World Vegetable Center

ANNUAL REPORT 2017

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World Vegetable Center
P.O. Box 42 Shanhua, Tainan 74199
Taiwan
T +886 6 583 7801
F +886 6 583 0009
E info@worldveg.org

worldveg.org

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Editor: Maureen Mecozzi
Graphic Design: Amy Chen
Production Team: Kathy Chen, Vanna Liu

Contributors
Victor Afari-Sefa, P.V.L. Bharathi, Amy Chen, J.J. Chen, Narinder Dhillon, Fekadu Dinssa, Thomas Dubois, Warwick Easdown, Roman Fortunatus, David Johnson, Peter Hanson, Hsu Yun-che, Regine Kamga, Nick Kao, Radegunda Kessy, Sorawit Limsiriwat, Jessica Lin, Vanna Liu, Lu Shu-fen, Adrienne Mak, Ravishankar Manickam, Ravza Mavlyanova, Hassan Mndiga, I.R. Nagaraj, Ramakrishnan Nair, Kabirou Ndiaye, Rhiannon O'Sullivan, Arshad Pal, Srinivasan Ramasamy, Ralph Roothaert, Pepijn Schreinemachers, Caroline Sobgui, Nora Wagman, Marco Wopereis

Cover photo
Photographer Rhiannon O'Sullivan captured Bibi Mwanaidi showing her grandson the African nightshade seeds she harvested from her garden in Tanzania. Mwanaidi will plant these seeds to produce another crop of this nutrient-rich, hardy and productive leafy vegetable next season. This photo was the second-place winner in the 2017 Feed the Future photo competition.

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Foreword from the Chair

Board Chair **JJ Chen** (*left*) with **Leong Hon Keong,** who represents Singapore in the ASEAN-AVRDC Regional Network for Vegetable Research and Development (AARNET).

As a member of the World Vegetable Center Board of Directors since 2011, I have seen WorldVeg extend its reach as a leading international agricultural research institution dedicated to the idea that healthier lives and more resilient livelihoods are possible through greater diversity in what we grow and eat. We can get the most answers from vegetables. Appointed as Chair in 2017, I now preside over a Board ready to guide WorldVeg forward into new areas of research and practice.

It's the right time for expansion: The increasing recognition worldwide that people must be nourished, not merely fed, has attracted more partners and potential donors to the Center's activities. In response, in 2017 WorldVeg opened its fifth regional office—West and Central Africa - Coastal & Humid Regions in Cotonou, Benin—to increase vegetable production in an area with great potential to provide fresh, nutritious, and safe food for millions of malnourished people.

Director General Marco Wopereis, now two years at the helm, has skillfully put the Center's well-crafted strategy into action. The new flagship/innovation cluster structure allows for more rapid response to changing climates, markets, and donor priorities, and greater flexibility to serve beneficiaries' needs. Marco's emphasis on scientific rigor coupled with an open, collaborative approach is delivering important outcomes, as the stories and highlights in this Annual Report illustrate. The Board will give Marco continuous support and provide timely evaluation of effectiveness.

The Center's outreach to the private seed sector—WorldVeg's vital partners for research and distribution—took a big leap forward under Deputy Director General – Research David Johnson. Nineteen companies already have joined the Asia & Pacific Seed Association (APSA)/WorldVeg Vegetable Breeding Consortium to share information and collaborate on research. A WorldVeg-Taiwan Seed Industry Exchange Platform was established to strengthen ties with Taiwan seed companies and public organizations, and the Center's global cucurbit breeding program is now funded through bilateral agreements with 15 seed companies. These strong private-sector relationships help ensure the products of WorldVeg vegetable breeding reach more farmers. The Board will monitor and adjust these activities as necessary.

Monitoring the financial practices and other activities of a globally diffuse institution such as WorldVeg is a significant challenge. The Board engaged the services of AuditAsia, a private auditing firm that has experience working with international research organizations, to provide independent, objective assurance and consulting activities. We will conduct annual assessments and make changes as appropriate.

During the year we said farewell to seven Board members, including Vice-Chair David Sammons. David's tireless efforts on behalf of WorldVeg, his exceptional focus, depth of understanding, and goodwill will not be easy to replicate. We will miss Dae-Geun Oh's insight, Emmy Simmons' provocative and lively questions, and thoughtful probing from Jon Wilkinson. Takashi Hamada, Sophia Kaduma, and Vivencio Mamaril made important contributions during their board terms. We thank them for their service and dedication.

I am confident our new members appointed in 2017—Julie Howard, Richard Ellis, Nishiumi Shigehiro, George Culaste, Myoung Rae Cho, and Bonnie McClafferty—will provide valuable guidance and bring new ideas and concepts to the fore. It has been my pleasure to work with other committed individuals on the WorldVeg Board. Together, our diverse talents make WorldVeg a better and more productive institution.

-- Dr. Junne-Jih Chen

Foreword from the Director General

Marco Wopereis (with plant) and WorldVeg Board members review pest protection research at WorldVeg HQ.

This year's report provides many examples of our commitment to work in partnership and to contribute to healthier lives and more resilient livelihoods through greater diversity in what we grow and eat—the vision behind our new 2017-2025 Strategic Plan published in September 2017. We provide highlights of our work conducted in partnership in our five target regions in Asia and Africa within the context of three global, outcome-oriented flagship programs: Safe and Sustainable Value Chains, Healthy Diets, and Vegetable Diversity and Improvement, and one global, cross-cutting program: Enabling Impact.

Our new strategy is based on extensive partner consultations and face-to-face meetings. The strategy is implemented by teams of WorldVeg staff and partners working towards a clear and measurable set of outcome targets through discovery, piloting, and scaling activities and continuous improvement of a coherent set of products and services.

The 12th steering committee meeting of the ASEAN-AVRDC Regional Network for Vegetable Research and Development (AARNET) held in Taiwan in May, paved the way for a more active partnership between WorldVeg and R&D partners from the 10 ASEAN nations. Three common areas of interest were identified: genetic diversity, biocontrol and bio-pesticides, and protected cultivation. Collaborative research activities in these areas are expected to start by the second half of 2018.

The inaugural workshop of the WorldVeg – Asia and Pacific Seed Association (APSA) Vegetable Breeding Consortium, our growing partnership with the private seed sector in Asia, was held in June at WorldVeg HQ. The consortium connects seed companies with active breeding programs in tomato, pepper and cucurbits, and it provides WorldVeg with effective impact pathways for our breeding products and valuable feedback on performance and uptake in Asia. A similar consortium is in the making for Africa under the umbrella of the African Seed Trade Association (AFSTA). In November, WorldVeg opened an exchange platform with the Taiwan seed industry to strengthen our ties with Taiwan's seed companies and public organizations working in vegetable improvement.

In August we signed a new partnership and host country agreement with the Benin government, establishing a second regional center for WorldVeg in West Africa, to cater to vegetable R&D needs for the rapidly industrializing West African coastline, from Abidjan to Lagos.

The Global R&D Week held in Taiwan in November brought together WorldVeg staff from all over the world to translate our new strategic plan in an operational plan for 2017-2020. Representatives from Taiwan knowledge institutions also participated in the discussions. We hope more of our partners will do likewise and join us in future editions of the Global R&D Week!

I hope you enjoy reading this report—the fruit of many diverse partnerships. I am extremely grateful to the WorldVeg teams and the many technical and financial partners who worked with us in 2017. Our joint efforts are contributing to healthier lives and more resilient livelihoods across the world.

-- Dr. Marco Wopereis

Timeline

01 JANUARY

Through the Agricultural Innovation Program (AIP) funded by USAID, WorldVeg provided training specifically for **women farmers** in Faisalabad, Pakistan on crop production, protection and marketing, as well as occupational health hazards.

02 FEBRUARY

U.S. Ambassador Elisabeth Millard officially opened a **commercial greenhouse** established by WorldVeg and USAID in Ghayrat village near Qurghonteppa, Tajikistan.

03 MARCH

Solar drying—a simple but effective vegetable preservation method that ensures food and nutrients are available year-round—was promoted with dryer designs and manuals in Tanzania, Mali, and India.

07 JULY

Lin Tsung-Hsien, Minister, Taiwan Council of Agriculture, visited HQ.

"International research on vegetable improvement in East and Southern Africa: adoption, impact, and returns," a study published in the journal *Agricultural Economics*, demonstrates the reach of vegetable research and shows that **WorldVeg tomato varieties** now account for 50% of the tomato seed sold commercially in East Africa.[1]

08 AUGUST

WorldVeg signed a Memorandum of Understanding with the Government of Benin, and established its fifth regional office worldwide and third in Africa in Cotonou: **West and Central Africa – Coastal & Humid Regions.**

Bred by WorldVeg, Lakateu-AV and Kiukae-AV are the first **mungbean** varieties released in Timor-Leste.

09 SEPTEMBER

WorldVeg launched a **new strategy** to realize the immense potential of vegetables to improve nutrition and incomes. It focuses on discovery research, piloting innovations, and scaling best technologies and practices.

The Center's **new logo** represents the institution's fresh outlook and vibrant activities.

[1] Schreinemachers P, Sequeros T, Lukumay PJ. 2017. International research on vegetable improvement in East and Southern Africa: adoption impact and returns. AGRICULTURAL ECONOMICS. 48(6):707-717. https://worldveg.tind.io/record/57751/files/oa0080.pdf

04 APRIL

WorldVeg **tomato breeders** developed a pest-resistant tomato plant that produced big, good-tasting fruit in the first generation, promising more rapid delivery of tomato varieties that can be grown using less pesticides.

51st meeting of the WorldVeg **Board of Directors** in Seoul, Korea.

05 MAY

Participants from nine member countries of the Association of Southeast Asian Nations (ASEAN) learned about the horticultural practices and policies of Taiwan during the 12th Steering Committee Meeting of the **ASEAN-AVRDC Regional Network for Vegetable Research and Development (AARNET)** at WorldVeg headquarters.

The **Asia & Pacific Seed Association (APSA)-World Vegetable Center Vegetable Breeding Consortium** held its inaugural annual workshop at WorldVeg HQ.

A **Field Day** for Taiwan seed companies was held at WorldVeg HQ.

06 JUNE

7 Steps to Connecting Farmers to New Markets: A Practical Guide, prepared by WorldVeg for the Australian Centre for International Agricultural Research-funded VINESA project, emphasized the need for **market analysis** to grow what will sell.

10 OCTOBER

A **groundbreaking review** of the economic and nutritional benefits of vegetables points to the urgent need for greater public and private investment in vegetable research.[2]

DG Marco Wopereis addressed the **Yushan Forum** in Taipei, Taiwan.

11 NOVEMBER

WorldVeg participated in the **21st Seed & Seedling Festival** at the Tainan District Agricultural Research and Extension Station, Xinhua, Taiwan.

The **Taiwan Seed Industry Exchange Platform** was launched.

Demand increased for commercial quantities of African nightshade, a **traditional vegetable** in Cameroon.

12 DECEMBER

Eighty-eight WorldVeg staff representing more than 25 countries participated in the **2017 Global R&D Week** at WorldVeg HQ.

Bitter Gourd Field Days in Bangalore, India, showcased 180 hybrids bred with WorldVeg lines.

A **Youth Vegetable Business Hub** was piloted in Tanzania with Catholic Relief Services.

52nd meeting of the WorldVeg **Board of Directors** at WorldVeg HQ.

[2] Schreinemachers P, Simmons EB, Wopereis MCS. 2017. Tapping the economic and nutritional power of vegetables. GLOBAL FOOD SECURITY. DOI: 10.1016/j.gfs.2017.09.005

A NEW STRATEGY

In 2017, WorldVeg embarked on a new path to foster healthier lives and more resilient livelihoods. Read the strategic plan guiding this endeavor.

The world is experiencing rapid economic, environmental, social and political changes bringing a host of new opportunities and challenges. In response, WorldVeg must continuously adapt and trace a way forward.

We have made great progress toward becoming a more nimble and responsive institution through the creation of *Healthier lives, more resilient livelihoods*—our new strategic plan for 2017-2025. The plan was published in September 2017 and a French translation became available near the end of the year.

WorldVeg will implement its science-for-development agenda through a new flagship program structure. It includes three outcome-oriented flagship programs: Safe and Sustainable Value Chains, Healthy Diets, and Vegetable Diversity and Improvement, and one cross-cutting flagship program, Enabling Impact.

These flagship programs emerged from partner consultations in 2016 and extensive discussions among WorldVeg staff. The flagships are based on relative strengths, identified trends, and potential for impact. They bring together WorldVeg staff and partners from the public and private sector, from research and development organizations, and from farmer organizations and civil society. They are gateways to achieving outcomes and impact.

