



World Vegetable Center

# ANNUAL REPORT 2018





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## **2018**



# World Vegetable Center

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## 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.

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## Foreword from the Director General

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.



Mellissa Wood (ACIAR) and Marco Wopereis sign a new four-year agreement.

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

# Timeline

01 JANUARY



Visitors to WorldVeg HQ: **Russell T. Caplen**, Area Director for Taiwan, Animal and Plant Health Inspection Service (APHIS) Office, American Institute in Taiwan (AIT); **Ravi Khetarpal**, Executive Secretary, Asia Pacific Association of Agricultural Research Institutions (APAARI) and **Rishi Kumar Tyagi**, Coordinator, Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB); **Duncan Barker**, Livelihoods Advisor, Agricultural Research Team of the Department for International Development (DFID).

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.

02 FEBRUARY

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.

03 MARCH

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.



On 20-21 March 2018, the **13th AARNET steering committee meeting** was held in Tagaytay City, Philippines, organized by the Bureau of Plant Industry (BPI), Philippine Department of Agriculture.

04 APRIL

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.



05 MAY

**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.

06 JUNE

**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.



07 JULY



**Bitter Gourd Open Field Days** showcased 600 elite bitter gourd breeding lines and 900 bitter gourd F<sub>1</sub> 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.

08 AUGUST

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.

*(left to right)* Marco Wopereis accepts the Yuan-Ye Award from Taiwan President Tsai Ing-wen and Taiwan Secretary General Chen Chu.

09 SEPTEMBER

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.



10 OCTOBER

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



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.

11 NOVEMBER

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

54<sup>th</sup> 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.

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.

12 DECEMBER



WorldVeg participated in the **22<sup>nd</sup> 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.





# On the RIM

*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 CO<sub>2</sub>, 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."



# FOOD SAFETY FIRST

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 37<sup>th</sup> 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



*The International Vegetable Training Course (IVTC) emphasizes safe production methods.*

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>

*\*Bangladesh, Brunei Darussalam, Cambodia, China, Kingdom of Eswatini, India, Jordan, Lebanon, Mali, Morocco, Myanmar, Nigeria, Papua New Guinea, Philippines, Republic of Kiribati, Republic of Marshall Islands, Republic of Palau, Solomon Islands, Sri Lanka, and Uganda.*



## East and Southeast Asia

- **Activities** were conducted in six countries: **Cambodia, Korea, Myanmar, Philippines, Thailand, and Vietnam.**
- The 37<sup>th</sup> edition of the **International Vegetable Training Course (IVTC)** held in Thailand trained 28 professionals in “Safe Vegetable Production”.
- On 20 March 2018, the 13<sup>th</sup> **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.



# TWO-in-ONE TOMATOES FOR INDIA

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 Abhivruddhi 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.

