits, and a total of 439 women benefited.
- A **nutrition training program** hosted in collaboration with USAID Food and Enterprise Development (FED) and the Mali Ministry of Health reached 300 girls and 317 boys.
- A **community cross-sectional study** on the number of children between the ages of 6 and 23 months with a minimum acceptable diet in Mali was conducted in villages in Sikasso and Mopti regions of Mali from January to March. A structured questionnaire was used to elicit socioeconomic and anthropometric data for 959 boys, 856 girls, and their mothers (1,764 households). The prevalence of underweight, stunting and wasting was 23.9%, 28.4% and 13.9% respectively. About 16.5% of children were undernourished.

PROJECTS in 2016

Project Title	Donor Name	Duration	Project budget (US$)
Multi-location evaluation of tomato lines carrying different combinations of Ty genes for resistance against begomovirus infection	Asia and Pacific Seed Association	2014-2017	278,263
International training workshop on postharvest management technology for horticultural crops	Asian Food & Agriculture Cooperation Initiative	2015-2017	137,158
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 Agricultural Research	2013-2017	2,001,075
Strengthening integrated crop management research in the Pacific Islands in support of sustainable intensification of high-value crop production	Australian Centre for International Agricultural Research	2011-2017	844,816
Increasing productivity of *Allium* and solanaceous vegetable crops in Indonesia and sub-tropical Australia	Australian Centre for International Agricultural Research	2013-2016	49,518
Improving livelihoods with innovative cropping systems on the East India plateau	Australian Centre for International Agricultural Research	2012-2016	90,939
Establishing the International Mungbean Improvement Network	Australian Centre for International Agricultural Research	2016-2019	1,611,072
Promoting traditional vegetable production and consumption for improved livelihoods in Papua New Guinea and Northern Australia	Australian Centre for International Agricultural Research	2014-2018	128,123
CGIAR Research Program: Integrated Systems for the Humidtropics	CGIAR	2012-2016	2,329,956
Operations of CRP Humidtropics Innovation Platform in Cameroon	CGIAR	2015-2016	41,300
Strengthening cooperation between the World Vegetable Center and Council of Agriculture on vegetable research and development	Council of Agriculture, Taiwan	2016-2016	458,265
GlobeE Diversifying Food Systems - Horticultural innovations and learning for improved nutrition and livelihoods in East Africa	Federal Ministry for Economic Cooperation and Development, Germany	2013-2016	213,988
Nutrition-Sensitive Promotion of Vegetables - Increasing vegetable consumption through public and private partnerships efficiently delivering effective nutrition messages in the vegetable value chain	Federal Ministry for Economic Cooperation and Development, Germany	2016-2018	106,994
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	85,595
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	1,283,928

Project Title	Donor Name	Duration	Project budget (US$)
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	2014-2017	178,932
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	1,283,928
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	119,726
Linking genetic resources, genomes and phenotypes of Solanaceous crops	European Commission	2016-2021	447,238
GlobE UrbanFoodPlus - African-German partnership to enhance resource use efficiency in urban and peri-urban agriculture for improved food security in West African cities	Federal Ministry for Economic Cooperation and Development, Germany	2016-2018	123,074
GlobeE Diversifying Food Systems - Horticultural innovations and learning for improved nutrition and livelihood in East Africa - Phase 2	Federal Ministry for Economic Cooperation and Development, Germany	2016-2018	176,540
Improving rural livelihoods through innovative scaling-up of science-led participatory research for development in Karnataka	Government of Karnataka, India	2013-2017	320,000
Multiple disease resistant and heat tolerant tomato lines evaluation	I & B Seeds Private Limited	2016-2017	20,000
Good Seed Initiative	Irish Aid, Ireland	2013-2016	130,951
Selection of tropically-adapted lines of vegetables to improve productivity of the vegetable value chain in Southeast Asia	Japan Ministry of Agriculture, Forestry and Fisheries	2015-2016	147,058
Selection of tropically-adapted lines of vegetables to improve productivity of the vegetable value chain in Myanmar and Vietnam	Japan Ministry of Agriculture, Forestry and Fisheries	2016-2017	131,214
Screening for development of begomovirus-resistant processing tomato hybrids	Kagome Co. Ltd., Japan	2010-2017	128,880
Networking to Enhance International Cooperation in Vegetable Research and Development - Phase 1	Ministry of Foreign Affairs, Taiwan	2015-2015	600,000
Networking to Enhance International Cooperation in Vegetable Research and Development - Phase 2	Ministry of Foreign Affairs, Taiwan	2016-2016	400,000
A holistic approach towards the design of new tomato varieties and management practices to improve yield and quality in the face of climate change	Ministry of Science and Technology, Taiwan	2016-2019	109,548
Identification and introgression of whitefly (*Bemisia tabaci*) resistance genes from *Solanum pimpinellifolium* to tomato	Ministry of Science and Technology, Taiwan	2015-2016	19,332

Project Title	Donor Name	Duration	Project budget (US$)
Mobilize resistance genes from wild tomato for breeding salt tolerant tomato cultivars	Ministry of Science and Technology, Taiwan	2014-2017	81,098
Support for the implementation of PADFA's onion seed programme	PADFA (Commodity Value-Chain Development Support Project), Cameroon	2015-2017	166,570
The World Vegetable Center global cucurbit breeding program	Private seed companies	2016-2019	204,975
Development of breeding techniques and selection of disease resistant germplasm in cucurbits	Rural Development Administration, Korea	2014-2016	120,000
Identification of molecular markers associated with disease and insect resistance for marker assisted selection (MAS) in tomato (*Solanum lycopersicum*) breeding programs	Rural Development Administration, Korea	2016-2018	120,000
Vegetables Go to School: Improving nutrition through agricultural diversification (Phase 1)	Swiss Agency for Development and Cooperation	2013-2016	3,509,539
Cambodian Horticulture Project for Advancing Income and Nutrition	Swiss Agency for Development and Cooperation	2015-2017	520,992
Vegetables Go to School: Improving nutrition through agricultural diversification (Phase II)	Swiss Agency for Development and Cooperation	2016-2017	52,718
Evaluation and screening of Syngenta maize and vegetable hybrids for adaptation in Nigeria and skills development program for Syngenta staff	Syngenta Crop Protection AG	2014-2016	42,000
Vegetables for All	Amsterdam Initiative against Malnutrition, the Netherlands	2014-2018	54,682
Utilizing the genome of the vegetable *Cleome gynandra* for the development of improved cultivars for West and East African markets	The Netherlands Organisation for Scientific Research	2015-2017	5,885
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	2012-2016	418,037
Africa RISING: 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 & Southern Mali	United States Agency for International Development	2012-2017	976,846
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	2015-2016	60,000
Postharvest Program	United States Agency for International Development	212-2017	5,000,000
Promoting Science and Innovation in Agriculture in Pakistan - Agricultural Innovation Program	United States Agency for International Development	2013-2016	2,583,126

Project Title	Donor Name	Duration	Project budget (US$)
Enhancing partnership among Africa RISING, NAFAKA and TUBORESHE CHAKULA programs for fast-tracking delivery and scaling of agricultural technologies in Tanzania	United States Agency for International Development	2014-2017	592,278
Deploying Improved Vegetable Technologies to Overcome Malnutrition and Poverty in Mali (Module 1)	United States Agency for International Development	2014-2017	4,300,000
Deploying Improved Vegetable Technologies to Overcome Malnutrition and Poverty in Mali (Module 2)	United States Agency for International Development	2015-2017	2,250,000
Nutrition Sensitive Vegetable Technologies	United States Agency for International Development	2014-2018	838,934
Deploying vegetable seed kits to tackle malnutrition in Cambodia, Kenya, Liberia, Tanzania and Uganda	United States Agency for International Development	2014-2018	6,000,421
Research on the WAKATI storage chamber for storage of vegetable crops in Arusha, Tanzania	Wakati B.V.B.A.	2016-2017	28,888
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

THANK YOU

The World Vegetable Center's generous donors and partners—including governments, foundations, organizations, and corporations—share our mission to improve the nutrition and livelihoods of small-scale vegetable producers and their families worldwide. Together we are committed to research that supports healthy horticultural food systems to nourish people and strengthen their communities.