Each flagship is operationalized through two to four “innovation clusters.” Innovation clusters are teams of WorldVeg staff and partners working toward a clear and measurable set of outcome targets through discovery, piloting, and scaling activities and continuous improvement of a coherent set of products and services. This is not a linear, predictable process moving from ideas to application to impact, but rather an iterative pathway to impact with numerous feedback and feedforward loops that allow for unexpected outcomes and trajectories.

The World Vegetable Center seeks partnerships that address the organizational, policy, and institutional changes needed for further improvement, uptake, and scaling of innovations. Join us!

Download ***Healthier lives, more resilient livelihoods: World Vegetable Center Strategy 2017-2025:***

https://worldveg.tind.io/record/57792/files/World Vegetable Center Strategy 2017-2025.pdf?version=1

PARTNERING FOR IMPACT

Seed companies are extending the Center's reach to smallholder farmers in Asia

Private vegetable seed companies in Asia have seen spectacular growth over the past two decades while the public sector and the informal seed sector have declined in importance. A recent study by the World Vegetable Center on tomato and chili pepper in India estimated that private companies nowadays account for 92% of seed production for these crops, and that the hybrid segment is 95%. Studies also showed that the private sector is widely utilizing the Center's breeding material: 144 tomato and chili varieties currently sold in Asia contain WorldVeg-developed traits and the seed quantity is enough to supply more than 1 million smallholder farmers annually.

Recognizing the importance of the private sector for the Center's ability to reach smallholder farmers in Asia, partnerships with seed companies were strengthened through three major initiatives:

First, a vegetable breeding consortium was created with seed companies in Asia under the umbrella of the Asia & Pacific Seed Association (APSA). Nineteen companies already have joined the **APSA/WorldVeg Vegetable Breeding Consortium** to share information and collaborate on research and other activities.

Second, the WorldVeg **global cucurbit breeding program** (2016-2019) is funded through bilateral agreements with 15 seed companies. This initiative includes the Center's highly successful bitter gourd breeding program, which provides seed companies with unique lines and F_1 hybrids.

Third, the **WorldVeg-Taiwan Seed Industry Exchange Platform** was established to strengthen ties with Taiwan seed companies and public organizations working in vegetable improvement. The platform facilitates information exchange between the Center's researchers and vegetable breeders in Taiwan and fosters special initiatives to serve the interests of Taiwanese companies.

More intense collaboration on vegetable improvement with the private sector in Asia does not rule out collaboration with the public sector, which remains an essential partner in key areas such as biodiversity conservation, development of novel plant traits, and research on underutilized vegetables. In the future, the Center will seek to strengthen private sector partnerships in areas other than breeding, and focus on building strong private and public partnerships in sub-Saharan Africa as well.

EAST AND SOUTHEAST ASIA

- **Research activities** were conducted in six countries: Cambodia, Indonesia, Laos, Myanmar, Thailand, and Vietnam.
- Two **Innovation Fund projects** were implemented in Thailand, one focusing on anthracnose resistance in chili, the other on insect resistance of eggplant.
- To commemorate the late King Bhumibol Adulyadej of Thailand, 800 **Seven Color Seed Kits** and 300 **Food Security Seed Kits** were provided to vulnerable households in Thailand through the Department of Agriculture and Kasetsart University.
- In Cambodia, 2,075 poor rural households were supported with **training in household gardening and nutrition** and received seed kits to help improve nutrition.
- **Bitter Gourd Open Field Days** were held at the WorldVeg East and Southeast Asia Research and Training Station on Kasetsart University's Kamphaeng Saen campus from 14-30 August 2017. Forty-one staff of 21 seed companies from across Asia viewed 400 elite bitter gourd lines and another 400 F1 hybrids. Early stage products of recurrent selection also were displayed.
- WorldVeg and the Department of Agricultural Research (DAR) of Myanmar organized a **Cucurbit Open Field Day** on 7 September 2017 to showcase WorldVeg improved bitter gourd and pumpkin lines to 45 farmers from three villages around Nay Pyi Taw, 20 government staff, and East-West Seed Co.
- The 36th edition of the **International Vegetable Training Course** (IVTC; https://ivtc.avrdc.org) was organized in partnership with Kasetsart University during October-November. The two-module course attracted 23 participants from various countries.
- An **ASEAN-AVRDC Regional Network for Vegetable Research and Development** (AARNET) postharvest workshop and tour was organized in Malaysia from 17 September to 6 October 2017. The event was facilitated by the Malaysian Agricultural Research and Development Institute (MARDI) and funded by the government of Japan.
- WorldVeg strengthened links with the **Food & Fertilizer Technology Center (FFTC)** in Taiwan.

- The Australian Centre for International Agricultural Research (ACIAR)-funded project “Improved Mungbean Harvesting and Seed Production Systems for Bangladesh, Myanmar and Pakistan” got started with an **inception workshop** in Nay Pyi Taw, Myanmar on 11-12 October 2017.
- The Federal Ministry for Economic Cooperation and Development, Germany (BMZ)-funded project “Attraction in Action” held its final workshop in Vientiane Capital, Lao PDR from 20-23 November 2017. The project made important contributions to the promotion of b**iological-based integrated pest management (IPM) solutions** in Cambodia, Laos and Vietnam for vegetable legumes and leafy brassicas.
- Comprehensive studies were conducted on opportunities for **vegetable postharvest management** in Cambodia and Myanmar. Outcomes of the United States Agency for International Development (USAID)-funded postharvest project were evaluated for Cambodia.
- The **12th AARNET Steering Committee and Science Review** was held from 23-25 May 2017 at WorldVeg headquarters and included a tour of Taiwan research institutions and visits with commercial leaders. Thematic priorities were identified, including germplasm, biopesticides and protected cultivation.
- In May, representatives from Taiwan seed companies, universities, and the Council of Agriculture joined in an **“Information Exchange and Field Demonstration of Vegetable Breeding Research”** at WorldVeg HQ in Taiwan.
- The **Taiwan Seed Industry Exchange Platform** was launched in November to strengthen ties with seed companies and public organizations working in vegetable improvement.
- In March, a 33-person delegation representing the **Philippine Higher Education Career System** met WorldVeg HQ staff to explore opportunities for students’ professional advancement.
- Three **mungbean researchers** from the Chai Nat Field Crops Research Center, Department of Agriculture, Thailand presented their work to WorldVeg HQ staff.
- In July, a group of 30 **aboriginal farmers** from Fangshan, Pingtung County, Taiwan discussed the production and use of traditional vegetables with WorldVeg genebank staff.

ONIONS NOW SMELL DIFFERENT IN ODISHA

Ensuring a steady supply of a daily dietary staple demands improved storage practices

No Indian meal is complete without onions, but rotten onions stink. In the past many consumers and any Indian farmer who kept their crop for months after harvest were all too familiar with the smell. But thanks to a WorldVeg project in the Indian state of Odisha, farmers who keep their onions now experience the sweet smell of success and the promise of much higher incomes.

Fearing the usual gluts when everyone else harvests, and the consequent price drops, Odisha onion farmers previously harvested their onion crops as early as possible. If they were able to store their onions for a month they could double their

Duryodhan Hati has successfully stored onions for two months. Improved storage methods extend the shelf life of a vegetable that makes a daily appearance in the diets of people in Odisha.

returns—and after three months, they could get at least four or five times the price. But many could not, because their crops were harvested at an immature stage, and immature onions do not store well. The losses affected everyone, including traders and consumers who were buying inferior products that wouldn't keep.

"This year I invested a big amount of money in onions and also bought a huge quantity from small farmers," said **Mr. Shanta Susree Sarabit**, a progressive farmer and trader from Patra village in Titilagarh district. "I stored 3,350 bags with a capacity of 50 kg each, but after two months of storage, most of the onions were spoiled and I could recover only 150 bags. This is a huge loss for me."

Reducing the storage losses of onions depends on many factors, starting with the variety through to the design of the storage facility. A WorldVeg project team led by **Dr. Arshad Pal** with five project officers based across Odisha has been teaching farmers new techniques for storing onions.

The onions they produced look (and smell) remarkably different to those conventionally handled. Farmers are delighted with the results.

"Previously I wouldn't store onions as I didn't know about postharvest handling and used to sell my crop immediately after harvest," said **Mr. Duryodhan Hati** from Kalimati village in Nuapada district. "WorldVeg staff trained us about proper harvesting, curing, sorting, and storage techniques. This year I've been storing my onions for the past two months and not a single onion has spoiled. I'm expecting a storage life of 2-3 more months to get a better price."

Having been shown what is possible, farmers are now keen to store their onions for longer periods, and sell for higher prices during the off-season. In the long term, improved handling and postharvest practices will help to balance seasonal supplies and demand, ensuring a more even and fairer price—and fewer rotten onions.

SOUTH ASIA AND CENTRAL ASIA

- **Research activities** were conducted in seven countries: India, Bangladesh, Pakistan, Nepal, Bhutan, Uzbekistan and Tajikistan

Improved mungbean production

- Successful field testing of new mungbean lines with high levels of resistance to mungbean yellow mosaic disease caused by *Mungbean yellow mosaic virus* (MYMV) and bruchids has been conducted across India and the WorldVeg mungbean mini-core collection is being field testing by Departments of Agriculture in India, Bangladesh, Pakistan, Uzbekistan, Myanmar, and Australia.
- Research across the region has identified mungbean lines that can flower successfully at over 45°C, lines that have good root-rot resistance, and lines with high tolerance to salinity.
- In India, improved mungbean varieties and better production practices have increased average yields in Odisha up to six-fold, and helped increase the incomes of Karnataka rice farmers by an average of USD 1500/ha.
- A new three-year Australian Centre for Agricultural Research (ACIAR)-funded project to develop and promote mechanical harvesting and seed production of mungbean has begun in collaboration with Departments of Agriculture in Bangladesh, Pakistan, Myanmar, and Australia.

New tomato and capsicum production options

- In a GIZ-funded project in India, on-station trials and more than 50 on-farm trials of disease-resistant dual purpose tomato lines for processing as well as the fresh market have performed well with strong interest from the seed sector and farmers. Tomato trials using pheromones to manage the new invasive pest *Tuta absoluta* have been conducted in Karnataka and Andhra Pradesh, showing 30-70% yield improvements over controls. 600 farmers are further testing the best treatments across 240 hectares of crops.
- In Karnataka, India the introduction of staking and plastic mulching for tomato production increased yields 14% and reduced labor costs by 30-40%
- The construction of 14 demonstration small-scale polynet houses and promotion of improved practices in Chikmagalur and Raichur districts, Karnataka, India has shown that capsicum and tomato yields can be increased by 150-300% and pesticide use reduced by 70% compared to open field production.

Seedling systems

- In a United States Agency for International Development (USAID)-funded project in Tajikistan promoting vegetable seedling production under protected cultivation, more than 450,000 seedlings were produced by women entrepreneurs from 20 improved small-scale nurseries that earned each of them more than 1.3 times the average national per capita income in less than 70 days.
- Model tomato seedling nurseries have been set up in Madanapalle, Andhra Pradesh in India—the site of the largest tomato market in Asia—as a part of a GIZ-funded project. Training programs were held for nursery owners and a training manual on good nursery management was produced with input from public and private sector experts and top nursery owners.
- Grafted tomato seedlings were successfully introduced into Karnataka, India to control bacterial wilt, showing 10% yield increase and 35% increase in net incomes.

Seed industry training

- Six short targeted training courses have been successfully run for the seed industry in Bangladesh over the last two years, showing there is a self-sustaining commercial market for this type of training. Training needs analyses with more 80 seed industry staff in India confirmed strong interest in continuing a regular series of short targeted training courses.

Postharvest management

- In Odisha, India new onion varieties, harvesting and postharvest handling practices successfully extended the storage of harvested bulbs from one to six months, enabling farmers to realize higher incomes.
- Development and promotion of new management practices have enabled onions to be profitably grown during the wet season in Odisha state for the first time.
- Small-scale solar dryers were demonstrated to farmers in Karnataka, showing that 50 kg lots of chilies could be dried in 4 days vs. 9 days under the open sun—and fetch a higher price because solar drying producers a higher quality dried product. A solar dryer with a half-ton capacity has now been installed for community use.

MAFICHONI HAS IT IN THE BAG

The **Mafichoni Farmer Group** in Kibaya village, in the semi-arid Kiteto District of Tanzania, has been cultivating vegetables since 2015 after receiving training from the United States Agency for International Development (USAID)-funded **Homegarden Scaling Project**. The project has been working to improve vegetable production and utilization methods, encouraging the use of improved seeds, and promoting behavior change to increase vegetable consumption.

The Mafichoni garden serves two purposes: to provide vegetables for members to take home and cook, and to produce vegetables for sale.

