World Vegetable Center

ANNUAL REPORT 2019

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Cover photo
In Nepal, Mrs. Tamang was among the adults participating in a novel school garden initiative that involved parents as well as students. Learn more about the impact of the activity on page 50. *Photo by Pepijn Schreinemachers.*

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Foreword from the Director General

The World Vegetable Center is keen to contribute to the transformation of our food systems towards healthier diets and more sustainable production systems while creating value and jobs, in particular for young people. This year's report covers progress made in 2019, from our work on precision phenotyping in Taiwan to finding new markets for traditional vegetables in East Africa and working with farmers on improved vegetable production practices in India.

Two important institutional milestones occurred in 2019: On May 1, the WorldVeg Korea Office opened at the National Institute of Horticultural and Herbal Science of the Korea Rural Development Administration (RDA) (page 10). This new office will facilitate collaboration between WorldVeg and Korean institutions and networks, building on the strong links between RDA and WorldVeg dating back to the 1970s. In November, a groundbreaking MoU between WorldVeg and the Indian Council of Agricultural Research (ICAR) was signed to guide future collaboration with ICAR institutions working on vegetable research.

In 2019, WorldVeg staff contributed to the organization of the *8th International Conference on Management of the Diamondback Moth and Other Crucifer Insect Pests* held at WorldVeg headquarters; the *6th International Symposium on Tomato Diseases*, held at National Chung Hsing University, Taichung, Taiwan; and the *International Symposium on Smart Agriculture for Environmentally and Consumer Friendly Food Production* at the National Pingtung University of Science and Technology, Pingtung, Taiwan.

Our consortia with the private seed sector continue to grow. The Asia & Pacific Seed Association (APSA) - WorldVeg Vegetable Breeding Consortium, set up in December 2016, now includes 43 seed companies (up from 33 in 2018 and 19 in 2017). Companies reported having incorporated WorldVeg germplasm in 45 varieties (mostly chili pepper and tomato). The Africa Vegetable Breeding Consortium, established mid-2018, gained momentum, with 9 seed companies now on board. Read more about these successful partnerships on page 38.

Research from our Enabling Impact team in 2019 shows WorldVeg mungbean varieties are grown on 1.9 million hectares in Asia, covering 60% of the area planted and benefiting 1.5 million farmers. The International Mungbean Improvement Network (IMIN) convened by WorldVeg and implemented with partners from Australia, Bangladesh, Myanmar and India is building on this success to introduce even better material to farmers. The network is expected to expand in 2020 to include new countries in Asia and Africa with continued support from the Australian Centre for International Agricultural Research.

Vegetables were very much in the spotlight when the founder of a pioneering vegetable seed company, Simon Groot of East-West Seed, was awarded the Word Food Prize in the USA in October. The last words of his acceptance speech still ring in my ears: "Looking back our success has really come from sticking to our philosophy of being a true friend of the farmer, because the small guys really do matter — and so do vegetables."

At the 56th meeting of the World Vegetable Center Board of Directors, held in November at WorldVeg headquarters in Taiwan, the directors were updated on the Research Infrastructure Modernization (RIM) Project—a US$ 22 million project funded by the Taiwan Council of Agriculture to modernize HQ research facilities. In 2019 we moved into construction mode with the placement of electric cabling to support the planned new research building. Board directors also visited the newly installed Phenospex field phenotyping system. The RIM project remains on schedule to be completed by the end of 2021.

During the 56th board meeting we said farewell to member Cathy Reade, whose energy and dedication served WorldVeg enormously during her two full terms. We welcomed two new board members: A.K. Singh from India and Gordon Rogers from Australia.

In December, an Open Day at WorldVeg HQ attracted nearly 10,000 visitors to learn more about vegetables and WorldVeg activities around the world. See pictures of this memorable event on page 43.

Our accomplishments in 2019 were possible because of the confidence and support of our funders listed on page 36. Thanks to all for supporting our mission to contribute to healthier lives and more resilient livelihoods around the world.

-- Marco Wopereis

Timeline

01 JANUARY | 02 FEBRUARY | 03 MARCH | 04 APRIL

Using WorldVeg **tomato breeding line** AVTO1003 (CLN3125L), **Rijk Zwaan Breeding B.V.** released a new semi-determinate plum tomato variety 'Jarrah RZ F1 (71 102)' specifically for the African market.

The **AfricaRISING Sudano Sahel project** targeted 90 farmers to conduct trials to select elite high-yielding and disease resistant vegetable varieties. More than 130 farmers responded to the call.

WorldVeg launched "Teach and Text: Combining on-farm demonstration and phone messaging to scale vegetable IPM in Cambodia", a project to **test cost-effective IPM scaling methods**, on 11-12 January in Phnom Penh.

The **Afro–Asian Rural Development Organization (AARDO)** and WorldVeg renewed a Memorandum of Understanding on 19 February to address sustainable diversification of food systems, good agricultural and manufacturing practices, and safe and sustainable development of vegetable value chains. AARDO, formed in 1962, is an inter-governmental organization with 17 members from Africa, 14 from Asia, and 2 associate members.

Participants from WorldVeg, the **Taiwan Seed Trade Association**, and the **Thailand Seed Trade Association** met at the WorldVeg East and Southeast Asia Research and Training in Kamphaeng Saen, Thailand on 21 February to view **trials of Taiwan vegetable varieties** under local conditions.

More than 70 researchers from around the world gathered at WorldVeg HQ, Taiwan from 4-8 March to participate in the **8th International Conference on Management of the Diamondback Moth and Other Crucifer Insect Pests**, organized in conjunction with Cornell University.

The new **African Vegetable Breeding Consortium (AVBC)**, a joint initiative of the World Vegetable Center and the **African Seed Trade Association (AFSTA)**, held its first workshop on 11-12 March at WorldVeg Eastern and Southern Africa in Arusha, Tanzania. The 41 participants included scientists from nine African vegetable seed companies, the **Tanzanian Agricultural Research Institute (TARI)**, the **Tanzania Seed Trade Association (TASTA)**, and AFSTA.

AARNET (ASEAN-AVRDC Regional Network for Vegetable Research and Development) held its 14th annual meeting in Singapore on 9-10 April, co-organized by WorldVeg and the Singapore Food Agency.

WorldVeg East and Southeast Asia and Kasetsart University hosted a **regional mungbean workshop** on 23-24 April to enhance farmers' access to improved mungbean varieties and good agricultural practices in Southeast Asia.

WorldVeg showcased **validated technologies** at the 9th Annual Pre-Season Networking and Exhibition Forum on 4 April in Tamale, Ghana, organized by the National Seed Trade Association of Ghana (NASTAG).

05 MAY | 06 JUNE | 07 JULY

The **WorldVeg Korea Office** at the National Institute of Horticultural and Herbal Science (NIHHS) in Jeonju, Korea opened on 1 May.

National Chung Hsing University and WorldVeg hosted the **ISHS VI International Symposium on Tomato Diseases** in Taichung, Taiwan, 6-9 May.

The annual **APSA-WorldVeg Vegetable Breeding Consortium Workshop** brought participants to WorldVeg HQ from 15-16 May to view field trials and discuss vegetable breeding opportunities.

WorldVeg and the **Food and Fertilizer Technology Center, Taiwan Agricultural Research Institute**, and **National Pingtung University of Science and Technology (NPUST)** held a symposium on "Smart Agriculture for Environmental and Consumer Friendly Food Production" at NPUST from 27-31 May.

30 participants joined a training course on **solar drying technologies** with the Tanzania Horticulture Association (TAHA) from 28-30 May at WorldVeg Eastern and Southern Africa.

Professors from partner institutions **Kasetsart University**, Thailand and **National Chung-Hsing University**, Taiwan toured WorldVeg HQ on 11 June.

Her Excellency **Aynalem Nigussie Ali**, Ethiopia's State Minister of Agriculture, welcomed a WorldVeg delegation for discussions on 17 June in Addis Ababa.

On June 27, the **WorldVeg Mali** team displayed USAID-supported project interventions and innovative technologies during an event to announce a new USAID / Mali partnership initiative.

A **training course** on "Screening for tomato yellow leaf curl virus (TYLCV) disease resistance" was held at WorldVeg South Asia in Hyderabad from 9-14 July, with 15 representatives from the seed industry and public sector.

Marco Wopereis gave the keynote presentation at the **Southeast Asia Vegetable Symposium (SEAVEG)**, 9 July in Melaka, Malaysia.

WorldVeg was accorded "Authorization to Practice" by the **Ministry of Territorial Administration (MINAT), Cameroon** on 16 July.

The five-year **Hort4Nutrition** project to highlight the nutritional and economic benefits of Africa's traditional vegetables concluded with a meeting of project participants from 18-20 July in Nairobi, Kenya.

WorldVeg hosted the **5th Annual Bitter Gourd Open Field Days** to showcase 700 elite bitter gourd breeding lines and bitter gourd F1 hybrids from 25-26 July at the East and Southeast Asia Research and Training Station in Kamphaeng Saen, Thailand.

08 AUGUST

Director General Marco Wopereis gave two keynote presentations at the **7th Tokyo International Conference on African Development (TICAD7)**, 28-30 August in Japan.

WorldVeg staff displayed a range of **traditional African vegetable seeds** and related pamphlets and publications in the Kilimo Endelevu Local Seed and Food Fair in Karatu Town, Tanzania on 30 August.

09 SEPTEMBER

WorldVeg participated in the **African Green Revolution Forum (AGRF)** in Accra, Ghana from 2-6 September 2-6, with >150 participants visiting the WorldVeg booth daily. Board members Julie Howard, Ndidi Nwuneli and Lindiwe Sibanda were speakers at the forum.

An **open field day** on 12 September at Katierla, Sikasso, Mali showcased WorldVeg project activities to more than 2,000 visitors.

On September 16, a WorldVeg delegation visited **National Taiwan University's College of Bio-Resources & Agriculture** to discuss opportunities for strengthened collaboration.

Representative **HE Tommy Kambu Kunji**, Papua New Guinea Trade Office, visited HQ on 20 September.

WorldVeg hosted an **international training workshop** on "Methods for disease and insect resistance screening for germplasm characterization and vegetable breeding" at HQ from 23 September-4 October.

With support of the **Crop Trust:** An evaluation of the **WorldVeg Genebank** in Arusha, Tanzania was conducted on 26-27 September, and WorldVeg Genebank Manager Maarten van Zonneveld participated in the **CGIAR Annual Genebanks Meeting** on 29 September – 2 October in Hanoi, Vietnam.

Fifty-seven participants joined in a **one-day regional workshop** on "Development of IPM strategy for tomato leaf miner (Tuta absoluta) and mungbean cultivation technology in Tajikistan" on 27 September.

10 OCTOBER

DG Marco Wopereis and board member Lindiwe Sibanda participated in the **World Food Prize Borlaug Dialogue International Symposium**, 16-18 October in Des Moines, Iowa, USA. Marco also spoke at "Farmers, Food and the Future: Vegetable Seeds for a Healthier World," a symposium side event organized by **East-West Seed**.

The **38th International Vegetable Training Course** offered two well-attended sessions: *Safe Vegetable Production* (21 October - 1 November) and *Vegetable Breeding for the Tropics* (18-29 November) at the Research and Training Station in Kamphaeng Saen, Thailand.

HE William Brent Christensen, Director, American Institute in Taiwan, visited HQ on 23 October.

Staff from WorldVeg West and Central Africa Coastal & Humid Regions presented papers at the inaugural **African Plant Breeders Conference** held 23-25 October at the University of Ghana, Legon, Accra.

Marco Wopereis gave the keynote presentation during the **APSA-Asian Solanaceous Round Table** 2019 in Bangalore, India on 24 October.

Marco participated in a panel discussion on "Dysfunctional Agriculture Markets and Malnutrition" during the **Asian Development Bank 2019 Rural Development and Food Security Forum**, ADB HQ, Manila, Philippines on 28 October.

WorldVeg and the **Indian Council of Agricultural Research (ICAR)** signed a Memorandum of Understanding on 30 October at ICAR HQ to guide collaboration.

Ralph Roothaert, Global Project Coordinator for Rural Household Gardens, spoke at the Center for Strategic and International Studies, Washington, DC USA on 6 November.