We recognize those that have provided US$ 100,000 or more to further the Center's work during 2016.

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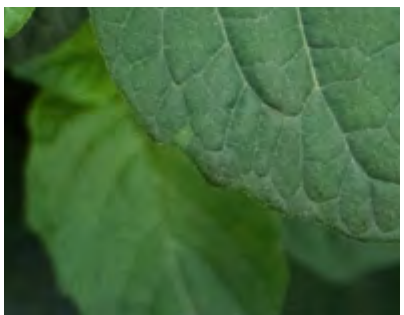


WORTH THEIR SALT

Worldwide, about 20% of irrigated agricultural land is affected by salts. **Soil salinity** decreases plant water uptake and leads to osmotic stress. In addition, salt accumulation in plant tissues has toxic effects for plants. Salt susceptibility of vegetable crops varies strongly from species to species. While tomato is moderately salt tolerant, legume crops such as mungbean are much more susceptible to soil salinity, probably due to suppression of the nitrogen fixing ability of bacterial symbionts.

Organisms endemic to salt-affected areas, over time, have evolved tolerance to salt stress. For example, wild relatives of tomato such as *Solanum pimpinellifolium*, *S. peruvianum* and *S. cheesmaniae* contain genotypes with strongly elevated salt tolerance compared to cultivated tomato. Genes contributing to salt tolerance in *S. pimpinellifolium* such as *DRE1AB* recently have been identified and were tagged with markers for breeding. Grafting tomato on salt-tolerant rootstocks is an alternative technology that can improve the stress tolerance of cultivated tomato.

Mungbean varieties also vary in salt tolerance, and salt-tolerant wild relatives such as *Vigna marina* are available, but their use in breeding has not yet been shown. A collaboration project between the World Vegetable Center and institutions in Germany, Pakistan and Uzbekistan, funded by the Federal Ministry for Economic Cooperation and Development, Germany, is currently selecting salt tolerant mungbean lines.

In parallel, the University of Agriculture in Faisalabad, Pakistan, is developing a special consortium of nitrogen-fixing rhizobia with growth-promoting rhizobacteria. These mixtures significantly enhance nodulation of mungbean under saline conditions (*see photo above*). Until now, significant yield increases under salt stress were obtained only for a specific combination between a mungbean genotype and the bacterial consortium. More trials are planned in 2017 to find mungbean genotypes that respond well to bacterial inoculation under salt stress.

To produce salt-tolerant vegetables and legumes, look to crop wild relatives

GERMPLASM

- The World Vegetable Center Genebank holds in trust a total of **61,952 vegetable germplasm accessions**, and 27,614 accessions are safety duplicated at the National Plant Genetic Resources Center in Taichung, Taiwan.
- 6,727 genebank **accessions and breeding lines** were distributed worldwide to 40 countries (including Taiwan) to public and private institutions for research, education and commercialization purposes.
- WorldVeg Eastern and Southern Africa has produced 219.5 kg **seed** of 12 vegetable accessions from 10 species and has distributed the seed to 8 universities, 8 research institutes, and 3 private companies in Burundi, Ethiopia, Kenya, The Netherlands, Tanzania, Zimbabwe and Zambia.
- **New sources for virus resistance:** a resistance source for *Turnip mosaic virus* was identified among leafy *Brassica* species; a PepMoV (strain APB6) resistant pepper accession was isolated; and five *Cucurbita moschata* accessions moderately resistant to *Squash leaf curl Philippines virus* were found.
- **New sources for resistance to bacterial and fungal diseases:** 13 *Vigna unguiculata* accessions resistant to *Fusarium oxysporium* f.sp. *tracheiphilum* and three bacterial wilt (*Ralstonia solanacearum*) resistant eggplant accessions were identified.
- **New sources for pest resistance:** High resistance against thrips, red spider mite and the South American tomato leaf miner (*Tuta absoluta*) was identified in two accessions of the tomato wild relative *S. galapagense*. Five amaranth accessions highly resistant to *Spoladea recurvalis* were found.
- The World Vegetable Center **mungbean mini-core collection** consisting of 300 genotypes has been submitted for seed increase and first evaluations in Bangladesh, India, Myanmar and Australia. Accessions expressing resistance against *Mungbean yellow mosaic virus* and dry rot were detected.
- The mungbean mini-core collection has been densely **genotyped** and more than 10,000 molecular markers became available for genome-wide association genetics analyses.
- A rapid **salt tolerance screening protocol** in a hydroponic system was developed for *Solanaceae* germplasm. 160 eggplant accessions from the World Vegetable Center Genebank were submitted for salt tolerance screening, and five accessions with high salt tolerance and compatibility to tomato scions were identified.

- A protocol to test the compatibility of **scion/rootstock combinations** for tomato was established using a greenhouse fertigation system.
- **Late blight resistance** of wild tomato *Solanum habrochaites* accession LA1755 was mapped to two locations on chromosomes 4 and 8, and two additional resistance loci were mapped in *S. pimpinellifolium* accession VI030462 on chromosomes 7 and 11.
- Genome editing by **CRISPR/Cas9** was successfully established and mutations in three tested tomato genes were obtained.

PUMPKINS FOR HEALTH AND PROSPERITY

Pumpkin is nutritionally and economically the most important cucurbitaceous vegetable in the world. Multiple viruses such as *Cucumber mosaic virus* (CMV), *Papaya ringspot virus* (PRSV), *Zucchini yellow mosaic virus* (ZYMV) and *Squash leaf curl virus* (SLCV) constrain pumpkin production in the tropics. These viruses are endemic in the pumpkin fields at the World Vegetable Center Research and Training Station in Kamphaeng Saen, Thailand.

'Nigerian Local', a wild pumpkin, is the only available source of resistance to CMV, PRSV, and ZYMV. While Nigerian Local is a valuable source of virus resistance, it also brings along many undesirable horticultural traits that must be eliminated during the process of breeding an acceptable pumpkin variety.

The WorldVeg cucurbit team joined with scientists from the National Institute of Horticultural and Herbal Sciences (NIHHS) in Rural Administration Agency (RDA) of Korea and virologists from Kasetsart University - Kamphaeng Saen, Thailand to develop multi-virus resistant breeding lines of pumpkin with good fruit quality and other horticultural traits.