Farmers in Kibaya always face challenges: to find water for irrigation, deal with pests and diseases, prevent damage by livestock, and contend with low soil fertility. The project works through partners and community-based trainers to address these problems using appropriate technologies.

Mafichoni decided to rotate the responsibility of watering the vegetable garden among its more than 20 members. At least once a week, several members join together to irrigate the vegetable garden. “Each group member is required to bring a bucket of water when it is their turn to water the vegetables,” said Elimi, a group member. “Due to water scarcity, we are now using our own money to buy the water.” Despite incurring costs for watering the crops, the group is capable of maintaining the garden and is still earning income from it.

One gardening method that has proven beneficial to the group is the sack garden. Large sacks are filled with soil and openings cut into the sides. Seeds and seedlings are planted in the openings and at the top. The sacks help retain precious water in the root zone, where it is most needed.

"The introduction of the sack garden by the project is very useful in our area with the water shortage problem," said Elimi. "We save water but still get vegetables for our households. We are planning to develop more sack gardens to save what little water we have."

The group works closely with an extension officer from the Kiteto District Council for guidance on vegetable production. The main buyers for Mafichoni's vegetables are neighbors. The group sells about Tshs 1,000-2,000 Tshs (USD 0.45-0.90) of vegetables per day, and the money earned from vegetable sales is added to the Village Community Bank, where the group is building its cash savings fund. Each group member contributes 3,000 Tshs (USD 1.35) to the fund each week. When the saved amount is sufficient, the money is available for lending to members who need financial assistance.

With sack gardens and other water management methods, this Tanzanian farmer group is growing vegetables for a community

EASTERN AND SOUTHERN AFRICA

- **Research activities** were conducted in eight countries: Burundi, Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Uganda and Zambia.
- WorldVeg Eastern and Southern Africa continues to **host** the International Institute of Tropical Agricultural (IITA). Two other international organizations joined the campus, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the French Agricultural Research Centre for International Development (CIRAD). The Real IPM Company, Africa's largest biocontrol company, joined in 2017, creating a vibrant and synergistic atmosphere to tackle some of the urgent problems facing smallholder vegetable systems.
- Together with CIRAD, WorldVeg catalyzed its **research on protected cultivation** and is working on micro-climate modelling, colored nets, and low-cost prototypes of nethouses for smallholders.
- Research on **amaranth and African eggplant breeding** started in earnest, with an evaluation of segregating populations: three F_3 and two F_4 amaranth populations were evaluated, and selected individual plants were advanced to F_4 and F_5 populations, respectively. Five F_2 African eggplant populations were evaluated and promising individual plants were retained for development of F_3 populations.
- New **cultivars are being released** in Tanzania and Kenya. Three amaranth and two African nightshade candidate lines were DUS (distinctiveness, uniformity and stability)-tested and submitted to the Tanzania Official Seed Certification Institute (TOSCI) for conformational DUS tests prior to release in Tanzania. In Kenya, two amaranth cultivars were released by Kenya Agriculture and Livestock Research Organization (KALRO).
- A total of 13,885 **home garden seed kits**, containing different nutritious traditional African vegetables, were distributed to smallholder farmers and their households in Tanzania, including Zanzibar, and Uganda, while some were distributed to schools for establishing school vegetable gardens. In Tanzania and Uganda, some accessions in the seed kits are increasingly being sourced by the private sector, while in Kenya, the seed kits are already entirely produced by the private sector. Farmers are willing to co-invest, and seed kits are being distributed through farmer co-payment.

- 29 public and private sector researchers and extensionists from Kenya, Zambia and Tanzania received **training in experimental protocols for selection and breeding**.
- A state-of-the-art **seed dryer** was installed, allowing for much improved short-term storage of seeds through temperature and relative humidity control.
- In 2017, **25 students** (5 diploma holders, 14 BSc, 2 MSc, and 4 PhD) from Germany, Kenya, Rwanda and Tanzania conducted their research at the regional office, in collaboration with African and other universities.
- In collaboration with the Tanzania Horticultural Association (TAHA), WorldVeg implemented **several trainings on vegetable drying** for 12 trainer-of-trainers and 500 farmers in four regions (Arusha, Moshi, Tanga and Babati) in Tanzania, using newly developed and constructed solar dryers.
- The VINESA project, funded by the Australian Center for International Agricultural Research (ACIAR) and implemented in four countries in East Africa, came to an end with a June 2017 workshop comprising all stakeholders. This unique project focuses on a 'market first' approach, and equips youth to earn money growing vegetables for lucrative markets. Together with Catholic Relief Services (CRS), WorldVeg started piloting **vegetable business hubs** in Tanzania built on the VINESA experience. Hubs are a sustainable way to link youth groups with each other, input and output markets, and finance—transforming unemployed youth into agripreneurs.
- The regional office organized two week-long **international training workshops** in March 2017, one for quarantine and plant inspection officers from more than 10 countries on combatting *Tuta absoluta,* commissioned by the Food and Agriculture Organization (FAO), and one on technical aspects of vegetable farming commissioned by the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN). 193 professionals benefited from WorldVeg's knowledge through these and other training events.
- WorldVeg participated in the **Nane Nane agricultural show** with Africa RISING, a United States Agency for International Development (USAID)-funded initiative. More than 100,000 farmers saw demonstrations of postharvest and seedling production technologies.

INSPIRED TO GROW

It takes a village to tackle malnutrition. Here's how they did it in Djalé.

The aim of the USAID-funded project Deploying Improved Vegetable Technologies in Mali is to reduce malnutrition, especially among children, by diversifying diets with vegetables, and to promote vegetable production. Farmers interested in improving their vegetable production skills are encouraged to work together and establish community gardens.

Djalé village near Molobala initially was not among those villages selected for the project, but some women residents were so inspired by the successful vegetable harvests of participating neighboring communities that they approached project staff and asked to join the project activities.

The **Best Practice Hub (BPH)** established by the project in Molobala had been training farmers in the area to use improved vegetable production techniques, focus on nutrition, and follow water, sanitation and health (WASH) practices. After some mediation with Djalé community leaders, land was made available for a 2.5 hectare garden and Djalé villagers received training at the BPH.

"The garden is managed mainly by women," said Mrs. Salimata Dembélé, the chief of the local women's association. "However, men provide support for physically demanding work like digging the well or fencing the garden." A total of 165 women are involved in garden activities; husbands assist their wives with watering the vegetable crops, and also step up when the women are not available for health reasons or social commitments.

The women of Djalé are now producing onion, hot pepper, African eggplant, amaranth, okra, tomato, and shallot. Previously, it was a tough challenge for farmers to cultivate vegetables during the rainy season—a time normally devoted to staple food crops. However, through training and the introduction of new vegetable varieties and technologies, Djalé's residents and those of other communities in most project sites now produce vegetables in both rainy and dry-cool seasons.

Salimata Dembélé added that children benefit the most now that vegetable consumption has increased in tandem with the availability of fresh produce in her village. "Malnourishment among them is a problem of the past," she said.

WEST AND CENTRAL AFRICA

Dry Regions

- **Research activities** were conducted in four countries: Ghana, Niger, Burkina Faso, and Mali.
- **Memoranda of Understanding** were signed between WorldVeg and seven countries in the region: Guinee Bissau, Guinée Conakry, Gambia, Mali, Mauritania, and Niger.
- WorldVeg staff attended a workshop at the National Directorate of Agriculture in Mali to validate a **national portfolio of vegetables** and other crops resilient to the effects of climate change in the Mopti, Gao, and Tombouctou regions.
- With the expansion of the Mali Scaling project in Mopti, three **Best Practice Hubs (BPHs)**, 11 **Vegetable Technology Immersion Clusters (VTICs)**, and two **boreholes** were constructed in Douna-Toroli and Ganaguinikoro. **Solar irrigation systems** were set up in Koro Jean d'Arc and Souan. There are now 33 sites in Mopti within five districts.
- Four new **boreholes** were established in Soukourani, N'Tosso, N'Tjila and Kouri in Sikasso for vegetable production and WASH (water-sanitation-hygiene). **Irrigation systems** at four BPHs were rehabilitated and wells deepened.
- 37,680 **Mali Scaling** beneficiaries participating in VTICs and BPHs received seed kits (okra, tomato, African eggplant, pepper, amaranth and onion) in Mopti (17,520) and Sikasso (20,160).
- 14,502 farmers received training in **production and postharvest methods** through the Mali Scaling project.
- Twenty cooperatives in Sikasso region were officially authorized to work in any OHADA (Organization for the Harmonization of African Business Law) country. Training on **cooperative governance** was provided to 126 management committee members (75 men and 51 women).
- Under a six-month **contract**, project beneficiaries of Blédougou Cooperative provided vegetables to the Morila Gold Mining Company for the company's catering needs. Morila was so pleased with the service that it extended the contract for a year.
- FASO KABA Seed Company has signed contracts with two farmers for **seed production**.

- A **Public Private Partnership** subcontract was signed with ICCO, Madougou Agribusiness, and LAWAL International in September to begin planning with cooperatives for future growing seasons.
- **Seed kits** (okra, tomato, African eggplant, pepper, amaranth seeds and sweet potato cuttings) were distributed to 6,525 women and 790 men to improve accessibility and consumption of vegetables. The kits were used to establish 1,018 home gardens in Mopti and 966 in Sikasso, and 152 community gardens in Sikasso (77) and Mopti (75).
- **Nutrition awareness activities for adults and youth** in Mopti (17,928 participants, mostly women), Sikasso (15,190), and Tombouctou (844) benefited thousands of children under 5.
- Among 54 villages targeted, 51 (18 in Sikasso and 33 in Mopti) were certified for **good sanitation practices;** 22,933 adults (12,186 women) had access to basic sanitation.
- **WASH awareness sessions** attracted the participation of 140,357 adults, including 82,786 women in Mopti, Sikasso, and Tombouctou. 85% of households in target communities are now drinking safe water, and 64% use water treatment methods. Nearly half of all households in target communities have a handwashing station with soap.
- Through the Liberia Scaling project, 9,500 (3,834 men and 5,666 women) **vegetable growers** were trained and received vegetable seed kits. Two BPHs were established in Nimba (Kpein) and Bong (Duta) counties to introduce four types of **irrigation systems** (drip, treadle pump, watering can, and gravity). Two **VTICs** were established in Bong (Tomato Camp, Gbondoi) and Nimba (Zao, Neegbein) counties.
- Liberia Scaling introduced **six nutritious vegetables** to farmers: okra ('Konni'), amaranth, hot pepper ('Bafarima'), African eggplant ('I10,' 'Jaxatu'), tomato ('Icrixina') and onion ('Violet de Galmi').
- Six interspecific high yielding and disease-resistant **onion lines** (AVON1278, AVON1282, AVON1290, AVON1605, AVON1701, and AVON1602) showed better performance than the parent lines during dry and humid seasons. Embryo rescue techniques were used to generate successful interspecific crosses between *Allium cepa* and *Allium fistulosum*.

PRODUCING CERTIFIED ONION SEED IN CAMEROON

Onion is the top-ranked market gardening crop in northern Cameroon. Although national production of onion has increased over the past five years due to an expansion in production area, yields are declining.

To help remedy the situation, the International Fund for Agricultural Development (IFAD)/ Commodity Value-Chain Development Support Project (PADFA) funded a project to improve the onion value chain and engage communities to produce onion seed in the country's Far North and North regions.

Through the project, farmers have acquired skills as **certified onion seed producers** to help meet the demand for quality seed, and they have established a network of seed-producing groups to supply growers with this essential input. Ensuring farmers' access to quality

Seed groups find strong demand for their product after applying improved production methods

seed requires production of high quality seed using research-proven approaches and effective distribution networks. Ten Common Initiative Groups (CIG; 5 women's groups and 5 men's groups) were selected to become specialized seed producers producing seed on contract. CIG, an organization of economic and social development volunteers with common interests, mobilizes its membership for joint initiatives. The CIGs contributed 0.25 hectares each, used their group labor, and received inputs. The 10 CIGs produced 250 kg of certified seed in 6 months, and sold it at USD 60/kg, yielding a net income of USD 15,000. This amount of seed can sow more than 60 hectares of land.

A field day to promote professionalization of seed producers held at one of the multiplication sites attracted about 150 participants. "We didn't know onion seed production could be so profitable, so next year we will increase our production area and apply all the techniques demonstrated by WorldVeg," said Mr. Adama Goura, a CIG group leader. "We were not able to satisfy the demand and we intend to meet the optimum yield of 300 kg/ha as WorldVeg did." He said onion growers who purchased CIG seed were very pleased with the product, as the high germination rate allowed them to cover more land area compared to imported seed.

