Cover photo 
Small-scale farming families from Africa to Asia benefit from the World Vegetable Center’s improved vegetable varieties and production practices. Mrs. Priscilla Kwoyiri Awinibisa and her family learned how to cultivate pepper, tomatoes and onions through the USAID-sponsored Africa RISING Project in Bonia, Ghana.

This work is licensed under the Creative Commons Attribution-ShareAlike 3.0 Unported License. Please feel free to quote or reproduce materials from his report. The World Vegetable Center requests acknowledgement and a copy of the publication or website where the citation or material appears.

Suggested citation
This year’s report provides highlights of our work conducted in partnership across flagship programs and our five target regions in Asia and Africa. It is heartening to see the growing number of students welcomed at our research locations and I particularly recommend reading their stories in this report.

In March, WorldVeg officially opened its new building for West and Central Africa – Dry Regions in Bamako, Mali, generously provided for by the Government and People of Taiwan through the Ministry of Foreign Affairs. Mali’s Minister of Agriculture, Dr. Nango Dembele, was there to mark the event.

In April, WorldVeg was awarded US$1.7 million from the Taiwan Council of Agriculture to begin planning for the construction of a new laboratory building and renovation of WorldVeg headquarters campus infrastructure. In addition to the lab, other improvements will include a new seed treatment facility and capacity for controlled environment phenotyping. It is expected WorldVeg will ultimately receive a total of US$22 million to complete the Research Infrastructure Modernization (RIM) project by the end of 2021. Facilities to produce quality science will help WorldVeg attract top-notch researchers and remain a leading international agricultural research institute that can deliver on its mission. We aim to create a vibrant open science center for global and local researchers, students, and public and private sector partners, working from our headquarters in Taiwan and our five regional offices in Asia (India, Thailand) and Africa (Benin, Mali, Tanzania).

As advances in biotechnology and genomics accelerate the pace of vegetable cultivar development, seed companies of all sizes must have a robust understanding of the latest vegetable breeding research, the practical skills to apply new breeding methods, and access to a diverse collection of vegetable germplasm. The Africa Vegetable Breeding Consortium (AVBC), a new initiative launched in 2018 under the umbrella of the African Seed Trade Association, aims to invigorate the seed sector in Africa by linking seed companies with WorldVeg research teams and the WorldVeg Genebank. The AVBC is based on the successful APSA-WorldVeg Vegetable Breeding Consortium, a similar body established in 2016 for Asia. You will find more information on these consortia in this report.

During the 54th meeting of the World Vegetable Center Board of Directors, held 26-29 November 2018 at WorldVeg Eastern and Southern Africa in Arusha, Tanzania, board members saw research in action through demonstrations of solar dryers, below-ground grafting chambers, lab assays for insect pests, and amaranth variety selections. Members also interacted with farmers producing crops in low tunnels and participating in vegetable business hubs—groups linking young growers with profitable markets.

In 2018 we said farewell to board members Jen-Pin Chen and Hsueh-Shih Lin. Their insight and dedication served WorldVeg well. New board members from Africa—Lindiwe Sibanda and Ndidi Nwuneli—were approved for initial three-year terms, and two new country representatives for Taiwan, Chen Chi-chung and Dennis Wang Shyh-Shyan, were welcomed. The board also thanked Board Secretary Didit Ledesma for her capable service since 2009; she will retire in April 2019.

The astute, thoughtful, and dedicated individuals that together make up the WorldVeg Board, led by our Chair, Dr. Junne-Jih Chen are a significant resource for positive action. The Center was fortunate to draw upon their perspectives throughout the year, and I look forward to our continuing interaction in the years ahead.

A big thank you to our technical and financial partners who worked with us in 2018, helping us to realize the potential of vegetables for healthier lives and more resilient livelihoods across the world.

-- Marco Wopereis
WorldVeg palates sizzled during the 2018 Chili Challenge!

WorldVeg joined in the celebration of the 10th Anniversary of the Svalbard Seed Vault, sending more than 1000 accessions of 21 vegetable species for storage.

Workshops at WorldVeg South Asia to evaluate training needs for the seed industry attracted private sector partners from across the Indian subcontinent.

WorldVeg technologies captured attention of policymakers at the 6th Annual Week of Scientific Research and Innovation in Yaoundé, Cameroon.

WorldVeg introduced the idea of a new Africa Vegetable Breeding Consortium at the African Seed Trade Congress 2018 in Cairo, Egypt.

On 2 March 2018, WorldVeg officially opened its new building for West and Central Africa - Dry Regions in Bamako, Mali. Mali’s Minister of Agriculture, Dr. Nango Dembele, cut the ribbon.

Workshops at WorldVeg South Asia to evaluate training needs for the seed industry attracted private sector partners from across the Indian subcontinent.

WorldVeg technologies captured attention of policymakers at the 6th Annual Week of Scientific Research and Innovation in Yaoundé, Cameroon.

WorldVeg received a USD 1.7 million planning grant from the Taiwan Council of Agriculture (COA) to begin moving forward on a major construction and renovation project to modernize the Center’s research infrastructure at headquarters.

WorldVeg started working from a new office in Dushanbe, Tajikistan.

WorldVeg trainers worked with farmer groups in Zanzibar supported by the Tanzania Horticulture Association (TAHA) on postharvest handling and healthy cooking methods for vegetables.

Research funded by the Bill & Melinda Gates Foundation and UK aid began testing the hypothesis that school garden programs can nudge children aged 8-12 toward healthier diets.
The Asia & Pacific Seed Association (APSA)/World Vegetable Center Vegetable Breeding Consortium held its second annual workshop on 16-17 May 2018 at WorldVeg HQ. Fifty-two participants from 32 consortium companies attended the event.

Board Chair Dr. JJ Chen led a Taiwan delegation to the WorldVeg East and Southeast Asia Research and Training Station, Kasetsart University, Kamphaeng Saen campus, Thailand on 30 May 2018.

Dr. Charles Murekezi, Director General of Agriculture Development of Rwanda, toured WorldVeg Eastern and Southern Africa in Arusha, Tanzania.

The Taiwan Control Yuan Financial and Economic Affairs Committee visited WorldVeg HQ.

The Association of International Agricultural Research Centers (AIARC) held its 2018 board meeting at WorldVeg HQ.

MOU signed with the African Seed Trade Association to establish the Africa Vegetable Breeding Consortium.

WorldVeg HQ Demonstration Garden received the 2018 Yuan-Ye Award for landscape architecture from the Kaohsiung Judicious Creative Architecture Association.

Bitter Gourd Open Field Days showcased 600 elite bitter gourd breeding lines and 900 bitter gourd F1 hybrids at the WorldVeg East and Southeast Asia Research and Training Center, Kamphaeng Saen, Thailand.

The Crop Trust’s Eggplant and Carrot Pre-breeding Project teams met at WorldVeg HQ to discuss progress and future plans.

WorldVeg and the College of Bioresources and Agriculture of National Taiwan University (NTU), Taipei, Taiwan signed a Memorandum of Agreement for further research collaborations.

Cameroon’s Ministry of Agriculture and Rural Development (MINADER) and WorldVeg signed a Memorandum of Understanding.

DG Marco Wopereis spoke on “Tapping the nutritional potential of vegetables” at the Crawford Fund Conference, organized by WorldVeg board member Cathy Reade.
WorldVeg highlighted improved cherry tomato and sweet pepper and virus resistance research at the Taiwan INNOTECH Expo.

Mr. Charles Bastienne, Honorable Minister of Agriculture, Seychelles and his team visited WorldVeg South Asia.

HQ staff participated in a visioning workshop for the Research Infrastructure Management project, led by consultant Dr. Tony Agostino.

MOU signed with Taiwan’s National Cheng Kung University.

The WorldVeg booth at the African Green Revolution Forum in Kigali, Rwanda and the participation of DG Marco Wopereis in two panel discussions heightened visibility of Center activities in Africa.

15 members of a high-level committee from the East African Community (EAC) visited WorldVeg Eastern and Southern Africa in Arusha, Tanzania.

2018 Global R&D Week brought together 90 staff from five regional offices for planning and team building at WorldVeg HQ.

54th meeting of the WorldVeg Board of Directors at WorldVeg Eastern and Southern Africa, Arusha, Tanzania.

WorldVeg signed a Memorandum of Understanding (MOU) with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) during the International Conference on Nutrition-Sensitive Agriculture and Food Systems in Tagaytay City, Philippines.

WorldVeg participated in the 22nd Seed & Seedling Festival at the Tainan District Agricultural Research and Extension Station, Xinhua, Tainan.

WorldVeg and the Australian Centre for International Agricultural Research (ACIAR) signed a new four-year agreement to guide future collaboration.

A delegation from the Japan International Research Center for Agricultural Sciences (JIRCAS) explored future opportunities for collaboration and ongoing preparations for a JIRCAS scientist to be seconded to WorldVeg.

WorldVeg and the Rural Development Administration (RDA) Korea signed an MOU to reaffirm and modernize collaboration between RDA and WorldVeg.

WorldVeg hosted The Power of Produce: How Vegetables and Fruits Can Conquer Malnutrition and Poverty, a side event at the 2018 World Food Prize Borlaug International Symposium. US. Ambassador Kenneth Quinn, President of the World Food Prize Foundation, presented WorldVeg with a certificate of gratitude for hosting Borlaug-Ruan International Interns at WorldVeg HQ and South Asia.

The IFDC/2SCALE project constructed Nigeria’s first improved onion storage facility in Sokoto.
Planning for the construction of a new laboratory launched an exciting phase in the Center’s growth as an international center for agricultural research.
On 18 April 2018, the World Vegetable Center received a US$1.7 million (NTD 50,000,000) grant from the Taiwan Council of Agriculture (COA) to begin planning a major construction and renovation project to modernize the Center’s research facilities. The Research Infrastructure Modernization (RIM) project will reinvigorate the research labs and build new fit-for-purpose facilities to ensure WorldVeg is properly equipped to deliver high impact science and applications.

“The Center’s laboratories are in urgent need of renewal,” said WorldVeg Director General Marco Wopereis. “We’re grateful to Taiwan COA for the financial support that will allow us to start making our vision of a modern open science center for vegetable research a reality.”

A new seed treatment facility, capacity for field phenotyping, and upgraded laboratory facilities will be part of activity zones devoted to research, training, administration, and social interaction designed to inspire, attract, and retain a vibrant community of research professionals.

New faces were seen around WorldVeg headquarters as RIM gained momentum. Dr. Tony Agostino, Technical Consultant from Australia, provided advice from the earliest inception of the RIM idea. Civil Engineer Alex Hsu began consulting on RIM processes in June 2018. Yedda Palemeq joined WorldVeg in December 2018 as RIM Project Administrative Manager in the Office of the Deputy Director General – Administration & Services.

The collective thinking caps were on during the RIM Visioning Workshop, 11-12 September 2018 at WorldVeg HQ. Staff members gathered together to share their views, needs and hopes for RIM, guided by the expertise and perspective of Dr. Agostino and Dr. Ming-Che Shih of Taiwan’s Academia Sinica.

Proposals for a field phenotyping system were solicited, and on 17 September 2018 WorldVeg signed a contract with Netherlands-based Phenospex B.V. to construct such a system. Phenotypic data can help explain gene functions, and provide insight into how plants cope with limitations of water and nutrients, how they respond to light or CO₂, and how they are influenced by pests and pathogens. In December 2018 the earthmovers began reshaping the soil in Field 35 to accommodate concrete foundation rails to support the movable Phenospex frame.

Expressions of Interest were placed in Taiwan media and on websites for international construction projects to alert architectural and engineering firms to the RIM project. In October 2018, three architectural firms were selected from an initial pool of six applications. The three firms submitted detailed proposals outlining their approach for constructing a new lab building and modernizing the WorldVeg campus. Evaluations were held at WorldVeg HQ in mid-December and a clear winner emerged: EDS International’s flexible, modular lab design and reimagining of the campus landscape as a garden won high marks from the reviewers. Contract negotiations with the firm were initiated. It’s expected WorldVeg will receive a total of US$22 million (NTD 660,000,000) to complete the RIM project.

“We’re at the beginning of our journey to shape this campus into a place where we can deliver the research and products that will improve the lives and livelihoods of the people we serve,” said Wopereis. “It’s a once-in-a-lifetime opportunity to create a world-class research facility, and we intend to make the most of it.”
The World Vegetable Center has a proud history of training professionals and scientists through the International Vegetable Training Course (IVTC). Since 1982, WorldVeg has offered intensive training to 927 students from 55 countries. IVTC training programs cover a range of topics from vegetable breeding, germplasm conservation, and seed production to Integrated Pest Management (IPM), water management, postharvest care and market assessment, as well as human nutrition and health.

Every year through the IVTC, WorldVeg contributes to building the capacity and careers of global participants through a combination of classroom lectures, hands-on exercises, and excursions to vegetable markets and farmers’ fields.

In 2018, WorldVeg East and Southeast Asia and partner Kasetsart University (KU) Thailand organized the 37th IVTC on the topic of “Safe Vegetable Production” at the WorldVeg Research and Training Station, on KU’s Kamphaeng Saen campus.

Pesticide use is particularly high in vegetable production, causing increasing concern about the safety of vegetables among consumers in poor and rich countries alike. Microbial contamination of vegetables—usually resulting from the use of contaminated water in production and postharvest handling—is also a major challenge. Food safety must become a priority and WorldVeg believes sharing concrete techniques for safe vegetable production can make a lasting difference.

Thailand leads the way in Southeast Asia with a public Good Agricultural Practices (GAP) standard, already adopted by hundreds of thousands of farmers, and various private standards for organic and safe production. While standards are usually explicit about
what farmers are not allowed to do, there is scant guidance available about how to manage vegetable pests and diseases without the use of chemical pesticides.

The 2018 IVTC attracted 28 professionals (16 men and 12 women) from 20 different countries*. Representatives from national and international agricultural research institutes, universities, non-governmental organizations, and the private sector participated in the two-week intensive course, which covered GAP and the development of GAP standards and certification, healthy seeds and seedlings, sustainable soil fertility management, diagnosis of pests and diseases and integrated pest management (IPM), and postharvest management and processing.

Farmers’ lack of knowledge on pest management methods is strongly correlated with excessive pesticide use. Through the IVTC and its flagship programs, WorldVeg contributes practical solutions backed by research to address pesticide misuse, pointing the way forward to a safer food supply.

https://ivtc.avrdc.org

• **Activities** were conducted in six countries: Cambodia, Korea, Myanmar, Philippines, Thailand, and Vietnam.

• The 37th edition of the **International Vegetable Training Course (IVTC)** held in Thailand trained 28 professionals in “Safe Vegetable Production”.

• On 20 March 2018, the 13th **ASEAN-AVRDC Regional Network for Vegetable Research (AARNET) Steering Committee** met in the Philippines, bringing together 19 delegates from nine ASEAN member states and 30 observers from the Bureau of Plant Industry, Philippines Department of Agriculture.