The program began six years ago by accessing pumpkin accessions originating from many parts of the world available in the WorldVeg Genebank. These accessions were tested for resistance to a broad spectrum of viruses present in Kamphaeng Saen campus fields. Resistant plants were discovered in some accessions and seed from these plants was harvested and tested again for resistance. Multiple cycles of inbreeding and field selection led to the development of five pumpkin lines (THMC 114-2-2-2, THMC 119-2-3-4-10, THMC 120-1-3-2, THMC 122-1-6-8-7, and AVPU1504) resistant to local unidentified mixtures of potyviruses and geminiviruses.

Artificial screening of these resistant lines against local virulent strains of CMV, PRSV, ZYMV and SLCV, maintained by Kasetsart University, was completed in 2016. The local virulent strain of SLCV has 98% genomic similarity with *Squash leaf curl China virus* (SLCCV). Artificial inoculation followed by enzyme linked immunosorbent assay (ELISA) test and field screen tests were used in combination to evaluate the virus resistance of these pumpkin lines.

All five lines were resistant to CMV, and most were also resistant to SLCCV and PRSV. Because these viruses are common in many countries, these resistant lines could benefit farmers in other parts of Asia and Africa.

"We plan to conduct multi-location field tests of these pumpkin lines at virus hot spots in other Asian countries and in Africa," said Narinder Dhillon, WorldVeg Cucurbit Breeder. "It was interesting to see the multiple virus resistance potential of WorldVeg pumpkin breeding lines in Kamphaeng Saen fields."

Vigorous, virus-resistant lines are ready for field testing in Asia and Africa

"We are eager to test these lines at different virus hot spots in India," said Vimal Chawda, Managing Director of VNR Seeds, India. VNR Seeds is a research partner in the WorldVeg Global Cucurbit Breeding Program.

BREEDING

- Four **fresh market tomato** lines resistant to late blight (caused by *Phytophthora infestans*), tomato yellow leaf curl disease, bacterial wilt (caused by *Ralstonia solanacearum*) were developed, evaluated, and seed multiplied for international distribution. Two related journal articles were published.
- **Dual purpose tomato** lines CLN3900A, CLN3900B, and CLN3900C with resistance to tomato yellow leaf curl diseases, bacterial wilt, and root-knot nematode that produced relatively high yields and developed excellent internal fruit color were identified in the 2016 Spring Preliminary Yield Trial and seed multiplication for international distribution is ongoing.
- Four tomato lines CHT2109, CHT2110, CHT2124, and CHT2126 resistant to tomato yellow leaf curl disease, high yielding with good other horticultural traits, targeted for the **Taiwan market**, were selected and seed multiplied.
- Multiple disease resistant (*Tobamovirus* and *Phytophthora* blight) **sweet pepper hybrid** 'Hsing AVRDC no.5' was released and the Taiwan Council of Agriculture awarded Suntech Seed the right to commercialize it in Taiwan.
- Ten promising mungbean yellow mosaic disease resistant and high yielding lines of **mungbean** were developed and seed multiplied for distribution.
- Two high yielding **Japanese type cucumber** lines 13TWFC15 (43 t/ha) and 13TWFC13 (40.5 t/ha) were selected and seed multiplied for distribution.
- Inheritance of resistance to cucurbit powdery mildew (*Podosphaera xanthii*) in **bitter gourd** was studied and found to be controlled by recessive polygenes.
- Using locally adapted lines of **onion** in Mali, populations for recurrent selection were developed for further selection in subsequent seasons
- Improved lines of **amaranth** (UG-AM-27, RW-AM-22-ES-13-2, DB 2003889-ES13-1, UG-AM-27-ES13-4), **African nightshade** (RC10-ES13-3, SV-ES13-2, RC09-ES13-2), and **spider plant** (ST69-ES13-1, ST93-ES13-3, ST93-ES13-2) were identified on the basis of multilocation trials in Tanzania.
- On the basis of **multilocation trials** in Central Asia and the Caucasus, 'Ashgabad,' a new variety of cucumber, was released in Turkmenistan; eggplant 'Tukhva' and marrow 'Gayrat' were released in Uzbekistan.

- Two new **on-line seed catalogs** for amaranth (7 lines), Malabar spinach (4 lines) and cherry tomato (3 lines) were developed.
- **Seed** of amaranth (7 lines), Ethiopian mustard (7), African eggplant (7), African nightshade (6), spider plant (50), mungbean (22), urdbean (18), broccoli (3), Chinese cabbage (3), leafy brassicas (7), pumpkin (5), and bitter gourd (50) was distributed globally to stakeholders.
- Seed of 15 **Ty-gene combination** lines was produced by a seed company in India for distribution to a local collaborator in India.
- **Breeder seed** of WorldVeg elite lines of chili pepper (2 kg), amaranth (3 kg), African nightshade (2 kg), Ethiopian mustard (3 kg), tomato (1.5 kg), mungbean (5 kg), pumpkin (4 kg), and bitter gourd (5 kg) was produced for international distribution.
- 144 **commercial hybrids** marketed in India and Southeast Asia contained genetic material that originated from the World Vegetable Center and a related article was published.

A SAFER PATH TO MARKET

Alternatives to synthetic pesticides for sustainable vegetable production

Lack of knowledge about the risks and alternatives, combined with the perceived consumer preference for blemish-free vegetables, leads vegetable farmers to overuse or misuse pesticides, particularly in the more intensive production systems of South and Southeast Asia. A focus for the Center's Production team in 2016 was to continue to develop and test integrated pest and disease management (IPM) components to combine with improved cultivation methods for sustainable vegetable production that is less reliant on pesticide inputs.

In IPM trials in Cambodia, formulations of the biocontrol agents *Metarhizium anisopliae* and *Bacillus thuringiensis* controlled

diamondback moth (*Plutella xylostella*), common armyworm (*Spodoptera litura*) and flea beetles (*Phyllotreta* spp.) on leafy brassicas resulting in improved yields compared to untreated plots. The formulations also controlled pod borer (*Maruca vitrata*) on yard-long bean (but did not improve bean yields).

In Vietnam, *B. thuringiensis* was as effective as a synthetic pesticide against cabbage worm (*Pieris rapae*) on leafy brassicas. Although *M. anisopliae*, *Beauvaria bassiana*, and neem (a biopesticide) significantly reduced flea beetle damage on brassicas, they were not as effective as the synthetic pesticide. An IPM approach proved to be a cost-effective, environmentally friendly (low pesticide) alternative for managing *M. vitrata* on yard-long bean in peri-urban Hanoi, Vietnam.

In Karnataka, India, vegetable farmers were able to extend the crop cycle and harvest better quality produce more frequently while reducing the number of pesticide applications by combining improved cultivation practices (such as plastic mulching, drip irrigation/fertigation, and staking), with IPM components (including yellow sticky traps and water lures for monitoring and reducing insect pest populations).