The project approach involved sowing whole bulbs for seed production rather than half bulbs as was traditionally practiced. "People thought we were being foolish, seeing us sow the entire bulb, but when they saw the yield and quality of our seed, they adopted our seed production approach," said Mrs. Yaya Habiba, a seed producer. "In fact, we have 95% germination rate with our seed, compared to 85% for the imported seed we were using previously."

Onion is typically viewed as a "man's crop." At some project sites, women were not allowed to enter the onion seed multiplication fields, as the seed would have been considered impure. But, as seed producer Mrs. Marie Gapsou reported, now that women have been empowered with the knowledge to produce their own high quality onion seed, the taboo is receding. "Men certainly have noticed now that onion seed production makes us financially self-sufficient," said Mrs. Martine Doudou. "They acknowledge the fact that women can support them when they are broke!"

And there is an additional benefit: "We are able to send our daughters to school even if our husbands choose to only to send our sons," Mrs. Doudou said.

WEST AND CENTRAL AFRICA

Coastal & Humid Regions

- A new regional office—**West and Central Africa - Coastal & Humid Regions**—was set up in Cotonou, Benin, on the campus of the International Institute of Tropical Agriculture (IITA). Four new national staff were recruited for the Benin office, and a demonstration garden has been established on the site.
- **Research activities** were conducted in two countries: Cameroon and Ghana.
- A major development was the signing of the **host country agreement** in Benin, with full diplomatic status and privileges.
- An impact assessment was conducted after the closure of Phase I of a project on **commercial certified onion seed production** in the Far North region of Cameroon funded by the International Fund for Agricultural Development (IFAD)/ Commodity Value-Chain Development Support Project (PADFA). The study evaluated the impact of the project on key onion production and livelihood outcome indicators and provided an in-depth understanding of the constraints to and incentives for households to adopt improved production methods. A video of the project's activities was produced and shared with farmer beneficiaries.
- In the second phase of the Urban Food Plus project in Cameroon, a Cameroonian PhD student (a former employee of WorldVeg) began conducting field work on the use of **biochar** as a soil amendment; the experiment is expected to be completed in mid-2018.
- Under an Institute of Agricultural Research for Development (IRAD)-funded **dry season onion variety trial** study in the Far North region of Cameroon, local onion 'Goudami' has shown potential for both wet season and dry season production. Farmers earn higher revenues in the dry season, when onion prices can be three times higher than in the rainy season.
- Dry season variety trials and agronomic research activities were conducted in six hubs equipped with facilities for dry season vegetable production and integrated **livestock-vegetable-nutrition interventions** under the Africa RISING Sudano-Sahel project. Protocols for trial implementation were designed and implemented, and optimal integrated and rotation systems for diverse vegetable and cereal crops were identified.

- **Donor / stakeholder meetings** held in Benin, Cameroon, Ghana and Nigeria have led to the development of several concept notes and proposals submitted to target donors for funding.
- **Strategic partnerships** have been strengthened or forged with private sector partners, national agricultural research systems—for example, Institut National des Recherches Agricoles du Bénin (INRAB); Council for Scientific and Industrial Research of Ghana - Crops Research Institute (CSIR-CRI) and the University of Ghana; Institute of Agricultural Research for Development (IRAD) and Le Ministre de l'Agriculture et du Développement Rural (MINADER) in Cameroon; Tomato Jos (tomato processing company) and Catholic Relief Services (CRS) in Nigeria.
- WorldVeg is part of the IITA-led **Biorisk Management Facility** (BIMAF) that is building a consortium of researchers to look into the one-health approach to biorisk management, including several aspects of food safety.
- With funding from UK aid, CSIR-CRI is assisting WorldVeg in **multi-locational trials** in Ghana to test 14 new tomato lines for heat tolerance and multiple disease resistance.

Projects in 2017

Project Title	Donor Name	Duration	Project budget (USD)
Multi-location evaluation of tomato lines carrying different combinations of Ty genes for resistance against begomovirus infection	Asia and Pacific Seed Association	2014 - 2017	278,263
APSA-WorldVeg Vegetable Breeding Consortium	Asia and Pacific Seed Association	2017 - 2019	18,000
International Training Workshop on Postharvest Management Technology for Horticultural Crops	Asian Food & Agriculture Cooperation Initiative	2015 - 2017	137,158
Strengthening Integrated Crop Management Research in the Pacific Islands in Support of Sustainable Intensification of High-Value Crop Production	Australian Centre for International Agricultural Research	2011 - 2017	844,816
Improving livelihoods with innovative cropping systems on the East India plateau (LWR/2010/082)	Australian Centre for International Agricultural Research	2012 - 2017	90,939
Increasing productivity of allium and solanaceous vegetable crops in Indonesia and sub-tropical Australia	Australian Centre for International Agricultural Research	2013 - 2017	49,518
Improving income and nutrition in Eastern and Southern Africa by enhancing vegetable-based farming and food systems in peri-urban corridors	Australian Centre for International Agricultural Research	2013 - 2017	2,001,075
Promoting traditional vegetable production and consumption for improved livelihoods in Papua New Guinea and Northern Australia (ASEM/2012/084)	Australian Centre for International Agricultural Research	2015 - 2018	128,123
Establishing the International Mungbean Improvement Network	Australian Centre for International Agricultural Research	2016 - 2019	1,611,072
Improved mungbean harvesting and seed production systems for Bangladesh, Myanmar, and Pakistan	Australian Centre for International Agricultural Research	2017 - 2021	795,112
Implementing market-driven vegetable agricultural service providers (ASPs) linking smallholder farmers to services and markets	Belgian Government	2017 - 2018	149,195
Training ATONU Project Staff on Vegetable Production in Tanzania	Bill & Melinda Gates Foundation	2017 - 2017	20,650
Implementation of the Youth Vegetable Business Hub (YVBH) Project	Catholic Relief Services	2017 - 2018	92,341

Project Title	Donor Name	Duration	Project budget (USD)
Improving Food Security in the South West Region of Cameroon by Promoting Nutritious Vegetables	CHEDE Cooperative Union LTD.	2017 - 2018	29,381
Improved Livelihoods through Crop Diversification into Vegetables in Jharkhand and Odisha under the Central India Initiative	Collectives for Integrated Livelihood Initiatives (CInI)	2016 - 2019	233,501
Strengthening cooperation between AVRDC and COA on vegetable research and development	Council of Agriculture, Taiwan	2017 - 2017	483,582
Screening of tomato germplasm for resistance to important diseases and using molecular markers to assess the resistance of tomato to phylotype II of bacterial wilt	Council of Agriculture, Taiwan	2017 - 2017	68,000
Use of grafting technology for disease resistance and climate resilience for tomato production in Taiwan and USA	Council of Agriculture, Taiwan	2017 - 2017	24,820
Evaluation of F1 vegetables in Thailand and India	Council of Agriculture, Taiwan	2017 - 2017	32,130
Tomato Variety Trials in Thailand and Market Survey	Council of Agriculture, Taiwan	2017 - 2017	32,300
Linking genetic resources, genomes and phenotypes of Solanaceous crops	European Commission	2016 - 2021	447,238
Attraction in Action: Using pheromones and other safe and sustainable management strategies to reduce losses from insect pests and plant diseases on vegetable legumes and leafy brassicas in Southeast Asia	Federal Ministry for Economic Cooperation and Development, Germany	2014 - 2017	1,283,928
Enhancing the Livelihood Opportunities of Smallholder African Indigenous Vegetable (AIV) Producers through the Development and Implementation of IPM Measures for Arthropod and Nematode Pests	Federal Ministry for Economic Cooperation and Development, Germany	2014 - 2017	178,932
Beans with Benefits: Integrating improved mungbean as a catch crop into the dryland systems of South and Central Asia for increased smallholder farmer income and more sustainable production systems	Federal Ministry for Economic Cooperation and Development, Germany	2015 - 2018	1,283,928

Project Title	Donor Name	Duration	Project budget (USD)
Wild Relatives to Fight Blight: Using wild tomato to enhance the resistance of tropical tomato cultivars against late blight	Federal Ministry for Economic Cooperation and Development, Germany	2015 - 2017	85,595
Nutrition-Sensitive Promotion of Vegetables (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
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
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
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 *C. annuum* 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
Small grants for construction of a Zero Energy Cooling Chamber in Mali	Federal Ministry for Economic Cooperation and Development, Germany	2017 - 2017	2,195
Training Service on *Tuta absoluta* Management	Food and Agriculture Organization of the United Nations	2017 - 2017	17,384
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

Project Title	Donor Name	Duration	Project budget (USD)
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
Implementation support on High Value Agriculture (HVA) through demonstration, research studies, technical support and capacity building on various vegetables and horticulture crops under the JOHAR project	Government of Jharkhand, India	2017 - 2023	1,377,911
Improving Rural Livelihoods through Innovative Scaling-up of Science-led Participatory Research for Development in Karnataka	Government of Karnataka (GoK), India	2013 - 2017	320,000
Improve Mungbean and Urdbean Productivity in Odisha State	Government of Odisha, India	2015 - 2018	373,440
Onion Value Chain Improvements in Odisha	Government of Odisha, India	2016 - 2018	392,112
Multiple disease resistant and heat tolerant tomato lines evaluation	I & B Seeds Private Limited	2016 - 2017	20,000
Selection of tropically adapted lines of vegetables to improve productivity of the vegetable value chain in Myanmar and Vietnam	Japan Ministry of Agriculture, Forestry and Fisheries	2016 - 2018	273,068
Screening for development of begomovirus-resistant processing tomato hybrid	Kagome Co., Ltd., Japan	2010 - 2018	143,333
Networking to Enhance International Cooperation in Vegetable Research and Development	Ministry of Foreign Affairs, Taiwan	2017 - 2018	400,000
Mobilize resistance genes from wild tomato for breeding salt tolerant tomato cultivars	Ministry of Science and Technology, Taiwan	2014 - 2017	81,098
A holistic approach towards the design of new tomato varieties and management practices to improve yield and quality in the face of climate change	Ministry of Science and Technology, Taiwan	2016 - 2019	109,548
Support for the implementation of PADFA's onion seed programme	PADFA (The Commodity Value Chain Development Support Project), Cameroon	2015 - 2017	166,570
Private seed sector support to WorldVeg's global cucurbit breeding program	Private seed companies	2016 - 2019	204,975
Broadening the narrow genetic base of commercial bitter gourd cultivars by exploiting the genetic diversity of WorldVeg's breeding lines	Private seed companies	2017 - 2020	530,000

Project Title	Donor Name	Duration	Project budget (USD)
Identification of molecular markers associated with disease and insect resistance for marker assisted selection (MAS) in tomato (*Solanum lycopersicum*) breeding programs	Rural Development Administration, Korea	2016 - 2018	120,000
Development of Breeding Techniques and Selection of Disease Resistant Germplasm in Vegetables	Rural Development Administration, Korea	2017 - 2019	105,000
Cambodian Horticulture Project for Advancing Income and Nutrition	Swiss Agency for Development and Cooperation	2015 - 2017	520,992
Vegetables Go to School: Improving Nutrition through Agricultural Diversification (Phase 2)	Swiss Agency for Development and Cooperation	2016 - 2017	52,718
Development and Utilization of Indigenous Vegetables	Taiwan Sugar Corporation	2017 - 2017	11,220
Vegetables for All	The Amsterdam Initiative against Malnutrition, the Netherlands	2014 - 2019	54,682
Utilizing the genome of the vegetable *Cleome gynandra* for the development of improved cultivars for the West and East African markets	The Netherlands Organisation for Scientific Research (NWO)	2015 - 2017	5,885
IMMANA Project ENRICH	UK Department for International Development	2017 - 2019	22,947
Africa RISING: Enhancing vegetable value chains in rice-based and sole crop production systems to improve farm household income and consumer access to safer vegetables in Morogoro, Tanzania	United States Agency for International Development	2012 - 2017	527,252
Cereal-based Systems of West Africa: Vegetables and associated best management practices in cereal-based crop production systems to improve income and diets of rural and urban households in Northern Ghana & Southern Mali	United States Agency for International Development	2012 - 2018	1,110,926
Postharvest Program	United States Agency for International Development	2012 - 2018	3,400,000
Promoting Science and Innovation in Agriculture in Pakistan (PSIAP) - Agricultural Innovation Program (AIP)	United States Agency for International Development	2013 - 2017	2,583,126
Deploying Improved Vegetable Technologies to Overcome Malnutrition and Poverty in Mali (Module 1)	United States Agency for International Development	2014 - 2017	6,100,000

Project Title	Donor Name	Duration	Project budget (USD)
Deploying Improved Vegetable Technologies to Overcome Malnutrition and Poverty in Mali (Module 2)	United States Agency for International Development	2015 - 2017	3,650,000
Nutrition Sensitive Vegetable Technologies	United States Agency for International Development	2014 - 2017	838,934
Deploying Vegetable Seed Kits to Tackle Malnutrition in Cambodia, Kenya, Liberia, Tanzania and Uganda	United States Agency for International Development	2014 - 2018	4,621,230
Enhancing partnership among Africa RISING, NAFAKA and TUBORESHE CHAKULA Programs for fast-tracking delivery and scaling of agricultural technologies in Tanzania	United States Agency for International Development	2014 - 2017	592,278
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 - 2017	95,000
Support the 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
Evaluation of Low-Cost Vegetable Cooling and Storage Technologies in Mali	United States Agency for International Development	2017 - 2017	15,000
Women in Agriculture Network (WAgN) Cambodia: Gender and Ecologically Sensitive Agriculture	United States Agency for International Development	2016 - 2018	17,060
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
Research on the WAKATI Storage Chamber for storage of vegetable crops in Arusha, Tanzania	Wakati B.V.B.A.	2016 - 2017	28,888
Facilitating Value Addition and Processing in the Context of the Cassava, Maize, Banana, Vegetable, and Livestock Value Chains (PRODEMA) Activities to Support Fruit and Vegetable Value Chains	World Bank	2017 - 2019	292,239

We Couldn't Do It Without You

STRATEGIC LONG-TERM FUNDING

Our donors—governments, foundations, organizations, and corporations—make the World Vegetable Center's work possible. Their generous support strengthens our commitment to research that realizes the potential for healthier lives and more resilient livelihoods for small-scale farmers and their families across Asia and Africa.