2019 Global R&D Week (11-15 November) brought together more than 100 staff from five regional offices for planning and team building at WorldVeg HQ.

The 56th meeting of the WorldVeg **Board of Directors** was held at headquarters from 18-21 November.

WorldVeg participated in the **23rd Annual Seed and Seedling Festival** on 23 November at the Tainan District Agricultural Research and Extension Station in Xinhua, Taiwan.

WorldVeg staff attended the **2019 Asian Seed Congress**, 25-29 November in Kuala Lumpur, Malaysia to promote the APSA-WorldVeg Vegetable Seed Consortium.

Open Day 2019 (7 December) at WorldVeg HQ attracted more than 10,000 visitors to campus to walk through colorful, thriving vegetable fields, view informative science displays, take guided tours of the Demonstration Garden and Phenospex facility—and sample tasty food and snacks from 50 local vendors.

WorldVeg scientists published important **research papers** on pesticide dependence of smallholder vegetable farmers in Southeast Asia; the capacity of global agriculture to meet food demand as Body Mass Index (BMI) rises; and the need to protect wild relatives of vegetables for climate resilience.

Toward an Open Science Center

Transforming the WorldVeg campus into a modern hub for agricultural research

The **Research Infrastructure Modernization (RIM)** project at WorldVeg headquarters is underway, supported by a US$ 22 million grant from Taiwan distributed in four allocations (2018-2021). The massive construction project is the first step in the transformation of our 50-year-old campus into an Open Science Center with research facilities and amenities to attract top-notch talent.

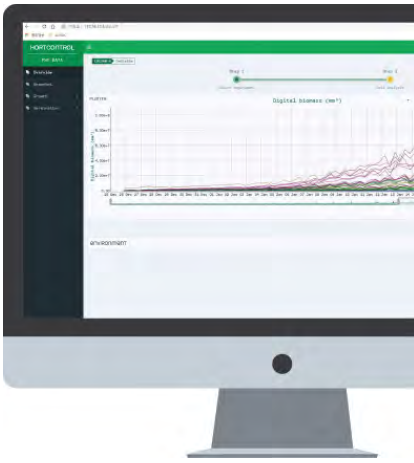
After initial brainstorming in 2016 followed by fundraising efforts in 2017, RIM officially kicked off in 2018 with the first allocation (US$ 2 million) invested in procuring high throughput phenotyping facilities from Netherlands' supplier Phenospex and selecting Taiwan architectural firm EDS International as the project's principal designer.

In 2019, the second allocation (US$ 6 million) was put toward:

- Completion of the phenotyping facilities in Field #35, with experiments now booked up to two years in advance.
- Engaging EDS International to design four major construction contracts: Contract 1—new virology and insectary greenhouses; Contract 2—campus power cabling; Contract 3— campus landscaping; Contract 4—new lab building.
- Contracting with AD Engineering Corporation for the construction of power cabling and landscaping and De Yuan Construction for the construction of two new greenhouses.
- Commencing work on contracts 1, 2 and 3 for completion in 2020.

The WorldVeg Field Phenotyping Platform

Watching Vegetables Grow



Phenotyping vegetable plants means to quantitatively describe what they look like, how they grow and how they function—their morphological, developmental, physiological and biochemical properties. But phenotyping is laborious and prone to error; it's a major bottleneck in germplasm characterization and breeding.

New sensor technologies have revolutionized plant phenotyping and are now helping researchers overcome previous limitations.

With funding from the Government of Taiwan, the World Vegetable Center established an automatized field phenotyping system large enough to accommodate about 6,000 plants. The system consists of two pairs of Phenospex Plant Eye multispectral 3D sensors mounted on a gantry that automatically moves the sensors over the field to collect data from each plant at least three times per day.

The sensors collect both morphological and physiological parameters without destroying the plants, and produce 3D data clouds combined with color information. Analysis software automatically translates the 3D data clouds into phenotypic information useful for breeders. Precise information on plant height, leaf area, digital biomass and other morphological parameters over time is available in an instant. Data can be converted into growth curves, resolving the increase of height, leaf area or biomass over the whole growing period, or the data can be analyzed to obtain information on growth increment per day, or during any other time span a researcher may choose. Color data can indicate chlorophyll levels, detect plant senescence, or show lesions caused by pests and diseases at high resolution and over time.

The system was put into operation in May 2019. In the first trial, the automatic measurements of plant height, leaf area and biomass were verified with manual measurements on two crops. In a subsequent trial, growth of okra and amaranth was assessed under flooding stress and led to the identification of four stress-tolerant okra accessions that continued growing when flooded while the other accessions stopped growing or died. The third experiment in 2019 measured the growth speed of 300 Amaranthus tricolor accessions.

The WorldVeg Field Phenotyping Platform is fit for high throughput phenotyping of vegetable crops. In 2020, it will be applied for heat stress studies on pepper and harvest index measurements of mungbean. The system is available for our partners to investigate the performance of vegetable crops in a field setting.

A NEW WORLDVEG OFFICE IN KOREA

The Republic of Korea has been a long-time supporter of the World Vegetable Center (WorldVeg)— it was one of the founding members that signed the charter in 1971, along with six other countries and the Asian Development Bank (ADB), to establish what was then called the Asian Vegetable Research and Development Center (AVRDC). The Korean Sub-Center was set up in May 1974 in Suwon to evaluate breeding materials under Korean conditions, and a technical assistance agreement signed in September 1975 by Korea, the ADB, and AVRDC provided funds for a resident horticulturist at the Sub-Center and training for Sub-Center staff at AVRDC.

After almost 50 years of successful collaboration through joint research projects and the exchange of resources and scientists, the two institutions have decided to bring the partnership to another level.

On 21 January 2019, WorldVeg signed a Memorandum of Arrangement with the Rural Development Administration (RDA) of Korea to establish the WorldVeg Korea Office at RDA's National Institute of Horticultural and Herbal Science (NIHHS) and further enhance collaboration among the two institutions. Marco Wopereis (WorldVeg Director General), Delphine Larrousse (WorldVeg Regional Director for East and Southeast Asia), and Gyeong Gyu Kim (Administrator of RDA Korea) officially opened the new office on 1 May 2019. Dr. Seonghoe Jang was appointed as Country Director.

Having a presence in-country underscores the benefits of a valued relationship.

The first collaborative project between WKO and NIHHS-RDA, "Development of vegetable breeding technology in Asia," was launched on 1 November 2019. Funded by the Asian Food and Agriculture Cooperation Initiative (AFACI) through the International Technology Cooperation Center (ITCC), RDA, for three years, the project will strengthen chili pepper and tomato breeding programs in the 13 AFACI member countries by building capacity of relevant public sector institutions.

Going forward, NIHHS and WorldVeg will cooperate on the conservation and use of vegetable genetic resources, plant breeding, precision agriculture, management of insect pests, nematodes and diseases, postharvest management and processing technology, soil health management, and other areas of mutual interest, including capacity building and the exchange of scientists.

The new office is a major step for Korea RDA and WorldVeg to together realize the potential of vegetables for healthier lives and more resilient livelihoods.

Members of RDA senior management attended the opening ceremony including **Yongbeom Lee**, Director General, National Institute of Agricultural Science; **Chang-Bum Yang**, Director General, National Institute of Animal Science; **Dooho Kim**, Director General, National Institute of Crop Science; **Jeong-hwan Hwang**, Director General, National Institute of Horticultural and Herbal Science; **Ji-Won Lee**, Director, International Technology Cooperation Center, RDA; **Taek-Ryoun Kwon**, Secretary General, International Technology Cooperation Center, RDA; **Hak Ki Shin**, Department Director, Department of Horticultural Crops, NIHHS; **Yun-Chan Huh**, Division Director, Division of Vegetable Research, NIHHS; **Myoung Rae Cho**, World Vegetable Center Board Member; and **Dae-Geun Oh**, former WorldVeg board member.

East and Southeast Asia

- **Activities** were conducted in six countries: **Cambodia, Korea, Myanmar, Philippines, Thailand** and **Vietnam.**
- The **BMZ Teach and Text** project, launched in Cambodia in January, combines on-farm demonstrations and phone messaging to scale vegetable integrated pest management (IPM) methods. Baseline data were collected in May 2019 and starting in December, farmers began receiving training and advice on protecting brassicas and yardlong bean. In 2020, an evaluation will show which training approach was most cost-effective in raising incomes and reducing hazardous pesticide use.
- WorldVeg, the Taiwan Agricultural Research Institute (TARI), and Taiwan Council of Agriculture (COA) organized a **Field Demonstration Day** (100+ participants) on 21 February to demonstrate disease resistance (e.g. cherry tomato varieties from Taiwan seed companies) and foster dialogue and collaboration among seed companies from Taiwan and Thailand.
- **AARNET** (ASEAN-AVRDC Regional Network for Vegetable Research and Development) held its 14th Steering Committee meeting in Singapore on 9-10 April with representatives from nine ASEAN countries. Members endorsed four WorldVeg proposals on *Tuta absoluta* in Southeast Asia to be submitted to the ASEAN Secretariat.
- WorldVeg and Kasetsart University (KU) organized a workshop on **mungbean improvement** in Southeast Asia on 23-24 April, with researchers from Laos, Cambodia, Thailand, China, Vietnam, Philippines, and Indonesia. New members joined the International Mungbean Improvement Network.
- The new **WorldVeg Korea Office** opened on 1 May at the National Institute of Horticultural and Herbal Science, Rural Development Administration (RDA). Attending the official opening: RDA Senior Management, WorldVeg Board member Myoung Rae Cho, WorldVeg Director General Marco Wopereis, East and Southeast Asia Regional Director Delphine Larrousse, and new WKO Director Seonghoe Jang.
- The **5th Annual Bitter Gourd Open Field Days** (50+ participants) on 25-26 July showcased 700 elite bitter gourd breeding lines (S4-S7 generation), a large set of bitter gourd F1 hybrids in preliminary yield trials, and observational trials with early stage bitter gourd products of recurrent selection.
- In 2019, the **Asia and Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium** membership increased to 43 seed companies (up from 33 in 2018 and 17 in 2017). Data reported by 21 companies in 2017 and 2018 showed WorldVeg germplasm was incorporated in 45 commercial varieties and in 9.5 tons of chili/sweet pepper and tomato seed.
- WorldVeg hosted **International Vegetable Training Courses** (IVTC) on "Safe vegetable production" in October and "Vegetable breeding for the tropics" in November. WorldVeg, Kasetsart University and other lead R&D organizations imparted knowledge and skills to 40 participants from 17 countries.

- Observational and Preliminary Yield Trials (PYT) of WorldVeg **bitter gourd F1 hybrids** were completed in 2019 and promising entries will be promoted to next year's Advanced Yield Trials (AYT). **Pumpkin** plants resistant to multiple viruses were selected in various populations, and selected plants hand pollinated to raise the next generation for further selection. **Luffa** populations were screened for virus resistance and fruit quality traits, and selected plants hand pollinated to save seed for next season.
- Trials of 13 **disease-resistant tomato lines** from COA-Hualien were completed in Kamphaeng Saen. COA-TARI-Fengshan Branch evaluated **horticultural traits** of 18 chili pepper commercial varieties, 27 cauliflower varieties, 30 tomato varieties, 9 pumpkin commercial varieties, and hybrid eggplant for grafted eggplant in Thailand.
- **Mungbean** accessions resistant to dry root rot identified by WorldVeg were field tested in Myanmar by the Department of Agriculture; high levels of resistance were confirmed in four accessions.
- A novel IPM package for managing **eggplant fruit and shoot borer** and **cucurbit fruit fly** in Thailand was evaluated, which included the use of mating disruption component and female attractants. **Pepper accessions** (98) were screened for resistance to *Pepper leaf curl virus disease* using augmented inoculation by viruliferous whiteflies.
- **Trap crops** (cotton and okra) can be used as a low input IPM component to manage hopper burn damage and whitefly-transmitted eggplant yellow mosaic virus on eggplant.
- A study on the adoption of **improved mungbean varieties** in Southeast Asia showed that about 48% of the mungbean area in Laos, Cambodia, Thailand, Vietnam, Philippines, and Indonesia is planted to varieties containing WorldVeg-developed material. An **impact study** for Myanmar showed that four mungbean varieties derived from improved WorldVeg germplasm created economic gains of US$ 1.4 billion from 1980 to 2016, which is projected to increase to US$ 3.7 billion by 2030. The internal rate of return was 27% and the benefit-cost ratio was 81:1 through 2016.
- WorldVeg developed **crop decision trees** for tomato, green mustard, cabbage, bitter gourd, yard-long bean, cucumber, eggplant and okra production in Cambodia through the Angkor SALAD project.
- The **Crop Trust** and WorldVeg organized an expert consultation workshop on "Global Conservation Strategy for Crops in the Cucurbitaceae Family" for 18 participants from 15 organizations from 11-14 December 2019 at the WorldVeg Research and Training Station in Kamphaeng Saen, Thailand.