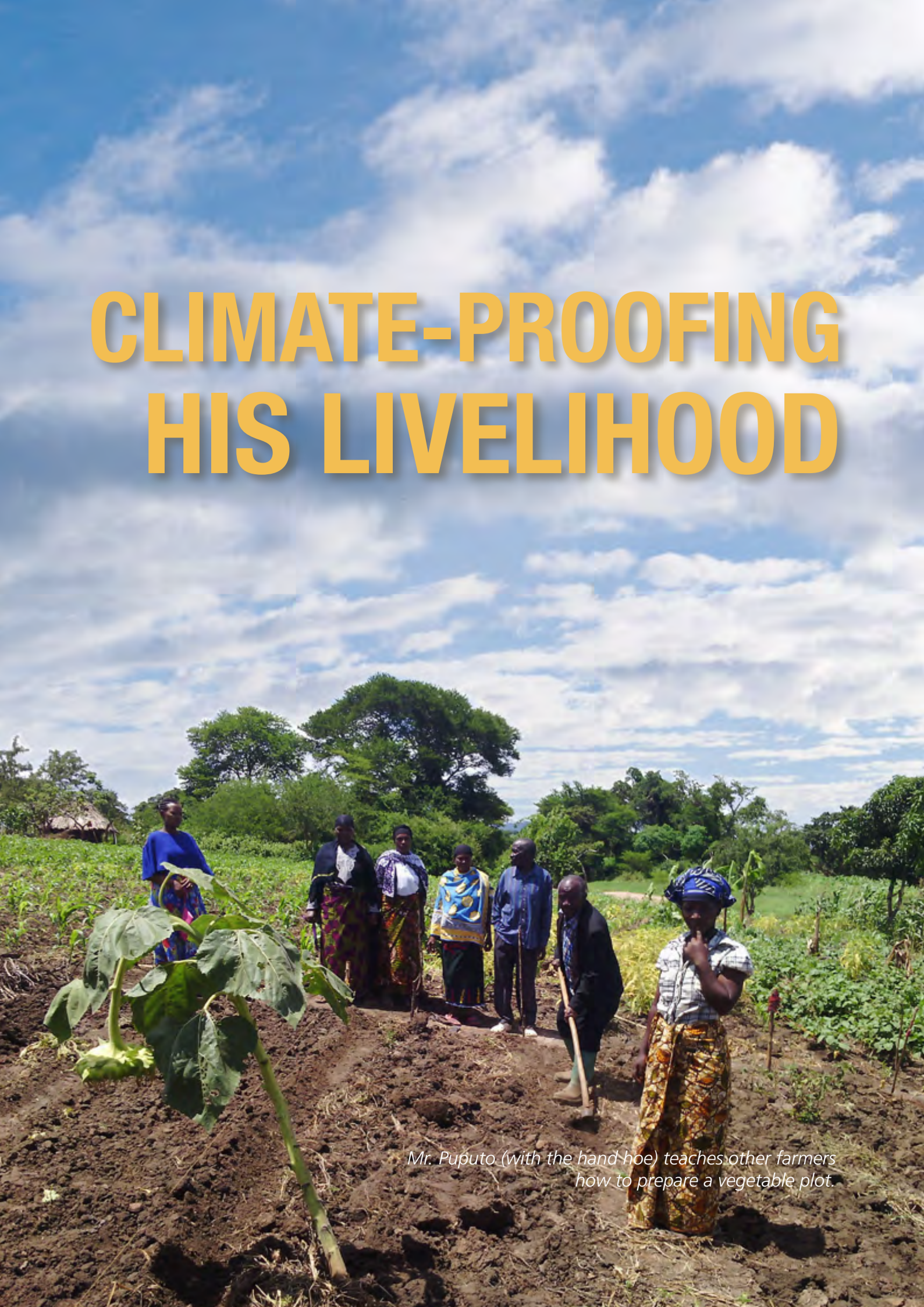
Other biocontrol agents and IPM technologies need to be developed and validated as packages with those already tested in more diverse production environments. The challenge will be to communicate the most useful vegetable IPM components to farmers for wide-scale adoption.

PRODUCTION

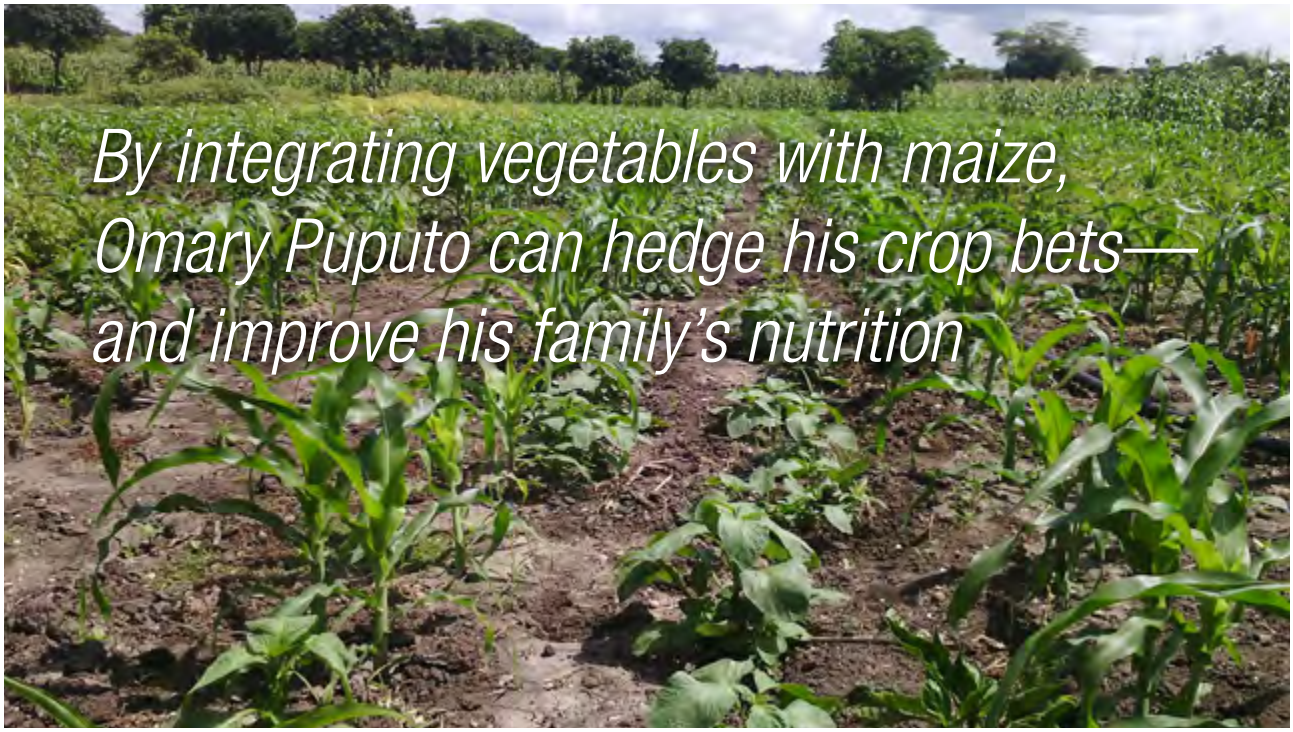
- *Pteromalus puparum* (Chalcidoidea, Pteromalidae) was identified as a potentially useful **parasitoid** species from the pupae of imported cabbageworm (*P. rapae*) in Taiwan, Cambodia, Lao PDR and Vietnam.
- In Taiwan, *Apanteles opacus* (Hymenoptera: Braconidae) was confirmed to be a specific parasitoid of the amaranth leaf-webber (*Spoladea recurvalis*), and has potential as a **biocontrol agent**.
- Mungbean yellow mosaic disease-resistant **mungbean** 'NM94,' grown as a pre-*kharif* crop in the rice fallow in India, can provide additional income to the farmers while also increasing the yield of the following rice crop by improving soil texture, structure and fertility.
- **Vegetable cowpea** (60-65 days to maturity) as an intercrop in sugarcane and coconut gardens in India can provide additional income to farmers while increasing soil fertility.
- Many **leafy brassica** seed lots from Cambodia, Lao PDR and Vietnam were found to be contaminated with *Alternaria* spp., whereas the crucifer black rot bacterium (*Xanthomonas campestris* pv. *campestris (Xcc))*, was detected in some seed lots from Lao PDR. Hot water treatment (50° C) was effective at decontaminating both pathogens from seed, but treatment with 1% sodium hypochlorite (NaClO [bleach]) only was effective against Xcc.
- Whitefly-transmitted **begomoviruses** remain the most prevalent viruses of tomato, pepper and cucurbit crops in most WorldVeg areas. In legume crops, begomoviruses also were predominant in India. *Bean common mosaic virus* was the most prevalent virus in Cambodia and Lao PDR, and *Cucumber mosaic virus* was the most prevalent in Vietnam.
- In southern Taiwan, although the incidence of *Tomato chlorosis virus* (ToCV) is increasing, **leaf curl** begomoviruses remain the main viral constraint to tomato production.
- *Bitter gourd yellow vein virus* and a begomovirus species with the highest genome sequence identity to *Tobacco curly shoot virus* were associated with disease of **bitter gourd** in Bangladesh. Similarly, a begomovirus with greatest sequence identity to *Tomato leaf curl Uganda virus* was associated with a disease of **amaranth** in Tanzania.