We recognize those donors that have provided USD 100,000 or more to further the Center's work during 2017.

PROJECT FUNDING

Federal Ministry for Economic Cooperation and Development

行政院農業委員會
COUNCIL OF AGRICULTURE, EXECUTIVE YUAN

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

USAID FROM THE AMERICAN PEOPLE

APSA THE ASIA & PACIFIC SEED ASSOCIATION

中華民國外交部
MINISTRY OF FOREIGN AFFAIRS REPUBLIC OF CHINA (TAIWAN)

MAFF Ministry of Agriculture, Forestry and Fisheries

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

RDA RURAL DEVELOPMENT ADMINISTRATION

Australian Government
Australian Centre for International Agricultural Research

THREE CROPS TO WATCH

Project and long-term donors, particularly UK aid, BMZ, and ACIAR, support research to develop vegetable crops suited for the needs of small-scale producers in Asia and Africa. Three crops to note:

AMARANTH

Nutritious and easy to grow, this healthy and profitable crop is a winner for small-scale farmers

WorldVeg scientists and field staff in Arusha, Tanzania have been selecting individual 4th and 5th generation amaranth plants to use in developing improved open-pollinated varieties of this versatile vegetable. Open-pollinated varieties allow farmers to save their own seeds for planting in the following seasons.

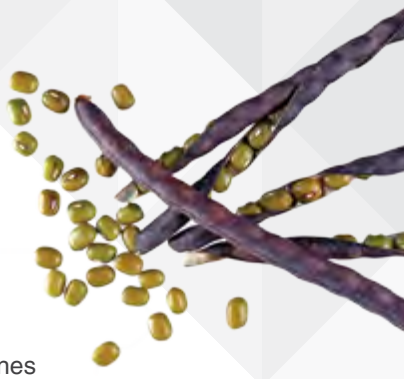
There are three types of amaranth: *Vegetable types*, grown for their nutritious and tasty leaves; *grain types*, which are favored for the production of high-protein grain (seed); and *dual-purpose types*, which are used for both leaves and grain.

To develop improved open-pollinated amaranth varieties, WorldVeg breeders have been crossing grain and vegetable type parents to improve the seed yield of the vegetable type. Seed producers want the vegetable type to produce more seed while also maintaining leaf quality.

Amaranth offers an assortment of nutritional benefits, including highly digestible proteins (99% digestibility) as well as vitamins and minerals such as potassium and iron. Plus, it is an easy crop to grow. Within 28 days of transplanting the leaves can be harvested for home consumption and/or sale, making amaranth a healthy and profitable crop for small-scale farmers.

MUNGBEAN

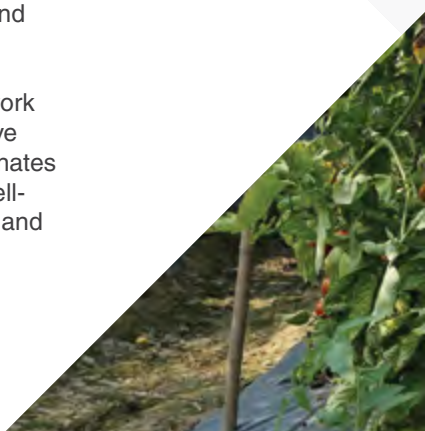
A short-season legume with a long history in Asia begins a new chapter in Africa



Mungbean, a short-season legume (50-60 days) that fits well into rice, wheat and other crop rotations, helps improve soil fertility and provides additional income for farmers. High in protein and easy to digest, mungbean has long appealed to palates across Asia—and African consumers are beginning to develop a taste for it as well.

Mungbean has been part of the Center's research portfolio since the 1970s. Over the years, the Center has bred 132 improved mungbean lines worldwide—including the first mungbean varieties released in Timor-Leste, in 2016. Recent work involves developing suitable machinery and cropping practices to facilitate mechanical harvesting, assessing the impact of mechanization on women (who typically harvest the crop by hand), and providing options to benefit women's livelihoods.

WorldVeg established the International MungbeanImprovement Network in 2016 to ensure work to unlock the potential of mungbean to improve system productivity livelihoods can continue. The network and coordinates and performs research resulting in the development andrelease of well-admungbean varieties that raise the profitability of smallholder farms and the sustainability of local production systems.



TOMATO

"Hairy" lines hold the promise of reduced pesticide use

Producing top-quality tomato for the tropics has long been the goal of WorldVeg tomato breeding. More than 194 tomato varieties based on WorldVeg breeding materials are now used around the globe, especially in tropical regions of Asia and Africa. These high-yielding, disease-resistant varieties increase the productivity and incomes of tropical vegetable farmers, and provide opportunities for processing and off-season production.

Pest resistance, however, has proven more difficult to find or breed into tomato. A cultivated tomato variety able to resist the predations of whitefly, spider mites, *Tuta absoluta* and other troublesome pests would be of great benefit to everyone: Farmers could reduce pesticide applications and their costs for operation, produce safer tomatoes for consumers, and contribute to a healthier environment for all.

WorldVeg tomato breeders recently identified such a tomato when they screened thousands of plants—including some wild relatives of tomato from the WorldVeg genebank—for trichomes, the plant hairs that interfere with pest movement or feeding. They then crossed these plants with other WorldVeg tomato lines.

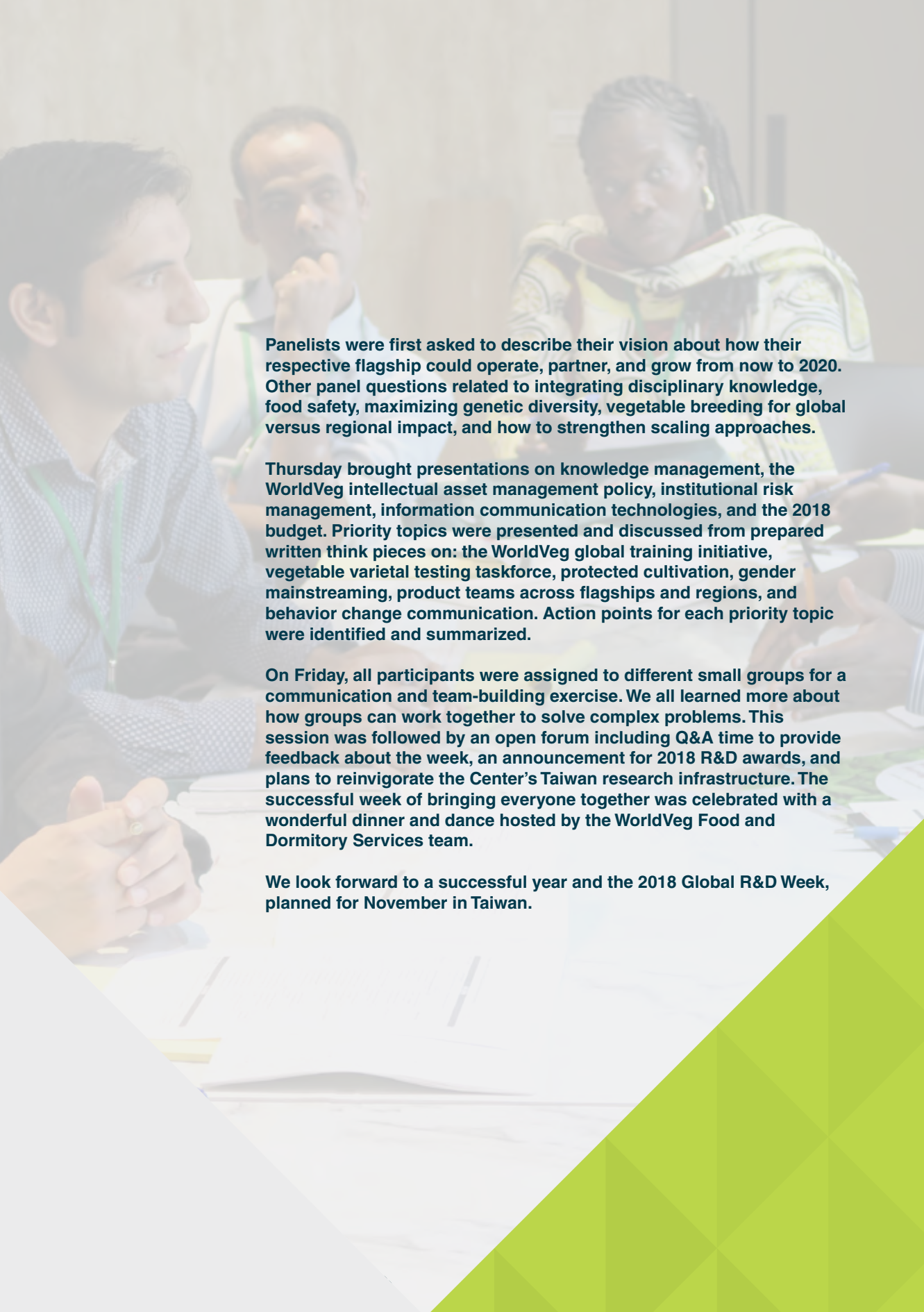
A first generation backcross produced a remarkable result: large fruit and a pest-resistant plant. It can take many generations of backcrossing and years of work to achieve such a breeding goal. Now, with the discovery of this big hairy tomato, the work of breeding pest and disease resistant tomato can move along faster, and the useful traits can be used to improve other tomato lines.

GLOBAL R&D WEEK

The world came to Shanhua, Taiwan from 4-8 December 2017 when 87 staff members from regional and project offices in Benin, Mali, Cameroon, Tanzania, India, Uzbekistan, Cambodia, and Thailand met at WorldVeg headquarters for **Global R&D Week**—an annual opportunity to get acquainted with colleagues, learn about their progress, and plan for future activities. Members of the WorldVeg Board of Directors also participated in various Global R&D sessions during and after the annual board meeting, held concurrently with the R&D week.

The week started on Monday with one-on-one staff meetings about new and ongoing research projects. On Tuesday, concurrent flagship program meetings were held in the newly renovated meeting space above the canteen. Each flagship (*Safe and Sustainable Value Chains; Healthy Diets; Vegetable Diversity and Improvement;* and *Enabling Impact*) reviewed 2017 achievements and organization of innovation clusters—the outcome targets pursued through discovery, piloting and scaling activities and ongoing improvement of products and services. Future strategic opportunities, new product concepts, and detailed 2018 deliverables were identified for staff to use when writing their annual work plans.

Joint flagship sessions were held on Wednesday. Each flagship leader presented blueprints to update the 2017-2020 Operational Plan with reorganized or updated innovation clusters. This session was followed by flagship panel discussions. Five staff from each flagship were invited to participate and share their thoughts on three questions, followed by open questions from board members and staff.



Panelists were first asked to describe their vision about how their respective flagship could operate, partner, and grow from now to 2020. Other panel questions related to integrating disciplinary knowledge, food safety, maximizing genetic diversity, vegetable breeding for global versus regional impact, and how to strengthen scaling approaches.