PROOF IS IN THE POP

Vegetable farmer Puspa Ranjan Dhar, 52, lives in Kalain Block of Cachar district, Assam state, India, with his wife and two children. For the past three decades, Mr. Dhar has raised vegetable crops with some success, but his attempts at tomato production brought frequent disappointment.

"Although I have been producing tomatoes for three decades, I have never really reaped a good harvest," said Mr. Dhar. "Even with all my years of farming experience, I felt there was more to learn."

He discovered some new approaches for producing tomatoes by participating as a demonstration farmer in the World Bank-funded Assam Agribusiness and Rural Transformation (APART) project. Improved cropping practices, based on a package of practices (PoP) developed by the World Vegetable Center and Assam Agricultural University (AAU), led to better plant growth, improved plant health and higher yield—all of which increased Mr. Dhar's income.

The demonstration was conducted on an area of 0.125 ha. A popular local tomato variety was planted in both the WorldVeg demonstration plot and the farmer's control plot to effectively display the outcomes from adopting improved agricultural practices such as using the proper amount of fertilizer, establishing a nursery to produce healthy seedlings, and following correct plant spacing, weed management, plant staking, irrigation and protection methods.

A field-proven package of practices was an eye-opener for tomato farmers in Assam.

Mr. Dhar harvested 27 quintals (2.7 t) of marketable tomatoes from the WorldVeg demonstration plot, which gave an income of Rs. 40,000 (US$ 556) from sales at a price of Rs. 15 per kg. In comparison, only 19 quintals (1.9 t) of marketable tomatoes were harvested from the control plot, which sold for Rs. 28,500 (US$ 396)—a difference of more than Rs. 11,000 (US$ 160).

Applying the techniques recommended in the PoP incurred some additional costs for staking as well as labor for hand weeding and pesticide application. Taking into account the additional cost, the higher tomato yields generated income of more than Rs. 5,400 (US$ 73) on the demonstration plot as compared to the farmer's practice. Per hectare, this translates into a potential increase in income of Rs. 43,360 (US$ 603).

"After learning about protected nursery management and staking from WorldVeg, I was able to grow disease-free plants and achieve higher yields," said Mr. Dhar. "And my customers were happier with the tomatoes I brought to market."

The APART project has trained 1,323 (1,032 men and 291 women) local farmers and Agricultural Technology Management Agency (ATMA) staff in all 15 project target districts. Women's participation has nearly doubled since 2018. A total of 27 on-farm demonstration plots have been established to train extension staff and farmers.

South Asia

- **Activities** were conducted mainly in **India, Pakistan, Bangladesh, Myanmar** and **Tajikistan.**
- WorldVeg and ICAR signed a **Memorandum of Understanding** on 30 October to guide collaboration.
- **Tomato:** Two **Farmer Field Days** were conducted at Seed Works International Research Farm in Gowribidanur, Karnataka and on a farm in Rayalpadu, Andhra Pradesh in January to promote dual-purpose and processing tomatoes to GIZ-GIC staff, ICAR-Indian Institute of Horticultural Research scientists, University of Horticultural Sciences-Bagalkot scientists, APMAS staff, processors and farmers. WorldVeg conducted **nine classroom and field programs**, training 239 growers (133 women and 106 men). A **workshop** on "Screening for tomato yellow leaf curl virus (TYLCV) disease resistance" for 15 participants from the seed industry and public institutes was held from 9-14 July.
- WorldVeg conducted four **staking vs. non-staking tomato trials** with seed companies (Metahelix, Seed Works International, Namdhari Seeds Ltd, and United Genetics) using five WorldVeg advanced breeding lines (AVTO 1706, AVTO 1707, AVTO1424, AVTO1724 and AVTO 1726) and three popular hybrids (Abhinav, Ryna, JKTH-811). Non-staking reduced production costs by 39% without compromising yield for the first three harvests. WorldVeg shared two of its best dual purpose/processing tomato breeding lines (AVTO 1706 and AVTO 1707) with ICAR-Indian Institute of Horticultural Research to support the development of processing hybrids. WorldVeg field tested two processing hybrids (Deepam and UG-156) from United Genetics Pvt. Ltd. and three popular fresh-market hybrids (Abhinav, Ryna, JKTH-811) with support from project partners (APMAS and AFC) in Karnataka and Andhra Pradesh; non-staking reduced production costs up to 40%.
- **Mungbean:** ACIAR-IMIN partners (Bangladesh, India and Myanmar) were trained in **database management** (KDDart) and mungbean product pipelines were developed. Screening of the **mungbean mini-core collection** at WorldVeg South Asia identified resistant sources to anthracnose, powdery mildew, Cercospora leaf spot and thrips. Dry root rot resistant accessions were field-tested in Myanmar, with high levels of resistance found in four accessions. AVMU lines resistant to anthracnose, bruchids and thrips were identified. **Mungbean harvesting trials** with and without desiccants and with modified cereal harvesters are in progress in Bangladesh, Myanmar and Pakistan. **Mungbean value chain mapping** in Tajikistan showed that of the 128 farmers interviewed, about 86% are producing mungbean on an average area of 0.22 ha. Farmers mostly do not use herbicides for weed control. The main pests and diseases affecting mungbean production are spider mite (73%), aphids (32%), whitefly (19%), cotton worm (*Helicoverpa armigera*) (14%) and powdery mildew. Farmers mostly rely on pesticides to control diseases and pests. About 97% of farmers harvest mungbean manually and thresh by hand. Farmers do not retain seeds for the next growing season. Around 65% of surveyed farmers sold harvested mungbean to traders in the market.

- **APART Project:** Training was provided for 1,323 (1,032 men and 291 women) local farmers and Agricultural Technology Management Agency (ATMA) staff in all 15 project target districts in Assam. Women's participation has nearly doubled since 2018. A total of 27 on-farm **demonstration plots** were established to train extension staff and farmers.
- **JOHAR Project:** A state-level **Stakeholders cum Buyers and Sellers meeting** was hosted by the Jharkhand Opportunities for Harnessing Rural Growth (JOHAR) project under the ambit of the Jharkhand State Livelihood Promotion Society on 23 April in Ranchi, Jharkhand, India to link the project's farmer-producer companies with terminal market buyers. WorldVeg South Asia and Synergy Technofin facilitated the meeting. 2,247 participants joined in 66 **master trainings** across project locations; a total of 535 trainings/technical advice were provided to technical and extension officers at block level. The project developed a **package of practices** (PoPs) with improved production technologies for tomato, chili, eggplant, cauliflower, bitter gourd, okra, cabbage, green peas, cucumber and watermelon, and shared the PoPs with project partners and growers in the region.
- **Tajikistan Project:** New varieties of tomato (5), eggplant (2) and sweet pepper (2) comprising WorldVeg improved lines and commercial hybrids were introduced for **greenhouse production** in Tajikistan–a first for eggplant and sweet pepper. More than 82 greenhouses produced the new varieties. Non-traditional crops such as cherry tomatoes, broccoli and kale were introduced for greenhouses for the first time. To promote consumption of the new crops, the Tajikistan team distributed a brochure with 18 nutritious **recipes** adapted to local preferences. 140 youth and women were trained in six **nutrition events** in Khatlon; mungbean recipes were distributed and a **video**, "Delicious dishes with mungbean" was shown.
- **Tuta absoluta:** An IPM package based on pheromones and biopesticides was piloted against *Tuta absoluta* in three locations in Andhra Pradesh from January-April 2019. Infestations were significantly reduced in IPM plots (3-4%) and yield was higher (22-32 t/ha) compared to untreated control (11-12%; 10-16 t/ha). A one-day workshop on "Development of IPM strategy for tomato leaf miner (*Tuta absoluta*) and mungbean cultivation technology in Tajikistan" was conducted in Bokhtar for 57 participants. Farmers from the Khatlon region, agriculture officers from target districts and representatives of Hukumat, USAID Tajikistan, NGOs, and media attended. An IPM package to manage Tuta is being validated in Tajikistan.
- **BMZ-GIC delegates** from India participated in the IV International Symposium on Tomato Diseases in Taiwan and visited WorldVeg HQ labs, greenhouses and field-based research from 5-10 May.
- Four students (2-Taiwan, 1-Germany, 1-World Food Prize intern from the U.S.) completed **internships.**
- An **urdbean** (black gram) trial with 2,266+ accessions from ICAR-National Bureau of Plant Genetic Resources (NBPGR) was established at ICRISAT, Hyderabad.

NEW MARKETS FOR TRADITIONAL TASTES

No plant food exists in isolation, even on an island. The path from field to plate is part of a complex system of production and distribution, elements of which are not always apparent to consumers or even producers.

Mohamed Ally Bakari, 29, from Chaani in Unguja Island, Zanzibar obtained a bachelor's degree in Procurement and Logistics Management from Zanzibar University in 2018. Like many other young people in Tanzania, Mohamed spent a lot of time searching for a white-collar job; he also attempted to raise capital to start a business venture.

With no success on either front, he decided to become a vegetable entrepreneur. But after planting fields of okra and amaranth, he realized there were some gaps in his knowledge about vegetable crop production and distribution.

In 2019 Mohamed discovered a WorldVeg project in the Zanzibar Islands promoting production of traditional African vegetables. Funded by the USAID Feed the Future Program through FINTRAC, the project aims to improve the nutrition and income of smallholders by increasing the production and consumption of these nutrient-dense vegetable crops.

Mohamed joined a group of farmers for training sessions at a local demonstration plot where 11 varieties of amaranth, okra, African nightshade, Ethiopian mustard, pumpkin leaves, cowpea leaves, and African eggplant were raised. The participants learned good agricultural practices to produce the crops.

Enterprising farmers and a WorldVeg project open opportunities for traditional vegetables in Zanzibar.

On land inherited from his parents, Mohamed employed the skills he had acquired through training. He first conducted a rapid survey of Mwanakwerekwe wholesale market to learn more about local demand for vegetables. Based on his self-collected market intelligence, he saw that there was especially high demand in Unguja for amaranth, African nightshade, okra and cowpea. He focused his farm on these crops and started commercial production.

He sold his vegetables at farm gate and made a total profit of 777,600 Tsh (US$ 338) by selling nightshade from 0.5 acres and 510,000 Tsh (US$ 221) by selling amaranth from 0.5 acres. Nightshade sold at 800 Tsh per bunch while in the market it was 1200 Tsh per bunch. He sold amaranth at 500 Tsh per bunch while in the market it sold at 700 Tsh per bunch.

Mohamed also strengthened his public speaking skills by participating in a cooking show hosted by WorldVeg during a nutrition sensitization session. He now has the self-confidence to interact with potential buyers, explain to them the health benefits of each vegetable, and convince them to use vegetables in their daily meals. His marketing approach has a personal touch: by giving neighbors a free bunch of each vegetable to taste, he is building demand for fresh produce right at his farm. Mohamed is considering going into seed production of the four crops. He already has bought another acre of land to expand his enterprise.

On the neighboring island of Pemba, Mchafu Ali Haji produces Ethiopian mustard—not a common crop on the island, but one for which demand is growing. "Perhaps it is a result of the cooking shows that the project did, and now more people know about this vegetable," said Mchafu. "I can now easily sell this crop at the farm to neighbors, or to market traders along with other high value vegetables like tomatoes. Sometimes I sell door to door."

Insect pests are the most common problem in Ethiopian mustard. "I usually produce organically," Mchafu said. "So I tested some locally made organic pesticides including a mixture of pepper and onions; ashes; garlic; and neem extract. Among these, neem repelled worms, and this is helping to keep the pests under control." Through pest management and other production methods and skills she learned from the project, Mchafu and other farmers are now better able to manage their farm operations.