- A WorldVeg study showed that vegetable farmers in Cambodia, Lao PDR and Vietnam who seek pesticide advice from friends and neighbors use **less pesticide** than those who take advice from pesticide dealers. Having a greater awareness of pesticide-related health risks is associated with fewer observed poisoning symptoms.
- Bitter gourd and eggplant farmers in Bangladesh given increased knowledge about **pest management options** and who adopt IPM methods following training spend less on pesticides, but the effect on net household income was significant only for eggplant production.

CLIMATE-PROOFING HIS LIVELIHOOD



Mr. Puputo (with the hand hoe) teaches other farmers how to prepare a vegetable plot.



By integrating vegetables with maize, Omary Puputo can hedge his crop bets—and improve his family's nutrition

WorldVeg amaranth 'Madiira I,' African nightshade 'Nduruma' and jute mallow 'SUD 2' are encouraging farmers in Tanzania to mix it up in the field.

"When the WorldVeg/HORTI Tengeru team delivered training in our village last year, I thought of adopting the practices taught and the varieties given by the project," said **Mr. Omary Puputo**, a 69-year-old man in Sunya village, Tanzania with the energy and drive of someone much younger. "No farmer in our village had ever tried integrating maize with vegetables. But I did—and it turned out to be very successful. I could contribute more vegetables to feed my family, and I sold a lot, too."

Mr. Puputo is the chairman of the Sunya farmers' group trained under the USAID-funded Africa RISING-NAFAKA partnership project for fast-tracking delivery and scaling of agricultural technologies in Tanzania.

Mr. Puputo integrated the WorldVeg varieties in his production schedule for his one-acre maize field. In the first season, he harvested 1600 bundles of African nightshade, of which 300 bundles were consumed by his household and neighbors and 1300 bundles were sold for TZS 200-300 per bundle. This brought him an additional profit of TZS 330,000 (US$ 157) after harvesting maize, when the land usually is left to fallow.

"Last year (2015) was a bad year with very low maize yields due to a severe drought," he said. "But the vegetables contributed a lot to our household income and consumption. And this actually brought my attention to the fact that vegetables can do what cereal crops might not—namely, to gain yields in times of climate variability."

Encouraged by the results, in 2016 Mr. Puputo planted three leafy vegetables. On another one-acre plot he planted amaranth, African nightshade and jute mallow together with maize. Leaving one meter of space between the maize rows, Mr. Puputo sowed two rows of one of the leafy vegetables.

Mr. Puputo and other farmers from Sunya who participated in the WorldVeg/HORTI-Tengeru training also started to reproduce the varieties handed out to them by the project team. He and other members of the training group shared some of their seed with others and also taught them how to grow and reproduce the seeds for their own production.

CONSUMPTION

- The Center's **strategy on home gardens** was published as a booklet, entitled *The World Vegetable Center's Approach to Household Gardening for Nutrition* and presented at various conferences and scholarly society meetings in the course of the year.
- As part of **home garden intervention scaling** efforts for enhanced household nutrition and diversified incomes, more than 35 functional and equipped Best Practice Hubs and Vegetable Technology Immersion Clusters were set up in Mali, Liberia, Kenya, Uganda and Tanzania. Establishment involved use of locally available materials and communal labour to the extent possible to inculcate a sense of ownership as well as a sustainable exit strategy.
- **Impact evaluation studies** conducted for school gardens showed significant improvements for children's awareness, knowledge and perceptions in Bhutan and Nepal. For Bhutan, the study also found a significant increase in the percentage of children consuming vegetables. For Burkina Faso, there was no significant improvement in any target outcome indicator.
- More than **6,500 nutritional vegetable seed kits** were distributed to trainers and their trainees for home gardens in Sikasso and Mopti regions of Mali. Seed kits contained okra, tomato, African eggplant, pepper, and amaranth seed and sweet potato cuttings, and were packed and distributed to beneficiaries of the Mali Horticulture Scaling project.
- More than **30,000 nutritional seed kits** containing six different vegetable crops were assembled and distributed to home gardeners and smallholder farmers in Cameroon, Liberia, Kenya, Mali, Tanzania, Uganda and Uzbekistan. In some countries, sweet potato cuttings (leaves eaten as vegetables) were included in the seed kits. About 18,000 of the seed kits distributed in East Africa involved direct public-private partnership collaboration with private seed companies as part of project intervention sustainability and exit strategies.
- **Postharvest progress:** In Bangladesh, new WorldVeg tomato lines have been identified with a shelf life of 18 days compared to 10 days for the local check. A range of improvements to the eggplant/brinjal value chain in Bangladesh have shown that losses can be profitably reduced from 49% to between 6-16%. In Cambodia, improvements to the tomato value chain reduced overall losses from 25% to 14% and for leaf mustard from 31% to 17%. In Tanzania, economic analyses showed that traders and producers could improve their returns by 17-22% by using

plastic crates for tomato transport. Using the right combination of onion variety and storage methods resulted in a ten-fold improvement in keeping quality.