Thursday brought presentations on knowledge management, the WorldVeg intellectual asset management policy, institutional risk management, information communication technologies, and the 2018 budget. Priority topics were presented and discussed from prepared written think pieces on: the WorldVeg global training initiative, vegetable varietal testing taskforce, protected cultivation, gender mainstreaming, product teams across flagships and regions, and behavior change communication. Action points for each priority topic were identified and summarized.

On Friday, all participants were assigned to different small groups for a communication and team-building exercise. We all learned more about how groups can work together to solve complex problems. This session was followed by an open forum including Q&A time to provide feedback about the week, an announcement for 2018 R&D awards, and plans to reinvigorate the Center's Taiwan research infrastructure. The successful week of bringing everyone together was celebrated with a wonderful dinner and dance hosted by the WorldVeg Food and Dormitory Services team.

We look forward to a successful year and the 2018 Global R&D Week, planned for November in Taiwan.

REDUCING RELIANCE ON PESTICIDES

Pests and diseases continue to constrain vegetable production in tropical Asia and Africa. In an attempt to produce blemish-free vegetables, growers resort to the indiscriminate use of chemical pesticides, which increases the cost of production and makes vegetables less safe for consumption. To reduce the quantity of chemical pesticides being used in vegetable production—and thus make our food supply safer— WorldVeg has developed alternative pest management techniques and validated several of them in South and Southeast Asia.

In collaboration with national partners in Cambodia, Lao PDR and Vietnam, WorldVeg demonstrated that integrated pest management (IPM) strategies combining **biopesticides**, pheromone and colored sticky

traps, and need-based application of chemical pesticides reduces pest populations to levels on par with farmers' usual practices of calendar-based spraying.

These IPM strategies have reduced the amount of pesticides used on leafy brassicas and yard-long bean in Lao PDR and Vietnam, and on tomato, cucumber, Chinese mustard, and yard-long bean in Cambodia—without compromising yield. With less chemical pesticides in the fields, natural enemies have proliferated, such as the gregarious larval parasitoid (*Cotesia glomerata*) that feeds on imported cabbage worm (*Pieris rapae*) in cabbage fields in Vientiane province, Lao PDR.

IPM practices were promoted through Field Days at pilot sites for 300 progressive farmers, researchers, and extension staff from public and private institutes and NGOs in all three countries during 2016-2017.

Although biopesticides and pheromones are highly effective against pests, they are not easy to obtain in local markets in Southeast Asia. However, good agricultural practice (GAP) standards recently developed and launched in Lao PDR and Cambodia are providing the impetus to make these safe products more widely available to farmers. With the concerted efforts of GIZ's ASEAN Sustainable Agrifood Systems project, Cambodia instituted a registration system for biocontrol agents at the end of 2017. This new system will enable Cambodian companies to import, distribute, and market biopesticides.

WorldVeg's successful validation of IPM strategies during 2015-2017 demonstrated the value of using biocontrol agents on vegetable legumes and brassicas in Cambodia. The conducive regulatory environment and availability of effective IPM strategies encouraged private sector companies such as Eco-Agri Co. Ltd. to import biopesticides and pheromones into the country with the support of WorldVeg. With the prevailing policy support from the government and sustained interest among the private sector, countries like Lao PDR and Cambodia will be able to phase out the use of noxious chemical pesticides in vegetable production, while promoting GAP.

Safer products and practices for integrated pest management proven in the field

SAFE AND SUSTAINABLE VALUE CHAINS

- **Phylogeographical structure** in the populations of selected pests of yard-long bean and brassicas in Cambodia, Lao PDR, Taiwan, Thailand and Vietnam developed. Aphid (*Aphis craccivora*) and thrips (*Megalurothrips usitatus*) on yard-long bean and striped flea beetle (*Phyllotreta striolata*) and imported cabbage worm (*Pieris rapae*) are the predominant species.
- *Fusarium proliferatum*, associated with internal fruit rot, and *Colletotrichum coccodes*, causing fruit and leaf anthracnose, were identified as **emerging pathogens** on sweet pepper in Taiwan.
- *Cercospora capsici*, cause of pepper leaf spot, *Passalora fulva*, cause of tomato leaf mold, *Psudocercospora fuligena*, cause of **tomato black mold**, and *Phoma destructiva*, cause of Phoma leaf spot, were detected from tomato and pepper samples collected from the Sigatoka Valley in Fiji and from East Honiara in the Solomon Islands.
- **Begomoviruses** were the most commonly detected viruses on tomato and pepper collected in Mali, while the major virus detected in eggplant from Mali was *Potato virus Y* (PVY). Begomoviruses also were the most commonly detected viruses in samples of pepper, cucumber, bitter gourd, squash, wax gourd, sponge gourd and ridge gourd from Cambodia. *Bean common mosaic virus* was commonly detected in yard-long bean samples from Cambodia, Lao and Vietnam, and *Soybean mosaic virus* (SMV) was important on yard-long bean in Vietnam.
- Treatment of tomato plants with the **plant defense activator**, Beta-Aminobutyric acid (BABA), significantly reduced the extent of bacterial wilt (*R. solanacearum*) infection. The incidence of black rot (*Xanthomonas campestris* pv. *campestris*) on cabbage was also reduced with the defense activators BABA and phosphorous salt or by either of two commercial biocontrol agents, synergistic enzyme (includes *Bacillus* spp. and *Enterococcus* spp.) or *Bacillus amyloliquefaciens*.
- **Biocontrols** *Trichoderma* spp., *Streptomyces* spp. and "Synergistic enzyme" (includes *Bacillus* spp. and *Enterococcus* spp.) were effective at reducing the severity of southern blight (*Sclerotium rolfsii*) on tomato, pepper, and cabbage.
- Three **grafting workshops** were held in Thailand, Honduras and Cambodia, and a total of 128 participants were trained.

- Five eggplant accessions showed stable **resistance to bacterial wilt;** two were highly resistant to eight strains of *R. solanacearum* isolated from different hosts. Newly developed resistant rootstocks were introduced to Cambodia and USA.
- Forty **salt tolerant eggplant accessions** were selected and tested for their grafting compatibility with tomato scions. Seventeen accessions had both salt tolerance and bacterial wilt (*R. solanacearum*, PSS97) resistance. Ten elite rootstocks were selected for further yield trial and fruit quality analysis.
- **Protected cultivation technology** including nethouses, polyhouses and low tunnels were validated and scaled out in India, Kenya, and Tanzania.
- **Integrated Pest Management (IPM) packages** based on pheromones, colored traps and biopesticides were validated and promoted for brassicas, bitter gourd, eggplant, pepper, tomato and yard-long bean in Bangladesh, Cambodia, India, Lao PDR, Mali, Taiwan, Tanzania, and Thailand.
- At four Best Practice Hubs in Ethiopia, Malawi, Mozambique and Tanzania, 120 (62 male, 58 female) **youth** were equipped with skills on integrated crop management, soil health management, and pest management to enable them produce nutritious, safe and affordable vegetables. During an impact assessment survey in March/April 2017, 68% of those who attended training were found to be applying the various skills they had learned.
- 64 **elite germplasm** (high-yielding, disease and insect resistant) from the WorldVeg Genebank in Arusha and Taiwan were piloted in peri-urban centers in Ethiopia, Malawi, Mozambique, and Tanzania to improve nutritional status and increase market returns for smallholder farmers and their families. For example, between April and June 2017, VINESA trainees in Tanzania realized USD 18,500 from selling 30 tons of French beans, broccoli, lettuce, cauliflower, and snow peas through an association of horticultural farmers' groups called *Muungano wa Vikundi Vya Kilimo cha Horticulture* (MVIKIHO).
- **Solar dryers**, curing, sorting, grading and storage methods, Zero Energy Cool Chambers (ZECC), and Zeer pots (two earthenware pots with a layer of wet sand in between) were evaluated for vegetables in India, Mali and Tanzania.

DOING DOUBLE DUTY

Tomato production generates valuable income for smallholder vegetable farmers in developing countries, but during the peak season, markets may become saturated and farm gate prices can drop dramatically, making tomato farming unprofitable. Transforming tomato into ketchup, juice or puree during gluts helps to stabilize prices and can generate additional income from cottage industries.

The best fruit for processing has specific characteristics: The fruit should be firm, have deep red internal color (due to abundant lycopene), and a high content of soluble solids (brix >4.5).

The World Vegetable Center tomato breeding team used the *hp*$^{-1}$ allele and the crimson gene (*og*^{c}) to increase the lycopene content in tomato fruit. This trait was brought into heat tolerant cultivars with high brix and good fruit firmness, and was combined with resistance genes against Tomato yellow leaf curl disease (TYLCD, Begomovirus) and bacterial wilt.

Enjoy the fruit fresh or processed—either way, these dual-purpose tomato cultivars adapted to the tropics produce high quality fruit farmers and consumers appreciate and processors demand

In trials conducted at WorldVeg HQ in Shanhua, Taiwan from March-June 2017, the yield and quality of the dual-purpose cultivars for fresh consumption and processing were clearly superior to common tomato.

While the check varieties developed severe TYLCD symptoms resulting in stunted plants and high yield losses, the new lines showed only very mild to moderate virus infection symptoms. Their marketable fruit yield reached up to 42 t/ha compared to 14 t/ha for the control lines. The red color of the new lines was much deeper than in the control lines due to a 60% higher lycopene content. In addition, their pro-vitamin A and vitamin C contents were twice as high as in common tomato.

The new dual purpose tomato lines are currently being tested in India, Bangladesh, and Tanzania to assess their adaptation to tropical conditions.

Above: **CLN3661 plants resistant to TYLCD and bacterial wilt with heavy fruit load, March-June 2017, WorldVeg HQ, Shanhua, Taiwan.**

VEGETABLE DIVERSITY AND IMPROVEMENT

Vegetable Diversity and Improvement

- 1,300 genebank accessions were regenerated and 680 were characterized, including 360 traditional African vegetable accessions.
- 15,800 genebank accessions and breeding lines were distributed to public and private entities in 53 countries.
- > 10,000 traditional African vegetable seed kits were distributed to smallholder farmers in Tanzania and Uganda.
- >15,800 DNA samples of tomato, pepper and eggplant were submitted to genotyping for genetic characterization in the EU-funded Horizon 2020 project G2P-SOL.
- Whitefly resistance was identified in wild relatives of eggplant and pepper.
- New eggplant germplasm resistant to bacterial wilt discovered.
- New mungbean germplasm resistant to mungbean yellow mosaic disease, powdery mildew, tan spot, halo blight and dry root has been identified.
- Molecular markers associated with two nuclear male sterile genes for pepper were developed.
- Molecular markers for *Tomato mosaic virus* (ToMV) resistance were validated in pepper and mutations in the *L2* gene associated with differences of disease symptom severity were found.
- Fifteen multiple disease-resistant dual purpose tomato lines with improved processing quality and increased vitamin content were tested in India, Bangladesh, and Tanzania.
- Horticultural traits and disease resistance of 100 advanced bitter gourd breeding lines were documented and shared with WorldVeg's bitter gourd breeding consortium.
- The seed-to-seed cycle of onion in West Africa was shortened by 50% using protective tunnels during the rainy season.
- Vernalization conditions were optimized for onion seed and germination rates of >60% were achieved in West Africa.

Cultivar releases

- Two tomato varieties based on WorldVeg materials were released in Pakistan and two in Bangladesh.
- Thirteen hot pepper and 9 sweet pepper improved lines were released, constituting new sets of the International Chili and Sweet Pepper Nurseries available to APSA-WorldVeg consortium members.
- Three amaranth lines, one vegetable type (*Amaranthus dubius*), one grain and vegetable type (*A. hypochondriacus*) and a grain type (*A. cruentus*), as well as two African nightshade lines (*Solanum scabrum and S. villosum*) were tested for distinctness, uniformity, and stability (DUS) and submitted to the Tanzania Official Seed Certification Institute.
- Two mungbean varieties 'Lakateu-AV' and 'Kiukae-AV' derived from WorldVeg materials were released in Timor-Leste. Three early maturing (65 days), large seeded mungbean varieties were released in Kenya and two in Uganda.
- Variety certification was applied for one F_1 hybrid pumpkin, and one open-pollinated pumpkin variety ('Hualien AVRDC No. 1' - Taisun) was released in Taiwan.

The Feed the Future-funded Homegarden Scaling Project in four countries in Africa and in Cambodia focuses on improving nutritional outcomes. Some project participants in Cambodia, however, are going a step further and finding ways to turn their household garden plots into the anchors of family livelihood strategies.

Most rural Cambodians do not specialize in a single crop or one type of livestock. They usually generate income through paddy, mungbean, cattle, and poultry in addition to some off-farm work.