"The project's local promotion of traditional vegetables broadened the market for us," she said. "We met with buyers, and we learned about market demand and off-takers. So now I will produce knowing where to sell."

Eastern and Southern Africa

- **Activities** were conducted in five countries: **Burundi, Kenya, Tanzania, Uganda** and **Zambia.**
- The Director General and the Chairman of the Board of Trustees of the **Tanzania Agricultural Research Institute** (TARI) visited WorldVeg in Arusha on 1 March to strengthen ties and collaboration.
- 41 participants, including representatives from nine African vegetable seed companies, the Tanzanian Agricultural Research Institute (TARI), the Tanzania Seed Trade Association (TASTA), and the African Seed Trade Association (AFSTA) attended the inaugural **Africa Vegetable Breeding Consortium** (AVBC) Workshop, 11-12 March at the WorldVeg regional office in Arusha, Tanzania.
- On 11 April, Director General **Marco Wopereis** and Officer-in-Charge **Ralph Roothaert** met with the Director General of TARI, **Dr. Geoffrey Mkamilo**, and about 10 other staff at TARI HQ to discuss opportunities for enhanced collaboration.
- WorldVeg Board Member **Lindiwe Sibanda**, DG Marco Wopereis, and Officer-in-Charge Ralph Roothaert met with the Minister for Agriculture of the United Republic of Tanzania, **Hon. Japhet N. Hasunga**, and the permanent secretary for agriculture, **Eng. Mathew J. Mtigumwe** on 19 April.
- Ralph Roothaert visited the **Agribusiness and Innovation Platform** of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Hyderabad on 1 July to explore joint development of a business model for dried vegetables with food processing companies in Telangana State, India.
- WorldVeg Plant Health Scientist Wubetu Bihon Legesse, based at WorldVeg Mali, came to Arusha to survey **amaranth diseases** in major amaranth production regions of Tanzania from 1-22 July.
- **Training-of-Trainers** sessions on nutrition were held for extension staff, field officers, community health volunteers, and staff from the Mboga na Matunda (MnM) project from 19-21 June on Unguja, the main island of Zanzibar (24 participants) and from 25-28 June on Pemba Island (28 participants).
- WorldVeg displayed traditional African vegetable seeds and related pamphlets and publications in the **Kilimo Endelevu Local Seed and Food Fair** in Karatu Town on 30 August. The event celebrated the value of local crop varieties and amplified farmers' voices in seed policy formulations and priorities.
- **CGIAR Global Crop Diversity Trust** visited the WorldVeg Tanzania genebank on 26-27 September.
- 30 **African eggplant** entries were screened under low moisture conditions in the field during the dry season at WorldVeg in Arusha, Tanzania. Several low-yielding entries under both irrigation frequencies stayed green in the field and are of interest for breeding programs; eight promising entries for drought were retained for screenhouse evaluation.

- **Nutrition training** was conducted for 332 farmers (172 women and 160 men) from eight villages in Karatu through the **Africa RISING** project; a baseline survey (458 households) was conducted in Tanzania.
- 9 **amaranth** entries (4 entries each of *A. cruentus* and *A. dubius*, and one *A. hypochondriacus*) were evaluated for **heat tolerance** in a growth room at 35°C mean and 47°C maximum temperatures. Based on wilt damage score, leaf size extension, and shoot and root biomass, *A. dubius* entries were tolerant to heat while the other two species were highly susceptible.
- Amaranth was assessed for **adaptation** across five diverse growing locations and two seasons in Tanzania to investigate sites for amaranth production. Results suggest two mega environments based on plant performance, soil, physical and chemical characteristics, weather, and altitude: A relatively high altitude, cooler environment with high soil fertility (represented by the current WorldVeg breeding station in Arusha) and low altitude, high temperature and low soil fertility areas (represented by the coastal areas of Tanzania and Dar es Salaam).
- 214 **genebank accessions** regenerated; characterization and regeneration of 202 accessions is ongoing. 98 accessions of eggplant, okra, amaranth, and mungbean were acquired from Spain, Ghana and Taiwan.
- **Seed distribution**: 1,876 seed kits of 25 breeding lines and 4 accessions (276.5 kg) in Tanzania and Madagascar; 67 lines and 10 accessions (792 grams) to Tanzania, Kenya, Nigeria and the Netherlands; 49 lines and 4 accessions (2,684 grams) to WorldVeg offices in Benin, Taiwan and Tanzania.
- **Ongoing studies:** baseline **agrobiodiversity**, monitoring and evaluation, and seed network data collection in Madagascar under the Darwin Initiative Traditional African Vegetables project; agronomic characterization of the **amaranth core collection** under the GIZ Amazing Amaranth project in Tanzania and Kenya.
- **Best practices:** Studies continue on the impact of different **nets** (mesh size/color) on vegetable crops; profitability of **small tunnels** vegetable cultivation; **tomato grafting** to overcome soil-borne diseases and abiotic stresses with suitable rootstocks; efficiency of **natural enemies** (predators, parasitoids, entomopathogenic fungi) collected in Tanzania. Training in good **postharvest management** practices was conducted and collection centers constructed for **solar drying** and **juice production** in Burundi.
- The **Mboga na Matunda** project in Zanzibar trained farmers (especially women and youth) in production and marketing, and worked with the private sector to develop seed systems for traditional vegetables. Nursery operators received training in agronomy and business development. Cooking shows / nutrition training were held for 486 participants (363 women, 123 men). 40 demonstration plot groups were established in Pemba; 25 groups in Unguja. Seed kits worth a total of USD 723 were sold to farmers in Zanzibar (37 in Pemba; 44 Unguja).

A mother plants vegetables and produces a nurse for the community.

THANKS, MOM!

Bintou Diarra lives with her family in Finkolo village, a rural commune of Sikasso district in Mali with about 8,450 people. Like many in the community, Bintou was drawn to informal gold mining as a way to earn money for her household. But gold mining is tedious, dangerous to health and safety, and didn't bring in much income.

Bintou heard neighbors talking about a USAID project in the community to help villagers learn how to produce vegetables and decided it was worth a try. In 2012 she joined activities in the USAID Mali Production Project (2012-2014) and then continued on with the USAID Mali Horticulture Scaling Project (2014 -2019).

At the project demonstration garden / Best Practice Hub, Bintou received training in good agriculture practices and learned how to use improved vegetable production technologies. The training helped her increase vegetable crop yields and ultimately, her income.

The income Bintou realized from the sale of her vegetables was well spent: She invested in the education of her daughter, Mineta Sangaré, who now holds a bachelor's degree in nursing from the Paul Diallo School of Health Practice in Sikasso.

"Over three years, I was able to pay the tuition fees of CFA 930,000 (~US$ 1550) (CFA 310,000 per year; ~US$ 525) and the living expenses of my daughter in Sikasso without any problem," said Bintou. Today, Mineta serves her community as an intern at the Finkolo Health Center and is grateful for her mom's investment choice.

As a village leader and current President of the Union of Women Cooperative Societies, Bintou has inspired other women in her community to apply the income generated from their vegetable production activities to their children's education. Some have also purchased small livestock and fencing for their gardens to enhance the productivity of their farms.

"Vegetable production nourishes my family better than gold mining," said Bintou. "It makes my husband prosperous, and I am proud we have a new nurse for our village."

West and Central Africa Dry Regions

- **Activities** were conducted in three countries: **Burkina Faso, Côte d'Ivoire** and **Mali.**
- The **Mali Horticulture Scaling** project reached thousands of families with improved practices for food production, household nutrition, and sanitation.

Through the project's **production** module:

- 16,973 farmers (78% women) in Sikasso, Mopti and Timbuktu were trained in **Good Agricultural Practices (GAP)** for vegetable production and processing.
- 359 leaders from the 45 **cooperatives** created by the project were trained in good management practices, agribusiness, and seed production.
- Three cooperatives were formally linked to markets to produce 8.5 hectares of **onion.**
- Two **field days** were organized and attended by governors, mayors and other authorities and partners in Sikasso and Mopti.
- Water tanks, fences, irrigation systems and solar panels were repaired in eight **demonstration gardens** in Mopti.
- 4,432 **seed kits** were distributed to beneficiaries.

Through the project's **nutrition** and **WASH modules**:

- 7,636 primary **beneficiaries** were trained (Mopti: 2,269 women, 599 men; Sikasso: 3,874 women, 894 men), and there were 27,951 secondary beneficiaries (Mopti: 13,771women, 2,839 men; Sikasso: 9,307 women, 2,034 men)
- 20,121 children aged less than 5 years old including 8,815 (4,654 girls) aged 0-23 monthswere reached through **nutrition activities** in Mopti and Sikasso.
- 1,830 **cooking demonstrations** were completed in Sikasso (1,084) and Mopti (746). A total of 1,200 **sack gardens** were established in the Sikasso.
- 36 new **community support groups** were established in Mopti, raising the total to 140. In Sikasso, 32 new support groups were added, reaching a total of 175 groups. The groups reached 38,731 beneficiaries (Mopti: 13,037 women and 4,222 men; Sikasso: 18,561 women and 2,911 men). Group activities focused on breastfeeding practices, nutrition awareness, prevention of malnutrition, WASH, birth spacing, maternal and child health, vegetable home gardens, and small livestock husbandry.
- 391 **household visits** were organized in Sikasso and Mopti for women experiencing difficulties breastfeeding or feeding their children and to encourage adoption of good nutrition and health practices.
- **Post open defecation-free activities** were implemented in 33 villages in Mopti and 45 villages in Sikasso, involving a total of 20,422 adults (Mopti: 5,352 women, 1,467 men; Sikasso: 11,438 women, 2,165 men).

- After behavior change communication on birth spacing and maternal and child health, a total of 16,890 adults in Mopti (6,635 women, 1,699 men) and Sikasso (1,650 men, 6,906 women) have started practicing **family planning**. 9,752 women are new users of family planning services. Child immunization reached 10,863 children with Penta 1; 9,630 with Penta 3, and 9,111 with tetanus vaccine. 8,856 pregnant women attended their first antenatal clinic check-up and 2,446 their fourth antenatal clinic check-up.
- Under the Netherlands-funded 2SCALE project led by IFDC, WorldVeg trained 24 field technicians, lead farmers and input dealers in Côte d'Ivoire and 13 in Mali in IPM, postharvest technologies and vegetable production systems. One **vegetable production demo site** in Côte d'Ivoire and three in Mali were established.
- A low-cost surveillance system for early detection and control of **plant viruses** using sentinel crops (tobacco, quinoa and cowpea) was tested at two sites in Mali producing tomato, pepper and African eggplant. A total of 339 leaf samples and 55 samples of vectors (whiteflies and leafhoppers) was sent to Food and Environment Research Agency Sciences Limited (UK) for genome sequencing.
- Five interspecific onion lines developed for **tolerance to high moisture** and **heat** and twoprototypes of **mini tunnels** were tested to enable bulb production during the rainy season and to shorten the onion seed-to-seed production cycle. WorldVeg onions **AVON1308** and **AVON1310** out-yielded local checks in Mali and Ghana.
- In 2019, about 200 kg of **mother bulbs** of WorldVeg onion variety AVON1074 were produced by ZAMOHO seed enterprise in Mali. About 150 kg of mother bulbs of WorldVeg onion variety AVON1073 were produced by NAFASO seed enterprise in Burkina Faso. More than 200 kg of shallot mother bulbs of five lines were produced at WorldVeg's Samanko Research Station.
- Production of **breeder seed** for African eggplant, amaranth, roselle, okra, pepper and onion is ongoing to meet SAFEVEG project needs. Twenty-two tomato and 15 pepper varieties from WorldVeg and local checks are being tested for **multiple disease resistance** in the open field.
- The University of Newcastle, WorldVeg, and East-West Seed company won a project on **high throughput sequencing** to characterize virus diversity and enable targeted resistance breeding for tomato and pepper in the Bristol University-led CONNECTED (Community Network for African Vector-borne Plant Viruses).
- WorldVeg works with the **Massachusetts Institute of Technology** (MIT) to test low-cost vegetable cooling and storage technologies for households, farmers and vendors in Mali.
- Eight tomato varieties registered in the **Mali vegetable seed catalogue** are being characterized for fruit quality and shelf-life during indoor storage.
- The effect of **deep placement of fertilizer** on the nutrient content and postharvest attributes of tomato fruit and onion bulbs is being investigated.