- Nineteen **videos** and 2 production guides were added to the Center's *Household Garden Capacity Development Manual* compilation. The outline of compiled materials and filename guide were updated. Five videos on low cost cooling, construction of zero-energy cooling chambers, improved packaging, solar dehydration of vegetables, and production of pickles were produced and promoted through the internet.
- The VINESA project's *7 Step Guide to Connecting Farmers to New Vegetable Markets* is being used in Malawi, Mozambique and Tanzania to identify specific **market opportunities** and to link farmers to markets.
- **Training:** More than 1,000 trainers and 30,000 farmers were trained on various vegetable value chain topics (i.e., postharvest management, farm business skills, nutrition, and food utilization) in Cambodia, Cameroon, India, Pakistan, Liberia, Kenya, Mali, Nepal, Malawi, Mozambique, Tanzania, Uganda, and Uzbekistan. 30 community workers and 370 adults (357 women, 13 men) plus 246 young people were trained in food preparation; 10,257 direct beneficiaries were trained in vegetable production and postharvest management. In Bangladesh, Cameroon, Mali, Uganda, Tanzania and Central Asia and the Caucasus, several field days and cooking demonstrations were held to promote vegetable consumption.
- Nutritional and functional properties of selected **indigenous vegetables** in Taiwan were evaluated. This involved 55 Taiwan Ami traditional vegetables collected from markets and farmer's fields in Hualien in collaboration with the Hualien District Agricultural Research and Extension Station. Nutrient content was measured and nutrient data included in the WorldVeg nutrient database.
- Comparative assessment of the **nutritional content** of sun- and solar-dried vegetables with fresh untransformed produce—especially for dry regions where year-round availability of fresh vegetables is a major challenge—was undertaken. Studies on the effects of four drying methods (freeze-, oven-, solar- and direct sun-drying) on nutrient retention in 10 traditional African vegetables (6 species) were conducted; nutrient analyses for solar- and direct sun-dried samples are in progress.

TOGETHER

Meet the WorldVeg team!

Every day our global community of **394 dedicated, talented staff members** (44% women) **from 36 countries** use their knowledge and expertise for the benefit of vegetable farmers and their communities.

We're glad to be part of the effort to nourish the world!

Careers leap ahead at WorldVeg

PhD students can expand their scientific knowledge and practical skills by participating in the Center's ongoing research programs. Meet a few of the students that furthered WorldVeg research—and their careers—in 2016.

Derek W. Barchenger, a U.S. Borlaug Fellow in Global Food Security and PhD candidate in Plant and Environmental Sciences at New Mexico State University (NMSU) USA, worked with the WorldVeg global pepper team for six months in 2016 on race characterization of *Phytophthora capsici* as a basis for a global anticipatory resistance breeding program in *Capsicum*. This complex pathogen has two mating types and numerous races in different locations worldwide. With a standardized global protocol for the concentration, naming, and scoring of *P. capsici* races, breeders can address virulent pathogen races before they become prevalent and cause significant losses. Derek's study of host differentials and recombinant inbred lines for race characterization is an important step toward this goal.

For her PhD, **Rawdzah Mata Ali**, University Kebangsaan, Malaysia, is investigating low-cost, environmentally safe and sustainable pest management strategies for improving leafy brassica production. Farmers frequently misuse pesticides in an effort to protect these commercially important crops from damage; Rawdzah's research at WorldVeg will contribute to safer pest control methods. In addition to her field and lab experiences, Rawdzah also participated in the 20th Seed and Seedling Festival in Xinhua, Taiwan in November 2016, where she promoted the Center's many research and development activities to interested visitors that stopped by the WorldVeg booth.

Oshingi Shilla, PhD candidate in horticulture at Jomo Kenyatta University of Agriculture and Technology in Kenya, is working on the characterization of spider plant lines for morphological and phytochemical diversity and performance under different moisture regimes with WorldVeg Vegetable Breeder Fekadu Dinssa. Spider plant (*Cleome gynandra*) leaves and shoots are eaten boiled or in stews and soups. High in beta-carotene, folic acid, ascorbic acid and calcium, spider plant is of particular interest for its drought tolerance. Oshingi is exploring spider plant diversity as part of the Horticultural Innovation and Learning for Improved Nutrition and Livelihoods in East Africa (HORTINLEA) project, a partnership between 19 East African and German research institutions and universities.

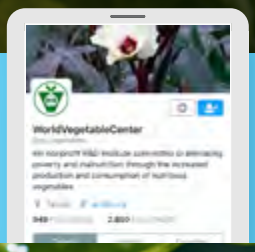
Whitefly (*Bemisia tabaci*) spreads begomoviruses, which cause yellow leaf curl disease in tomato and pepper. **Sopana Yule**, studying for her PhD in entomology at Kasetsart University's Kamphaeng Saen campus, Thailand, is developing technical practices to help farmers control this tiny but troublesome pest under the guidance of WorldVeg Entomologist Srinivasan Ramasamy. Sopana's work received recognition when she was awarded Best Oral Presentation at the Southeast Asia Vegetable Symposium (SEAVEG 2016) for her talk on "The integrated pest management (IPM) strategy against Bemisia tabaci to control disease caused by tomato yellow leaf curl on tomato in Thailand and Vietnam."

WorldVeg in the news

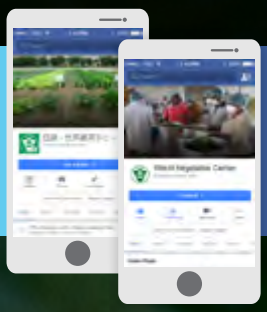
Want to know more about the World Vegetable Center? We reach out through various media to engage and inform the public:

Monthly unique visitors to avrdc.org: **19,000+**

Subscribers to *Fresh*, the WorldVeg newsletter: **4,500**



Twitter followers: **2,850**



Facebook followers (English + Chinese pages): **5,000 + 3,100 = 8,100**

Media mentions in 2016: **140**, including articles in the *New York Times, Huffington Post, Common Health Magazine* (Chinese), *Pakistan Morning Post*

Videos: **56** produced to promote project activities and demonstrate best practices

Presentations: **36** given by researchers at important global conferences

VISITORS

Thousands of **visitors** (more than 3667 in 2016) tour WorldVeg headquarters and regional offices to learn about the Center's research, get updates on project progress, and see WorldVeg improved varieties, traditional vegetables, and new technologies in our Demonstration Gardens.

VIDEO: *Seed Kits for the Baraa Primary School Garden*

Get kids in front of the camera and anything can happen! At the **Baraa Primary School** in Arusha, Tanzania, volunteer videographer **Rhiannon O'Sullivan** recorded school gardening activities that began with the distribution of WorldVeg seed kits. Vegetables from the garden now are served for healthy school lunches, and the young gardeners encourage their parents to set up home gardens so the whole family can enjoy the nutritional benefits vegetables contribute to the diet.

Rhiannon joined WorldVeg Eastern and Southern Africa through Australian Volunteers International in 2016. During her year with WorldVeg, she produced 21 short videos to promote WorldVeg projects and demonstrate how to build zero energy cooling chambers, make compost, produce seedlings, and much more.

View Rhiannon's videos and others on the WorldVeg You Tube channel: https://www.youtube.com/user/WorldVegetableCenter

When the World Vegetable Center's Monitoring & Evaluation group asks the questions, fellow researchers, donors, and clients want to know the answers: Did an intervention work, and why or why not? What can we learn? How can we change? M&E asked several big questions in 2016 and as the data is analyzed, the answers are becoming clear.

MONITORING, EVALUATION AND IMPACT

Public vs. private R&D?