Ms. Mei and her husband were selected by their fellow project participants to host a demonstration site for the introduction of **household gardens** in their village. The couple had the respect of others in their community because they already were leading a rice farming group and had a larger site in which to demonstrate the World Vegetable Center's techniques.

Through the coordination of a local NGO, Ms. Mei established a 100 m^2 vegetable demonstration plot following the best practices

COMMERCIAL RETURNS FROM A HOUSEHOLD GARDEN

she learned through the project. But simply showing crops to passers-by wasn't enough for this entrepreneurial woman. After she saw how her 3-year-old son and 6-year-old daughter were benefiting from consuming the readily available vegetables from her garden, she realized there was unmet demand for clean, nutritious fresh produce in the local market.

Ms. Mei increased her household garden size to cover 400 m^2 and is now selling large quantities of kangkong, leaf amaranth and bitter gourd in the market to customers who appreciate the quality of the vegetables she produces.

With an income stream from her garden, Ms. Mei has been able to afford other necessities for the family. Her experience shows that in addition to seeking improved nutritional outcomes, the World Vegetable Center's household garden concept could be expanded to incorporate opportunities for income generation as well.

HEALTHY DIETS

- Over 2,000 households in Cambodia, 2,700 in Kenya, 9,500 in Liberia, 5,800 in Tanzania, and 3,700 in Uganda received **seed kits** containing various types of nutrient-dense vegetables. 26,900 households received training on good agricultural practices, nutrition and health in all countries, benefitting a total of 22,000 children under the age of five. These activities resulted in 21,000 households using at least two improved technologies, such as improved seed, transplanting, proper spacing, use of compost, mulching, irrigation, IPM, and crop rotation.
- In Cambodia, the use of on-line system **Akvo Flow** was mainstreamed for monitoring technical assistance in household gardens. This mobile phone-enabled data collection system facilitated swift reaction to problems as they arise from the field, such as pest outbreaks and identification.
- Effectiveness of **message delivery channels** and nutrition education of household garden program on nutrition knowledge, attitudes and practices were studied in Cambodia. Messaging resulted in significantly higher household garden adoption, but did not increase household dietary diversity scores with 10 food groups. Trainers from government agencies delivered higher outcome scores in nutrition practices, gender, and vegetable production than trainers from local NGOs.
- **Training manuals** for community-based trainers on improved agronomic practices, postharvest management, nutrition, WASH and seed saving were developed in collaboration with SNV and used to train 5,000 household garden farmers in Cambodia.
- In Kenya, Tanzania, and Uganda, 374 **demonstration plots** have been established as learning centers for agronomic practices, and 248 community-based trainers have been trained to train other beneficiaries to improve household garden production methods and nutrition practices.
- In Liberia, two fully equipped **Best Practice Hubs** (BPH) and five **Vegetable Technology Immersion Clusters** (VTIC) were completed and have become operational, training thousands of smallholder vegetable producers.
- In Mali, more than 32,400 farmers were trained in vegetable production, 13,500 people were trained on improved nutrition, and 7,300 seed kits were distributed. More than 150 **community gardens** and 2,300 household gardens were established.

- **Randomized controlled trials** in Burkina Faso, Bhutan, Nepal and Indonesia for the Vegetables Go to School project were conducted, and country-specific implementation documentation were completed. Methods and results including scaling plans and cost per school over 3 years each were described in booklets (http://vgts.avrdc.org/research/research-publications/). The WorldVeg team led 13 publications and were co-authors for 5 papers, from the total of 32 project publications.
- 61 vegetables (48 species) were obtained from local markets in southern Taiwan during the 2017 summer season to measure content of fiber, sugar, flavonoids, oxalate, total phenols, oil, carotenoids, vitamin C, and vitamin E as well as **antioxidant activity**. A paper was published.

VEGETABLES GO TO SCHOOL, BUT NOT NECESSARILY TO CHILDREN'S PLATES

Is the available supply of fruit and vegetables the key factor in getting children to eat both?

There is a surge of interest in school garden programs for low-income countries, but there is very little evidence to date that such programs drive children to make healthier food choices. The Vegetables Go to School project (2013-2017), funded by the Swiss Agency for Development and Cooperation, evaluated the impact of school vegetable gardens linked to complementary education and promotion on a range of indicators along the intervention's impact pathway from awareness creation to food behavior. The project used a cluster randomized controlled trial design in Bhutan, Burkina Faso, and Nepal and measured the 1-year effect of the intervention.

The studies found that school gardens significantly improved children's knowledge about food and agriculture in all three countries. For Bhutan and Nepal, there also were significant improvements in children's awareness of fruit and vegetables and their stated preferences for eating these. However, all three studies found that school gardens did not prompt children's actual food choices toward healthier diets. These research findings broadly confirm the findings of two major reviews of school garden programs in high income countries, which showed that school garden programs are more effective in changing knowledge and attitudes than in driving actual food choices.

Children's food choices may have been constrained by limited availability of fruit and vegetables at their homes, or by parents' overriding influence on children's food choices. A new project, funded by the Bill & Melinda Gates Foundation and UK aid through the Drivers of Food Choice program managed by the University of South Carolina, will test these hypotheses for Nepal. It will add a household garden component to increase home vegetable supplies and influence parents' food behavior.

Governmental and non-governmental organizations may need to be more cautious in promoting school garden programs to low income countries and may need to use more comprehensive intervention designs that address local constraints in fruit and vegetable demand and supply.

Schreinemachers P, Bhattarai DR, Subedi GD, Acharya TP, Chen H-p, Yang R-y, Kashichhawa NK, Dhungana U, Luther GC, Mecozzi M. 2017. Impact of school gardens in Nepal: a cluster randomised controlled trial. Journal of Development Effectiveness 9(3):329-343. doi:10.1080/19439342.2017.1311356

Schreinemachers P, Rai BB, Dorji D, Chen H-p, Dukpa T, Thinley N, Sherpa PL, Yang R-y. 2017. School gardening in Bhutan: Evaluating outcomes and impact. Food Security 9(3):635-648. doi:10.1007/s12571-017-0673-3.

Schreinemachers P, Ouedraogo MS, Diagbouga S, Thiombiano A, Kouamé SR, Sobgui CM, Chen H-p, Yang R-y. 2018. Impact of school gardens and complementary education in Burkina Faso. Under review.

ENABLING IMPACT

- Six **papers** documenting the impact of the Center's work in Asia and Africa were published in international peer-reviewed journals. Various other papers were published that characterize vegetable production and consumption in various countries.
- **Countrywide adoption studies** of improved varieties and associated agronomic practices were launched for mungbean in Bangladesh, India, Myanmar, and Pakistan and for amaranth in Tanzania and Kenya.
- An **online monitoring system** was launched to better track the use of WorldVeg germplasm by seed producers.
- Scaling strategies were defined for **amaranth, tomato and mungbean** for UK aid priority countries (as a pilot).
- A scoping study was completed on **vegetable sector development** in Myanmar.
- The **APSA-WorldVeg Vegetable Breeding Consortium** got started with 19 companies of the Asia & Pacific Seed Association (APSA) joining the consortium in 2017. The inaugural workshop, held in Taiwan, was attended by 17 companies.
- The **WorldVeg-Taiwan Seed Industry Exchange Platform** was established to strengthen ties with Taiwan seed companies and public organizations active in vegetable improvement. The platform was launched on 1 November 2017 and promoted during 2017 Taiwan Seed Trade Association's annual convention and Seed and Seedling Festival.
- The Center's new **knowledge management system**, called HARVEST (https://worldveg.tind.io/), was launched in December 2017. The system provides easy access to publications as well as research data, study protocols, and data collection tools.
- **Biometrics support** including evaluation and advice on experimental designs, management and analyses of data, statistical review of papers and presentation of results was provided to around 31 scientists, trainees and students.

Marwan Benali

Gain knowledge, pick up practical skills, and launch a career

PhD candidates participating in WorldVeg research programs find opportunities to grow.

Marwan Benali, a German Research Council-funded PhD candidate at the Georg-August University Goettingen, Germany, worked with WorldVeg from July 2015 on "Export vegetable supply chains, household labor allocation and poverty effects among small producers – Evidence from Northern Tanzania" under the co-supervision of WorldVeg Agricultural Economist Victor Afari-Sefa. On 17 November 2017, Marwan successfully defended his thesis in Germany.

Marwan evaluated effects of small producer participation in two types of modern export supply chains (high-value and regular) on poverty reduction. Using an endogenous switching regressions model, Marwan assessed the effect of participation in modern export supply chains on household per capita income. Although overall participation in modern export supply chains has a positive effect on household per capita income, larger and richer producers benefit the most. Poorer producers can benefit by supplying regular export supply chains, which tends to increase their household per capita income. Overall, Marwan found that participation in modern export supply chains *per se* may not translate directly into poverty reduction. Participation dynamics and modalities of different types of modern export supply chains can affect participating producers' livelihoods differently. Two peer-reviewed papers from Marwan's work were presented at the 15th European Association of Agricultural Economists (EAAE) Conference in Parma, Italy and the 3rd GlobalFood Symposium in Goettingen, Germany. The papers are currently under review for publication by peer-reviewed journals *Agricultural Economics* and *World Development*.

Ijang Emily Gawum, a PhD student at the University of Dschang, Cameroon is working on the "Effect of manure and biochar on the growth yield, soil properties and mineral composition of improved and local variety of African nightshade and Amaranth" under the GlobE UrbanFoodPlus project funded by the Federal Ministry for Economic Cooperation and Development, Germany. Emily's work for 2017 involved an experiment that consisted of four treatments: manure, biochar, manure plus biochar, and a control arranged in a randomized complete block design with four replicates at two sites in Bamenda, northwest Cameroon. The results on the residual effect showed that manure plus biochar increased dry matter by 42.1%

Ijang Emily Gawun

compared to the application of manure alone, while for the local variety, manure plus biochar increased dry matter 50.7% more than manure alone. For amaranth, application of manure plus biochar increased dry matter to 37.3% for the improved variety and 43.7% for the local variety. The improved variety of African nightshade had a 53.2% higher increase in dry matter than the local variety for manure alone, and 46.4% for manure plus biochar. The improved varieties of both crops had higher yield than the local varieties for all treatments at both sites. Treatments with biochar had higher growth yield and soil mineral content than the control. Treatments with manure plus biochar in all cases had higher soil mineral content and higher growth yield than the manure-only treatment. Applications of biochar plus manure are thus beneficial to farmers in terms of cost and soil fertility maintenance.

Stephen Tarmogin Omburo Othim

Stephen Tarmogin Omburo Othim, PhD candidate in Agricultural Entomology at the School of Agriculture and Enterprise Development, Kenyatta University, Nairobi, Kenya worked with WorldVeg Eastern and Southern Africa in Arusha, Tanzania for two years (November 2015 – October 2017) on "Identification of amaranth germplasm resistant to leaf webbers and stem weevil" under the guidance of WorldVeg's Lead Entomologist, Dr. Srinivasan Ramasamy. He was co-supervised by Drs. Komi Fiaboe and Sunday Ekesi from the International Centre of Insect Physiology and Ecology (*icipe*) and Dr. Ruth Gathu from Kenyatta University. Stephen's work identified several lepidopteran defoliators and stem weevil species infesting amaranth. He also identified an array of natural enemies that attack these pests, and detected 10 insect-resistant amaranth accessions. Stephen's work contributed to the project "Enhancing the Livelihood Opportunities of Smallholder African Indigenous Vegetable (AIV) Producers through the Development and Implementation of IPM Measures for Arthropod and Nematode Pests" led by *icipe* in collaboration with WorldVeg.

Diversity at WorldVeg: MOVING FORWARD

The World Vegetable Center values diversity among its staff, teams, and partners. In 2017:

The Center's **387 staff members** represented **32 nationalities**

44% of WorldVeg staff were **women**

38% of staff recruited internationally were **women professionals**

60 students from **14 countries** received training/internships at WorldVeg facilities.

70% of students trained were **women**

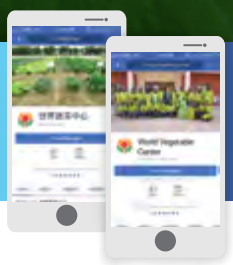
COMMUNICATING WITH THE WORLD

The World Vegetable Center reaches out through various media to inform the public about our activities and engage all in the effort to diversify diets and economies with vegetables. In 2017:

Monthly unique visitors to worldveg.org: **20,000+**

Subscribers to *Fresh*, the WorldVeg newsletter: **5,473**

Twitter followers: **3,500** (@go_vegetables)



Facebook followers: **12,226**

Media mention: **212**,
including articles in *Science, Appropriate Technology, Nature, Huffington Post*

Presentations: **262** given by researchers at important global conferences

Videos: **15** on how-to topics, from producing and transplanting vegetable seedlings to solar drying vegetables; **5** promoting project activities, such as women seed producers in India, the VINESA project in Tanzania and the PADFA Onion Seed Production project in Cameroon.