COMMITTING PERSONAL RESOURCES TO VEGETABLE TRIALS

Since 2012, the World Vegetable Center through the USAID-sponsored AFRICA RISING Sudano Sahel project has conducted trials with lead farmers to select elite high-yielding and disease resistant vegetable varieties, and also built the capacity of farmers in good agronomic practices for vegetable production within the Upper East and Northern Regions of Ghana.

However, expanding project activities to cover non-lead farmers in the intervention communities has been a challenge. "Non-lead farmers" are those willing to commit personal resources (land, labor, capital) to undertake vegetable trials with minimal support from the project. Project staff made an extra effort to explain the situation to non-lead farmers: Although these farmers do not receive intensive support from the project, they can gain much by participating in trials, as they can try new varieties and learn new skills.

It takes individual effort for the benefits of a project to take hold on farms and in communities after activities conclude.

About 130 non-lead farmers have now realized the benefits of committing their personal resources to conduct vegetable trials. Project activities were expanded to cover Gia and Bonia, two new non-lead farmer communities located within the Kasenena Nankana West district of the Upper East Region. Some non-lead farmers have used their own resources to buy fencing materials, set up mechanized boreholes, and purchase inputs. This is a good step toward ensuring the sustainability of the intervention after the project concludes.

"Instead of putting the good knowledge that I have learned from farming projects into practice, I have always folded my hands and waited for capital support from the project," said **Mr. Awebura Nabaare**, a 52-year-old non-lead farmer and father of four from Gia. "But now, thanks to WorldVeg, I have changed that mentality. I am currently testing elite varieties of tomato, hot pepper and onions on my farm with technical support from WorldVeg. I have been able to set up a mechanized borehole on my farm and purchase a zinc fence with my personal savings. I will continue to employ these good practices to produce vegetable crops even if the project is not there."

Most non-lead farmers have now realized that projects come and go. It is their best interest to commit themselves to learn new skills when the opportunity is presented, and then put that knowledge into practice once a project has ended.

West and Central Africa – Coastal & Humid Regions

- **Activities** were conducted in four countries: **Benin, Cameroon, Ghana** and **Nigeria.**
- WorldVeg staff attended the 2019 **Africa Seed Trade Congress** (AFSTA) in Mombasa, Kenya in March. Roland Schafleitner, Vegetable Diversity and Improvement Flagship Leader, gave a presentation on "The African Vegetable Breeding Consortium (AVBC) for a better vegetable seed trade in Africa." WorldVeg participated in the Special Interest Group on Vegetables (SIGV) Steering Committee meeting. Regional Director Victor Afari-Sefa was elected as the committee's Vice Chair and presented the 2019 SIGV activities to the AFSTA Board in Nairobi, Kenya.
- Regional staff participated in the inaugural **African Vegetable Breeding Consortium** (AVBC) **workshop** held in Arusha, Tanzania, 11-12 March. Results from an **AVBC needs assessment study** are helping WorldVeg refine products and provide customized services to different categories of members.
- On 21 March, WorldVeg participated in a **USAID Global Food Security Strategy** (GFSS) partners meeting in Abuja. Staff joined in the official launch of the GFSS (18-19 July) and in stakeholders meetings in Abuja as part of an upcoming public-private sector nutrition and resilience intervention in Nigeria.
- At the 9th Annual Pre-Season Networking and Exhibition Forum organized by the **National Seed Trade Association of Ghana** (NASTAG) in Tamale in April, WorldVeg showcased validated technologies at the forum, attracting the interest of farmers and potential partners for future collaboration.
- WorldVeg staff participated in the **African Green Revolution Forum** (AGRF) in Accra, Ghana from 2-6 September. Considered the world's most important and impactful forum for African agriculture, the AGRF attracted more than 2,500 delegates, with >150 participants visiting the WorldVeg booth daily. Three WorldVeg Board members (Julie Howard, Ndidi Nwuneli and Lindiwe Sibanda) spoke at the forum and facilitated partnerships for the Center.
- Two regional staff (Peter Hanson and Herbaud Zohoungbogbo) presented papers at the inaugural **African Plant Breeders Conference** in October at the University of Ghana, Legon, Accra.
- The regional office received >150 **visitors** (including 40 students, trainees and interns) from universities, research institutions, companies, and NGOs.
- On-station (NIHORT) and on-farm (Tomato Jos) trials with 31 **tomato lines**, including some commercial varieties, were undertaken in Nigeria under a UK aid-funded project. High yielding varieties (55 t/ha) with best agronomic practices were identified with over 95% germination rate, disease resistance, long shelf life, and good postharvest quality. Several lines will soon be available for scaling partners. Hot peppers and amaranth were also trialed on-station. Candidate lines will be identified for on-farm trials in different agroecological zones for dissemination to farmers in Benin, Ghana, and Nigeria.

- 35 tomato hybrids and open-pollinated lines were screened for **dual-purpose use** (fresh and processing) on-station and on-farm in Benin and Ghana. Promising lines (mostly hybrids) identified include: CLN 4333, CLN 3902C, CLN 4332, CLN 4375, CLN 4344, CLN 4335 and TLCV15.
- Tomato grafting trials to manage bacterial wilt were conducted at Cotonou station: Hawaii 7996 was the most successful **rootstock**, with 90% resistance to bacterial wilt when grafted with the most susceptible local variety, Tounvi.
- Performance evaluation trials of Asian and Central American **habanero peppers** conducted on- station in Benin identified the most promising lines (AVPP1922, VI047123, AVPP1503, VI028597, VI014921) for promotion in West Africa.
- On-station trials were conducted for tomato, mungbean, pepper and okra in Benin for the **Africa Vegetable Breeding Consortium** (AVBC) workshop in August 2020. All lines performed well and will be of great interest to member seed companies.
- Under the UrbanFoodPlus project in Cameroon, the final results of a PhD studentship on the effect of **biochar** on soil and leaves of selected vegetables indicated plots with manure + biochar recorded significantly higher soil pH values and major soil nutrient content (N, P, C content) than manure alone after two years.
- In Ghana, **varietal trials** were conducted for tomato, hot pepper and onion under the Africa RISING Sudano-Sahel project. Average yields per hectare ranged from 10.25 - 11.45 tons for Tropimech and Pectomech (commercial tomato varieties), which out-yielded UC82 and the local check. Beneficiary farmers selected UC82 (for its large fruit) and Tropimech (for its higher yields, bright red color, and firm fruit) as their preferred varieties during a participatory varietal selection session.
- Under the 2SCALE Nigeria public-private partnership project, selected **onion hybrids** from Bejo Seeds Inc. (White Columb, Yellow Trophy, Sakana), East West Seed (Super Yali), and Technisem (Onion Dimani) were made available to farmers. Smallholder demand shows huge adoption potential, with WorldVeg providing technical backstopping in agronomy. UNILEVER signed a MoU with Tays Food and AACE Foods for supply of white onion powder processed from White Columb, one of the varieties demonstrated by WorldVeg, IFDC and Tays Foods.
- More than 550 cocoa farmers (350 in Ghana; 200 in Cameroon) participated in the Barry Callebaut-funded **Gardening for Cocoa Communities Project.** About 130 farmers received training in home garden nursery and field management with 24 elite vegetable varieties disseminated for individual vegetable gardens. Rapid assessment studies were conducted in Cameroon and Ghana; paper-based M&E data collection was replaced with **tablet-enabled Akvo Flow** software. A **training manual** was developed and distributed to project beneficiaries in Ghana.
- Project workshops were conducted in five communities in Cameroon's Far-North Region to launch a UNICEF-Cameroon funded project on **improving diet diversity** among children aged 0-23 months.

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Consumer demand for vegetables is increasing rapidly in Asia and Africa, driven by income growth, urbanization, and a growing recognition of vegetables as an important part of healthy diets. Yet many farmers in Africa and parts of Asia seeking to grow more vegetables or different kinds of vegetables often find their crop choices are limited to a small selection of old, underperforming varieties and seed of variable quality.

Producing a diverse range of quality vegetable seed can be challenging for seed companies large and small. Investing in research to generate own varieties of a disease-resistant pepper, for instance, can take years and absorb considerable resources.

The World Vegetable Center helps small and large seed companies to reduce the cost of this investment by providing capacity building to vegetable breeders, developing new methods of crop management, and sharing improved breeding lines of a diverse range of vegetable crops. Seed companies of all sizes are essential partners in ensuring seed reaches vegetable producers of all sizes, from home gardeners to smallholder farmers to large-scale greenhouse growers.

To more closely collaborate with these important partners in the vegetable value chain, WorldVeg established two **seed company consortia**, one for Asia and one for Africa.

Consortia members attend annual workshops for professional interaction with WorldVeg researchers, discuss common problems and explore solutions, evaluate field trials, and have early access to some improved WorldVeg lines. The seed consortia provide a platform for action to work together for better impact in a faster time.

Asia Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium
The APSA-WorldVeg Vegetable Breeding Consortium was launched with 19 companies in 2017 and expanded to 43 companies in 2019. "The vegetable breeding consortium is the right step toward feeding the world's

PARTNERS IN THE VEGETABLE VALUE CHAIN

The World Vegetable Center's breeding consortia foster collaboration among seed companies seeking to expand crop choices for farmers in Asia and Africa.

growing population," said one of the workshop participants. "The purpose of the consortium is quite meaningful as it gives equal opportunity to all companies, small or large, to access breeding materials."

Monitoring data received from 21 consortium companies in 2017 and 2018 and showed that WorldVeg germplasm was incorporated in 45 commercial varieties and in 9.5 tons of chili/sweet pepper and tomato seed.

Africa Vegetable Breeding Consortium (AVBC)
WorldVeg established the Africa Vegetable Breeding Consortium (AVBC) under the umbrella of the African Seed Trade Association (AFSTA) in 2018. There are now 9 members in the AVBC and interest in the consortium continues to grow.

"It was good to meet other key players in the market and know more about what they are doing," said a consortium member from a multinational seed company who participated in the inaugural workshop in Tanzania. Another member expressed that "The consortium can help policy makers to change their mindset, to give higher priority for funding vegetable research and innovation."

Strengthening the private seed sector
The consortia facilitate discussion among member companies to improve practices throughout the seed sector. Small companies in particular can benefit from the knowledge and vegetable lines shared in the consortia to become more competitive by developing their own proprietary varieties.

The ultimate goal: help seed companies provide quality seed to producers, who can then provide a greater choice of healthy vegetables to consumers.