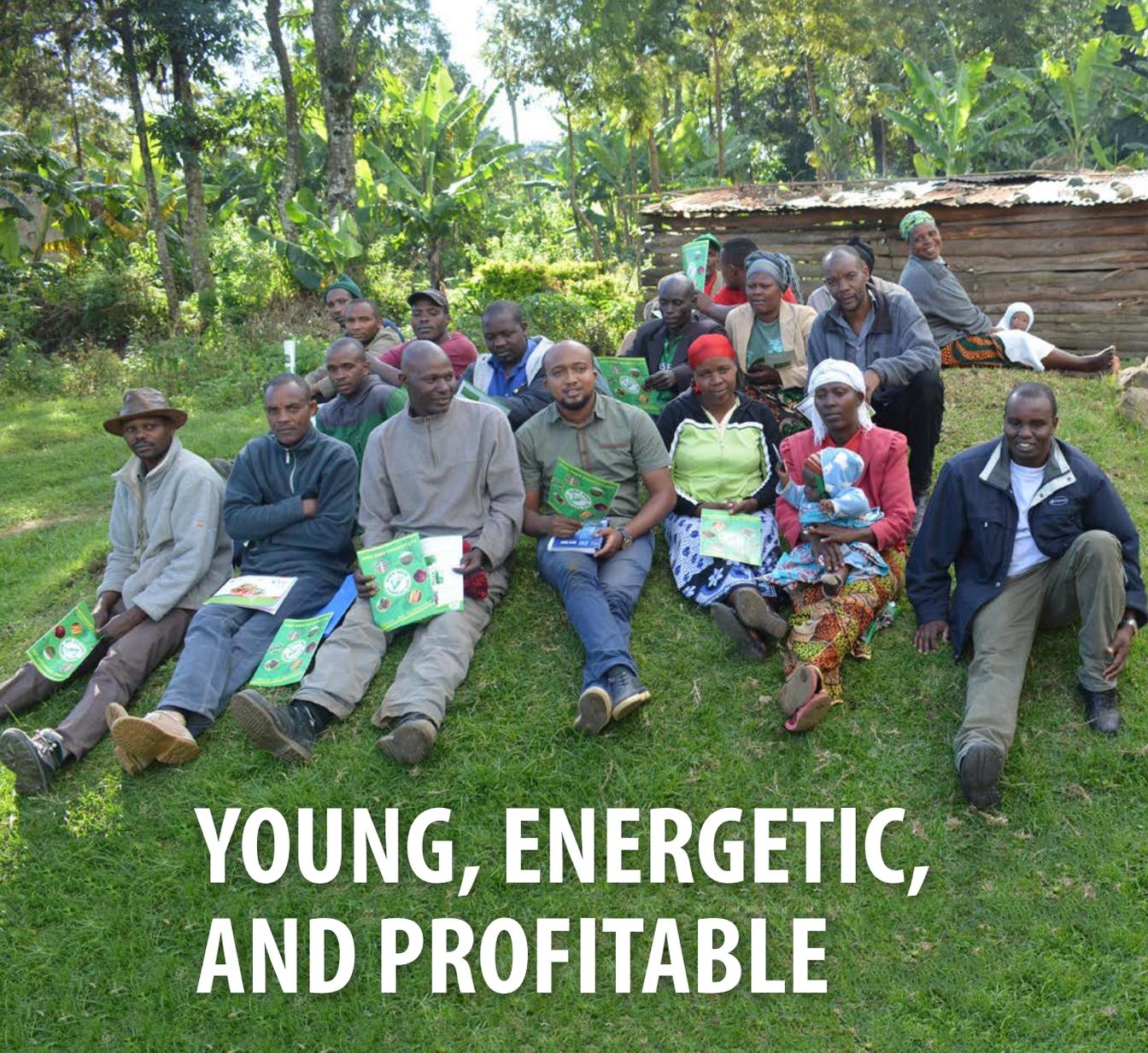


## South and Central Asia

- 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.



# YOUNG, ENERGETIC, AND PROFITABLE

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. "I have struggled for years to have a reliable market," he said. "I hoped to be lucky all

those years; luck was the only song I sang. Now I no longer need that song because I am assured of a market through the hub."

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.



## Eastern and Southern Africa

- **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 Mikochei 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 **54<sup>th</sup> 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.



# FITINI NAFA THIAMA

Vegetables are incredibly versatile plants. They can be grown without soil, thrive indoors or out, under natural or artificial light. They even can be grown in a bag.

In Djalé, a village in Koutiala District, Sikasso Region, Mali, 30 mothers with children aged 4-8 months from 30 different households each agreed to set up 10 sack gardens with the help of neighbors and staff from the USAID-funded project “Deploying Improved 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

*These “small gardens with big benefits” delight and nourish families in Mali.*



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.



## 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.



## West And Central Africa - Coastal & Humid Regions

- **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 Zattoo (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

Project Name	Donor	Duration	Amount (US\$)
Vegetables for all	Amsterdam Initiative against Malnutrition	2014 - 2019	57,803
Asia & Pacific Seed Association-WorldVeg Vegetable Breeding Consortium	Asia & Pacific Seed Association	2017 - 2019	18,000
Improved mungbean harvesting and seed production systems for Bangladesh, Myanmar and Pakistan	Australian Centre for International Agricultural Research	2017 - 2021	727,973
Promoting traditional vegetable production and consumption for improved livelihoods in Papua New Guinea and Northern Australia	Australian Centre for International Agricultural Research	2015 - 2018	121,681
Establishing the International Mungbean Improvement Network	Australian Centre for International Agricultural Research	2016 - 2019	1,530,066
Analyzing schools as platforms to improve livelihoods and the environment in East Africa	Australian Centre for International Agricultural Research	2018	24,471
Diversify and improve household incomes and tackle malnutrition in cocoa communities through vegetable home gardens in Ghana	Barry Callebaut	2018 - 2020	122,015
Diversify and improve household incomes and tackle malnutrition in cocoa communities through vegetable home gardens in Cameroon	Barry Callebaut	2018 - 2020	114,884
Implementing market-driven vegetable agricultural service providers linking smallholder farmers to services and markets	Belgian Government	2017 - 2018	135,719
A trial program to evaluate the efficacy of a natural growth enhancement product for six vegetable crops	BIO 520 LLC	2018 - 2019	62,500
Youth Vegetable Business Hubs	Catholic Relief Services	2017 - 2018	92,341
Improved livelihoods through crop diversification into vegetables in Jharkhand and Odisha under Central India Initiative	Collectives for Integrated Livelihood Initiatives	2016 - 2019	233,501
Geodata for Water and Agriculture - Angkor SALAD	Dutch Ministry of Foreign Affairs	2018 - 2021	234,545
2SCALE - Vegetable pilots in Mali	Dutch Ministry of Foreign Affairs	2018	17,200
2SCALE - Vegetable pilots in Cote d'Ivoire	Dutch Ministry of Foreign Affairs	2018	43,753