Crop breeding research by international agricultural research centers usually serves public sector crop breeding, but does it still have a role when research and development have shifted to the private sector?

The research team set out to answer this question by examining the contribution of international vegetable breeding to private seed companies in India with data from 27 private companies and 9 public organizations. The focus was on tomato (*Solanum lycopersicum* L.) and chili pepper (*Capsicum annuum* L.)—two of India's most important vegetables, and the role of international germplasm received from the World Vegetable Center.

As the role of the private sector in vegetable breeding increased, and with it the share of hybrids in the market, the role of international agricultural research shifted from the provision of ready-made varieties to the provision of specific resistance traits. Still, international germplasm continued to be used in varietal development with 11.6 t (14% of the total market) of hybrid tomato seed and 15.0 t (13%) of hybrid chili pepper seed sold in 2014 containing international germplasm in its pedigree. The research team estimated that more than half a million farmers use such seed.

The conclusion? For tomato and chili pepper, international breeding needs to focus on pre-breeding research, capacity strengthening of smaller seed companies, and the delivery of open-pollinated varieties for marginal environments.

Schreinemachers P, Rao KPC, Easdown W, Hanson P, Kumar S. 2016. The contribution of international vegetable breeding to private seed companies in India. GENETIC RESOURCES AND CROP EVOLUTION, DOI 10.1007/s10722-016-0423-y

Can home gardens deliver on their nutritional promise?

Household-based production of fruit and vegetables has the potential to abate micronutrient undernutrition in low income countries. However, there is a lack of robust evidence for nutritional outcomes and a lack of understanding of the mechanisms by which such interventions improve nutrition. M&E is putting the World Vegetable Center's household gardening model, which builds on more than 30 years of experience in this area, to the test across Asia and Africa.

The Center's model has three components: Year-round production of nutrient-dense fruit and vegetables, awareness raising about nutrition and health, and strengthening of key support systems, including women's groups and seed systems. Garden interventions target rural women in households vulnerable to the effects of micronutrient malnutrition.

Robust evidence for the impact of household gardens is being gathered through the use of randomized controlled trials, which requires the random allocation of villages to intervention groups and a control group; such trials are ongoing in Cambodia, Kenya, Tanzania and Uganda. A non-experimental design is being used in Bangladesh and Mali.

For Bangladesh, the annualized cost per household for a home garden intervention was calculated to be US$ 23.2 (including women's time spent). Comparing this to the benefits in terms of healthy life years saved (DALYs) from micronutrient undernutrition, the intervention was cost-effective according to World Health Organization standards. While biofortification of staple crops, micronutrient supplementation, and food fortification might be more cost-effective to address micronutrient deficiencies as these are less costly to scale, they do not provide the same wide range of nutritional, social and economic benefits as household garden interventions.

Schreinemachers P, Patalagsa MA, Uddin Md N. 2016. Impact and cost-effectiveness of women's training in home gardening and nutrition in Bangladesh. JOURNAL OF DEVELOPMENT EFFECTIVENESS, 8(4):473-488

2016
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* term ended in 2016
** term began in 2016

FINANCE

	WorldVeg	CGIAR** recommended range
Cash management on restricted operations*	0.66	less than 1
Adequacy of reserves	99 days	75-90 days
Short-term solvency	122 days	90-120 days

2016 Revenues (in '000 USD)		
Unrestricted grants	7,372	35%
Restricted grants	13,483	64%
Other revenues	236	1%
Total	21,091	100%

Unrestricted Grants	
Republic of China (ROC)	4,407
UK Department for International Development (UK/DFID)	1,026
United States Agency for International Development (USAID)	1,104
Australian Centre for International Agricultural Research (ACIAR)	323
Germany	277
Thailand	127
The Philippines	50
Korea	50
Japan	9
Sub-total	***7,372***
Other revenues	236
Total	**7,608**
Restricted Grants	
United States Agency for International Development (USAID)	7,723
Swiss Development Cooperation (SDC)	1,409
Republic of Germany / BMZ / GIZ	1,074
Australia / Australian Centre for International Agricultural Research (ACIAR)	965
Republic of China / Ministry of Foreign Affairs	799
Republic of China / Council of Agriculture	446
Consultative Group on International Agricultural Research (CGIAR)	273
West and Central African Council for Agricultural Research and Development (CORAF/WECARD)	132
Japan - Ministry of Agriculture, Forestry and Fisheries	129
Korea/Rural Development Administration (RDA)	92
Government of Karnataka	78
Others (projects with expenses less than 100K USD)	364
Sub-total	***13,483***
Total Revenues	**21,091**

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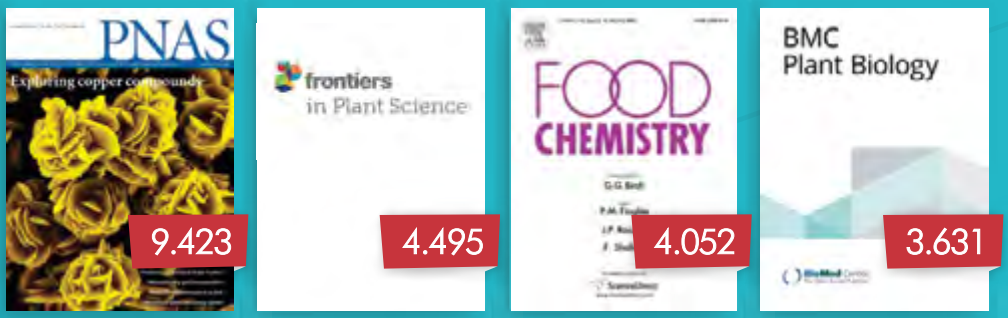
RESEARCH FOR DEVELOPMENT

In 2016, WorldVeg researchers shared their knowledge and results in international peer-reviewed journals, at conferences, and in partnership with scientists from developing countries.

TOP 10 journals according to impact factor



2016 Publications

Thomson impact factors (48)