Asia Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium
https://avrdc.org/apsa-worldveg-vegetable-breeding-consortium/

Africa Vegetable Breeding Consortium (AVBC)
https://avrdc.org/africa-vegetable-breeding-consortium/

APSA-WorldVeg Vegetable Breeding Consortium
Acsen Hyveg Private Limited, India
Advanta Seed (United Phosphorus Limited Group), India
Beijing Bannerseeds Oriental Agriculture Development Co. Ltd., China
Chia Tai Co., Ltd., Thailand
Ch. Khair Din & Sons, Pakistan
Clover Seed Co., Ltd., Hong Kong
Comienzo Agri Science Ltd., India
Degao Vegetable Seed and Seedling Research Institute, China
East-West Seed International Ltd., Thailand
Enza Zaden Asia Sdn Bhd, Malaysia
Feltrin Sementes Ltda, Brazil
HM Clause (Thailand) Co. Ltd., Thailand
I & B Seeds Pvt. Ltd., India
Indo-American Hybrid Seeds (India) Pvt. Ltd., India
JK Agri Genetics Ltd., India
Kagome & Co., Ltd., Japan
Known-You Seed Co., Ltd., Taiwan
Mahindra Agri Solutions Ltd., India
Mehr Muhammad Din and Sons, Pakistan
Metahelix Life Sciences Pvt. Ltd., India
Monsanto Holdings Pvt. Ltd., India
Namdhari Seeds Pvt. Ltd., India
Nath Bio-Genes (I) Ltd., India
Nongwoo Seed India Pvt. Ltd., India
Nunhems BV, Netherlands
Onesh Agri Pvt. Ltd., Sri Lanka
PT. BISI International Tbk, Indonesia
PT. East West Seed Indonesia
Rijk Zwaan, Netherlands
Ruchi Hi-rich Seeds Pvt. Ltd., India
Sakata Seed Corporation, Japan
SeedWorks International Pvt. Ltd., India
Shouguang Yinong Horticulture Co., Ltd., China
Shriram Bioseed Genetics, India
Sing-Flow Seed Co., Ltd., Taiwan
Sungro Seeds Pvt. Ltd., India
Syngenta India Limited, India
Takii & Co., Ltd., Japan
Tierra Seed Science Pvt. Ltd., India
Tokita Seed India Pvt. Ltd., India
United Genetics India Pvt. Ltd., India
Welcome Crop Science Pvt., Ltd., India
Your Chain Seed Co., Ltd., Taiwan

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

Contributors: Bitter Gourd Breeding Project (Apr 2019 – Mar 2022)
Acsen HyVeg Pvt. Ltd., India
Chia Tai Co., Ltd., Thailand
CKD Seeds & Fertilizer, Pakistan
Clover Seed Co., Ltd., Hong Kong
Comienzo Agri Science Ltd., India
Kalash Seeds Pvt. Ltd., India
Metahelix Life Sciences Pvt. Ltd., India
Monsanto Holdings Pvt. Ltd., India
Namdhari Seeds Pvt. Ltd., India
Nath Bio-Genes (I) Ltd., India
SeedWorks International Pvt. Ltd., India
Shriram Bioseed Genetics, India

Taiwan companies in-kind contribution: multiplying WorldVeg germplasm
Besgrow Seed Co., Ltd.
Known-You Seed Co., Ltd.
Mu-Zi-Li Farm
Sing-flow Seeds Co., Ltd.
Your Chain Seeds Co., Ltd.

Global R&D Week

Put 100 vegetable researchers and colleagues in a room and what emerges? A salad of spirited discussions, lively exchanges, new ideas, and plenty of laughter and camaraderie. Global R&D Week, 11-15 November 2019 at WorldVeg headquarters, brought together staff from offices in Benin, Cambodia, Cameroon, Ghana, India, Korea, Mali, Taiwan, Tajikistan, Tanzania, and Thailand to review achievements, brainstorm strategy for 2020, get updates on institutional activities, visit the fields and greenhouses, and enjoy one another's company.

Regional directors opened the week with overviews for 2020, followed by concurrent meetings of the four flagship programs: Healthy Diets, Vegetable Diversity and Improvement, Safe and Sustainable Value Chains, and Enabling Impact. On Tuesday and Wednesday, the flagship teams updated colleagues on progress and new directions. Thursday brought updates on the Research Infrastructure Modernization (RIM) project and an important discussion of WorldVeg's strategic science agenda for climate-resilient agriculture and food systems. After Friday's breakfast in the Demonstration Garden and presentations on safety and risk management, participants cast votes and selected the Mali Scaling Project Team as the winners of the 2019 Science of Excellence Award (USD 2,500) for their great work in improving nutrition and livelihoods, and also chose the 2019 WorldVeg Photo Challenge winners: Sheela Mahato, Willie Chen, and Raki Diallo. Congratulations to all!

Open Day 2019

What a great day! That's what 10,000 curious and delighted people exclaimed during Open Day 2019 (7 December) at WorldVeg HQ—a day of fun, food and learning for the local community. As they entered campus under a beautiful bamboo arch designed by students from the Tainan National University of the Arts, our visitors were greeted by the big smile of Big Tom, the world's largest tomato. They walked through colorful, thriving vegetable fields, viewed informative science displays, and took guided tours of the Demonstration Garden and Phenospex facility. Kids folded origami eggplant, worked vegetable puzzles, and romped through a veggie maze and photo hunt. With all the activity, people were bound to be hungry; 50 local vendors and food trucks obliged by offering local tasty treats and snacks. Thanks to the community of Shanhua for hosting the WorldVeg campus for 47 years, and to the people of Taiwan for their generous support!

A PROFITABLE CHOICE

There is strength in numbers, as farmers in Bougouni district, Sikasso, Mali discovered when the USAID Mali Horticulture Scaling project encouraged them to form cooperatives to grow and market vegetable crops. The project offered training in good agricultural practices, marketing, cooperative management and nutrition. Farmers readily adopted the new production skills—but then had to develop markets for their produce.

"The project helped them form a cooperative and linked them to All Terrain Services (ATS), the catering service contracted by the Morila Gold Mine, to purchase vegetables," said Souleyman Mariko, president of the Blédougou vegetables producers' cooperative in Bougouni.

The relationship began when staff members from ATS visited Bougouni and were impressed by vegetable production activities at different project sites. ATS expressed interest to obtain vegetables from project participants—provided quality standards could be met and speedy delivery guaranteed.

Farmers in Koury, Chobougou, Finkoua, N'Tjila and Blédougou formed a cooperative to manage this golden market opportunity. "To date, we have signed three successive contracts with ATS and now have more than US$ 12,000 in our bank account," said Salif Doumbia, secretary of the cooperative. "Prices offered by ATS are usually double or triple the local market prices."

Can producing vegetables be more lucrative than panning for gold? For farmers in Sikasso, Mali, the answer is yes.

This linkage also has produced a positive spill-over effect on farmers who are not co-op members. "The contract with ATS has generated a particular craze in my village," said Mamadou Traoré, president of the N'Tjila community garden. "People who abandoned vegetable production for gold panning, charcoal making and firewood cutting are returning to growing vegetables as they hear more about the profitable experiences of the cooperative members." Mr. Traoré has observed a growing interest in vegetable production among women in the area.

Co-op members reap the benefits of year-round vegetable production. Karim Fomba, a project participant from Soussounkoro, said: "Previously, we only grew vegetables in the cool dry season; the rainy season was dedicated to raising cereals and cotton. Because we lacked the knowledge and skills to produce vegetables in the rainy season, vegetables were scarce and prices were high.

"With the good agricultural practices we learned from project training, we can now produce vegetables in both dry and rainy seasons," he said. "That's more income for us and more vegetables for our neighbors."

Safe and Sustainable Value Chains

- Preliminary results from tests of four **biostimulant products** (soil based microbial nutritional enhancer, free L-amino acids and essential minerals, chitin and plant nutrients, spores of vesicular-arbuscular mycorrhiza) indicate no significant yield increase with any of the treatments.
- In India, **phytohormones** improved overall growth-associated traits of tomato seedlings in the nursery and facilitated faster seedling establishment in the field.
- **Biochar** increased yields of African nightshade (*Solanum scabrum*) and amaranth (*Amaranthus cruentus*) and the efficiency of poultry manure in Bamenda, Cameroon.
- In a survey of **viruses in sweet pepper** in southern Taiwan, out of 126 samples, 41% carried Potyvirus, 36% Begomovirus, and 33% Polerovirus.
- 322 **virus disease** and 55 **whitefly samples** were collected in Mali and sent to Fera Sciences, UK for genome sequencing and identification. 26 disease samples were collected from Cote d'Ivoire and sent to WorldVeg HQ for analysis.
- **Molecular characterization** suggests a mix of *Mungbean yellow mosaic virus* and *Mungbean yellow mosaic India virus* may be partly responsible for apparent reduced resistance in mungbean in Ludhiana, Punjab, India.
- A **screening method** for reaction to tomato bacterial spot (TBS) (*Xanthomonas*) has been improved and used to understand changes in TBS species/races in Taiwan.
- **Trap crops** (cotton and okra) were used to manage hopper burn damage and whitefly- transmitted yellow mosaic virus in eggplant in Thailand.
- Eight ***Solanum viarum*** accessions were screened against *Helicoverpa armigera* in Taiwan; three accessions (VI042189, VI055088, VI042190) were preferred for oviposition compared to tomato and will be tested further for use as trap crops.
- **Spider plant** accessions were tested as trap crops against striped flea beetle (*Phyllotreta striolata*) on brassicas in Taiwan. None were found to be significantly attractive. In India, host plants of *Tuta absoluta* (potato, eggplant, nightshade and tobacco) failed to attract adult female moths for oviposition.
- Two **bacterial wilt-tolerant tomato lines** were identified in Benin: Benin local variety and UG-AMES13-2 from WorldVeg Tanzania.
- Evaluating four *S. pimpinellifolium* for reactions to different **bacterial wilt** (*Ralstonia*) phylotypes and strains in Taiwan showed that VI005591-S1 is resistant to Phylotype I (Pss4) and VI029740-S1 is resistant to Phylotype II (Pss1632).
- ***Solanum peruvianum*** accessions VI037301 (*Tomato chlorosis* Crinivirus) and VI006305, VI054267, VI051125, and VI057441 (*Tomato spotted wilt* Tospovirus) were found to be resistant in Taiwan.
- **Pepper varieties** AVPP1111 and 9905 were tolerant to virus diseases in Mali.
- 28 **tomato varieties** were tested for disease tolerance and yield performance in Mali. Bacterial leaf spot was the most frequently observed foliar disease. AVT01703 and AVT01710 provided >10t/ha total yield.

- Five new **eggplant accessions** (VIO41809A, VIO41G9r4a3f, VdlOo4k1r9a45, VIO41979A, VIO41984) were identified for stable resistance to bacterial wilt in Taiwan and three accessions were identified as best candidates for tomato grafting. VIO41809A and VIO41943 are also salt-tolerant.
- 22 ***Solanum torvum*** accessions recovered well from short-term waterlogging in Taiwan, indicating potential as rootstocks.
- Five waterlogging tolerant and rootknot nematode (*Meloidogyne incognita*) resistant accessions (VI047584, VI048294, VI059830, VI060115, VI060116) were identified in three **Malvaceous species** (*Hibiscus sabdariffa* [3], *H. radiates* [1], *H. acetosella* [1]), and showed good grafting compatibility with okra in Taiwan.
- Preliminary results from Cameroon indicate higher compatibility between tomato grafted onto eggplant (*Solanum aethiopicum* and *Solanum macrocarpon*) than tomato onto tomato. **Tomato grafting trials** in Benin showed that Hawaii 7996 was an effective rootstock, providing 90% resistance to bacterial wilt when grafted with the most susceptible local variety, Tounvi.
- WorldVeg developed a grafting **healing chamber** constructed with PVC pipes and polythene with a six-tray capacity (432 plants). A small USB-powered fan creates a favorable environment for healing and prevents formation of adventitious roots.
- 6 predators, 2 parasitoids, and more than 20 fungi strains were collected for the **biocontrol of aphids** in Tanzania. The predominant parasitoid is *Aphidius colemani* and the predators are mostly ladybird beetles.
- The efficiency of a *Metarhizium anisopliae* formulation in suppressing **red spider mite** on eggplant and tomato was on par with chemical pesticides in Mali.
- An IPM package to manage ***Tuta absoluta*** is being validated in Tajikistan.
- **Biopesticide** Eradicoat T (Maltodextrin 49%) efficiency testing on key pests of tomato, cabbage, amaranth and African eggplant in Benin showed a dosage of 10 ml/l of water is effective against major lepidopteran pests.
- **Postharvest practices:** In Mali, characterization of fruit quality of eight tomato varieties during indoor storage; effects of soil nutrient management on nutrient content and postharvest attributes of tomato and onion; low cost cooling / storage technologies for households, farmers, and vendors. In East Africa, assessment of solar dryers and their impact on nutritional quality; training in good postharvest practices; construction of collection centers, solar drying, and juice production.
- **Chemical desiccants** to dry mungbean crops in the field to improve mechanized harvesting were tested in India. Glyphosate, Thiourea, and Ethrel did not pose any threat to seed yield, color, or germination. No residue was detected in the seed samples, with the exception of Glyphosate (20% of samples, higher than the permissible limit).

AMARANTH TURNS OVER A NEW LEAF

Urban demand is on the rise for this dual-purpose traditional vegetable and grain.

Amaranth (*mchicha* in Swahili) is a popular traditional vegetable with a long cultural tradition in East Africa. The leaves are rich in essential vitamins and minerals (iron, zinc, calcium) often lacking in local diets. Amaranth grain provides high quality protein; it can be consumed directly or used to fortify starchy staples such as maize flour. The grain is easy to store.