• On 23–24 July 2018, **Bitter Gourd Open Field Days** at the WorldVeg Research and Training Station in Kamphaeng Saen, Thailand attracted 30 private seed industry staff and representatives from the Vegetable Research Institute, Faisalabad, Pakistan to view more than 600 elite bitter gourd breeding lines and 900 bitter gourd hybrids.

• In collaboration with the Asia & Pacific Seed Association (APSA) and Kasetsart University (KU), WorldVeg hosted the first **Asian Cucurbit Round Table (ACRT)** in Bangkok, Thailand on 21 May 2018, attended by more than 100 participants from 39 seed companies.

• Kasetsart University made available an **additional field** of 1.72 hectares to WorldVeg breeding programs.

• In Thailand, WorldVeg researchers are working with the **Department of Agriculture** to strengthen pest monitoring and preparedness after *Tuta absoluta* was confirmed to have entered bordering Myanmar; screen peppers for resistance to chili leaf curl with **Khon Kaen University**; and manage eggplant fruit and shoot borer and fruit fly using attractants and heat tolerance of eggplant and bitter gourd with the **KU Tropical Vegetable Research Center**.

• In Myanmar, WorldVeg coordinated with the Food Legume Section, **Department of Agricultural Research (DAR)** to implement integrated pest management methods against major insect pests on mungbean through the International Mungbean Improvement Network, and worked with teams from **Yezin Agricultural University** to interview more than 500 mungbean farmers in four provinces to understand how mechanization of harvesting will affect the lives and livelihoods. The work is funded by the Australian Center for International Agricultural Research (ACIAR).

• A project on **crop selection to improve productivity** of the vegetable value chain in Southeast Asia funded by Japan’s Ministry of Agriculture, Forestry and Fisheries (MAFF) shared final research results in May 2018 with representatives from DAR Myanmar, Vietnam’s Fruit and Vegetable Research Institute (FAVRI), and scientists from Yamaguchi University, Japan.
• With support from Taiwan’s Council of Agriculture (COA), the WorldVeg Research and Training Station evaluated horticultural traits of five crops (eggplant, chili pepper, cauliflower, tomato, pumpkin) from the Taiwan Agricultural Research Institute (TARI) and 10 disease-resistant tomato lines for the Hualien District Agricultural Research and Extension Station.

• **Angkor SALAD: Geodata for sustainable vegetable farming** Cambodia led by ICCO-Cooperation and funded by the Netherlands Space Office is making data easily accessible to farmers through mobile phone “decision trees” for 11 crops.

• Researchers in the Women in Agriculture Network (WAgN) ‘Wild Gardens’ project compiled a list of **perennial wild food plants** common to northern Cambodia, and interviewed smallholder farmers in Siem Reap and Battambang provinces who utilize such plants. A wild food plant nursery has been established at the University of Battambang for research.

• After training more than 4,700 individuals and reaching more than 5,100 children below the age of 5 in the trained households, the USAID-funded project “Deploying Vegetable Seed Kits to Tackle Malnutrition in Cambodia, Kenya, Liberia, Tanzania and Uganda” ended in September 2018. Researchers and partners provided instruction in **gardening and nutrition** at 272 demonstration sites and through videos. WorldVeg’s impact evaluation shows that on average the share of households having a home garden in the villages increased by 43%, the families grew five additional vegetable varieties for home consumption over the year, and expanded the growing period by more than five months, compared to villages that did not receive any training.
Over the last 3 years, demand for processed tomato products in India has grown by a whopping 30% annually, which has opened up opportunities to establish new processing facilities and create jobs.

Despite the rapid increase in demand, the country processes only 1% of its total tomato production. A key constraint is the lack of improved cultivars suitable for processing. Processing tomatoes should have a determinate plant habit, multiple disease resistance, high yield, compact vines, uniform quick ripening, jointless pedicels for mechanical harvesting/easy harvest, and deep red, firm fruit.

Because tomato processing occurs only during certain times of the year, it makes sense to develop varieties suitable for processing as well as the fresh market (known as “dual-purpose lines”). WorldVeg has developed a number of such lines and is trialling them for the first time in India on our research station and in farmers’ fields.

WorldVeg, under the GIZ-funded GIC project, began introducing dual-purpose tomato lines to cater both growers’ and traders’ needs. WorldVeg is extending its technical support to its partners, the Andhra Pradesh Mahila Abhivrudhi Society (APMAS) and Agriculture & Finance Consultants (AFC) in Karnataka and Maharashtra.
Suitable for fresh market sale or processing, WorldVeg dual-purpose lines attract interest around the subcontinent.

In the first phase of the project, WorldVeg compared nursery, production and harvesting practices of three dual-purpose lines with three popular commercial hybrids in participatory demonstration trials in farmers’ fields. All the dual-purpose lines showed similar crop growth characteristics for flowering, fruit setting and maturity, and responded well to normal management practices. Commercial fresh market hybrids yielded better in the first two pickings compared to the dual-purpose lines; however, for the subsequent pickings, no differences were found. Farmers across the regions preferred WorldVeg lines for their better vegetative growth, fruit setting, comparable yields, and better resistance to diseases and pests.

WorldVeg and APMAS evaluated a dual-purpose line for market acceptability through surveys with farmers and traders at Palamner, Kolar and Chennai markets. At Kolar market, respondents suggested planning for early harvest to ensure better fruit firmness. The Chennai and Palamner markets did not favor the line due to higher fruit softness. Processors preferred commercial hybrids, closely followed by WorldVeg dual-purpose lines.

This important feedback helps WorldVeg refine its research to further improve these tomato types.

In field days at WorldVeg South Asia, Hyderabad, and I&B Seeds, Bangalore, six new WorldVeg dual-purpose lines, two commercial processing types, and a few fresh market hybrids were showcased. These new lines demonstrated good potential for yield and improved fruit quality traits. Participants described these lines as having improved canopy structure, fruit size, color and the shape. Multilocation testing of the second generation dual-purpose lines is underway in the three Indian states mentioned above, with support from seed companies and other project partners.
Research activities were conducted in seven countries: Bangladesh, India, Myanmar, Nepal, Pakistan, Tajikistan, and Uzbekistan.

Through the ACIAR-funded International Mungbean Improvement Network:

- 296 mungbean minicore lines were screened for disease and pest resistance. Against dry root rot disease, line VI001509 AG was highly resistant and 28 were resistant. For anthracnose, 5 lines were highly resistant and 61 were resistant. For powdery mildew, 11 lines were highly resistant and 58 lines were resistant. Against thrips, 15 lines were found to be resistant. Identification of thrips in mungbean: Yellow thrips (Thrips palmi Karny) and Black thrips (Caliothrips indicus (Bagnall)).

- Screening of 15 mungbean AVMU lines along with three susceptible (VI004423 AG, VI000212 A-BLM, VI004666 AG) and two resistant lines (VI000020 AY, VI004743 AG) from the minicore collections against anthracnose showed that AVMU 1639 is resistant to this disease. Lines EC693368, EC693369, and IPM 99-125 showed resistance to dry root rot.

- Improved mungbean lines were screened for resistance against bruchids (Callosobruchus maculatus) Shiny green seeded, improved mungbean lines (AVMU1601, AVMU1605, and AVMU1606) are highly resistant to bruchids.

- In screening against thrips and whitefly, improved mungbean lines AVMU 16101, AVMU 1658, AVMU 1678 showed resistance to thrips (at WorldVeg South Asia, Hyderabad, India) and AVMU 1678 was resistant to whitefly (at Punjab Agricultural University, Ludhiana, India).

- Training events were conducted on database management (KDDart) in Bangladesh and Myanmar.

- ACIAR-funded field trials on dessicants for mungbean harvesting in Bangladesh and Pakistan (Glyphosate, Ethrel, Urea, and Thiourea) and in Myanmar (Glyphosate, Ethrel, and Urea) have been completed and data is being compiled. Residue analysis on seed samples will be done in India.

- Macrophomina phaseolina isolated from mungbean was identified by molecular characterization using 18S rRNA specifically ITS1 and ITS2 regions. Compatibility of insecticides with Trichoderma harzianum showed that Imidacloprid @ 2 g/L and Thiamethoxam @ 1-2 g/L are highly compatible and recommended to be used with T. harzianum @ 13 g/kg seed.

- Under the Rashtriya Krishi Vikas Yojana (RKVY) Onion Project funded by the Government of Odisha, WorldVeg conducted 240 varietal demonstrations during Rabi (dry winter) and 186 demonstrations during Kharif (wet summer) seasons. Thirty-four on-farm demonstrations of onion harvesting and storage techniques were conducted in all project districts. Twenty training programs, 14 workshops and 27 exposure visits were conducted for farmers and government officials. Six IPM demo trials and five IPM training programs on the management of insect pests on onion were conducted in India.
• The Syngenta Foundation for Sustainable Agriculture (SFSA) and WorldVeg signed an agreement for long term cooperation in October 2018 at WorldVeg South Asia in Hyderabad, India.

• Under the BMZ/GIZ project, WorldVeg, in association with APMAS and AFC, compared three of its dual-purpose tomato lines with three commercial hybrids in about 20 trials in Madanapalle (Andhra Pradesh), 6 in Narayanagoan (Maharashtra) and 5 in Kadur (Karnataka). AVTO1424 showed good crop growth, development, and fruit setting.

• WorldVeg compared five tomato lines based on 2nd generation dual-purpose/processing types with three commercial hybrids. The second generation dual-purpose/processing type tomatoes were planted under staking and no staking conditions. The trials were taken up by Indian seed companies in Andhra Pradesh, Karnataka and Maharashtra.

• An experiment with nine treatments to identify the optimum hormone concentration for tomato seedlings indicated hormone concentration at 10-20-10 PPM (Aux-GA-Cyt) with humic acid offered a 15-20% improvement in tomato seedling growth and development.

• In Assam, WorldVeg maintains 70 demonstration fields where climate resilient cropping practices are taught to farmers through the Assam Agribusiness & Rural Transformation Project (APART), funded by Assam Rural Infrastructure and Agricultural Services (ARIAS) Society of the Government of Assam with a loan from the International Bank for Reconstruction and Development (IBRD). The focus is on tomato, eggplant, pumpkin, cabbage and cauliflower, as well as black gram, garden peas, and lentils. Two workshops have been held on a package of practices (PoP) for the target crops with Assam Agricultural University to support local extension services.

• A standard package of practices (PoP) for priority vegetables is being demonstrated in 24 plots in project areas through the Jharkhand Opportunities for Harness Rural Growth (JOHAR) project funded by the Jharkhand State Livelihood Promotion Society with a loan from the International Bank for Reconstruction and Development (IBRD). Since March 2018, a total of 218 training events, field demonstrations, and on-field technical advice have been provided across the project sites.

• Vegetable variety trials with seed companies in India have been established with Taiwan’s Fengshan Tropical Horticultural Experiment Branch and Hualien District Agricultural Research and Extension Station, GIZ GIC tomato value chain, and the Crop Trust Carrot projects.

• Three short training courses were conducted at WorldVeg South Asia for Indian seed companies with technical support from Telangana State Agriculture University and the Genomics department of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Around 47 staff members from 24 private seed companies acquired new skills in the courses.
It takes knowledge, skill, access to inputs and finance, links to markets, and a limitless supply of enthusiastic energy to succeed as a producer of fresh vegetables. While young people have an abundance of the latter, they often lack the other elements needed to move from subsistence production to running a viable horticultural business.

Vegetable business hubs address these shortcomings in a sustainable, cost-effective way, and relatively little capital is needed to launch a hub into action.

The youth vegetable business hub model funded by Catholic Relief Services (CRS) and developed and implemented by WorldVeg and CRS combines education, group governance through saving and internal lending communities (SILC), and collective marketing of vegetables to increase farmer incomes.

In Arumeru District, Tanzania, the youth vegetable business hub engages unemployed young people ranging in age from 15 to 35 to work together in groups on various aspects of vegetable production and marketing.
With a market-first focus, vegetable business hubs transform young farmers into vegetable entrepreneurs.

The youth learn improved methods for growing high quality vegetable crops such as French beans or tomato seed, which are in demand locally and for export. With strength in numbers, the hub groups often can negotiate for better prices on inputs and equipment. The hub connects the groups with financial institutions to provide credit, encourages self-saving and lending among the groups, and provides assistance with essential bookkeeping skills.

It all comes together when the hub links the groups to high value markets. Through hub training activities, the group members learn how to meet their customers’ benchmarks for quality. They quickly learn that growing what the market desires is the best route for improving their incomes and livelihoods.

After receiving training at the vegetable business hub, Rayson Eliahu, a Tanzanian vegetable farmer and father of two, formed a farmer group called Bavega. In 2018, Rayson and his group signed a contract with Serengeti Fresh (a producer, processor, and exporter of fresh vegetables) to produce snow peas.

“I am now assured of the market for my produce, I have no worries of where I can sell my snow peas, and I have a good and close relationship with my customer,” Rayson said. The contractual agreement links Bavega’s members to a lucrative vegetable market.

In 2018, Rayson made a net profit of 2,920,000 Tanzanian shillings (TZsh) (US$~1,287) on one acre. Before he established Bavega, he was a non-contracted cabbage grower and made only 200,600 TZsh (US$~88) because he was at the mercy of falling cabbage prices.

Twenty-five youth have joined Bavega and Rayson is the seneca (chairperson) of the group. Bavega has a savings account currently worth 5,000,000 TZsh (US$~2,203). Galvanized by solid training in production, marketing and finance, and with continued advice from customers on production and quality assurance, Bavega’s young entrepreneurs will continue to make good incomes from growing vegetables.
• Activities were conducted in five countries: Burundi, Kenya, Tanzania, Uganda and Zambia.

• WorldVeg Eastern and Southern Africa hosts the International Institute of Tropical Agricultural (IITA) and the French Agricultural Research Centre for International Development (CIRAD), as well as the Real IPM Company, Africa’s largest biocontrol company and now a member of the Biobest Group, creating a vibrant and synergistic atmosphere to tackle some of the urgent problems facing smallholder vegetable systems.

• The genebank at the regional office continued to distribute and characterize germplasm, particularly of traditional African vegetables: 402 accessions were distributed to the public and private sectors in Benin, Ghana, India, Kenya, Rwanda, Taiwan, Tanzania and Uganda, while 300 African eggplant accessions and 56 different traditional African vegetables (amaranth, African nightshade, Ethiopian mustard, jute mallow and mungbean) were characterized morphologically using standard descriptors. In addition, about 60 accessions of okra, roselle, spider plant, amaranth, cowpea and pumpkin were regenerated.

• Amaranth and African eggplant breeding continued with an evaluation of segregating populations: 58 lines of a $F_6$ green leaf-type amaranth population were evaluated and 42 $F_7$ lines were evaluated in a replicated grain-yield trial.