Project Name	Donor	Duration	Amount (US\$)
2SCALE - Vegetable pilots in Nigeria	Dutch Ministry of Foreign Affairs	2018	58,513
Horizon 2020 - Linking genetic resources, genomes and phenotypes of Solanaceous crops	European Commission	2016 - 2021	447,238
Amazing Amaranth: Hardy and nutritious amaranth lines and food practices to improve nutrition in East Africa	Federal Ministry for Economic Cooperation and Development, Germany	2018 - 2021	1,357,188
GrAfrica: Introducing grafted plantlets to improve yield and income for smallholder tomato producers in sub-Saharan Africa	Federal Ministry for Economic Cooperation and Development, Germany	2018 - 2019	113,100
Enhance the use of biological pest control for growing ornamental plants in Arusha	Federal Ministry for Economic Cooperation and Development, Germany	2018 - 2019	90,426
GlobE Diversifying Food Systems: Horticultural Innovations and Learning for Improved Nutrition and Livelihood in East Africa (HORTINLEA) - Phase 2	Federal Ministry for Economic Cooperation and Development, Germany	2016 - 2018	176,540
Resist Detect Protect: Wide spectrum insect resistance and sound management strategies to sustainably manage insect pests on Solanaceous vegetables in South Asia	Federal Ministry for Economic Cooperation and Development, Germany	2017 - 2019	1,283,928
Action Against Anthracnose: Resistant <i>Capsicum annuum</i> chilli pepper introgression lines and cultivars for Bangladesh	Federal Ministry for Economic Cooperation and Development, Germany	2017 - 2018	124,000
Technical partnership to support tomato value chain development under the Green Innovation Center for the agriculture and food sector, India	Federal Ministry for Economic Cooperation and Development, Germany	2017 - 2018	185,060
Beans with Benefits: Integrating improved mungbean as a catch crop into the dryland systems of South and Central Asia for increased smallholder farmer income and more sustainable production systems	Federal Ministry for Economic Cooperation and Development, Germany	2015 - 2018	1,283,928
NutriSenseProm: Increasing vegetable consumption through public and private partnerships efficiently delivering effective nutrition messages in the vegetable value chain	Federal Ministry for Economic Cooperation and Development, Germany	2016 - 2018	106,994

Project Name	Donor	Duration	Amount (US\$)
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	Federal Ministry for Economic Cooperation and Development, Germany	2016 - 2018	123,074
Determining household dietary diversity score (HDDS) and individual dietary diversity score (IDDS) of rice producing households in Mbeya and Dodoma regions, Tanzania	Federal Ministry for Economic Cooperation and Development, Germany	2018	12,784
Genebank support 2018	Federal Ministry for Economic Cooperation and Development, Germany	2018 - 2019	264,420
Capacity building towards digitization of national vegetable databases to address regional and national priorities in food and nutritional security in Eastern Africa	Global Biodiversity Information Facility	2017 - 2019	24,407
Building the Genesys catalog of phenotypic datasets	Global Crop Diversity Trust	2017 - 2018	49,600
Development and preparation of eggplant pre-bred materials for adaptation to climate change	Global Crop Diversity Trust	2017 - 2019	280,000
Onion value chain improvements in Odisha	Government of Odisha, India	2016 - 2018	392,112
Improve mungbean and urdbean productivity in Odisha State	Government of Odisha, India	2015 - 2018	373,440
Food Trees project in Kitui and Tharaka Nithi, Kenya	International Fund for Agricultural Development	2018	35,000
Selection of tropically-adapted lines of vegetables to improve productivity of the vegetable value chain in Myanmar and Vietnam (Year 3)	Japan Ministry of Agriculture, Forestry and Fisheries	2017 - 2018	141,854
Selection of tropically-adapted lines of vegetables to improve productivity of the vegetable value chain in Myanmar and Vietnam (Phase 2, Year 1)	Japan Ministry of Agriculture, Forestry and Fisheries	2018 - 2019	159,169
Screening for development of begomovirus-resistant processing tomato hybrid	Kagome Co., Ltd., Japan	2010 - 2018	143,333
Private seed sector support to WorldVeg's global cucurbit breeding program	Private seed companies	2016 - 2019	204,975