1. Abang AF, Srinivasan R, Kekeunou S, Yeboah M, Hanna R, Lin MY, Tenkouano A, Bilong Bilong CF. 2016. Relationship of phenotypic structures and allelochemical compounds of okra (*Abelmoschus* spp.) to resistance against *Aphis gossypii* Glover. INTERNATIONAL JOURNAL OF PEST MANAGEMENT 62(1): 55-63.
2. Afari-Sefa V, Rajendran S, Kessy RF, Karanja KD, Musebe R, Samali S, Makaranga MA. 2016. Impact of Nutritional Awareness of Traditional African Vegetables on Farm Household Production Decisions: A Case Study of Smallholders in Tanzania. EXPERIMENTAL AGRICULTURE 52(2):200-313. DOI: 10.1017/S0014479715000101.
3. Ahmed S, Zaman S, Ahmed R, Uddin MN, Acedo A Jr, Bari ML. 2016. Effectiveness of non-chlorine sanitizers in improving the safety and quality of fresh betel leaf. LWT - FOOD SCIENCE AND TECHNOLOGY. DOI: 10.1016/j.lwt.2016.12.025.
4. Asare R, Afari-Sefa V, Muilerman S. 2016. Access to improved hybrid seeds in Ghana: Implications for establishment and rehabilitation of cocoa farms. EXPERIMENTAL AGRICULTURE 1:1-13. http://journals.cambridge.org/repo_A10r8aIMIFkcSk.
5. Aulakh PS, Dhaliwal MS, Jindal SK, Schafleitner R, Singh K. 2016. Mapping of male sterility gene ms10 in chili pepper (*Capsicum annuum* L.). PLANT BREEDING 135(4): 531-535.
6. Bannwarth M, Grovermann C, Schreinemachers P, Ingwersen J, Lamers M, Berger T, Streck T. 2016. Non-hazardous pesticide concentrations in surface waters: Simulating application thresholds and resulting farm income effects. JOURNAL OF ENVIRONMENTAL MANAGEMENT 165: 298-312.
7. Beran F, Jiménez-Alemán GH, Lin M-Y, Hsu Y-C, Mewis I, Srinivasan R, Ulrichs C, Boland W, Hansson BS, Reinecke A. 2016. The aggregation pheromone of *Phyllotreta striolata* (Coleoptera: Chrysomelidae) revisited. JOURNAL OF CHEMICAL ECOLOGY 42(8): 748-755.
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9. Bihon W, Cloete M, Gerrano AS, Oelofse D, Adebola P. 2016. Draft genome sequence of *Alternaria alternata* isolated from onion leaves in South Africa. GENOME ANNOUNCEMENTS 4(5): e01022-16.
10. Chagomoka T, Drescher A, Glaser R, Marschner B, Schlesinger J, Nyandoro G. 2016. Women`s dietary diversity scores and childhood anthropometric measurements as indices of nutrition insecurity along the urban-rural continuum in Ouagadougou, Burkina Faso. FOOD & NUTRITION RESEARCH 60: 29425. DOI: 10.3402/fnr.v60.29425.
11. Chang JC, Srinivasan R. 2016. Transcriptome analysis in the beet webworm, *Spoladea recurvalis* Fabricius (Lepidoptera: Crambidae). INSECT SCIENCE. DOI: 10.1111/1744-7917.12375.
12. Chen H-m, Lin C-y, Tsai W-s, Kenyon L, Chan M-t, Yen J-y, Chang S-y, de la Peña R, Schafleitner R. 2016. Resistance to Tomato yellow leaf curl viruses through RNAi targeting of two begomovirus species. JOURNAL OF PLANT BIOCHEMISTRY AND BIOTECHNOLOGY 25: 199-207. DOI: 10.1007/s13562-015-0325-7.
13. Dhillon NPS, Lin CC, Sun Z, Hanson PM, Ledesma DR, Habicht SD, Yang RY. 2016. Varietal and harvesting stage variation in the content of carotenoids, ascorbic acid and tocopherols in the fruit of bitter gourd (*Momordica charantia* L.). PLANT GENETIC RESOURCES: CHARACTERIZATION AND UTILIZATION. DOI: 10.1017/S147926211500057X.
14. Dhillon NPS, Sanguansil S, Schafleitner, Wang YW, McCreight JD. 2016. Diversity among a wide Asian collection of bitter gourd landraces and their genetic relationships with commercial hybrid cultivars. JOURNAL OF THE AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE 141: 475-484.

15. Dinssa FF, Hanson P, Dubois T, Tenkouano A, Stoilova T, Hughes J. d'A, Keatinge JDH. 2016. AVRDC - The World Vegetable Center's women-oriented improvement and development strategy for traditional African vegetables in sub-Saharan Africa. EUROPEAN JOURNAL OF HORTICULTURAL SCIENCE 81(2): 91-105. DOI: 10.17660/eJHS.2016/81.2.3

16. Elbaz M, Hanson P, Fgaier S, Laarif A. 2016. Evaluation of tomato entries with different combinations of resistance genes to tomato yellow leaf curl disease in Tunisia. PLANT BREEDING 135(4): 525–530.

17. Erismann, S., Shrestha, A., Diagbouga, S., Knoblauch, A., Gerold, J., Herz, R., Sharma, S., Schindler, C., Odermatt, P., Drescher, A., Yang, R.Y., Utzinger, J., Cissé G. 2016. Complementary school garden, nutrition, water, sanitation and hygiene interventions to improve children's nutrition and health status in Burkina Faso and Nepal: a study protocol. BMC PUBLIC HEALTH 16:244. DOI: 10.1186/s12889-016-2910-7.

18. Gonzales LMR, Acedo AL Jr. 2016. Reducing losses of cabbage in traditional and modern chain in Cebu, Philippines. INTERNATIONAL JOURNAL OF FOOD ENGINEERING 2: 48-54. DOI: 10.18178/ijfe.2.1.48-54.

19. Hanson P, Lu SF, Wang JF, Chen W, Kenyon L, Tan CW, Tee KL, Wang YY, Hsua YC, Schafleitner R, Ledesma D, Yang RY. 2016. Conventional and molecular marker-assisted selection and pyramiding of genes for multiple disease resistance in tomato. SCIENTIA HORTICULTURAE 201: 346-354.

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21. Karangwa P, Blomme G, Beed F, Niyongere C. 2016. The distribution and incidence of banana Fusarium wilt in subsistence farming systems in east and central Africa. CROP PROTECTION 84: 132-140.

22. Keatinge JDH, Imbach P, Ledesma DR, Hughes Jd'A, Keatinge FJD, Nienhuis J, Hanson P, Ebert AW, Kumar S. 2016. Assessing air temperature trends in Mesoamerica and their implications for the future of horticulture. EUROPEAN JOURNAL OF HORTICULTURAL SCIENCE 81(2): 63-77.

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Acronyms

AARNET	ASEAN-AVRDC Regional Network for Vegetable Research and Development
ACIAR	Australian Centre for International Agricultural Research
AFACI	Asian Food and Agriculture Cooperation Initiative
APAARI	Asia-Pacific Association of Agricultural Research Institutions
APSA	Asia & Pacific Seed Association
BMGF	Bill & Melinda Gates Foundation
CABI	Centre for Agriculture and Biosciences International
CARI	Central Agricultural Research Institute
CIAT	International Center for Tropical Agriculture
CIRAD	French Agricultural Research Centre for International Development
CMV	Cucumber mosaic virus
CORAF/WECARD	Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles / West and Central African Council for Agricultural Research and Development
ELISA	enzyme linked immunosorbent assay
FAO	Food and Agriculture Organization of the United Nations
GAPAD	Global Action Plan for Agricultural Diversification
ICRAF	World Agroforestry Center
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IPM	integrated pest management
IRAD	Institute of Agricultural Research for Development
IWMI	International Water Management Institute
MARDI	Malaysian Agricultural Research and Development Institute
MYMD	Mungbean yellow mosaic disease
NARI	National Agriculture Research Institute
NIHHS-RDA	National Institute of Horticultural and Herbal Sciences - Rural Administration Agency
OECD	Organisation for Economic Co-operation and Development
PADFA	Commodity Value-Chain Development Support Project
PNG	Papua New Guinea
PRSV	Papaya ringspot virus
SDC	Swiss Agency for Development and Cooperation
SLCV	Squash leaf curl virus
SPC	Secretariat of the Pacific Community
t	tons
TAHA	Tanzania Horticultural Association
USAID	United States Agency for International Development
ZYMV	Zucchini yellow mosaic virus