Farm households typically cultivate amaranth in small areas or collect leaves from the wild for consumption or for sale in local markets. Increasing demand for year-round supplies of fresh amaranth in Africa's burgeoning cities is motivating farmers to grow the crop in larger areas under more intensive, commercial-scale production. As more farmers seize the opportunity to improve their livelihoods through amaranth production, they need high-yielding varieties that meet or exceed market requirements.

Despite its many benefits, amaranth has been largely neglected in agricultural research and development. The lack of quality seed of diverse, resilient and high-yielding varieties in a range of leaf colors, shapes, sizes and grain qualities demanded by consumers and market traders has impeded commercial production of the crop.

"Amazing Amaranth: Hardy and nutritious amaranth lines and food practices to improve nutrition in East Africa," a project funded by the Federal Ministry for Economic Cooperation and Development, Germany (BMZ), is changing the prospects for this traditional crop.

WorldVeg and partners Simlaw Seeds Kenya and the Tanzania Agricultural Research Institute painstakingly tested candidate amaranth varieties in different locations across Tanzania and Kenya, evaluating them for vegetable yield, seed production, earliness, vigor, leaf qualities, size color, tolerance to heat and diseases, and nutrient content. Participating women and men farmers shared their vast expertise and knowledge, assessing candidate varieties for appearance, cooking qualities, taste and other critical characteristics.

Three outstanding amaranth varieties—AVAM1916, AVAM1938 and AVAM1939—came out on top and were selected to advance along the process toward variety release. Prior to release they will be re-named and seed will be made available to farmers through seed companies or public institutions.

VEGETABLE DIVERSITY AND IMPROVEMENT

- An analysis showed that more than 42,000 **seed kits** were distributed to farmers in East Africa (2013 -2017), with more than 183,000 seed samples. On average, there were four crops per kit. Nineteen traditional vegetables were among the seed distributed.
- A **diversity and conservation status analysis** was conducted for 126 traditional African vegetables in Benin, Cameroon, Ethiopia, Eswatini, Ghana, South Sudan, and Togo. Criteria to target collection missions included number of species observed per country; number of species for which germplasm is maintained in a national or foreign genebank; observed richness corrected by resampling; modelled richness; and vegetable composition structure.
- The **Phenospex Field Scan System** was launched in May. Studies using the new system included measuring growth curves of 30 okra accessions under waterlogged conditions. In addition, a high throughput pollen quantification device was put in operation to study pollen viability of tomato and pepper under heat stress conditions.
- **Breeding for insect resistance:** *Mungbean* – Thrips and stem fly resistant breeding lines and mini-core accessions identified. *Tomato* – *Solanum galapagense* x *Solanum lycopersicum* back-cross G19904#41 demonstrated whitefly resistance.
- **Breeding for virus resistance:** *Tomato* – *Crinivirus*-resistant lines identified. *Pepper* – An accession resistant to Pepper yellow leaf curl Thailand virus identified as new source for breeding.
- **Breeding for fungal disease resistance:** *Pepper* – Inheritance pattern of resistance to *Phytophthora capsici* and *Colletotrichum acutatum* (Anthracnose) identified in diverse pepper backgrounds. *Mungbean* – Anthracnose pathogen identified as *Colletotrichum truncatum* and two resistant mini-core accessions identified. Cercospora leaf spot resistant accessions identified.
- Four **high-yielding** (especially at first harvest) **dual-purpose tomato hybrids** identified: AVTO1864 F1 (72 t/ha first harvest); ATVO1866 F1 (45 t/ha); AVTO1870 F1 (74 t/ha); ATVO1871 F1 (39 t/ha).
- Two **sweet pepper hybrids** (CCA15404 and CCA15334) identified with improved heat tolerance, organoleptic and nutritional traits and higher yield than commercial hybrids in Taiwan.
- **Global bitter gourd breeding project:** 25 member companies now providing support for research into lines/F1 hybrids with inbuilt disease resistance and improved fruit quality.

- The **International Mungbean Improvement Network** now has 12 members in Asia and Africa. The Australian Centre for International Agricultural Research (ACIAR) has agreed to continue supporting this important platform for information exchange in Australia, Bangladesh, Myanmar and India. UK aid is funding mungbean trials in Africa. In April, WorldVeg and Kasetsart University hosted a mungbean workshop with researchers from Cambodia, China, Indonesia, Laos, Philippines, Thailand, and Vietnam.
- **Traditional African vegetables:** A drought-tolerant African eggplant accession was studied; it demonstrated low yield under drought stress, but the plants stayed green. Even after wilting, it demonstrated good recovery. 70 accessions of amaranth were screened for drought tolerance.

RESTORING A TRADITION

Nature provides an abundance of plant foods rich in micronutrients and medicinal properties. The island of Taiwan, due to its unique geography and environment, is rich in plant diversity. Yet many plant foods previously important in traditional Taiwan diets are now neglected. Today, the island's most commonly consumed plant foods are crops such as rice, wheat, cabbage and cucumbers.

With support from the Council of Agriculture of Taiwan, WorldVeg conducted a study to identify local indigenous vegetables and investigate their potential health benefits and role in current food systems.

WorldVeg researchers reviewed previously conducted ethnobotanical studies in Taiwan, covering approximately 800 ethnic plant species and their traditional uses. They found 380 edible plant species and among those 150 species considered as "Taiwan Indigenous Vegetables" traditionally consumed by indigenous peoples of Taiwan. Only 12-14% of these species overlap with the priority vegetables recorded in Plant Resources of Tropical Africa and Southeast Asia, indicating the diversity of Taiwanese vegetable species consumed in the past. According to traditional Chinese medicine records, about half of these vegetable species were used both as food and as herbal remedies. Anti-oxidant activity was the most mentioned functional property, followed by anti-inflammatory, anti-diabetic, anti-carcinogenic and anti-microbial properties. Relatively well known are bitter gourd (*Momordica charantia*) for anti-hyperglycemia (anti-diabetes) and Chinese yam (*Dioscorea alata*) for reducing risks of breast cancer and cardiovascular disease.

Results showed that protein, dry matter, beta-carotene and iron content as well as anti-oxidant activity are all much higher for traditional vegetables than for the commonly consumed vegetables. Sugar content is higher in the commonly consumed vegetables in Taiwan. The diversity of staple foods (cereals, grain legumes, roots, tubers) was higher in the past; over the last 50 years, rice (42%) and wheat (34%) have become the major staple foods.

Amaranth had the highest annual production in 2017 (8566 tons), followed by chayote vines (2549 tons), and okra (2545 tons). Consumers purchase traditional vegetables at local and wholesale markets, and through online shopping. An internet search listed 44 local markets offering traditional vegetables and 73 restaurants with traditional vegetables on the menu. The restaurants were mostly tribal restaurants offering more than 46 different traditional vegetable dishes.

Exciting and tasty recipes can influence consumer behavior and increase consumption of traditional vegetables. Together with a team of chefs and video producers, nutritionists from WorldVeg developed 25 new amaranth and okra recipes and produced videos following five food themes: (1) Elderly and Children: High in vitamin A and calcium content and easy to chew; (2) Eat Out at Home: Easy and quick-to-prepare meals at home; (3) Taiwan Summer: Cool and refreshing recipes (radish, green vegetables, etc.); (4) Reduce Food Waste: Dumplings/wontons to use all edible parts of a vegetable; (5) Tasty Green Leaves: Reduce fibrous texture of vegetables and use sauces to enhance flavors. Thirty-five students from the Department of Culinary Art and Management, I-Shou University tested and sampled the recipes. "These recipes are a means to promote healthy diets and nutrition," said Dr. Hong, Department Chair and Associate Dean of Tourism and Hospitality. "This project brings real collaboration among experts from culinary art, food science, nutrition, and media."

Can new recipes revive a taste for Taiwan's traditional food plants?

Healthy Diets

- **Rapid screening methods were developed for nutrients and anti-nutrients in amaranth.** Fresh samples of elite lines and genebank accessions were tested for oxalate content and nutrient and anti-nutrient content. Storing fresh samples in a cold room (8-10 °C) prior to sample preparation did not affect the oxalate content. Oven drying can be used to process a large number of samples. Preliminary results indicated a narrow content range of oxalate among sampled accessions, which will limit breeding for low oxalate varieties.
- **Preparation of traditional amaranth dishes:** Traditional food preparation methods include the following steps: Plucking the edible parts (leaves and tender shoots); washing, chopping (optional); boiling (optional and time varies); stir-frying in oil with onions and tomatoes. The addition of an iron bioavailability enhancer (e.g. lemon juice) to traditional recipes increased the dialyzable iron content of amaranth by 39%. Ugali (corn flour porridge) served with amaranth prepared with an iron bioavailability enhancer has a higher dialyzable iron content by 21.5% than ugali served with amaranth prepared in the traditional manner.
- **Schools as a platform to improve nutrition, livelihoods and environmental sustainability in Tanzania:** A literature review was conducted and an information gap analysis carried out using focus group discussions and key informant interviews in Meru and Babati districts. Clear policy documents about school feeding programs in Tanzania were lacking. Each school had its own procurement system. Vulnerable students from poor families who were unable to pay were excluded from school feeding programs. School meals were characterized as not nutritious and in some cases inadequate. Introducing a school feeding program patterned after pilot projects in Kenya can address these concerns.
- The **Mboga na Matunda Project** aims to develop a seed system for traditional African vegetables in Zanzibar. In 2019, the project team conducted research on agribusiness and nursery business operators, and provided training in agronomy and business development.
- **Barry Callebaut Project - Vegetable Gardens in Cocoa Communities:** In Ghana, the project promoted the "4Rs" of nutrient stewardship (right source, right rate, right time, and right place) to 78 beneficiary farmers to enhance healthy vegetable production and avoid overuse of chemical fertilizers. WorldVeg developed a vegetable production guide, and trained farmers in postharvest management of tomato, chili pepper, African eggplant, and okra to preserve micronutrients. In Cameroon, a project rapid assessment indicated cocoa farmers are aware that malnutrition, anemia, blindness and eye-related diseases, high blood pressure and heart-related diseases, and rickets are relatively common in their community. At four demonstration plots in four different communities of cocoa producers, the cocoa farmers grew 1.5 tons of leafy vegetables and more than 70% of the produce was consumed.


- **Mali Scaling Project:** The project's nutrition and WASH (water-sanitation-hygiene) activities reached 6,742 primary beneficiaries, 27,951 secondary beneficiaries, and 20,121 children aged less than 5 years old. Child immunization reached 29,600 children. A total of 140 community support groups in Mopti and 175 community support groups in Sikasso are operational.
- A scoping mission on the **potential of school gardens to improve nutrition** in Papua New Guinea was conducted in August, with a focus on primary and secondary schools. The project will be funded by DFAT (Australia) and implemented with Charles Darwin University.
- **Understanding Food Choices in Nepal:** A qualitative study analyzed food choices among school children in Nepal. Rising incomes and the 2015 earthquake were identified as key drivers of food consumption behavior. The study is part of the Drivers of Food Choice Program.
- **Taiwan Council of Agriculture (COA) Project:** With a local chef in Taiwan, recipes were developed for traditional vegetables with different thematic topics (elderly and children, eat-out group, recipes for summer, reducing food waste, and tasty leafy greens) to raise public awareness of healthy food choices and eating behaviors.
- Funded by IMMANA and implemented in collaboration with Wageningen University, a study was conducted in Nairobi to **measure fruit and vegetable intake and food choice motives** among different populations in Nairobi, Kenya. New metrics were developed to collect data through a smart phone app, the ENRICH Bot. The ENRICH Bot was compared with a paper-based survey. A total of 289 households were sampled and interviewed from three different settlements in Nairobi: (1) low income neighborhood, (2) low- to middle-income neighborhood; and (3) high income neighborhood. Recommendations were formulated to improve smart phone-based interview applications.
- WorldVeg, in collaboration with the Competitive African Rice Initiative (CARI) project in Tanzania, with funds from GIZ and the Kilimo Trust, organized a training of trainers (ToT) course to **improve knowledge and technical capacity of agriculture officers and community health workers on nutrition and healthy diets.** ToTs are expected to facilitate farmers to implement nutrition-sensitive vegetable production interventions in four project regions: Shinyanga, Rufiji-Pwani, Morogoro and Mbeya. A total of 30 trainers (14 women and 16 men) were trained from 18-22 December 2019.
- The ToT nutrition training course in Tanzania was followed up with **on-the job training** of trainees in the field, who trained rice farmers on improved nutrition and healthy diets, from 6-13 January 2020. A total of 148 farmers (113 women and 35 men) participated in the community nutritional training.