Project Name	Donor	Duration	Amount (US\$)
Broadening the narrow genetic base of commercial bitter melon cultivars by exploiting the genetic diversity of WorldVeg breeding lines	Private seed companies	2017 - 2020	530,000
Identification of molecular markers associated with disease and insect resistance for marker assisted selection in tomato ( <i>Solanum lycopersicum</i> ) breeding programs	Rural Development Administration, Korea	2016 - 2018	120,000
Development of breeding techniques and selection of disease resistant germplasm in vegetables	Rural Development Administration, Korea	2017 - 2019	105,000
Developing screening methods and germplasm to improve tolerance to abiotic stress in pepper ( <i>Capsicum</i> spp.)	Rural Development Administration, Korea	2018 - 2019	120,000
Nudging children toward healthier food choices: An experiment combining school and home gardens	Bill & Melinda Gates Foundation and UK aid	2018 - 2020	270,000
Evaluation of F <sub>1</sub> vegetables in Thailand and India	Taiwan Council of Agriculture	2017 - 2018	30,240
Tomato variety trials in Thailand and market survey	Taiwan Council of Agriculture	2017 - 2018	30,400
Development of screening systems to evaluate the resistance of tomato germplasm to major diseases	Taiwan Council of Agriculture	2018	54,802
Strengthening cooperation between WorldVeg and COA on vegetable research and development	Taiwan Council of Agriculture	2018	342,200
Research Infrastructure Modernization (RIM) - Phase I	Taiwan Council of Agriculture	2018	1,600,000
Tomato trials for Hualien District Agricultural Research and Extension System	Taiwan Council of Agriculture	2018 - 2019	28,320
2017 Networking to Enhance International Cooperation in Vegetable Research and Development	Taiwan Ministry of Foreign Affairs	2017 - 2018	400,000
2018 Networking to Enhance International Cooperation in Vegetable Research and Development	Taiwan Ministry of Foreign Affairs	2018	600,000
Whole-genome resequencing of tomato to identify genes associated with durable resistance to bacterial wilt ( <i>Ralstonia solanacearum</i> )	Taiwan Ministry of Science and Technology	2018 - 2019	35,607

Project Name	Donor	Duration	Amount (US\$)
Cool peppers for climate-resilient <i>Capsicum</i> production in Taiwan	Taiwan Ministry of Science and Technology	2018 - 2021	98,880
Fine mapping of the late blight resistance genes derived from <i>Solanum pimpinellifolium</i> accession VI030462	Taiwan Ministry of Science and Technology	2018 - 2021	108,480
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	Taiwan Ministry of Science and Technology	2016 - 2019	108,800
Phenotypic evaluation of the Vavilov mungbean accessions in Taiwan	Taiwan Ministry of Science and Technology	2018 - 2020	31,680
Unleashing the economic power of vegetables in Africa through quality seed of improved varieties	UK Department for International Development	2018 - 2020	2,555,580
IMMANA Project ENRICH	UK Department for International Development	2017 - 2019	22,947
Improving production of <i>Solanum aethiopicum</i> in Africa	UK Biotechnology and Biological Sciences Research Council	2018 - 2021	384,203
Improving diet diversity among children aged 0-23 months in Mokolo in the Far-north region of Cameroon	United Nations International Children's Emergency Fund	2018 - 2019	163,444
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	United Nation Food and Agriculture Organization	2018	90,847
Improving the nutritional status and income of smallholder farmer households through scaling improved, nutrient-dense traditional African vegetables in the Zanzibar Islands	United States Agency for International Development	2018 - 2020	298,423
Deploying improved vegetable technologies to overcome malnutrition and poverty in Mali	United States Agency for International Development	2014 - 2019	12,595,166
Tajikistan nutrition-sensitive vegetable technologies - Phase 2	United States Agency for International Development	2018 - 2020	350,000
Development of fertilizer deep placement for vegetables in Mali	United States Agency for International Development	2018 - 2019	16,151
Hort4Nut: Improving nutrition and income of smallholder farmers in Eastern Africa using a market-driven approach to enhance value chain production of African indigenous vegetables	United States Agency for International Development	2015 - 2018	130,000