• Three amaranth and two African nightshade varieties, originating from WorldVeg, were released in Tanzania by the Tanzania Agricultural Research Institute (TARI) after obtaining DUS (distinctiveness, uniformity and stability) certificates. Another 22 amaranth and 21 African eggplant lines are being evaluated in Tanzania and Kenya in collaboration with Mikocheni Agricultural Research Institute (MARI) and Simlaw Seeds, respectively. Research on amaranth is funded by BMZ; African eggplant, by BBSRC.

• Together with CIRAD, WorldVeg is making great strides in introducing low-cost novel agronomic and pest control practices. In Arusha, Tanzania, 50 farmers are testing the use of low tunnels for cabbage cultivation. New projects have started on biological control of aphids on kalanchoe with Multiflower, a private export company. Together with Seeds for the Vegetable Industry of Africa (SEVIA) and the Tanzania Horticulture Association (TAHA), WorldVeg is assessing tomato rootstocks for resistance to bacterial wilt in grafting experiments in Arusha, Kilimanjaro and Zanzibar.

• In Burundi, production groups were set up for vegetable drying, pineapple, citrus and tamarillo juice. WorldVeg is training 20 farmer groups to manage these groups with funding from the USAID Africa Rising project.

• In 2018, 13 students (6 BSc, 5 MSc and 2 PhD) from France, Kenya, Tanzania, USA and Zambia conducted their research at the regional office, in collaboration with African and other universities.
• Funded by and in partnership with Catholic Relief Services (CRS), WorldVeg assessed vegetable business hubs in Tanzania. Vegetable business hubs focus on a ‘market first’ approach, and are a sustainable way to link youth groups with each other, input and output markets, and finance to transform unemployed youth into vegetable business entrepreneurs. Youth groups were linked to lucrative markets (French beans for export through Frigoken, snowpeas for export through Serengeti Fresh, and tomato seeds for Africasia Seed, a seed company in Arusha) and are making a net profit of US$3,592-17,225 per season.

• A total of 3,260 home garden seed kits containing different nutritious traditional African vegetables and produced by the private sector were distributed to smallholder farmers and their households in Kenya. Using a randomized control trial, 1,250 households were interviewed in Kenya, Tanzania and Uganda to investigate the effect of home gardens on nutritional and other outcomes. The USAID Bureau for Food Security provided funds for the kits and trials.

• The regional office successfully hosted the 54th Board of Directors meeting in Arusha, Tanzania from 26-29 November 2018. The meeting included a field day to visit and interact with farmers, and to demonstrate technologies and improved practices.

• More than 40 delegations from all over the world visited the regional office during 2018, contributing to enhanced visibility and partnerships in vegetable research.

• Ten regional and international events and workshops were organized at the regional office, including the Australia Awards Africa short course organized in collaboration with the University of Sydney, the board meeting of the Tanzania Official Seed Certification Institute (TOSCI), a workshop on sustainable agri-food systems strategies (SASS), and a field visit of the board of the International Rice Research Institute (IRRI).

• Upon request by the Honorable Minister of Agriculture and Animal Resources and in collaboration with the Horticulture Innovation Lab, three scientists from the regional office conducted a scoping mission in Rwanda from 10-14 September 2018 to assess opportunities to strengthen the vegetable and fruit sector. Recommendations included a stronger focus on seed systems, building capacity, and nutrition.
Vegetable Technologies to Overcome Malnutrition and Poverty in Mali.” They grew carrots, beets, amaranth, tomatoes, African eggplant, pepper and okra in the sacks. The household members were in charge of watering the vegetables and protecting them from foraging animals.

Sack gardens allow families to grow vegetables in the family compound and offer quick access to nutrient-rich vegetables for children’s meals. They’re especially handy when mothers caring for newborns or very young children may be unable to visit distant garden plots. Sack production also offers a partial solution to the problem of land tenure. In areas where women are less
entitled to own land, a sack garden provides them with the means to produce fresh food on their own.

At first, the 30 mothers were skeptical about growing vegetables in a bag. How could the plants thrive in such a small space? Would there be enough room for the roots? And could the sacks produce enough food to make a difference in their diets?

Community leaders, including the village chief and area mayors, encouraged the mothers to work with the project team. The local health center in Koutiala was a big supporter of the sack garden project, with good reason: Koutiala has one of Mali’s highest rates of child malnutrition, and vegetables the householders grew would provide much-needed nutrients for children’s diets.

Everyone pitched in to help the families fill their bags with soil. Project members offered information and guidance on growing vegetables, and they provided recipes and nutrition information to help the families get the greatest nutritional benefit from the food they grew.

The sack gardens were introduced in May 2018 and over the following months proved to be so popular that even people not targeted by the project activities began growing vegetables in the big bags. Everyone calls the sacks fitini nafa thiama, which means “small garden with a lot of benefits.”

Quick-growing amaranth—ready to pick and eat just six weeks after planting—was the first crop the mothers were able to harvest from their sack gardens. Eggplant, tomatoes, beets and carrots soon followed.

From May to December 2018, the 30 sack gardeners from Djalé were able to harvest 116 kg of tomatoes, 50 kg of amaranth leaves, 268 kg of potato leaves and 60 kg of beets. They also produced sweet potato cuttings and 1,250 kg of orange fleshed sweet potatoes.

These “small gardens with big benefits” delight and nourish families in Mali.
West and Central Africa - Dry Regions

- **Activities** were conducted in three countries: Côte d’Ivoire, Burkina Faso and Mali.

- 2 **Memoranda of Understanding (MoU)** were signed with IFDC, followed by funding for “Optimizing Fertilizer Deep Placement in Vegetable Production” projects in Mali and Côte d’Ivoire.

- 1 UK aid project approved on **low-cost pest surveillance** for sub-Saharan Africa.

- 10 MoU’s signed with **national research institutes** in the region.

- Technical collaboration was established with the following projects and organizations: Société d’Exploitation des Mines de Sadiola (SEMOs) in Mali; Arche Nova, a World Bank project for Irrigation in the Sahel Region; and the EU/GIZ PARIZON program to support actors in the value chain for the sustainable development of the rice value chain.

- Partnership with six **private enterprises** established under the Africa Vegetable Breeding Consortium (AVBC): Coprosem (Mali), Faso Kaba (Mali), AMEED (Mali), Nafa-So (Burkina Faso), FAGRIS (Burkina Faso), Tropicasem (Senegal).

- **Seed kits** for rainy season (5,028) and dry season (4,400) production that included okra, tomato, African eggplant, pepper, amaranth and onion were distributed to project farmers in Mopti and Sikasso. The USAID Mali Horticulture Scaling Project provided funding for the kits.

- The USAID Mali Horticulture Scaling Project funded training sessions on production and postharvest methods for farmers in Sikasso (6,174; 80% women), Mopti (7,453; 81% women) and Tombouctou (1016; 65% women).

- Twenty cooperatives in Sikasso and 18 cooperatives and 4 cooperative unions in Mopti received **formalization certificates**, authorizing them to work legally as a cooperative in any OHADA (Organization for the Cooperation of Business Law in Africa) country. Training on cooperative governance and management was provided to 457 management committee members. These agribusiness activities were funded through the USAID Mali Horticulture Scaling Project.

- **Public-private partnerships** have been established through the signing of five contracts for rainy season onion production between Madougou agribusinesses and four cooperatives in Sikasso and one cooperative in Mopti. Morila Gold Mining Company renewed its contract with the Blédougou Cooperative, which will supply vegetables to the company for another year.

- 24 farmers, extension officers and field technicians were trained in **IPM** in Côte d’Ivoire and 21 people in Mali were trained in grafting.
• With funds from the USAID Mali Horticulture Scaling Project, vegetable garden seed kits were distributed to 10,754 women and 1,097 men to improve household accessibility and consumption of vegetables. The kits included seed of okra, tomato, carrots, beets, African eggplant, pepper, and amaranth, and sweet potato cuttings.

• 1200 sack gardens were established in Koutiala District, Sikasso Region in 120 households with children aged 4-8 months to improve accessibility of nutrient-rich vegetables and facilitate the transition from exclusive breastfeeding to a more diverse diet for young children. The activity was a joint effort of the USAID Mali Horticulture Scaling and USAID Africa Rising projects.

• WASH activities were implemented to foster adoption of improved behaviors and reduce incidence of infectious diseases. Forty-five villages (15 villages in Sikasso and 30 villages in Mopti) were certified as free of open defecation through Community Led Total Sanitation activities in Sikasso and Mopti. Post-certification activities were implemented in 33 villages in Mopti and 45 villages in Sikasso by agreement between each target community and the project. Behavior change communication witnessed the participation of 18,790 people in Mopti (59% of women) and 12,300 in Sikasso (58% of women).

• Nine bacterial wilt resistant eggplant rootstock varieties were tested in Mali and Burkina Faso. Two suitable varieties were identified.

• A bacteria causing bacterial wilt disease on tomato was identified and its distribution in Mali mapped.

• 680 kg of onion mother bulbs and 60 kg of breeder’s onion seed, and 371.6 kg of mother bulbs of five shallot varieties were regenerated and purified in Mali with funding from the USAID Mali Horticulture Scaling Project.

• 182 kg of mother bulbs of onion variety ‘Goudami’ were purified and produced for Cameroon.
MORE HARVEST, LESS LOSS
Nigeria's farmers change production and storage practices to increase the onion supply.

Nigeria loses half of its onion harvest due to poor production and postharvest management practices.

In the Sokoto region, onion farmers typically cultivate local landraces, which can transfer undesirable traits such as disease susceptibility to successive crops. The landraces produce bulbs of different colors, shapes and sizes—diversity that represents a challenge when farmers try to fulfill specific product requirements for traders. Farmers lack information on proper fertilizer formulation and irrigation is irregular. Bulbs often are harvested too early, and the immature bulbs are then cured under intense sunlight, causing sunscald or sunburn. *Rudu*—traditional storage structures—do not allow for good airflow or temperature regulation, hastening rot in the bulbs. Few farmers know how to grade (sort) their bulbs for market.

The IFDC 2SCALE project contracted WorldVeg to train onion farmers in Sokoto and equip them with knowledge and methods to improve onion yield and shelf life.

WorldVeg facilitated Training of Trainers workshops on onion production and postharvest management for extension agents from the Agriculture Graduate Association of Nigeria, the Sokoto Agricultural Development Project, staff of Tays Food Ltd., and smallholder farmers; the extension agents then went on to train 5,000 onion farmers in Sokoto.

WorldVeg also supported IFDC in constructing two improved storage facilities, and helped to establish demonstration plots in Gada, Kware, and Goronyo Sokoto states using improved onion seed varieties from Bejo, Technisem, and East-West Seed companies, with a local variety for comparison.

These interventions were first of their kind in Sokoto, and are expected to reduce postharvest loss to 10%, increase onion farmers' earnings by 40%, and ensure onion remains affordable throughout the year thanks to improved storage.

Nigeria's farmers change production and storage practices to increase the onion supply.
Activities were conducted in four countries: Benin, Cameroon, Ghana and Nigeria.

The Global Plant Breeding Lead Scientist was relocated from Taiwan to Benin in mid-June, to build research capacity in the region and across Africa.

Infrastructure for seed systems: A cold room for seed storage with four double-door refrigeration units and a seed drying machine was set up at WorldVeg West and Central Africa - Coastal & Humid Regions in Cotonou, Benin with funding from Taiwan’s Ministry of Foreign Affairs (MOFA).

The regional office maintains 3.2 hectares of experimental fields, including a demonstration garden.

Several field trials were conducted at the Cotonou office in 2018, including a tomato bacterial wilt (Ralstonia solanacearum) screening experiment involving 19 tomato lines brought from Taiwan; three promising resistant lines were identified.

Two regional inception workshops were held in Cotonou for the UK aid mungbean and seed systems subprojects, and were well attended by partners and stakeholders.

Funded by UK aid, a minicore mungbean trial involving 293 accessions was completed in Benin, Ghana, and Nigeria. Individual country data has been submitted for analysis and subsequent regional synthesis.

Multilocation trials for tomato, chilli pepper and amaranth are in progress in Benin, Ghana, and Nigeria, funded by UK aid and WorldVeg core funds for some trials in Cotonou, Benin.

WorldVeg activities in the 2SCALE-Nigeria public-private partnership project funded by the Dutch government via the International Fertilizer Development Center (IFDC) commenced with two pilot projects: 1) providing technical backstopping and training for farmers in good agricultural practices to supply high-end vegetables for the SPAR supermarket chain, and 2) training farmers in improved onion production and storage practices in collaboration with Tay Foods Ltd., Sokoto State, Nigeria.

Variety trials with commercial onion varieties identified promising lines for greenhouse production, and WorldVeg facilitated the design and construction of improved onion storage structures for commercialization and upscaling in Sokoto and other locations.
• Under the Africa RISING Sudano-Sahel project, **dry season variety** trials and agronomic research activities were conducted in six project hubs in northern Ghana with two new WorldVeg staff -- Paul Alhassan Zatoo (Research Assistant, Agronomy) and Desire Dickson (Research Technician, Horticulture) -- who are extending activities to three new farmer communities due to strong demand. The project is funded by USAID via IITA.

• Donor / stakeholder meetings were held in Benin, Cameroon, Ghana and Nigeria, several of which led to **concept notes and proposals** that were funded for 2019, including the Technologies for African Agricultural Transformation (TAAT) program, and home gardening for improving the nutrition and incomes of cocoa farmers in Cameroon and Ghana supported by Barry-Callebaut.

• **Bacterial wilt** also was identified on **amaranth** for the first time in the world, in southern Benin. This surprising discovery was re-confirmed in collaboration with Institut National des Recherches Agricoles du Bénin (INRAB) researchers and published in *Plant Diseases*.

• A selection trial in the greenhouse and field was conducted with **improved amaranth varieties** obtained from the WorldVeg team in Arusha through the Amazing Amaranth project; varieties with promising resistance against bacterial wilt have been identified for further testing.