Visitors: More than **1,837 visitors from 76 countries** toured WorldVeg headquarters and regional offices to learn about the Center's research, get updates on project progress, and see WorldVeg improved varieties, traditional vegetables, and new technologies in our Demonstration Gardens.

EVOLUTION

1971

2017

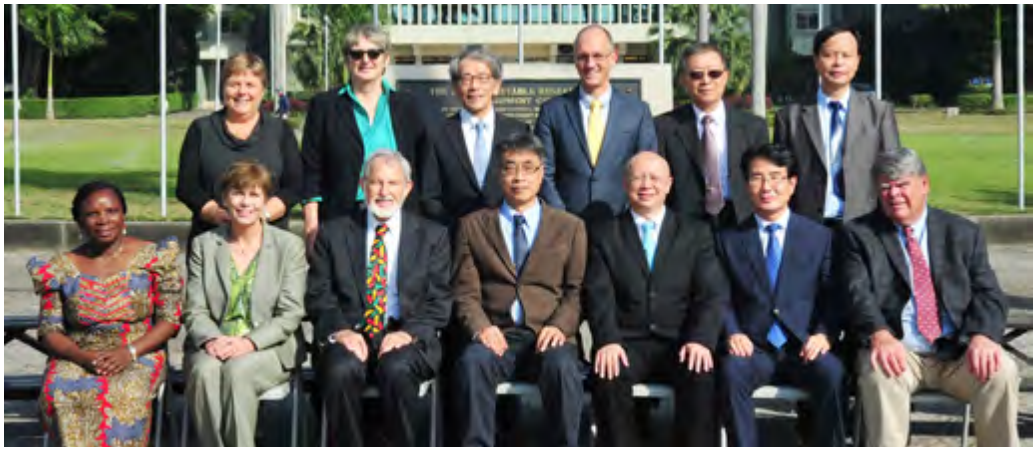
The **World Vegetable Center (WorldVeg)** was established in 1971 as the **Asian Vegetable Research and Development Center (AVRDC)** in Taiwan.

In 2017, recognition of the Center's expanding global reach led to a new strategy, a new logo, and a shorter, more memorable name: **World Vegetable Center**.

Our refreshed logo highlights the color and vitality of vegetables and emphasizes the importance of horticulture to the world. This brighter perspective serves as a reminder of the Center's dedication to the Sustainable Development Goals.

World Vegetable Center

2017 Board of Directors



NAME	COUNTRY	APPOINTED
Dr. Junne-Jih Chen – Board Chair	Taiwan	2011
Dr. Masa Iwanaga – Vice-Chair	Japan	2016
Dr. Myoung Rae Cho	Korea	2017
Mr. George Culaste	Philippines	2017
Dr. Richard Ellis	United Kingdom	2017
Dr. Julie Howard	United States of America	2017
Dr. Marlis Lindecke – Chair, Program Committee	Germany	2016
Mr. Gordon MacNeil – Chair, Audit Committee	Canada	2015
Dr. Bonnie McClafferty	United States of America	2017
Mr. Shigehiro Nishuimi	Japan	2017
Ms. Cathy Reade – Chair, Nominating Committee	Australia	2013
Dr. Chongrak Wachrinrat	Thailand	2016
Dr. Marco Wopereis – Director General (ex-officio)	The Netherlands	2016
Terms ended in 2017:		
Mr. Takashi Hamada	Japan	2014
Mrs. Sophia Kaduma	Tanzania	2012
Mr. Vivencio Mamaril	Philippines	2016
Dr. Dae-Geun Oh	Korea	2011
Dr. David Sammons	United States of America	2010
Ms. Emmy Simmons	United States of America	2011
Dr. Jonathan Wilkinson	United Kingdom	2011

Finance

	WorldVeg	CGIAR** recommended range
Cash management on restricted operations*	0.16	less than 1
Adequacy of reserves	107 days	75-90 days
Short-term solvency	132 days	90-120 days

2017 Revenues (in '000 USD)		
Unrestricted grants	8,324	41%
Restricted grants	11,626	57%
Other revenues	290	1%
Total	**20,239**	100%

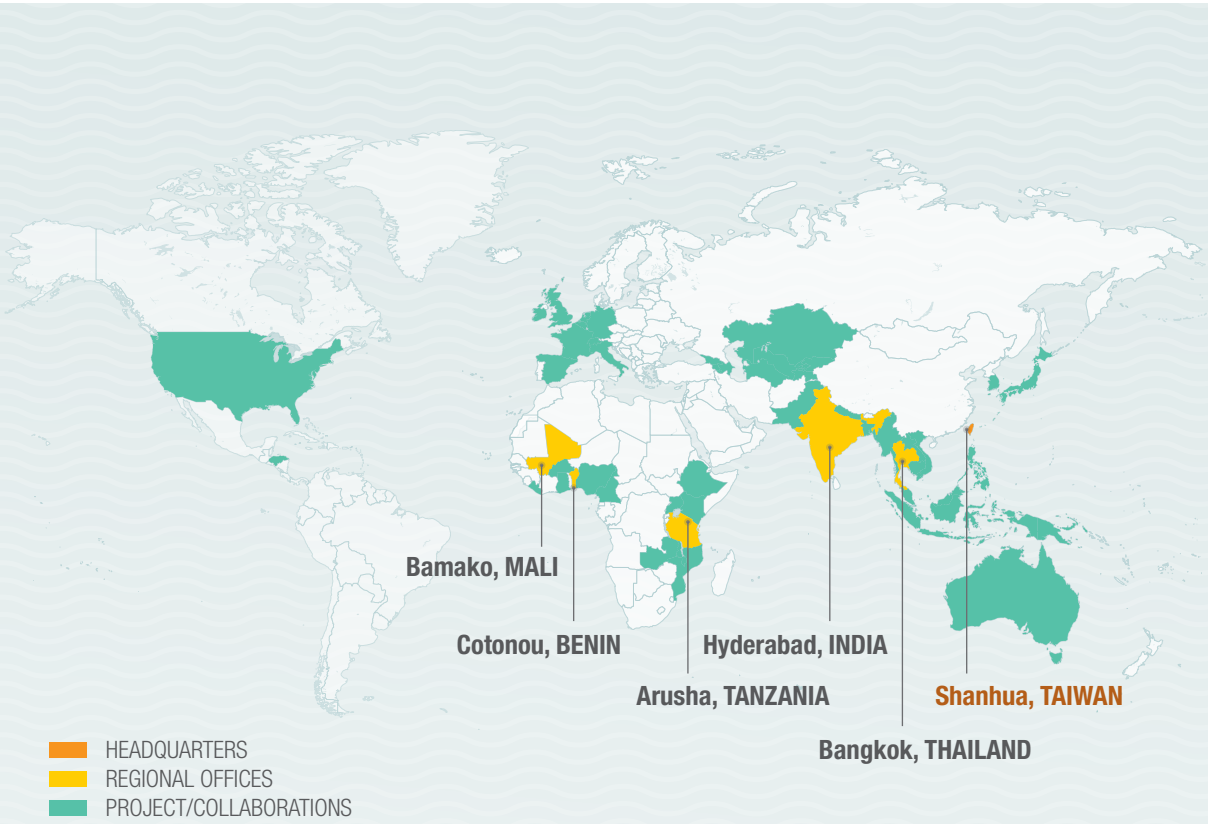
Strategic long-term funding

Republic of China (ROC) / Taiwan	4,687
United Kingdom / UK aid / UK Department for International Development (DFID)	1,895
United States / United States Agency for International Development (USAID)	906
Australia / Australian Centre for International Agricultural Research (ACIAR)	318
Germany	273
Thailand	135
The Philippines	50
Korea	50
Japan	9
Sub-total	***8,324***
Other revenues	290
Total	**8,614**

Project funding

United States / United States Agency for International Development (USAID)	7,343
Republic of Germany / BMZ / GIZ	1,455
Australia / Australian Centre for International Agricultrual Research (ACIAR)	700
Republic of China (ROC) / Taiwan	587
Switzerland / Swiss Development Cooperation (SDC)	241
India / Government of Odisha	211
Private sector seed companies	166
Japan / Ministry of Agriculture, Forestry and Fisheries (MAFF)	138
Asia and Pacific Seed Association (APSA)	104
Korea / Rural Development Administration (RDA)	98
Others (projects with expenses less than 100K USD)	582
Sub-total	***11,626***
Total Revenues	**20,239**

Map



Headquarters
P.O. Box 42
Shanhua, Tainan 74151
TAIWAN
Tel: +886-6-583-7801

East and Southeast Asia
P.O. Box 1010 (Kasetsart)
Bangkhen, Bangkok 10903
THAILAND
Tel: +66-2-942-8686

South Asia / Central Asia
ICRISAT Campus, Patancheru 502 324
Hyderabad, Telangana
INDIA
Tel: +91-40-3071-3754

Eastern and Southern Africa
P.O. Box 10
Duluti, Arusha
TANZANIA
Tel: +255-27-255-3093

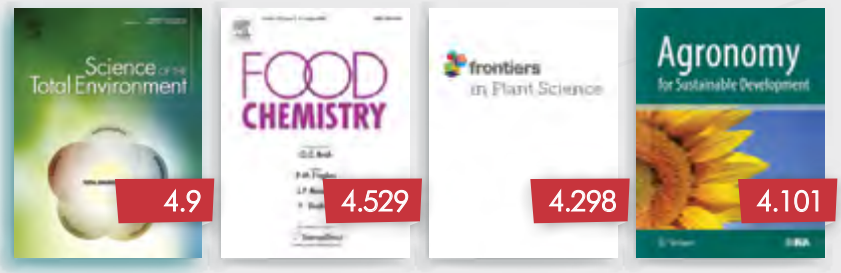
West and Central Africa – Dry Regions
BP 320 Bamako
MALI
Tel: +223-2070-9200

West and Central Africa – Coastal & Humid Regions
IITA-Benin Campus
08 BP 0932 Tri Postal, Cotonou
BENIN
Tel: +229-6418-1313

RESEARCH FOR DEVELOPMENT

In 2017, WorldVeg researchers shared their knowledge and results in international peer-reviewed journals, at conferences, and in partnership with scientists from developing countries.

TOP 10 journals according to impact factor



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Acronyms

AARNET	ASEAN-AVRDC Regional Network for Vegetable Research and Development
ACIAR	Australian Centre for International Agricultural Research
AFSTA	African Seed and Trade Association
APSA	Asia and Pacific Seed Association
ASEAN	Association of Southeast Asian Nations
BABA	Beta-Aminobutyric acid
BIMAF	Biorisk Management Facility
BMZ	Federal Ministry for Economic Cooperation and Development, Germany
BPH	Best Practice Hubs
CIG	Common Initiative Groups
CIRAD	French Agricultural Research Centre for International Development
CRI	Crops Research Institute, Ghana
CRS	Catholic Relief Services
CSIR	Council for Scientific and Industrial Research of Ghana
DAR	Department of Agricultural Research, Myanmar
DUS	Distinctness, Uniformity, and Stability
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agriculture Organization of the United Nations
FFTC	Food & Fertilizer Technology Center
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
icipe	International Centre of Insect Physiology and Ecology
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
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
IVTC	International Vegetable Training Course
KALRO	Kenya Agriculture and Livestock Research Organization
MARDI	Malaysian Agricultural Research and Development Institute
MINADER	Le Ministre de l'Agriculture et du Développement Rural
MVIKIHO	Muungano wa Vikundi Vya Kilimo cha Horticulture
MYMV	Mungbean yellow mosaic virus

OHADA	Organization for the Harmonization of African Business Law
PADFA	Commodity Value-Chain Development Support Project
PVY	Potato virus Y
SDC	Swiss Agency for Development and Cooperation
SMV	Soybean mosaic virus
SNV	Netherlands Development Organisation
TAHA	Tanzania Horticultural Association
ToMV	Tomato mosaic virus
TOSCI	Tanzania Official Seed Certification Institute
TuMV	Turnip mosaic virus
TYLCD	Tomato yellow leaf curl disease
USAID	United States Agency for International Development
VINESA	Improving Income and Nutrition in Eastern and Southern Africa by Enhancing Vegetable-based Farming and Food Systems in Peri-urban Corridors
VTIC	Vegetable Technology Immersion Clusters
WASH	Water - Sanitation - Hygiene
ZECC	Zero Energy Cool Chambers

World Vegetable Center
P.O. Box 42 Shanhua,
Tainan 74199

worldveg.org

P +886 6 583 7801
F +886 6 583 0009
E info@worldveg.org