Project Name	Donor	Duration	Amount (US\$)
Women in Agriculture Network (WAGN) Cambodia: Gender and ecologically sensitive agriculture	United States Agency for International Development	2016 - 2018	26,756
Africa RISING: Vegetables and associated best management practices in cereal-based crop production systems to improve income and diets of rural and urban households in Northern Ghana and Southern Mali	United States Agency for International Development	2012 - 2018	1,216,142
Validation of Pro-WEAI for the Gender, Agriculture, and Assets Project - Phase 2 (GAAP-2)	United States Agency for International Development	2016 - 2018	94,250
An assessment of three cash-based school meals modalities combined with complementary nutrition-sensitive literacy education	United States Department of Agriculture	2017 - 2018	103,380
Technical partnership to support the Jharkhand Opportunities for Harnessing Rural Growth (JOHAR) project	World Bank	2017 - 2023	1,377,911
Technical advisory assistance to Assam Agribusiness & Rural Transformation Project (APART) for the Vegetable Value Chains	World Bank	2018 - 2023	1,400,197
Facilitating value addition and processing in the context of the cassava, maize, banana, vegetable, and livestock value chains (PRODEMA) activities to support fruits and vegetables value chain in Burundi	World Bank	2017 - 2019	292,239

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## STRATEGIC LONG-TERM FUNDING



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# 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**

Bakker Brothers Seeds, Netherlands  
East West Seed International, Thailand  
Meru Agro-Tours & Consultants Co. Ltd., Tanzania  
NOVA GENETIC, France  
Premier Seed Nigeria Limited, Nigeria  
Rijk Zwaan Afrisem Ltd., Tanzania  
SeedCo International Limited, Botswana  
Simlaw Seeds Company Ltd., Kenya  
Techniseeds Limited, Nigeria  
Zamoho, Mali

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

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

## **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.



## **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 Ltd., 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 Bioplant 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  
Kalash Seeds Pvt. 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 Liou Organic Farm  
Mu-Zi-Li Farm  
Sing-flow Seed Trading Co., Ltd.  
Suntech Seed Co., Ltd.  
Your Chain Seeds Co., Ltd.



# Global R&D Week

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, 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.



## SAFE AND SUSTAINABLE VALUE CHAINS

- 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 melon 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/phylogroup 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 F<sub>1</sub> (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** (*Spoladea 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.

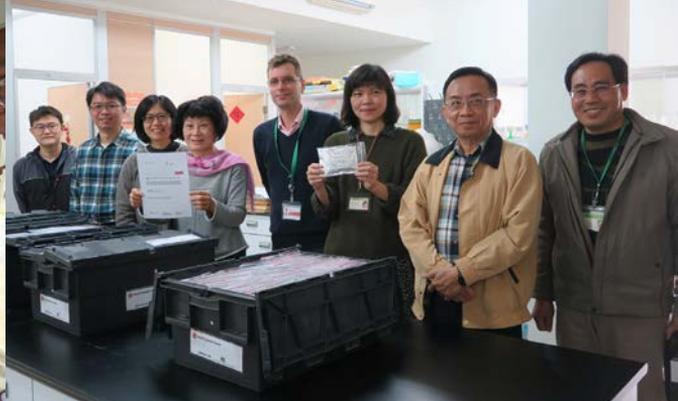
Storing the seeds, however, tests the mettle of mungbean growers, traders and consumers, who find they share far too much of their favorite legume with **bruchids** (*Callosobruchus* spp.). These tiny beetles can cause losses up to 100% in stored mungbean. Bruchids reduce the nutritional and market value 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 mosaic traits such as resistance to yellow mosaic disease, longer pods and high yield."



## VEGETABLE DIVERSITY AND IMPROVEMENT

- 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. *glabrusculum*, *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** F<sub>6</sub> 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 F<sub>1</sub> 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 F<sub>8</sub> 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 F<sub>7</sub> **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.



# HOME-GROWN HEALTH

*Thousands of households benefit from seed kits, garden training, and awareness about the elements of a healthy diet.*

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.



## HEALTHY DIETS

- 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 Kenya, 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 phytonutrients consumption patterns in Taiwan, 2) Major anti-nutrient components and their concentrations in vegetable families; and 3) Bitter melon 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.

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.

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 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.