• WorldVeg researchers tested the efficacy of **biopesticides** Eradicoat and SAAF/INGIFT in collaboration with private sector partners Positive Agro Solutions Ltd., Ghana and UPL, Nigeria, respectively. These biopesticides have proven to be effective at various levels and results will be published in 2019.
## Projects in 2018

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Donor</th>
<th>Duration</th>
<th>Amount (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables for all</td>
<td>Amsterdam Initiative against Malnutrition</td>
<td>2014 - 2019</td>
<td>57,803</td>
</tr>
<tr>
<td>Asia &amp; Pacific Seed Association-WorldVeg Vegetable Breeding Consortium</td>
<td>Asia &amp; Pacific Seed Association</td>
<td>2017 - 2019</td>
<td>18,000</td>
</tr>
<tr>
<td>Improved mungbean harvesting and seed production systems for Bangladesh,</td>
<td>Australian Centre for International Agricultural Research</td>
<td>2017 - 2021</td>
<td>727,973</td>
</tr>
<tr>
<td>Myanmar and Pakistan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promoting traditional vegetable production and consumption for improved</td>
<td>Australian Centre for International Agricultural Research</td>
<td>2015 - 2018</td>
<td>121,681</td>
</tr>
<tr>
<td>livelihoods in Papua New Guinea and Northern Australia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Establishing the International Mungbean Improvement Network</td>
<td>Australian Centre for International Agricultural Research</td>
<td>2016 - 2019</td>
<td>1,530,066</td>
</tr>
<tr>
<td>Analyzing schools as platforms to improve livelihoods and the environment</td>
<td>Australian Centre for International Agricultural Research</td>
<td>2018</td>
<td>24,471</td>
</tr>
<tr>
<td>in East Africa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversify and improve household incomes and tackle malnutrition in cocoa</td>
<td>Barry Callebaut</td>
<td>2018 - 2020</td>
<td>122,015</td>
</tr>
<tr>
<td>communities through vegetable home gardens in Ghana</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversify and improve household incomes and tackle malnutrition in cocoa</td>
<td>Barry Callebaut</td>
<td>2018 - 2020</td>
<td>114,884</td>
</tr>
<tr>
<td>communities through vegetable home gardens in Cameroon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementing market-driven vegetable agricultural service providers linking</td>
<td>Belgian Government</td>
<td>2017 - 2018</td>
<td>135,719</td>
</tr>
<tr>
<td>smallholder farmers to services and markets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A trial program to evaluate the efficacy of a natural growth enhancement</td>
<td>BIO 520 LLC</td>
<td>2018 - 2019</td>
<td>62,500</td>
</tr>
<tr>
<td>product for six vegetable crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth Vegetable Business Hubs</td>
<td>Catholic Relief Services</td>
<td>2017 - 2018</td>
<td>92,341</td>
</tr>
<tr>
<td>Improved livelihoods through crop diversification into vegetables in Jharkhand and Odisha under Central India Initiative</td>
<td>Collectives for Integrated Livelihood Initiatives</td>
<td>2016 - 2019</td>
<td>233,501</td>
</tr>
<tr>
<td>Geodata for Water and Agriculture - Angkor SALAD</td>
<td>Dutch Ministry of Foreign Affairs</td>
<td>2018 - 2021</td>
<td>234,545</td>
</tr>
<tr>
<td>2SCALE - Vegetable pilots in Mali</td>
<td>Dutch Ministry of Foreign Affairs</td>
<td>2018</td>
<td>17,200</td>
</tr>
<tr>
<td>2SCALE - Vegetable pilots in Cote d’Ivoire</td>
<td>Dutch Ministry of Foreign Affairs</td>
<td>2018</td>
<td>43,753</td>
</tr>
<tr>
<td>Project Name</td>
<td>Donor</td>
<td>Duration</td>
<td>Amount (US$)</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>2SCALE - Vegetable pilots in Nigeria</td>
<td>Dutch Ministry of Foreign Affairs</td>
<td>2018</td>
<td>58,513</td>
</tr>
<tr>
<td>Horizon 2020 - Linking genetic resources, genomes and phenotypes of Solanaceous crops</td>
<td>European Commission</td>
<td>2016 - 2021</td>
<td>447,238</td>
</tr>
<tr>
<td>Amazing Amaranth: Hardy and nutritious amaranth lines and food practices to improve nutrition in East Africa</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2018 - 2021</td>
<td>1,357,188</td>
</tr>
<tr>
<td>GrAfrica: Introducing grafted plantlets to improve yield and income for smallholder tomato producers in sub-Saharan Africa</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2018 - 2019</td>
<td>113,100</td>
</tr>
<tr>
<td>Enhance the use of biological pest control for growing ornamental plants in Arusha</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2018 - 2019</td>
<td>90,426</td>
</tr>
<tr>
<td>GloBE Diversifying Food Systems: Horticultural Innovations and Learning for Improved Nutrition and Livelihood in East Africa (HORTINLEA) - Phase 2</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2016 - 2018</td>
<td>176,540</td>
</tr>
<tr>
<td>Resist Detect Protect: Wide spectrum insect resistance and sound management strategies to sustainably manage insect pests on Solanaceous vegetables in South Asia</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2017 - 2019</td>
<td>1,283,928</td>
</tr>
<tr>
<td>Action Against Anthracnose: Resistant <em>Capsicum annuum</em> chilli pepper introgression lines and cultivars for Bangladesh</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2017 - 2018</td>
<td>124,000</td>
</tr>
<tr>
<td>Technical partnership to support tomato value chain development under the Green Innovation Center for the agriculture and food sector, India</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2017 - 2018</td>
<td>185,060</td>
</tr>
<tr>
<td>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</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2015 - 2018</td>
<td>1,283,928</td>
</tr>
<tr>
<td>NutriSenseProm: Increasing vegetable consumption through public and private partnerships efficiently delivering effective nutrition messages in the vegetable value chain</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2016 - 2018</td>
<td>106,994</td>
</tr>
<tr>
<td>Project Name</td>
<td>Donor</td>
<td>Duration</td>
<td>Amount (US$)</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>GlobE UrbanFoodPlus: African-German partnership to enhance resource use efficiency in urban and peri-urban agriculture for improved food security in West African cities - Phase 2</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2016 - 2018</td>
<td>123,074</td>
</tr>
<tr>
<td>Determining household dietary diversity score (HDDS) and individual dietary diversity score (IDDS) of rice producing households in Mbeya and Dodoma regions, Tanzania</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2018</td>
<td>12,784</td>
</tr>
<tr>
<td>Genebank support 2018</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
<td>2018 - 2019</td>
<td>264,420</td>
</tr>
<tr>
<td>Capacity building towards digitization of national vegetable databases to address regional and national priorities in food and nutritional security in Eastern Africa</td>
<td>Global Biodiversity Information Facility</td>
<td>2017 - 2019</td>
<td>24,407</td>
</tr>
<tr>
<td>Building the Genesys catalog of phenotypic datasets</td>
<td>Global Crop Diversity Trust</td>
<td>2017 - 2018</td>
<td>49,600</td>
</tr>
<tr>
<td>Development and preparation of eggplant pre-bred materials for adaptation to climate change</td>
<td>Global Crop Diversity Trust</td>
<td>2017 - 2019</td>
<td>280,000</td>
</tr>
<tr>
<td>Onion value chain improvements in Odisha</td>
<td>Government of Odisha, India</td>
<td>2016 - 2018</td>
<td>392,112</td>
</tr>
<tr>
<td>Improve mungbean and urdbean productivity in Odisha State</td>
<td>Government of Odisha, India</td>
<td>2015 - 2018</td>
<td>373,440</td>
</tr>
<tr>
<td>Food Trees project in Kitui and Tharaka Nithi, Kenya</td>
<td>International Fund for Agricultural Development</td>
<td>2018</td>
<td>35,000</td>
</tr>
<tr>
<td>Selection of tropically-adapted lines of vegetables to improve productivity of the vegetable value chain in Myanmar and Vietnam (Year 3)</td>
<td>Japan Ministry of Agriculture, Forestry and Fisheries</td>
<td>2017 - 2018</td>
<td>141,854</td>
</tr>
<tr>
<td>Selection of tropically-adapted lines of vegetables to improve productivity of the vegetable value chain in Myanmar and Vietnam (Phase 2, Year 1)</td>
<td>Japan Ministry of Agriculture, Forestry and Fisheries</td>
<td>2018 - 2019</td>
<td>159,169</td>
</tr>
<tr>
<td>Screening for development of begomovirus-resistant processing tomato hybrid</td>
<td>Kagome Co., Ltd., Japan</td>
<td>2010 - 2018</td>
<td>143,333</td>
</tr>
<tr>
<td>Private seed sector support to WorldVeg's global cucurbit breeding program</td>
<td>Private seed companies</td>
<td>2016 - 2019</td>
<td>204,975</td>
</tr>
<tr>
<td>Project Name</td>
<td>Donor</td>
<td>Duration</td>
<td>Amount (US$)</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Broadening the narrow genetic base of commercial bitter gourd cultivars by exploiting the genetic diversity of WorldVeg breeding lines</td>
<td>Private seed companies</td>
<td>2017 - 2020</td>
<td>530,000</td>
</tr>
<tr>
<td>Identification of molecular markers associated with disease and insect resistance for marker assisted selection in tomato (<em>Solanum lycopersicum</em>) breeding programs</td>
<td>Rural Development Administration, Korea</td>
<td>2016 - 2018</td>
<td>120,000</td>
</tr>
<tr>
<td>Development of breeding techniques and selection of disease resistant germplasm in vegetables</td>
<td>Rural Development Administration, Korea</td>
<td>2017 - 2019</td>
<td>105,000</td>
</tr>
<tr>
<td>Developing screening methods and germplasm to improve tolerance to abiotic stress in pepper (<em>Capsicum spp.</em>)</td>
<td>Rural Development Administration, Korea</td>
<td>2018 - 2019</td>
<td>120,000</td>
</tr>
<tr>
<td>Nudging children toward healthier food choices: An experiment combining school and home gardens</td>
<td>Bill &amp; Melinda Gates Foundation and UK aid</td>
<td>2018 - 2020</td>
<td>270,000</td>
</tr>
<tr>
<td>Evaluation of F₁, vegetables in Thailand and India</td>
<td>Taiwan Council of Agriculture</td>
<td>2017 - 2018</td>
<td>30,240</td>
</tr>
<tr>
<td>Tomato variety trials in Thailand and market survey</td>
<td>Taiwan Council of Agriculture</td>
<td>2017 - 2018</td>
<td>30,400</td>
</tr>
<tr>
<td>Development of screening systems to evaluate the resistance of tomato germplasm to major diseases</td>
<td>Taiwan Council of Agriculture</td>
<td>2018</td>
<td>54,802</td>
</tr>
<tr>
<td>Strengthening cooperation between WorldVeg and COA on vegetable research and development</td>
<td>Taiwan Council of Agriculture</td>
<td>2018</td>
<td>342,200</td>
</tr>
<tr>
<td>Research Infrastructure Modernization (RIM) - Phase I</td>
<td>Taiwan Council of Agriculture</td>
<td>2018</td>
<td>1,600,000</td>
</tr>
<tr>
<td>Tomato trials for Hualien District Agricultural Research and Extension System</td>
<td>Taiwan Council of Agriculture</td>
<td>2018 - 2019</td>
<td>28,320</td>
</tr>
<tr>
<td>2017 Networking to Enhance International Cooperation in Vegetable Research and Development</td>
<td>Taiwan Ministry of Foreign Affairs</td>
<td>2017 - 2018</td>
<td>400,000</td>
</tr>
<tr>
<td>2018 Networking to Enhance International Cooperation in Vegetable Research and Development</td>
<td>Taiwan Ministry of Foreign Affairs</td>
<td>2018</td>
<td>600,000</td>
</tr>
<tr>
<td>Whole-genome resequencing of tomato to identify genes associated with durable resistance to bacterial wilt (<em>Ralstonia solanacearum</em>)</td>
<td>Taiwan Ministry of Science and Technology</td>
<td>2018 - 2019</td>
<td>35,607</td>
</tr>
<tr>
<td>Project Name</td>
<td>Donor</td>
<td>Duration</td>
<td>Amount (US$)</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------</td>
<td>-----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Cool peppers for climate-resilient <em>Capsicum</em> production in Taiwan</td>
<td>Taiwan Ministry of Science and Technology</td>
<td>2018 - 2021</td>
<td>98,880</td>
</tr>
<tr>
<td>Fine mapping of the late blight resistance genes derived from <em>Solanum pimpinellifolium</em> accession VI030462</td>
<td>Taiwan Ministry of Science and Technology</td>
<td>2018 - 2021</td>
<td>108,480</td>
</tr>
<tr>
<td>Horizon2020: A holistic approach towards the design of new tomato varieties and management practices to improve yield and quality in the face of climate change</td>
<td>Taiwan Ministry of Science and Technology</td>
<td>2016 - 2019</td>
<td>108,800</td>
</tr>
<tr>
<td>Phenotypic evaluation of the Vavilov mungbean accessions in Taiwan</td>
<td>Taiwan Ministry of Science and Technology</td>
<td>2018 - 2020</td>
<td>31,680</td>
</tr>
<tr>
<td>Unleashing the economic power of vegetables in Africa through quality seed of improved varieties</td>
<td>UK Department for International Development</td>
<td>2018 - 2020</td>
<td>2,555,580</td>
</tr>
<tr>
<td>IMMANA Project ENRICH</td>
<td>UK Department for International Development</td>
<td>2017 - 2019</td>
<td>22,947</td>
</tr>
<tr>
<td>Improving production of <em>Solanum aethiopicum</em> in Africa</td>
<td>UK Biotechnology and Biological Sciences Research Council</td>
<td>2018 - 2021</td>
<td>384,203</td>
</tr>
<tr>
<td>A comparative study of seed legislation and policies and their effect on the private and public seed sector in countries of the Asia and Pacific Region</td>
<td>United Nation Food and Agriculture Organization</td>
<td>2018</td>
<td>90,847</td>
</tr>
<tr>
<td>Improving the nutritional status and income of smallholder farmer households through scaling improved, nutrient-dense traditional African vegetables in the Zanzibar Islands</td>
<td>United States Agency for International Development</td>
<td>2018 - 2020</td>
<td>298,423</td>
</tr>
<tr>
<td>Deploying improved vegetable technologies to overcome malnutrition and poverty in Mali</td>
<td>United States Agency for International Development</td>
<td>2014 - 2019</td>
<td>12,595,166</td>
</tr>
<tr>
<td>Tajikistan nutrition-sensitive vegetable technologies - Phase 2</td>
<td>United States Agency for International Development</td>
<td>2018 - 2020</td>
<td>350,000</td>
</tr>
<tr>
<td>Development of fertilizer deep placement for vegetables in Mali</td>
<td>United States Agency for International Development</td>
<td>2018 - 2019</td>
<td>16,151</td>
</tr>
<tr>
<td>Project Name</td>
<td>Donor</td>
<td>Duration</td>
<td>Amount (US$)</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Women in Agriculture Network (WAgN) Cambodia: Gender and ecologically</td>
<td>United States Agency for International Development</td>
<td>2016 - 2018</td>
<td>26,756</td>
</tr>
<tr>
<td>sensitive agriculture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa RISING: Vegetables and associated best management practices in cereal-</td>
<td>United States Agency for International Development</td>
<td>2012 - 2018</td>
<td>1,216,142</td>
</tr>
<tr>
<td>based crop production systems to improve income and diets of rural and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>urban households in Northern Ghana and Southern Mali</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Validation of Pro-WEAI for the Gender, Agriculture, and Assets Project -</td>
<td>United States Agency for International Development</td>
<td>2016 - 2018</td>
<td>94,250</td>
</tr>
<tr>
<td>Phase 2 (GAAP-2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An assessment of three cash-based school meals modalities combined with</td>
<td>United States Department of Agriculture</td>
<td>2017 - 2018</td>
<td>103,380</td>
</tr>
<tr>
<td>complementary nutrition-sensitive literacy education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical partnership to support the Jharkhand Opportunities for Harnessing</td>
<td>World Bank</td>
<td>2017 - 2023</td>
<td>1,377,911</td>
</tr>
<tr>
<td>Rural Growth (JOHAR) project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical advisory assistance to Assam Agribusiness &amp; Rural Transformation</td>
<td>World Bank</td>
<td>2018 - 2023</td>
<td>1,400,197</td>
</tr>
<tr>
<td>Project (APART) for the Vegetable Value Chains</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilitating value addition and processing in the context of the cassava,</td>
<td>World Bank</td>
<td>2017 - 2019</td>
<td>292,239</td>
</tr>
<tr>
<td>maize, banana, vegetable, and livestock value chains (PRODEMA) activities to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>support fruits and vegetables value chain in Burundi</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
YOU MAKE IT HAPPEN

STRATEGIC LONG-TERM FUNDING

PROJECT FUNDING

Federal Ministry for Economic Cooperation and Development

USAID from the American People

European Commission

WORLD BANK

BARRY CALLEBAUT

BILL & MELINDA GATES FOUNDATION

MAFF

Ministry of Agriculture, Forestry and Fisheries
Our donors—governments, foundations, organizations, and corporations—help make the World Vegetable Center’s vision a reality. Their generous support strengthens our commitment to conduct research that realizes the potential for healthier lives and more resilient livelihoods for small-scale farmers and their families across Asia and Africa.