**Farmer-participatory cultivar selection and channel superior amaranth lines into cultivar release processes**

- 22 lines
- Transplanting date: 21/09/2018



- 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**



# COMMUNICATING WITH THE WORLD



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](http://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

NAME	COUNTRY	APPOINTED
Dr. Junne-Jih Chen – Board Chair	Taiwan	Apr 2011
Dr. Masa Iwanaga – Vice Chair	Japan	Apr 2016
Dr. Chi-chung Chen	Taiwan	Feb 2018
Dr. Myoung Rae Cho	Korea	Aug 2017
Mr. George Culaste	Philippines	Nov 2017
Dr. Richard Ellis	UK	Apr 2017
Dr. Julie Howard	USA	Apr 2017
Dr. Marlis Lindecke	Germany	Jun 2015
Mr. Gordon MacNeil	Canada	Apr 2016
Dr. Bonnie McClafferty	USA	Dec 2017
Mr. Shigehiro Nishiumi	Japan	Nov 2017
Ms. Ndidi Nwuneli	Nigeria	Nov 2018
Ms. Cathy Reade	Australia	Apr 2013
Dr. Lindiwe Sibanda	Zimbabwe	Nov 2018
Dr. Chongrak Wachrinrat	Thailand	Feb 2016
Dr. Dennis Wang	Taiwan	Feb 2018
Dr. Marco Wopereis, ex-officio member	The Netherlands	Apr 2016
<b>Terms concluded in 2018</b>		
Dr. Jen-Pin Chen	Taiwan	Nov 2014
Dr. Hsueh-Shih Lin	Taiwan	Apr 2017

# FINANCE

	WorldVeg	CGIAR recommended range
<b>Cash management on restricted operations</b>	0.13	less than 1
<b>Adequacy of reserves</b>	116 days	75-90 days
<b>Short-term solvency</b>	135 days	90-120 days

2018 Revenues (in '000 USD)			
Unrestricted grants	8,742	48%	
Restricted grants	9,353	51%	
Other revenues	279	1%	
<b>Total</b>	<b>18,374</b>	<b>100%</b>	

## 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
<b>Sub-total</b>	<b>8,742</b>
Other revenues	279
<b>Total</b>	<b>9,021</b>

## 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
<b>Sub-total</b>	<b>9,353</b>
<b>Total Revenues</b>	<b>18,374</b>

# MAP



## Headquarters

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## Eastern and Southern Africa

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Duluti, Arusha  
TANZANIA  
Tel: +255-27-255-3093

## West and Central Africa – Dry Regions

BP 320 Bamako  
MALI  
Tel: +223-2070-9200

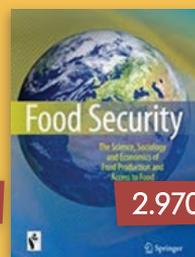
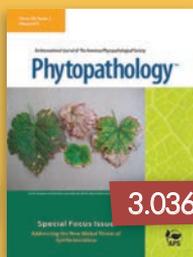
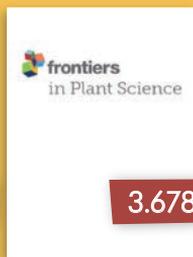
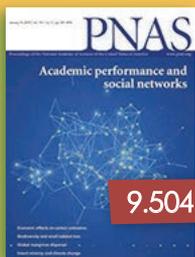
## West and Central Africa – Coastal & Humid Regions

IITA-Benin Campus  
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# RESEARCH FOR DEVELOPMENT



**TOP 10** journals according  
to impact factor



## 2018 PUBLICATIONS

### Thomson impact factor journal articles (54)

1. Abang, A.F.; Srinivasan, R.; Kekeunou, S.; Hanna, R.; Kamga, R.; Bilong Bilong, C.-F. 2018. Influence of okra (*Abelmoschus* spp.) accessions on colonization by *Aphis gossypii* (Hemiptera: Aphididae) and their effects on aphid biological parameters. *FLORIDA ENTOMOLOGIST*. 101(4):549-559.
2. Abdoulaye, T.; Wossen, T.; Awotide, B. 2018. Impacts of improved maize varieties in Nigeria: Ex-post assessment of productivity and welfare outcomes. *FOOD SECURITY*. 10(2):369-379.
3. Agbessenou, A.; Tounou, A.K.; Dannon, E.A.; Datinon, B.; Agboton, C.; Srinivasan, R.; Pittendrigh, B.R.; Tamò, M. 2018. Influence of rearing substrates and nontarget hosts on the bionomics of the tachinid parasitoid *Nemorilla maculosa* (Diptera: Tachinidae). *ENVIRONMENTAL ENTOMOLOGY*. 47(2):356-363.
4. Agbessenou, A.; Tounou A.K.; Dannon E.A.; Datinon B.; Agboton C.; Srinivasan R.; Pittendrigh B.R.; Tamo M. 2018. The parasitic fly *Nemorilla maculosa* exploits host-plant volatiles to locate the legume pod borer, *Maruca vitrata*. *ENTOMOLOGIA EXPERIMENTALIS ET APPLICATA* 166(8): 673–682.
5. Al-Shihi, A.A.; Hanson, P.; Al-Sadi, A.M.; Al-Yahyai, R.A.; Briddon, R.W.; Deadman, M.; Shafiq Shahid, M. 2018. Evaluation of tomato inbred lines for resistance to the tomato yellow leaf curl disease complex in Oman. *CROP PROTECTION*. 110:91-98.
6. Asare, R.; Afari-Sefa, V.; Muilerman, S. 2018. Access to improved hybrid seeds in Ghana: Implications for establishment and rehabilitation of cocoa farms. *EXPERIMENTAL AGRICULTURE*. 54(2):273-285.
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8. Barchenger, D.W.; Lamour, K.H.; Bosland, P.W. 2018. Challenges and strategies for breeding resistance in *Capsicum annuum* to the multifarious pathogen, *Phytophthora capsici*. *FRONTIERS IN PLANT SCIENCE*. 9:628.
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10. Barchenger, D.W.; Sheu, Z.-M.; Kumar, S.; Lin, S.-W.; Burlakoti, R.R.; Bosland, P.W. 2018. Race characterization of *Phytophthora* root rot on *Capsicum* in Taiwan as a basis for anticipatory resistance breeding. *PHYTOPATHOLOGY*. 108(8):964-971.
11. Benali, M.; Brümmer, B.; Afari-Sefa, V. 2018. Smallholder participation in vegetable exports and age-disaggregated labor allocation in Northern Tanzania. *AGRICULTURAL ECONOMICS*. 49(5):549-562.
12. Bhavana, P.; Singh, A.K.; Kumar, R.; Prajapati, G.K.; Thamilarsi, K.; Manickam, R.; Maurya, S.; Choudhary, J.S. 2018. Identification of resistance in tomato against root knot nematode (*Meloidogyne incognita*) and comparison of molecular markers for Mi gene. *AUSTRALASIAN PLANT PATHOLOGY*. online.
13. Bindumadhava, H.; Sharma, L.; Nair, R.M.; Nayyar, H.; Riley, J.J.; Easdown, W. 2018. High-temperature-tolerant mungbean (*Vigna radiata* L.) lines produce better yields when exposed to higher CO<sub>2</sub> levels. *JOURNAL OF CROP IMPROVEMENT*. 32(3):418-430.

14. Burlakoti, R.R.; Chen, J.R.; Hsu, C.F.; Burlakoti, P.; Kenyon, L. 2018. Molecular characterization, comparison of screening methods, and evaluation of cross-pathogenicity of black rot (*Xanthomonas campestris* pv. *Campestris*) strains from cabbage, choy sum, leafy mustard and pak choi from Taiwan. *PLANT PATHOLOGY*. 67(7):1589-1600.
15. Chang, C.H.; Chou, Y.Y.; Yndgaard, F.; Solberg, S.Ø. 2018. Trait patterns of mungbean, black gram and rice bean. *LEGUME RESEARCH*. 41(4):510-518.
16. Chang, J.-C.; Srinivasan, R. 2018. Transcriptome analysis in the beet webworm, *Spoladea recurvalis* (Lepidoptera: Crambidae). *INSECT SCIENCE*. 25(1):33-44.
17. Dhillon, N.P.S.; Sanguansil, S.; Srimat, S.; Schafleitner, R.; Manjunath, B.; Agarwal, P.; Xiang, Q.; Mohammed Abu Taher Masud; Myint, T.; Hanh, N.T.; Cuong, T.K.; Balatero, C.H.; Salutan-Bautista, V.; Pitrat, M.; Lebeda, A.; McCreight, J.D. 2018. Cucurbit powdery mildew-resistant bitter gourd breeding lines reveal four races of *Podosphaera xanthii* in Asia. *HORTSCIENCE*. 53(3):337-341.
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19. Dinssa, F.F.; Yang, R.Y.; Ledesma, D.R.; Mbwambo, O.; Hanson, P. 2018. Effect of leaf harvest on grain yield and nutrient content of diverse amaranth entries. *SCIENTIA HORTICULTURAE*. 236:146-157.
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22. Douglas, M.R.; Chang, J.; Begum, K.; Subramanian, S.; Tooker, J.F.; Alam, S.N.; Srinivasan, R. 2018. Evaluation of biorational insecticides and DNA barcoding as tools to improve insect pest management in lablab bean (*Lablab purpureus*) in Bangladesh. *JOURNAL OF ASIA-PACIFIC ENTOMOLOGY*. 21(4):1326-1336.
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29. Krawinkel, M.B.; Ludwig, C.; Swai, M.E.; Yang, R.-Y.; Chun, K.P.; Habicht, S.D. 2018. Bitter gourd reduces elevated fasting plasma glucose levels in an intervention study among prediabetics in Tanzania. *JOURNAL OF ETHNOPHARMACOLOGY*. 216:1-7.