We recognize those donors that have provided USD 100,000 or more to further the Center’s work in 2018:
VENTURES WITH THE PRIVATE SECTOR

WorldVeg builds strong relationships with seed companies, the essential partners in the vegetable value chain.

Part of WorldVeg’s scaling strategy is to bring the products developed in the Vegetable Diversity and Improvement flagship—such as tomato resistant to bacterial wilt or heat-tolerant broccoli—to end users. Seed companies of all sizes are essential partners in ensuring seed reaches vegetable producers of all sizes, from home gardeners to market farmers to greenhouse growers.

To more closely collaborate with these important partners in the vegetable value chain, WorldVeg established two seed company consortia, one for Asia and one for Africa. Consortia members attend annual workshops for professional interaction with WorldVeg researchers, discuss common problems and explore solutions, evaluate field trials, and have early access to some improved WorldVeg lines.

The seed consortia provide a platform for action to work together for better impact in a faster time.

Asia Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium
The APSA-WorldVeg Vegetable Breeding Consortium was launched with 19 companies in 2017 and expanded to 33 companies in 2018. Sales data received from 11 consortium companies in 2017 showed that 14.2 tons of tomato and chili pepper seeds containing WorldVeg-developed germplasm were sold. “The vegetable breeding consortium is the right step toward feeding the world’s growing population,” said a consortium member. “The purpose of the consortium is quite meaningful as it gives equal opportunity to all companies, small or large, to access breeding materials.”
**Africa Vegetable Breeding Consortium (AVBC)**

At the 2018 African Seed Trade Association (AFSTA) Congress in Cairo, Egypt, WorldVeg Deputy Director General - Research David Johnson introduced the Africa Vegetable Breeding Consortium (AVBC) to delegates from 16 countries. Under the umbrella of AFSTA, an agreement to create AVBC was signed on 15 June 2018 for an initial period of 5 years. The AVBC Inaugural Workshop will be held 11-12 March 2019 at WorldVeg Eastern and Southern Africa, Arusha, Tanzania.

**Contributors: Pumpkin Breeding Project (Apr 2016 – Mar 2019)**

Ajeet Seeds, India  
Noble Seeds, India  
Rasi Seeds Pvt. Ltd., India  
VNR Seeds, India

**APSA–WorldVeg Vegetable Breeding Consortium**

Advanta Seed (United Phosphorus Limited Group), India  
Ankur Seeds Pvt. Ltd., India  
Clover Seed Co., Ltd., Hong Kong  
East-West Seed International, Thailand  
Enza Zaden Asia Sdn Bhd, Malaysia  
HM Clause India Pvt. Ltd., India  
I & B Seeds Pvt. Ltd., India  
JK Agri Genetics Ltd., India  
Kagome & Co., Ltd., Japan  
Kalash Seeds Pvt. Ltd., India  
Kaveri Seed Co., Ltd., India  
KF Bioplasts Pvt. Ltd., India  
Mahindra Agri Solutions Ltd., India  
MetaHelix Life Sciences Pvt. Ltd., India  
Musashino Seed Co., Ltd., Japan  
Namdhari Seeds Pvt. Ltd., India  
Nethra Enterprises Pvt. Ltd., India  
Noble Seeds Pvt. Ltd., India  
Nongwoo Seed India Pvt. Ltd., India  
Nunhems BV, Netherlands  
PT. BISI International Tbk, Indonesia  
PT. East West Seed Indonesia  
Rijk Zwaan, Netherlands  
Sakata Seed Corporation, Japan  
Sattva Seeds Pvt. Ltd., India  
SeedWorks International Pvt. Ltd., India  
Sing-Flow Seed Trading Co., Ltd., Taiwan  
Sungro Seeds Pvt. Ltd., India  
Syngenta Asia Pacific Pte. Ltd., Singapore  
Takii & Co., Ltd., Japan  
Tokita Seed India Pvt. Ltd., India  
United Genetics India Pvt. Ltd., India  
VNR Seeds Pvt. Ltd., India

**Contributors: Bitter Gourd Breeding Project (Apr 2017 – Mar 2020)**

Ankur Seeds Pvt. Ltd., India  
Hortigenetics Research (S.E. Asia) Ltd., Thailand  
HM Clause, Thailand  
I & B Seeds Pvt. Ltd., India  
JK Agri Genetics, Ltd., India  
Kaveri Seed Co. Ltd., India  
KF Bioplants Co., India  
Nuziveedu Seeds Ltd., India  
Sungro Seeds Pvt. Ltd., India

**Taiwan companies in-kind contribution: multiplying WorldVeg germplasm**

Agronew Trading Co., Ltd.  
All Lucky Seed Co., Ltd.  
Besgrow Seed Co., Ltd.  
Known-You Seed Co., Ltd.  
Kuang-Che Liu Organic Farm  
Mai-Zhi Li Farm  
Sing-flow Seed Trading Co., Ltd.  
Suntech Seed Co., Ltd.  
Your Chain Seeds Co., Ltd.
The annual Global R&D Week is one of the most enthusiastically anticipated institutional events at WorldVeg. The 2018 edition drew 90 colleagues from around the world to headquarters from 12-16 November 2018 to review achievements, brainstorm strategic moves for 2019, get updates on institutional actions and functions, attend field visits, and participate in fun activities.

Participants hailed from headquarters (Taiwan), regional offices of East and Southern Africa (Tanzania), West and Central Africa – Dry Regions (Mali), West and Central Africa – Coastal & Humid Regions (Benin), South Asia (India), East and Southeast Asia (Thailand) and project offices of Malaysia, Cambodia, Tajikistan, Nigeria, and Ghana. Dr. Marlis Lindecke, Chair of the Board of Directors Program Committee, shared her thoughtful advice and counsel throughout the week. Meeting rooms and halls rang with lively discussions, friendly exchanges, and laughter from the participants.

The week opened with a CBS News “60 Minutes” video on “Making Ideas into Reality at MIT’s Future Factory” to inspire innovation and thinking outside-the-box. This was followed by concurrent meetings of the four flagship programs: Healthy Diets, Vegetable Diversity and Improvement, Safe and Sustainable Value Chains, and Enabling Impact. Each flagship evaluated progress in their innovation clusters—the targets pursued through discovery, piloting, and scaling activities and ongoing improvement of products and service—and then took a look ahead, discussing strategic planning to optimize use of resources for achieving next year’s targets.

Tuesday highlighted the matrix between WorldVeg’s flagship programs and regional centers, with updates from flagship leaders and regional directors.

Exciting new directions, tools to improve efficiency, updates on new policies and processes, improving skills and methods for sound project management were among topics featured during the week. Staff shared details about the Research Infrastructure Modernization (RIM) project and WorldVeg seed consortia, reviewed seed quarantine procedures and ethical guidelines for projects involving human participants, and discussed criteria for establishing new breeding programs and open access publishing. A system for handling seed requests online and KD-Dart breeding software were introduced, and participants also practiced using Akvo Flow, an app for survey data collection.

On the last day of the week, the winners of the 2018 WorldVeg Photo Challenge were announced: Sorawit Limsiriwat, Sanjeet Kumar and Sopana Yule received prizes for their great images.

Participants cast votes to select winners of WorldVeg 2018 Science of Excellence Awards: First Place (US$3,000) was awarded to the International Mungbean Breeding Network team; Second Place (US$1,500) went to the Bitter Gourd Breeding team. Congratulations to all the winners!

A field trip was organized to the Shang Sheng cherry tomato grafting nursery in nearby Chiayi, Taiwan where WorldVeg’s bacterial wilt resistant eggplant lines are used as rootstocks. The nursery is an example of the successful impact of WorldVeg’s work. Because of the high demand, farmers can order only a maximum of 20,000 grafted seedlings and must place their orders a year in advance. The nursery generates annual revenue of US$327,000.

The successful event was celebrated with a wonderful outdoor dinner where everyone enjoyed jovial conversation and impromptu dancing.

We’re looking forward to the 2019 Global R&D Week, 11-15 November at HQ!
BUILDING THE BASE

Finding suitable rootstocks for tomato grafting.
Bacterial wilt (BW), caused by *Ralstonia pseudosolanacearum* is one of the most damaging plant diseases for Solanaceous crops in the tropics and subtropics. Grafting seedlings onto resistant rootstocks is an effective method to manage bacterial wilt. However, there are only a few reliable resistant rootstock sources available to growers. The eggplant line EG203 and tomato variety ‘Hawaii’ have been the most widely used rootstocks in South and Southeast Asia for many years, but there are signs that their resistance to bacterial wilt is breaking down.

With funding from Taiwan’s Council of Agriculture, BMZ/GIZ and the WorldVeg Innovation Fund, WorldVeg conducted trials in Taiwan, Mali, Burkina Faso and Tanzania to identify more resistant rootstock sources against different strains of the pathogen in different environments. In Taiwan, five newly identified bacterial wilt-resistant accessions (VI041809A, VI041943, VI041945, VI041979A, and VI041984) showed stable resistance to the disease and good compatibility with tomato grafting. In Mali and Burkina Faso, nine WorldVeg accessions (VI046103, VI041943, VI041945, VI041979A, VI045276, VI0411976 and VI041809A) were tested; VI041945 was found to be the most tolerant to bacterial wilt and VI034845 and VI041979A were relatively susceptible. In Burkina Faso, all rootstocks were tolerant to bacterial wilt except VI041976 and VI046103. In Tanzania, EG203, ‘Hawaii’ and Tengeru rootstocks were not resistant to bacterial wilt at four locations (Arusha, Moshi, Pemba, and Ungunja); new rootstocks VI041809A, VI041943, VI041945, VI041979A, and VI041984 are being evaluated.

Solanaceous accessions with potential as rootstocks were screened for resistance to root knot nematode, *Meloidogyne incognita* (RKN) and tolerance to flooding in Taiwan. Three *Solanum torvum* and *S. viarum* accessions (VI042547, VI047629 and VI048662) were found to be immune to RKN, whereas six eggplant accessions (VI040283, VI040360, VI040622-B, VI040666, VI040780 and VI040833-A) were found to be resistant. All the accessions of *S. torvum* have the ability to tolerate waterlogging up to 14 days under greenhouse conditions in Taiwan. *S. melongena, S. torvum* and *S. mammosum* accessions had strong recovery indexes.

Rootstocks showing resistance to bacterial wilt, root knot nematode and tolerance to flooding will be further evaluated on tomato in the field. New rootstocks with stable resistance to BW will be identified for different geographical regions.

After a seedling scion is cut and attached to a rootstock, it needs time, moisture and low light to allow the graft to heal. In Tanzania a prototype of a bamboo underground healing chamber was developed to work under high temperature conditions. Costs to operate the chamber are about US$200 per cycle for about 1000 seedlings. Tube and clip grafting methods were tested in Mali and Tanzania, funded by the WorldVeg Innovation Fund and BMZ/GIZ, respectively; farmers found the clip method was more suitable to their needs.

Grafting was introduced in new areas in Mali and Tanzania, where field extension officers were trained and farmers were exposed to the practice. Four grafting training programs were conducted in Honduras, Mali, South Korea and Thailand, and a total of about 120 trainees were trained. Visiting students and lecturers from India, Sri Lanka, Pakistan and Taiwan also received training in the method.
• Effects of manure and residual effects of manure are enhanced if the manure is used in combination with biochar for amaranth and African nightshade in Cameroon.

• Application of half of the recommended dose of NPK (15 :15 :15) fertilizers (400, 325 and 565 kg/ha for okra, onion and African eggplant, respectively) at shallow depth (1 cm for okra and onion; 5 cm for African eggplant) was found to be the most profitable strategy in Mali.

• Virus incidence was more (>90%) on tomato and pepper in some areas/seasons in Mali. Begomoviruses were found to be predominant in African eggplant, okra, pepper and tomato. Incidence was higher during the dry season than in the wet season.

• Ralstonia pseudosolanacearum Phylotype I (Asia) was isolated more frequently than Phylotype III (Africa) on Solanaceous vegetables, amaranth and basil in Mali and Benin. Six sequevars were observed, and most of the isolates were grouped with reference sequevars 46, 31 & 23, and a few others were grouped with sequevars 44, 18 & 14.

• Viral diseases (most leaf curl begomoviruses), powdery mildew (most caused by Oidium neolycopersici and few by Leveillula taurica), leaf spots (most Alternaria alternata) and southern blight (Sclerotium rolfsii) were the major diseases on tomato in Taiwan. Whitefly, leafminer, mealy bug and Rust mite were the insect pests recorded in white and pink nethouses. Both white and pink nethouses effectively reduced the incidence of viral diseases. Compared to open field conditions, the viral diseases and leaf spot had a lower incidence. Powdery mildew was found to be higher under nethouse conditions than in the open field, particularly in pink nethouses.

• Leaf area of tomato plants grown under pink nethouse conditions at WorldVeg HQ in Taiwan was 40% higher than the leaf area of plants grown under open field conditions. Fresh and dry biomass of plants grown under pink net conditions were 50 and 40% higher than on plants under open field conditions, respectively. Tomato plants grown under pink nethouse conditions gave 50-65% greater yield than plants grown under open field or white nethouse conditions.

• No Xanthomonas vesicatoria or X. gardneri causing bacterial spot on tomato were found among the 97 strains of Xanthomonas collected during 2000-2017 in Taiwan. In Taiwan, the population structure of tomato bacterial spot has shifted from X. euvesicatoria (Tomato race T1) to X. perforans (Tomato races T3 and T4).

• Begomovirus remains the predominant virus (>80% of samples) limiting tomato production in Taiwan; TYLCTHV (TH) was the major virus detected. All samples tested negative for ToLCTWV (TW). Tomato chlorosis virus (ToCV, Crinivirus) was the second most-common virus in the samples.
- *Tomato leaf curl New Delhi virus* was identified as the predominant virus infecting bitter gourd samples from India.