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# ACRONYMS

AARNET	ASEAN-AVRDC Regional Network for Vegetable Research and Development
ACIAR	Australian Centre for International Agricultural Research
ACRT	Asian Cucurbit Round Table
AFC	Agriculture & Finance Consultants
AFSTA	African Seed Trade Association
AIARC	Association of International Agricultural Research Centers
AIT	American Institute in Taiwan
APAARI	Asia Pacific Association of Agricultural Research Institutions
APART	Assam Agribusiness & Rural Transformation Project
APCoAB	Asia-Pacific Consortium on Agricultural Biotechnology
APMAS	Andhra Pradesh Mahila Abhivruddhi Society
APSA	Asia & Pacific Seed Association
AVBC	Africa Vegetable Breeding Consortium
BABA	Beta-Aminobutyric acid
BBSRC	Bioscience for the Future
BIMAF	Biorisk Management Facility
BMZ	Federal Ministry for Economic Cooperation and Development, Germany
BPH	Best Practice Hubs
BW	Bacterial wilt
ChiVMV	<i>Chili veinal mottle virus</i>
CIRAD	Agricultural Research Centre for International Development, France
COA	Council of Agriculture, Taiwan
CRI	Crops Research Institute, Ghana
CRS	Catholic Relief Services
CSIR	Council for Scientific and Industrial Research, Ghana
DAR	Department of Agricultural Research, Myanmar
DFID	UK Department for International Development
DUS	Distinctness, Uniformity, and Stability
EAC	East African Community
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agriculture Organization of the United Nations
FAVRI	Fruit and Vegetable Research Institute, Vietnam
GAP	Good agricultural practices
GBS	Genotype by Sequencing
GIC	German International Cooperation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit

GWAS	Genome Wide Association Studies
HDDS	Household dietary diversity score
HGSF	Home-grown school feeding
IBREC	Institutional Biosafety and Research Ethics Committee
ICCO	Interchurch Coordination Committee for Development Aid
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDDS	Individual dietary diversity score
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
IITA	International Institute of Tropical Agricultural
INRAB	Institut National des Recherches Agricoles du Bénin
IPM	Integrated Pest Management
IRAD	Institute of Agricultural Research for Development
IRRI	International Rice Research Institute
IVTC	International Vegetable Training Course
JIRCAS	Japan International Research Center for Agricultural Sciences
JOHAR	Jharkhand Opportunities to Harness Rural Growth
KALRO	Kenya Agriculture and Livestock Research Organization
KU	Kasetsart University
MARDI	Malaysian Agricultural Research and Development Institute
MARI	Mikocheni Agricultural Research Institute
MINADER	Le Ministre de l'Agriculture et du Développement Rural
MOFA	Ministry of Foreign Affairs, Taiwan
MoU	Memorandum of Understanding
MVIKIHO	Muongano wa Vikundi Vya Kilimo cha Horticulture
MYMV	<i>Mungbean yellow mosaic virus</i>
NTU	National Taiwan University
OHADA	Organization for the Cooperation of Business Law, Africa
PADFA	Commodity Value-Chain Development Support Project
PAU	Punjab Agricultural University, India
PoP	Package of practices
PVY	<i>Potato virus Y</i>
QTL	Quantitative trait loci
RDA	Rural Development Administration, Korea
RIM	Research Infrastructure Modernization
RKN	Root knot nematode

SASS	Sustainable agri-food systems strategies
SDC	Swiss Agency for Development and Cooperation
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SEMOS	Société d'Exploitation des Mines de Sadiola
SEVIA	Seeds for the Vegetable Industry of Africa
SILC	Saving and internal lending communities
SMV	<i>Soybean mosaic virus</i>
SNP	Single Nucleotide Polymorphism
TAAT	Technologies for African Agricultural Transformation
TAHA	Tanzania Horticultural Association
TARI	Tanzania Agricultural Research Institute
TARI-Tengeru	Tanzanian Agricultural Research Institute-Tengeru
ToMV	<i>Tomato mosaic virus</i>
TOSCI	Tanzania Official Seed Certification Institute
TuMV	<i>Turnip mosaic virus</i>
UP	United Purpose
USAID	United States Agency for International Development
VTIC	Vegetable Technology Immersion Clusters
WACCI	West Africa Centre for Crop Improvement
WAgN	Women in Agriculture Network
WASH	Water-sanitation-hygiene
WEAI	Women's Empowerment in Agriculture Index
ZECC	Zero Energy Cooling Chambers



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