- In a survey by WorldVeg and the Taiwan Agricultural Research Institute, 56 *Colletotrichum* isolates were collected from *soybean* in Taiwan and identified by morphology criteria. *Colletotrichum truncatum* was the predominant pathogen, and few *C. gloeosporioides* isolates were also found. The molecular analysis based on ITS and beta-tubulin gene sequences of 10 representative strains also confirmed them as *C. truncatum*.

- The predominant *root knot nematode* (RKN) species isolated from nine vegetable crops including eggplant and tomato in WorldVeg HQ fields was identified as *Meloidogyne incognita*. Five virulent *M. incognita* pure line cultures were isolated and multiplied for nematode resistance screening.

- Pathogenicity/phylootype of *Ralstonia solanacearum* strains at WorldVeg HQ were characterized and Pss1632 was selected as a representative Phylotype II strain for further screening.

- Three *wild tomato* (*Solanum pimpinellifolium*) accessions (VI037272, VI044916, VI005591) showed resistance/tolerance to Phylotype I (Pss4), and 6 accessions (VI005797, VI009088, VI029740, VI030394, VI037270, VI037280) were resistant/tolerant to Phylotype II (Pss1632) in nethouse conditions in both spring and autumn seasons in Taiwan.

- 15,933 Solanaceous seedlings (~10% of total plants) were screened for viroids prior to planting in WorldVeg HQ fields in Taiwan.

- Of 1,584 Solanaceous seed lots screened for viroids by the WorldVeg HQ Seed Health Quarantine Lab (SHQL) in Taiwan, 1,217 seed lots were submitted to the Bureau of Animal and Plant Health Inspection and Quarantine (BAPHIQ) for testing and issue of Phytosanitary Certificates for export outside Taiwan.

- 4,422 Solanaceous seedlings were tested by the SHQL at WorldVeg HQ in Taiwan and viroid negative seedlings were distributed to district agricultural research offices, research institutes, seed companies and farmers within Taiwan.

- In Benin, six WorldVeg tomato accessions, VI043614 (Hawaii 7996), Padma F1 (East-West Seeds) and TOUNVI (local variety) were compared for bacterial wilt resistance. VI043614 and Padma were the best performing tomato varieties and the local variety was the most susceptible.

- WorldVeg tomato lines (AVTO1219, AVTO1311, LBR9 and LBR11) were resistant to *late blight*; no disease was found up to 55 days after transplanting in Cameroon. AVTO1219 recorded the highest yield (24.55 t/ha). WorldVeg lines need to be firmer to facilitate harvest and postharvest handling.

- The high percentage of bolting of the local *onion* variety ‘Chagary’ confirmed the low quality of local seed in Cameroon. Studies also confirmed that ‘Goudami’, a dry season variety, can be cultivated in the rainy season.
• Susceptibility of amaranth varieties to bacterial wilt in the field in Cotonou, Benin, increased with cutting, except for three varieties (AM-NKGN, UG-AMES13-2 & Benin local).

• Xentari® (Bacillus thuringiensis subsp. aizawai) was found to significantly reduce the larval survival time of leaf webber (Spoladaea recurvalis) on amaranth and horse purslane in Taiwan. The host plants do not alter the susceptibility of S. recurvalis to biopesticides.

• Three commercial fungal antagonists (Streptomyces spp., Trichoderma spp., synchronized enzymes) showed significant suppression of Southern blight disease (Sclerotium rolfsii) incidence in tomato and pepper seedlings under greenhouse conditions in Taiwan.

• Tuta absoluta was found to be susceptible to Beauveria bassiana (Green Beauveria® and BB Power®), Bacillus thuringiensis (Delfin® and Green larvicide®) and neem (Econeem® and Ecotin®) biopesticide formulations in India.

• A commercial Metarhizium anisopliae strain (ICIPE78: Achieve®) significantly controlled spider mite (Tetranychus sp.) on eggplant under nethouse conditions at Samanko, Mali.

• Three commercially available pheromone lures were evaluated against Tuta absoluta in repeated field trials in three different locations in Andhra Pradesh, India. The weekly trap catches of T. absoluta male moths by the pheromone lures (28-33) differed significantly from the untreated control (2 moths/trap) across locations and seasons. The trapped insects had no significant effects in reducing T. absoluta larval damage in the leaves (10-12%) and the fruit (31-32%).

• Four rootstocks (VI046103, VI041943, VI041945 and VI041809A) were tested for clip and tube grafting methods in Mali; the clip method was better (60 to 100% success rate) compared to the tube method (50-70%). The clip method also was found to be better in Tanzania.

• Fifty solanaceous accessions were screened at WorldVeg HQ in Taiwan for resistance to root knot nematode (RKN). Three Solanum torvum and S. viarum accessions (VI042547, VI047629 and VI048662) were found to be immune to RKN, whereas six eggplant accessions (VI040283, VI040360, VI040622-B, VI040666, VI040780 and VI040833-A) were found to be resistant.

• Solanum melongena, S. torvum, S. viarum and S. mammosum accessions were screened for short-term waterlogging tolerance. All the accessions of S. torvum have the ability to tolerate waterlogging up to 14 days under greenhouse conditions in Taiwan. S. melongena, S. torvum and S. mammosum accessions were found to have a strong recovery index.

• Five newly identified bacterial wilt-resistant accessions (VI041809A, VI041943, VI041945, VI041979A, and VI041984) showed stable resistance to the disease in field in Taiwan.
• Mungbean grains in hermetic storage bags (Zbag®) were consistently less damaged by bruchids (12% over a 9-month period), compared to 100% damage in normal storage bags in Taiwan.

• 575 participants [335 (58.2%) men and 240 (41.8%) women] attended three training sessions on “Recognizing tomato leaf miner (Tuta absoluta) and its life cycle”, “Preparation of healthy soil substrates for cultivation of healthy vegetable seedlings” and “Technology for cultivation of prospective varieties of mungbean and preparation of various dishes from them” in Tajikistan.

• Ten solar dryers, 18 sorting tables and 22 storage structures (different designs) were installed/demonstrated in Odisha, India. Twenty-six small scale processing demonstrations (production of onion flakes, paste and powder, for example) were conducted and processing equipment including grinders, peelers and slicers were provided to farmers.

• About 120 trainees received training on vegetable grafting in Honduras, Mali and South Korea.

• About 14,600 farmers (79% women) were trained on good agricultural practices in Sikasso, Mopti and Timbuktu regions in Mali. Almost 17,000 farmers have adopted GAP and GMP practices such as pest and disease management, soil fertility and conservation and postharvest management.

• Vegetable Business Hubs have been implemented with six young farmer groups in the Arumeru region in Tanzania. The well-coordinated groups improved their agronomic practices and vegetable production systems. Stronger intra- and inter-group organization has improved access to finance and made their enterprises more sustainable. Cost benefit analysis show that individual youths are making a net profit of US$575-1,581 per season and per acre depending on the crop grown, with snow peas, French beans and tomato seeds the most profitable.

• About 836 farmers (47% women and 31% youth) have been trained in good agricultural and manufacturing practices (GAP, GMP) in Zanzibar and Arumeru District, Tanzania.

• A study and focus group discussions on “Market assessment of solar dried vegetables in Northern Tanzania” collected data from 252 vegetable producers who had received training on vegetable drying. Households know that vegetables dried in enclosed solar dryers are more hygienic, retain original color of vegetables, are more nutritious, and have better taste than vegetables dried under the open sun. However, only 33% of the households were drying vegetables using solar dryers. Rural consumers were willing to pay an average of US$2 per kilogram for dried tomatoes.
TIME TO SHINE

The mungbean industry is about to be dazzled by bright, shiny, bruchid-resistant lines developed by WorldVeg.
A versatile legume that’s also an excellent source of digestible protein, mungbean forms an important part of daily diets as dal (thick stew from dehulled and split grains) and in sweets, snacks, and savory foods across in the Indian subcontinent, and as cake, sprouts, noodles, and soups in China, Iran, Indonesia, Myanmar, Thailand, and Vietnam. India accounts for 65% of the world’s mungbean acreage and 54% of global production.

Mungbean seeds can be dull green, shiny green, or yellow. The shiny green seeds are in great demand in India.

Storing the seeds, however, tests the mettle of mungbean growers, traders and consumers, who find they share far too much of their favorite legume with bruchids (Callosobruchus spp.). These tiny beetles can cause losses up to 100% in stored mungbean. Bruchids reduce the nutritional and market value of the grain and render the seeds unfit for human consumption, agricultural and commercial uses.

Although fumigation helps to keep the bruchids at bay, the highly toxic chemicals leave residues on the grain, compromising food safety. While there are a few dull green mungbean varieties resistant to bruchids, shiny green mungbean are susceptible to the pests.

Now, fans of the shiny type no longer must watch helplessly as bruchids devastate their mungbean stocks: WorldVeg has bred improved shiny green mungbean lines (AVMU1601, AVMU1605 and AVMU1606) that resist these destructive storage pests.

The improved lines were tested repeatedly against bruchids and produced positive results. Farmers growing improved shiny mungbean can store their seeds without worrying about bruchids munching the lot.

“Bruchid resistance is one of the most important traits that needs to be incorporated in Indian mungbean cultivars,” said Aditya Pratap, Principal Scientist (Plant Breeding) at the Indian Institute of Pulses Research. “There are few sources known for this trait. The AVMU lines available through the Australian Centre for International Agricultural Research (ACIAR) International Mungbean Improvement Network project are reported to be resistant to bruchids and will be a valuable resource for this trait as well as other important traits such as resistance to yellow mosaic disease, longer pods and high yield.”
A total of 7196 seed samples from 4197 genebank accessions were distributed to seed requesters from 39 countries, and a total of 2336 seed samples from 782 breeding lines were sent to seed requesters from 43 countries.

In 2018, 1004 accessions were deposited in the Global Seed Vault in Svalbard for long-term backup. In total 16,622 accessions of the WorldVeg collection are now stored in Svalbard.

In total, 1651 genebank accessions were regenerated in 2018.

Nine Taiwan seed companies collaborated with WorldVeg on germplasm regeneration.

The WorldVeg amaranth germplasm collection (about 800 accessions of 18 species) was genotyped and a core collection of 124 accessions representing the overall diversity was selected for characterization.

In the scope of the European Union-funded Horizon2020 G2P-SOL project, core collections of about 400 accessions were produced for tomato, pepper and eggplant. Half of the entries are WorldVeg materials. The collections will be phenotyped in 2019/20 at multiple locations in Europe and Asia.

Resistance to whitefly was mapped in populations derived from S. galapagense and S. pimpinellifolium. Two quantitative trait loci (QTLs) were detected on chromosomes 2 and 3 of S. galapagense and further two QTLs on chromosomes 5 and 11 were found in S. pimpinellifolium.

Two QTLs for resistance against late blight strain Pi41 from Taiwan were found in S. habrochaites on chromosomes 7 and 11.

105 inbred lines and germplasm accessions, including C. annuum, C. annuum var. glabriusculum, C. baccatum, C. chacoense, C. chinense, and C. frutescens were screened for Chili veinal mottle virus (ChiVMV) resistance at the seedling stage at WorldVeg HQ in Taiwan. 36 new resistant lines were identified for use as resistance sources in breeding.

47 advanced sweet pepper lines were screened for Tomato mosaic virus (ToMV) resistance at WorldVeg HQ in Taiwan and 8 resistant lines were identified.

The reaction of Capsicum annuum, C. baccatum, and C. chinense to chili anthracnose (Colletotrichum acutatum) was assessed in mature green and red fruit stages of F2 plants from interspecific crosses at WorldVeg HQ in Taiwan. The results indicated that two genes with epistatic interaction are conditioning resistance.

Screening of 186 African eggplant accessions and wild relatives with the most virulent Ralstonia solanacearum strains Pss97 and Pss2016 at WorldVeg HQ in Taiwan revealed high levels of bacterial wilt resistance in Solanum torvum, S. incanum and S. sisymbriifolium.

More than 100 vegetable variety demonstration trials were implemented in Mali, Ghana and Burkina Faso.
• **Mungbean** accessions highly resistant to dry root rot, anthracnose and powdery mildew were identified in the mungbean minicore collection in field trials in India, Bangladesh, Myanmar, Australia and at WorldVeg HQ in Taiwan through the International Mungbean Improvement Network.

• Screening of eggplant accessions including wild relatives at WorldVeg HQ in Taiwan revealed high levels of resistance to spider mite, eggplant and fruit and shoot borer and whitefly. The highest levels of resistance to spider mite were detected in *Solanum macrocarpon* accessions.

• 50 *urdbean* and 40 *vegetable soybean* F₆ lines resistant to Mungbean yellow mosaic disease were developed. The disease resistant soybean lines were developed with Punjab Agricultural University (PAU), Ludhiana, India.

• Four WorldVeg dual purpose tomato lines are undergoing multilocation testing in three Indian states in trials conducted by four seed company collaborators as part of the BMZ Green Innovation and Resist-Protect-Detect projects. Three lines were included in the UK aid trials established in Ghana and Nigeria.

• 100 advanced breeding lines and 900 F₁ hybrids of bitter gourd were characterized for horticultural traits and disease resistance at the WorldVeg East and Southeast Asia Research and Training Station, Kasetsart University, Kamphaeng Saen, Thailand. Trait data and a photo database of fruit traits were shared with breeders of private seed companies supporting WorldVeg’s bitter gourd breeding program.

• A gene for powdery mildew resistance in bitter gourd was fixed in 23 F₈ lines at the WorldVeg East and Southeast Asia Research and Training Station, Kasetsart University, Kamphaeng Saen, Thailand.

• Four open pollinated pumpkin lines resistant to multiple viruses were evaluated for nutritional quality in collaboration with Kasetsart University, Thailand.

• In Tanzania, promising F₅ amaranth (*Amaranthus cruentus*) lines were selected from bulk lines in replicated multilocation trials for high vegetable and seed yield.

• Multilocation trials in Tanzania identified a high yielding and farmer-preferred African eggplant (*Solanum aethiopicum*) line. The line also was tolerant to bacterial wilt in greenhouse trials at WorldVeg headquarters.

• **Demonstration trials** introducing 5 amaranth, African nightshade and Ethiopian mustard varieties to 400 farmers were held at two locations in Northern Tanzania.

• The second validation year for mini-tunnels in onion bulb production during the rainy season was accomplished at WorldVeg West and Central Africa - Dry Regions, Mali. The technology increased bulb yield from 9.8 t/ha in the open field to 20.7 t/ha.

• 15 high yielding onion families with high quality bulbs were selected and advanced during the dry and cool season in Mali.

• 680 kg of onion mother bulbs and 60 kg of onion breeder’s seeds, as well as 371 kg of purified mother bulbs of five shallot varieties were produced in Mali.
The World Vegetable Center strives to combat malnutrition and improve the diets of small children and women of reproductive age. In 2018 WorldVeg concluded the Homegarden Scaling Project funded by the United States Agency for International Development (USAID) Bureau of Food Security in Cambodia, Liberia, Kenya, Tanzania and Uganda. For three years, this project focused on improving the quantity and quality of traditional vegetables in home gardens by distributing seed kits and providing training on good agricultural practices and nutrition. The project also stimulated demand for vegetables by creating awareness about healthy diets.

Through collaboration with 32 partners, about 50,000 children were reached through training and distribution of seed kits to more than 40,000 households, organized in 1090 groups in 400 villages.

Randomized control trials and other studies revealed a range of pertinent outcomes and impacts. In the last year in Cambodia, Kenya, Tanzania and Uganda, the majority of households applied eight or more different improved agricultural practices such as use of improved seeds, transplanting, and production and use of safe compost. As the use of chemical pesticides declined in Kenya and Tanzania, the application of natural and safe homemade pesticides increased.
In Cambodia, Kenya and Tanzania, the number of species grown by each household went up significantly; this is an important outcome, as a diverse range of traditional vegetables from a home garden can provide many essential micronutrients to diets, such as vitamins A, B and C, folate, iron, calcium and zinc. However, measuring the impact of project activities on dietary diversity scores was a challenge; while many different species were grown, most fell within the same dietary group: dark green leafy vegetables.

In Cambodia we were able to demonstrate that through improved home garden practices, the availability of vegetables throughout the year was extended by 4 months, providing nutritious food during times of scarcity. The amount of vegetables consumed almost doubled in Cambodia. In Kenya, Tanzania, and Uganda, more than 90% of participating households mentioned that the quantity of vegetables consumed by children increased, and that the health of household members had improved.
• An endline survey was conducted for the randomized control trial of the Homegarden Scaling Project in Cambodia, Kenya, Tanzania and Uganda. A total of 1786 households were interviewed who had also participated in the baseline survey. Preliminary results show that the project intervention increased the share of households producing vegetables by 43% in Cambodia and 17% in Tanzania. The intervention had a positive effect on the diversity of vegetables grown for home consumption and selling, and the adoption of good agricultural practices in Cambodia, Kenya and Tanzania. Households were able to extend the period of producing vegetables by 4.1 months in Cambodia and 1.3 months in Tanzania.

• In the Mali Horticulture Scaling Project, 1,373 new latrines were built, 535 latrines rehabilitated, and 1,035 latrines equipped with a soap handwashing station in Mopti and Sikasso regions. A total of 9,811 households were reached through WASH (water-sanitation-hygiene) activities. A total of 12,189 primary beneficiaries (81% women) and 32,809 secondary direct beneficiaries (84% women) received training on improved nutrition in Mali.

• A collaborative research initiative with Wageningen University and Research and other partners was completed in Kenya to validate a smartphone application that collects and aggregates data on fruit and vegetable intake and food choice motives. Preliminary findings show that urban Kenyan consumers have different underlying motives related to their food choices, such as food safety, mood, nutrition, accessibility, functional health, accessibility, likeness, natural content, and familiarity.

• In Keyna, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)-funded NutriSensProm project assessed the effect of messages and delivery channels on rural farm households’ decisions to produce and consume vegetables. It was found that nutrition-specific training was more effective than nutrition-sensitive training.

• The Nepal School Meals Program plays a key role in the government’s strategy to increase children’s academic and nutritional outcomes. Home-grown school feeding (HGSF) may further strengthen local ownership and improve meal quality, but there is a lack of evidence for impact. With funding and in collaboration with the World Food Programme in Nepal, pilot HGSF approaches were compared and recommendations to the government shared in a workshop.

• With funds from the World Food Programme, 15 school gardens were set up in Nepal and 450 children in grades 4 and 5 received training in nutrition and gardening using the school garden as a learning tool. The children’s parents additionally received training in home gardening and nutrition.
• **Ethnobotanical studies** in Taiwan indicated a high diversity of primary/staple foods such as cereals, legumes, roots, and tubers in the past, but rice (42%) and wheat (34%) have become the major staple foods over the past 50 years. Thirty plant species considered to be traditional staple foods were identified and their nutritional values compared to rice and wheat.

• A list of 150 species considered **indigenous vegetables** in Taiwan were identified. They are highly nutritious and diverse, and half of them are used as food and herbal remedies. The study describes the plant foods native to the island and their potential to enrich current food systems for healthier diets.

• Reported **functional properties** (anticarcinogenic, antimicrobial, antioxidative, antidiabetic and anti-inflammatory, among others) and information on folk medicine uses or herbal remedies were reviewed for 150 Taiwan indigenous vegetables. The study helps to prioritize plant species for further research and future applications.

• Results from previous **collaborative studies** were published: 1) Vegetables, fruits and phytounutrients consumption patterns in Taiwan, 2) Major anti-nutrient components and their concentrations in vegetable families; and 3) Bitter gourd reduces elevated fasting plasma glucose levels in a randomized placebo controlled cross over studies among prediabetics in Tanzania and India.

• **Berries of black nightshade** (*Solanum scabrum*) were provided to Rutgers University (USA) to determine variation in phytochemical contents including toxic glycoalkaloids. Analytical tools developed for this purpose could guide selection and breeding of genotypes with good nutritional properties and safe levels of glycoalkaloids and saponins.

• Collaboration between WorldVeg and **Rutgers University** researchers led to the publication of two papers on micronutrient content and horticultural performance of traditional vegetables amaranth and black nightshade.
WORLDVEG MUNGBEAN VARIETIES REACH 1.2 MILLION SMALLHOLDER FARM HOUSEHOLDS
Research into this nutritious legume returns big benefits to agriculture in Asia.

Past studies have described the success of the World Vegetable Center’s mungbean improvement program in Asia, but WorldVeg lacked nationally representative data on the adoption of mungbean varieties. Such data are important to better target interventions and monitor progress over time. With support from the UK Government’s Department for International Development (DFID) and the Federal Ministry of Economic Cooperation and Development (Germany), the Center quantified the adoption of improved mungbean varieties in Bangladesh, India, Myanmar and Pakistan.

Mungbean farmers often are unable to tell the name of variety they grow as they use some of their own grain harvest as seed, or buy mungbean grains from the market for use as seed. The study employed a Delphi method in which local experts estimated varietal adoption rates, first individually and then through discussion in an expert panel.

The adoption studies were locally implemented by Teresa Sequeros in Myanmar, Saima Rani in Pakistan, Md. Abdur Rashid in Bangladesh, and Nithya Vishwanath Gowdru in India.

The study involved 259 experts and 19 expert panels. The results show that international mungbean breeding research conducted by the World Vegetable Center in partnership with national agricultural research systems created substantial impact. Improved mungbean varieties developed from WorldVeg germplasm accounted for 93% of the mungbean area planted in Pakistan, 77% in Myanmar, 67% in Bangladesh, and 27% in India. WorldVeg varieties were planted on 1.7 million hectares of land and reached an estimated 1.2 million smallholder farm households producing mungbean.

The data show much variation in the adoption of improved varieties and agricultural practices at subnational levels, which points at opportunities to increase mungbean yields through the adoption of existing and new technologies, including better varieties with more comprehensive resistance to major pests and diseases and tolerance to heat, drought and salinity.
ENABLING IMPACT

- A study on the adoption of mungbean varieties in Bangladesh, India, Myanmar and Pakistan showed that WorldVeg varieties were planted on 1.7 million hectares by about 1.2 million farm households.

- A study on the adoption on amaranth varieties in Tanzania and Kenya found that WorldVeg varieties were adopted on 47% of the area planted to amaranth in Tanzania and 20% in Kenya, benefiting 231,000 farm households.

- Primary data were collected for: (a) an ex-ante impact assessment of mechanical mungbean harvesting in Myanmar; (b) an ex-ante impact assessment of insect-resistant tomato varieties in India; (c) a randomized controlled trial of school and home gardens in Nepal; (d) an ex-post impact evaluation of WorldVeg amaranth varieties in Tanzania; and (e) an ex-post impact assessment of home gardens in Kenya, Mali, Uganda and Cambodia.

- The APSA-WorldVeg Vegetable Breeding Consortium expanded from 19 companies in 2017 to 33 companies in 2018. Sales data received from 11 consortium members in 2017 showed that they sold 14.2 tons of tomato and chili pepper seed containing WorldVeg-developed germplasm.

- HARVEST, the WorldVeg knowledge management system (https://worldveg.tind.io), was further populated with data during 2018. The system provides easy access to publications, research data, study protocols, and data collection tools.
The WorldVeg-Taiwan Seed Industry Exchange Platform, launched in 2017 to strengthen the Center’s relationship with the seed industry in Taiwan, expanded to 87 individuals representing 60 different companies and organizations. Twenty-four announcements were shared with platform members in 2018. A tour of the WorldVeg genebank attracted 37 participants from 20 seed companies. A demonstration of the Center’s vegetable breeding practices drew 74 participants.

Nine Taiwan companies contributed to the conservation of global vegetable genetic resources by **regenerating and multiplying seed** of 245 genebank accessions.

**Ethical guidelines** for research and development projects involving human participants were published by the Institutional Biosafety and Research Ethics Committee (IBREC).

About 30 scientists, trainees and students received **biometrics support** including evaluation and advice on experimental designs, management and analyses of data, statistical review of papers, and presentation of results.
OPPORTUNITIES TO GROW

PhD candidates gain knowledge and practical skills in WorldVeg research programs.

Rawdzah Mat Ali (above) Graduate Student from the Universiti Kebangsaan Malaysia, worked at WorldVeg headquarters in Shanhua, Taiwan for 32 months (November 2015 – July 2018) on “Phylogeographical structure in Pheromone Biosynthesis Activating Neuropeptide and/or Odorant Binding Proteins of Pieris rapae and Phyllotreta striolata populations in Southeast Asia” under the guidance of WorldVeg’s Lead Entomologist, Dr. Srinivasan Ramasamy. She was co-supervised by Dr. Malini Periasamy, Consultant (Biotechnology) at WorldVeg and Dr. Idris Abd. Ghani, Professor from Universiti Kebangsaan Malaysia. Rawdzah’s work characterized the genetic diversity of cabbage butterfly and striped flea beetle in Southeast Asia, which will enable the development of precise integrated pest management strategies, especially those based on pheromones and biocontrol agents. Her work contributed to the project “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” led by WorldVeg. Rawdzah presented a part of the work at the 30th International Horticultural Congress (IHC 2018) in Istanbul, Turkey in August 2018, during which she received the Best Oral Presentation award.

Mathieu A.T. Ayenan (left) from Benin is currently a PhD student in plant breeding at the University of Ghana, West Africa Centre for Crop Improvement (WACCI). His WACCI-funded project focuses on improvement of heat tolerance in tomato.

Heat stress is one of the major factors constraining tomato production in West Africa. Mathieu wants to contribute to address this challenge through his proposed PhD research. His project aims to map tomato farmers, traders and consumers’ preferences; evaluate the performance of tomato lines under heat stress; and dissect the genetic architecture of heat tolerance. In 2018, he successfully defended his proposal. He will commence the implementation of his research in 2019.
The project will be carried out in Ghana and Benin. Mathieu has benefited from the expertise and guidance of WorldVeg Tomato Breeder Dr. Peter Hanson, a member of his supervisory committee, in the development of his proposal. He also obtained lines from WorldVeg that he has included in his study. He is very excited about working under the supervision of Dr. Hanson to understand the genetics of heat tolerance and to ultimately develop tomato lines with increased heat tolerance.

**Caleb Manamik Breria (below right)** from Papua New Guinea spent 36 months (October 2015 to September 2018) in a PhD internship with the Biotechnology and Molecular Genetics Laboratory at WorldVeg headquarters in Taiwan. Caleb is sponsored under Taiwan’s ICDF scholarship and is registered as a PhD student in the Department of Tropical Agriculture & International Cooperation, National Pingtung University of Science and Technology.

For partial fulfillment of his PhD thesis, Caleb was attached to Dr. Roland Schafleitner’s Biotechnology & Molecular Genetics Lab. His research focused on Genome Wide Association Studies (GWAS) into the mungbean minicore collection. This included a population panel of 297 landraces in which a Genotype by Sequencing (GBS) library was created. He also assessed individual mungbean phenotypes for germination percentage under a certain salinity threshold. From the observed phenotypes and GBS library, Single Nucleotide Polymorphism (SNP) markers underlying the loci for salinity stress tolerance were mined through GWAS.

Results from the study included establishing the minicore GBS library, determining population structure for future GWAS investigation, and identifying a locus in chromosome 5 underlining seed coat luster. Loci associated to salinity tolerance in mungbean were also mined.

Caleb is compiling his dissertation and publications and intends to graduate in June 2019.

**Learn more about study opportunities at WorldVeg:**
[https://avrdc.org/join-us/research-and-training-opportunities/]
DIVERSITY IS THE KEY

Diversity is a key concept for research at the World Vegetable Center. It’s also the foundation for our approach to human resources. We value diversity among our staff, teams and partners. In 2018:

The Center’s 383 staff members represented 28 nationalities

45% of WorldVeg staff were women

20% of staff recruited internationally were women professionals

94 students (56 men and 38 women) from 17 countries received training/internships at WorldVeg facilities.

40% of students trained were women
The World Vegetable Center reaches out through various media to inform the public about our activities and engage people everywhere in the effort to diversify diets and economies with vegetables. In 2018:

Monthly unique visitors to worldveg.org: **24,000+**
Subscribers to *Fresh*, the WorldVeg newsletter: **7,827**

Facebook followers: **15,570**
Twitter followers: **4,673** (@go_vegetables)
WorldVeg channel, **YouTube**: **4,282**

Media mentions: **190**, including articles in *Appropriate Technology*, *FoodTank*, *Devex*, *HortiDaily*

Visitors: More than **1,804 visitors from 66 countries** toured WorldVeg headquarters and regional offices to learn about the Center’s research and projects, and see WorldVeg improved varieties, traditional vegetables, and new technologies in our Demonstration Gardens.

**REACHING OUT**

WorldVeg promoted its activities in numerous exhibitions in 2018, including:

**African Seed Trade Association (AFSTA) 2018 Congress**
Cairo, Egypt, 27 February - 1 March

**International Horticultural Congress**
Istanbul, Turkey, 12-16 August

**Crawford Fund Conference**
Canberra, Australia, 13-14 August

**African Green Revolution Forum**
Kigali, Rwanda, 3-7 September

**Taiwan Innotech Expo**
Taipei, Taiwan, 27-29 September

**World Food Prize Borlaug International Symposium**
Des Moines, Iowa USA, 17-19 October

**Intl Conference on Nutrition-Sensitive Agriculture and Food Systems**
Tagaytay City, Philippines 7-10 November

**Seed & Seedling Festival**
Xinhua, Taiwan, 1 December
# BOARD OF DIRECTORS

<table>
<thead>
<tr>
<th>NAME</th>
<th>COUNTRY</th>
<th>APPOINTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Junne-Jih Chen – Board Chair</td>
<td>Taiwan</td>
<td>Apr 2011</td>
</tr>
<tr>
<td>Dr. Masa Iwanaga – Vice Chair</td>
<td>Japan</td>
<td>Apr 2016</td>
</tr>
<tr>
<td>Dr. Chi-chung Chen</td>
<td>Taiwan</td>
<td>Feb 2018</td>
</tr>
<tr>
<td>Dr. Myoung Rae Cho</td>
<td>Korea</td>
<td>Aug 2017</td>
</tr>
<tr>
<td>Mr. George Culaste</td>
<td>Philippines</td>
<td>Nov 2017</td>
</tr>
<tr>
<td>Dr. Richard Ellis</td>
<td>UK</td>
<td>Apr 2017</td>
</tr>
<tr>
<td>Dr. Julie Howard</td>
<td>USA</td>
<td>Apr 2017</td>
</tr>
<tr>
<td>Dr. Marlis Lindecke</td>
<td>Germany</td>
<td>Jun 2015</td>
</tr>
<tr>
<td>Mr. Gordon MacNeil</td>
<td>Canada</td>
<td>Apr 2016</td>
</tr>
<tr>
<td>Dr. Bonnie McClafferty</td>
<td>USA</td>
<td>Dec 2017</td>
</tr>
<tr>
<td>Mr. Shige Hiro Nishiumi</td>
<td>Japan</td>
<td>Nov 2017</td>
</tr>
<tr>
<td>Ms. Ndidi Nwuneli</td>
<td>Nigeria</td>
<td>Nov 2018</td>
</tr>
<tr>
<td>Ms. Cathy Reade</td>
<td>Australia</td>
<td>Apr 2013</td>
</tr>
<tr>
<td>Dr. Lindiwe Sibanda</td>
<td>Zimbabwe</td>
<td>Nov 2018</td>
</tr>
<tr>
<td>Dr. Chongrak Wachrinrat</td>
<td>Thailand</td>
<td>Feb 2016</td>
</tr>
<tr>
<td>Dr. Dennis Wang</td>
<td>Taiwan</td>
<td>Feb 2018</td>
</tr>
<tr>
<td>Dr. Marco Wopereis, ex-officio member</td>
<td>The Netherlands</td>
<td>Apr 2016</td>
</tr>
</tbody>
</table>

**Terms concluded in 2018**

<table>
<thead>
<tr>
<th>NAME</th>
<th>COUNTRY</th>
<th>APPOINTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Jen-Pin Chen</td>
<td>Taiwan</td>
<td>Nov 2014</td>
</tr>
<tr>
<td>Dr. Hsueh-Shih Lin</td>
<td>Taiwan</td>
<td>Apr 2017</td>
</tr>
</tbody>
</table>
### FINANCE

<table>
<thead>
<tr>
<th>WorldVeg</th>
<th>CGIAR recommended range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash management on restricted operations</td>
<td>0.13</td>
</tr>
<tr>
<td>Adequacy of reserves</td>
<td>116 days</td>
</tr>
<tr>
<td>Short-term solvency</td>
<td>135 days</td>
</tr>
</tbody>
</table>

#### 2018 Revenues (in ’000 USD)

<table>
<thead>
<tr>
<th></th>
<th>WorldVeg</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted grants</td>
<td>8,742</td>
<td>48%</td>
</tr>
<tr>
<td>Restricted grants</td>
<td>9,353</td>
<td>51%</td>
</tr>
<tr>
<td>Other revenues</td>
<td>279</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18,374</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

#### Unrestricted Grants

- Republic of China (ROC) / Taiwan: 4,768
- United Kingdom / UK Department for International Development (UKaid / DFID): 2,496
- United States / United States Agency for International Development (USAID): 910
- Australia / Australian Centre for International Agricultural Research (ACIAR): 323
- Thailand: 136
- The Philippines: 50
- Korea: 50
- Japan: 9

**Sub-total**: 8,742

<table>
<thead>
<tr>
<th></th>
<th>WorldVeg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other revenues</td>
<td>279</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,021</strong></td>
</tr>
</tbody>
</table>

#### Restricted Grants

- United States / United States Agency for International Development (USAID): 3,321
- Republic of Germany / BMZ / GIZ: 1,569
- Republic of China (ROC) / Taiwan: 1,525
- Australia / Australian Centre for International Agricultural Research (ACIAR): 490
- United Kingdom -/ UK Department for International Development (UKaid / DFID): 464
- State Governments of India: 431
- Private seed sector companies; Asia and Pacific Seed Association (APSA): 361
- Japan / Ministry of Agriculture, Forestry and Fisheries: 158
- Others (projects with expenses less than 150K USD): 1,034

**Sub-total**: 9,353

<table>
<thead>
<tr>
<th></th>
<th>WorldVeg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Revenues</strong></td>
<td><strong>18,374</strong></td>
</tr>
</tbody>
</table>
RESEARCH FOR DEVELOPMENT

TOP 10 journals according to impact factor

- PNAS
- Diversity and Distributions
- frontiers in Plant Science
- Global Food Security
- Horticulture Research
- Journal of Ethnopharmacology
- Phytopathology
- Food Security
- plant disease
- Journal of Food and Drug Analysis
2018 PUBLICATIONS

Thomson impact factor journal articles (54)


42. Shahida Ibrahim; Mir, G.M.; Abdul Rouf; Abdul Rasheed War; Barkat Hussain. 2018. Herbivore and phytohormone induced defensive response in kale against cabbage butterfly, Pieris brassicaceae Linn. JOURNAL OF ASIA-PACIFIC ENTOMOLOGY. 21(1):367-373.


Journal articles (38)


Books


Book chapters


# ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AARNET</td>
<td>ASEAN-AVRDC Regional Network for Vegetable Research and Development</td>
</tr>
<tr>
<td>ACIAR</td>
<td>Australian Centre for International Agricultural Research</td>
</tr>
<tr>
<td>ACRT</td>
<td>Asian Cucurbit Round Table</td>
</tr>
<tr>
<td>AFC</td>
<td>Agriculture &amp; Finance Consultants</td>
</tr>
<tr>
<td>AFSTA</td>
<td>African Seed Trade Association</td>
</tr>
<tr>
<td>AIARC</td>
<td>Association of International Agricultural Research Centers</td>
</tr>
<tr>
<td>AIT</td>
<td>American Institute in Taiwan</td>
</tr>
<tr>
<td>APAARI</td>
<td>Asia Pacific Association of Agricultural Research Institutions</td>
</tr>
<tr>
<td>APART</td>
<td>Assam Agribusiness &amp; Rural Transformation Project</td>
</tr>
<tr>
<td>APCoAB</td>
<td>Asia-Pacific Consortium on Agricultural Biotechnology</td>
</tr>
<tr>
<td>APMAS</td>
<td>Andhra Pradesh Mahila Abhivruddhi Society</td>
</tr>
<tr>
<td>APSA</td>
<td>Asia &amp; Pacific Seed Association</td>
</tr>
<tr>
<td>AVBC</td>
<td>Africa Vegetable Breeding Consortium</td>
</tr>
<tr>
<td>BABA</td>
<td>Beta-Aminobutyric acid</td>
</tr>
<tr>
<td>BBSRC</td>
<td>Bioscience for the Future</td>
</tr>
<tr>
<td>BMZ</td>
<td>Federal Ministry for Economic Cooperation and Development, Germany</td>
</tr>
<tr>
<td>BPH</td>
<td>Best Practice Hubs</td>
</tr>
<tr>
<td>BW</td>
<td>Bacterial wilt</td>
</tr>
<tr>
<td>ChiVMV</td>
<td><em>Chili veinal mottle virus</em></td>
</tr>
<tr>
<td>CIRAD</td>
<td>Agricultural Research Centre for International Development, France</td>
</tr>
<tr>
<td>COA</td>
<td>Council of Agriculture, Taiwan</td>
</tr>
<tr>
<td>CRI</td>
<td>Crops Research Institute, Ghana</td>
</tr>
<tr>
<td>CRS</td>
<td>Catholic Relief Services</td>
</tr>
<tr>
<td>CSIR</td>
<td>Council for Scientific and Industrial Research, Ghana</td>
</tr>
<tr>
<td>DAR</td>
<td>Department of Agricultural Research, Myanmar</td>
</tr>
<tr>
<td>DFID</td>
<td>UK Department for International Development</td>
</tr>
<tr>
<td>DUS</td>
<td>Distinctness, Uniformity, and Stability</td>
</tr>
<tr>
<td>EAC</td>
<td>East African Community</td>
</tr>
<tr>
<td>FANRPAN</td>
<td>Food, Agriculture and Natural Resources Policy Analysis Network</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>FAVRI</td>
<td>Fruit and Vegetable Research Institute, Vietnam</td>
</tr>
<tr>
<td>GAP</td>
<td>Good agricultural practices</td>
</tr>
<tr>
<td>GBS</td>
<td>Genotype by Sequencing</td>
</tr>
<tr>
<td>GIC</td>
<td>German International Cooperation</td>
</tr>
<tr>
<td>GIZ</td>
<td>Deutsche Gesellschaft für Internationale Zusammenarbeit</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>GWAS</td>
<td>Genome Wide Association Studies</td>
</tr>
<tr>
<td>HDDS</td>
<td>Household dietary diversity score</td>
</tr>
<tr>
<td>HGSF</td>
<td>Home-grown school feeding</td>
</tr>
<tr>
<td>IBREC</td>
<td>Institutional Biosafety and Research Ethics Committee</td>
</tr>
<tr>
<td>ICCO</td>
<td>Interchurch Coordination Committee for Development Aid</td>
</tr>
<tr>
<td>ICRISAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics</td>
</tr>
<tr>
<td>IDDS</td>
<td>Individual dietary diversity score</td>
</tr>
<tr>
<td>IFAD</td>
<td>International Fund for Agricultural Development</td>
</tr>
<tr>
<td>IFDC</td>
<td>International Fertilizer Development Center</td>
</tr>
<tr>
<td>IITA</td>
<td>International Institute of Tropical Agricultural</td>
</tr>
<tr>
<td>INRAB</td>
<td>Institut National des Recherches Agricoles du Bénin</td>
</tr>
<tr>
<td>IPM</td>
<td>Integrated Pest Management</td>
</tr>
<tr>
<td>IRAD</td>
<td>Institute of Agricultural Research for Development</td>
</tr>
<tr>
<td>IRRI</td>
<td>International Rice Research Institute</td>
</tr>
<tr>
<td>IVTC</td>
<td>International Vegetable Training Course</td>
</tr>
<tr>
<td>JIRCAS</td>
<td>Japan International Research Center for Agricultural Sciences</td>
</tr>
<tr>
<td>JOHAR</td>
<td>Jharkhand Opportunities to Harness Rural Growth</td>
</tr>
<tr>
<td>KALRO</td>
<td>Kenya Agriculture and Livestock Research Organization</td>
</tr>
<tr>
<td>KU</td>
<td>Kasetsart University</td>
</tr>
<tr>
<td>MARDI</td>
<td>Malaysian Agricultural Research and Development Institute</td>
</tr>
<tr>
<td>MARI</td>
<td>Mikocheni Agricultural Research Institute</td>
</tr>
<tr>
<td>MINADER</td>
<td>Le Ministre de l'Agriculture et du Développement Rural</td>
</tr>
<tr>
<td>MOFA</td>
<td>Ministry of Foreign Affairs, Taiwan</td>
</tr>
<tr>
<td>MoU</td>
<td>Memorandum of Understanding</td>
</tr>
<tr>
<td>MVIKIHO</td>
<td>Muungano wa Vikundi Vya Kilimo cha Horticulture</td>
</tr>
<tr>
<td>MYMV</td>
<td><em>Mungbean yellow mosaic virus</em></td>
</tr>
<tr>
<td>NTU</td>
<td>National Taiwan University</td>
</tr>
<tr>
<td>OHADA</td>
<td>Organization for the Cooperation of Business Law, Africa</td>
</tr>
<tr>
<td>PADFA</td>
<td>Commodity Value-Chain Development Support Project</td>
</tr>
<tr>
<td>PAU</td>
<td>Punjab Agricultural University, India</td>
</tr>
<tr>
<td>PoP</td>
<td>Package of practices</td>
</tr>
<tr>
<td>PVY</td>
<td><em>Potato virus Y</em></td>
</tr>
<tr>
<td>QTL</td>
<td>Quantitative trait loci</td>
</tr>
<tr>
<td>RDA</td>
<td>Rural Development Administration, Korea</td>
</tr>
<tr>
<td>RIM</td>
<td>Research Infrastructure Modernization</td>
</tr>
<tr>
<td>RKN</td>
<td>Root knot nematode</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>SASS</td>
<td>Sustainable agri-food systems strategies</td>
</tr>
<tr>
<td>SDC</td>
<td>Swiss Agency for Development and Cooperation</td>
</tr>
<tr>
<td>SEARCA</td>
<td>Southeast Asian Regional Center for Graduate Study and Research in Agriculture</td>
</tr>
<tr>
<td>SEMOS</td>
<td>Société d’Exploitation des Mines de Sadiola</td>
</tr>
<tr>
<td>SEVIA</td>
<td>Seeds for the Vegetable Industry of Africa</td>
</tr>
<tr>
<td>SILC</td>
<td>Saving and internal lending communities</td>
</tr>
<tr>
<td>SMV</td>
<td>Soybean mosaic virus</td>
</tr>
<tr>
<td>SNP</td>
<td>Single Nucleotide Polymorphism</td>
</tr>
<tr>
<td>TAAT</td>
<td>Technologies for African Agricultural Transformation</td>
</tr>
<tr>
<td>TAHA</td>
<td>Tanzania Horticultural Association</td>
</tr>
<tr>
<td>TARI</td>
<td>Tanzania Agricultural Research Institute</td>
</tr>
<tr>
<td>TARI-Tengeru</td>
<td>Tanzanian Agricultural Research Institute-Tengeru</td>
</tr>
<tr>
<td>ToMV</td>
<td>Tomato mosaic virus</td>
</tr>
<tr>
<td>TOSCI</td>
<td>Tanzania Official Seed Certification Institute</td>
</tr>
<tr>
<td>TuMV</td>
<td>Turnip mosaic virus</td>
</tr>
<tr>
<td>UP</td>
<td>United Purpose</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>VTIC</td>
<td>Vegetable Technology Immersion Clusters</td>
</tr>
<tr>
<td>WACCI</td>
<td>West Africa Centre for Crop Improvement</td>
</tr>
<tr>
<td>WAgN</td>
<td>Women in Agriculture Network</td>
</tr>
<tr>
<td>WASH</td>
<td>Water-sanitation-hygiene</td>
</tr>
<tr>
<td>WEAI</td>
<td>Women’s Empowerment in Agriculture Index</td>
</tr>
<tr>
<td>ZECC</td>
<td>Zero Energy Cooling Chambers</td>
</tr>
</tbody>
</table>