HOME GROWN, SCHOOL TAUGHT

In Nepal, school and home gardens prompt children and their parents to eat more vegetables.

Vegetable consumption is low in Nepal, particularly in the mountainous parts of the country. The conditions for producing vegetables are challenging, but intake is also constrained because people are not aware of the importance of eating vegetables. School gardens could help stimulate vegetable consumption among children—possibly contributing to lifelong improvements in eating habits. However, previous WorldVeg studies indicate the impact of school gardens may be reduced if vegetables are not included in family meals at home.

WorldVeg and its partners tested a novel school garden design in which parents were given parallel training in home gardening and nutrition. The pilot was supported by a grant from the Drivers of Food Choice Program funded by the UK Department for International Development and the Bill & Melinda Gates Foundation and managed by the University of South Carolina. The study generated scientific evidence using a randomized controlled trial design in which 15 schools were randomly assigned to test the pilot and another 15 schools served as a control. The Nepal Agricultural Research Council (NARC) implemented the school gardens while the Asia Network for Sustainable Agriculture and Bioresources (ANSAB) implemented the home gardens. Furthermore, the Leibniz Institute of Vegetable and Ornamental Crops (IGZ) in Germany contributed to the study design and data analysis.

Results show that the combined home and school garden intervention increased parents' food and nutritional knowledge and that they were able to harvest more vegetables from their gardens. Children's and parents' liking for vegetables also improved. Most promisingly, the proportion of children's meals that included vegetables substantially increased (15-26%, depending on the period of the year). These results show that school gardens in low-income countries must not only try to influence children's food preferences and food behavior, but also that of their parents, while simultaneously making healthy food available in children's homes.

Enabling Impact

- **Adoption of WorldVeg improved mungbean varieties:** Planted on an estimated 1.99 million hectares by 1.55 million farmers in Bangladesh, India, Pakistan, Myanmar, Cambodia, Indonesia, the Philippines, Thailand, Vietnam and Uganda.
- **Impact of mungbean research for Myanmar from 1980-2016:** Economic gain -- US$ 1.4 billion; R&D costs – US$ 5 million; internal rate of return – 27%; net present value – US$ 1.7 billion; benefit-cost ratio – 91.5.
- **Evaluation of germplasm use in Central Asia and the Caucasus:** 100 vegetable varieties were released based on WorldVeg germplasm. Seed production systems were studied and challenges and opportunities identified.
- **Impact of household garden interventions:** In Bangladesh, the impact of household garden projects proved to be sustained three years after the project ended.
- A **study** by the Food and Agriculture Organization of the United Nations (FAO) and the Asia and Pacific Seed Association (APSA) **on seed policies and legislation in the Asia-Pacific region** compared progress in seed policies and legislation among 22 countries in the region using data collected from the public and private sectors. A key finding: Regulations should take into account differences between crops that are largely in the public or private domain.
- WorldVeg **vegetable breeding consortia** continue to grow: The *APSA-WorldVeg Vegetable Breeding Consortium* had 43 members in 2019 (up from 33 in 2018 and 19 in 2017). Companies reported to have incorporated WorldVeg germplasm in 45 varieties and 9.5 tons of seed (mostly chili and tomato). The new *Africa Vegetable Breeding Consortium* had 9 members in 2019.
- The **International Mungbean Improvement Network** expanded to 12 members in Asia and Africa. The Australian Centre for International Agricultural Research (ACIAR) agreed to continue its support of the network.
- ***International Vegetable Breeding: A Strategy to Create Development Impact at Scale***, published in 2019, articulates the WorldVeg strategy on breeding, outlines the key roles of consortia and partner networks, and specifies how we monitor outcomes.
- In 2019 **HARVEST**, the WorldVeg document and data archive, had 58,686 records. There were 62,441 visits to the site (an increase of 154.4% over 2018) and 60,904 unique document downloads (an increase of 29.6% over 2018).
- In Bangladesh, an **evaluation of home garden interventions** showed average vegetable production per household was 43 kg/year (+49% over baseline levels; $p < 0.01$), which was maintained for at least 3 years after the intervention. The study found positive effects on women's nutrition knowledge, gardening practices, vegetable consumption, empowerment and output market participation.


l Vegetable Garden for Nutrition Education
पोषण शिक्षाका लागि स्कुल तरकारी बारी
विद्यार्थीहरूबाट सञ्चालित
WorldVeg
प्लट नं. ७
प्लट नं. ६

SAVING TRADITIONAL TREASURES

WorldVeg conserves landraces and wild relatives of vegetable crops in Africa.

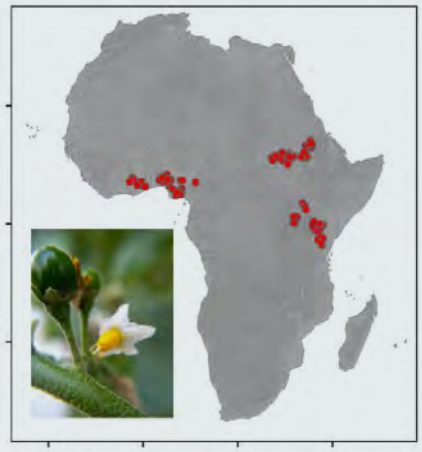


Figure 1. Sites in Africa where wild eggplant relatives were collected by Kew Royal Botanical Gardens and partners of the Global Wild Relatives Project. Seed of these plants is being multiplied, characterized, and safeguarded by WorldVeg. In the picture: *Solanum anomalum*, a wild relative of eggplant.

Landraces and wild relatives of vegetable crops in Africa have the potential to contribute to the development of nutritious and climate-resilient food production in African countries. However, the survival of these plants is uncertain. Human demand for land and water encroach on natural vegetation, less well-known crops often are neglected in agricultural crop research, and food marketing networks with a preference for common global vegetables standardize what's available to eat. These and other factors are contributing to a global decline in agricultural biodiversity.

In collaboration with international and national partners in Africa, the World Vegetable Center aims to rescue these vital genetic resources before they disappear in the coming decades.

Priorities for action: To identify hotspots of diversity, WorldVeg collaborates with National Plant Genetic Resources Centers in Eastern and Southern Africa to upload vegetable biodiversity data to public databases with support of the European Union. In total, 126 high-potential African vegetables relevant for people's diets in different regions of Africa have been identified with the World Agroforestry Centre and the Inland Norway University of Applied Sciences.

Among the vegetables with most potential to be mainstreamed into urban markets and consumer diets are leafy amaranth,

2019 seed sample distribution

5,764 seed samples sent to 44 countries

2019 WorldVeg Genebank stats
# of accessions: 63,498
# of countries: 158
# of species represented: 456
% available for distribution: 73%

Public databases

126 African vegetables

African eggplant, jute mallow, roselle, spider plant, Ethiopian mustard, okra, and vegetable cowpea. Areas of high vegetable diversity can be found in the coastal regions of West Africa, in Cameroon, South Sudan, Ethiopia, Tanzania, Madagascar, and Eswatini. These areas coincide with centers of historic cultural diversity or harbor high levels of natural plant species diversity. This vegetable diversity is poorly represented in genebanks and requires urgent conservation action.

Crop wild relatives: WorldVeg works with Kew Royal Botanic Gardens, UK and partners in the Global Crop Wild Relative project to rescue the diversity of eggplant wild relatives from Africa.

Through the project, WorldVeg has received seed of 217 accessions of 18 eggplant wild relatives. The WorldVeg Genetic Resources and Seed Unit is now multiplying seed of these accessions and characterizing the morphology of the plants.

Wild relatives of cucurbits, vegetable cowpea and okra are other priority species to collect in Africa, and new projects are needed to accomplish this. Partnerships are essential and WorldVeg continues to strengthen a network dedicated to conserving the landraces and wild relatives of vegetable crops in Africa.

2019 WorldVeg Africa Genebank stats
# of accessions: 2,707
# of countries: 38
# of species represented: 72
% available for distribution: 57%
# of seed samples distributed: 14,756 to 11 countries

WHERE KNOWLEDGE THRIVES

PhD candidates hone their research skills and dig deep into science at WorldVeg.

SENEGAL

For her thesis, **Ndeye Bouba Mbengue** explored the potential of Vigna wild relatives for mungbean breeding at WorldVeg headquarters in collaboration with Thies University and the Senegalese Agricultural National Institute. Pre-breeding offers opportunities to introgress desirable genes from wild germplasm into cultivated crops with a minimum of "linkage drag" (undesirable genes introduced along with beneficial genes). Ndeye conducted screening experiments on 19 *Vigna* accessions and three checks to identify accessions with whitefly (*Bemisia tabaci*) resistance. Climate change and rising temperatures threaten food production, and it is urgent to develop crop varieties that tolerate elevated temperatures during their developmental stages. She used impedance flow cytometry (IFC) to identify *Vigna* accessions with pollen that remained viable despite heat treatments above 40 °C. A substantial number demonstrated viability, which suggests these accessions can tolerate heat spikes during their reproductive stages. Finally, Ndeye tested crossing materials to look for the potential to introgress traits from wild relatives into mungbean. She found several promising accessions from the primary, secondary, and tertiary genepool with resistance to whitefly, including accessions for wild relatives *V. mungo* var. *silvestris*, *V. radiata* var. *sublobata*, and *V. aconitifolia*. Only accessions from the primary genepool could be successfully crossed with mungbean. Ndeye is continuing her data analysis and will evaluate *Vigna* germplasm in Senegal.

INDIA

Anthracnose has been a major issue for chilli producers worldwide for several decades. Breeding for anthracnose resistance is complex and challenging; the identification of genomic loci associated with resistance and the development of tightly linked molecular markers would greatly help plant breeders develop resistant lines. To increase resistance breeding efficiency, **Arjun Konana**, a PhD candidate at Tamil Nadu Agriculture University, worked on a research project entitled "Identification of Introgressed Loci Associated with Resistance to Anthracnose (*Colletotrichum acutatum* and *Colletotrichum truncatum*) in Chilli" at WorldVeg headquarters in Taiwan from 24 December 2018 to 24 January 2020. "Using genotyping by sequencing (GBS) technology, we identified anthracnose resistance associated quantitative trait loci (QTLs) on chromosomes 1, 2, 3, 6, 11, and 12," he said. "These QTLs contained regions with high sequence similarity to genes previously identified to be associated with host defense to fungal diseases, providing confidence to our results." Markers were developed and analysis of their selection accuracy in diverse genetic backgrounds revealed resistance might be controlled by the same gene at both green and red stages of fruit maturity. This work shed light on host resistance to one of the most devastating diseases facing chilli producers and provides a basis for future research in this important area.

KENYA

Winnie Akinyi Nyonje is a PhD student of food science and nutrition at Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Kenya. She undertook part of her research at WorldVeg headquarters in Taiwan from July-December 2019 on "Phenotypic characterization and food methods to improve nutritional quality of amaranth vegetables" under the Amazing Amaranth project funded by the Federal Ministry for Economic Cooperation and Development (BMZ), Germany. The project aims to enhance amaranth availability and promote utilization of improved cultivars for better nutrition. While at WorldVeg, Winnie used advanced research facilities including the Phenospex field phenotyping system and the biotechnology and nutritional analysis labs; she obtained amaranth seed from the WorldVeg Genebank. The major part of her work focused on enhancing nutritional quality and iron bioavailability of amaranth dishes through food preparation. She also examined phenotypic and nutritional trait associations in amaranth lines and studied the effect of water stress on nutrient accumulation in amaranth and on the expression of some nutrient biosynthetic genes. Winnie later applied the principles from her study to develop nutritionally improved recipes to enhance nutrient retention and bioavailability. The recipes are intended for promotion in parts of East Africa with the aim of reducing iron deficiencies.

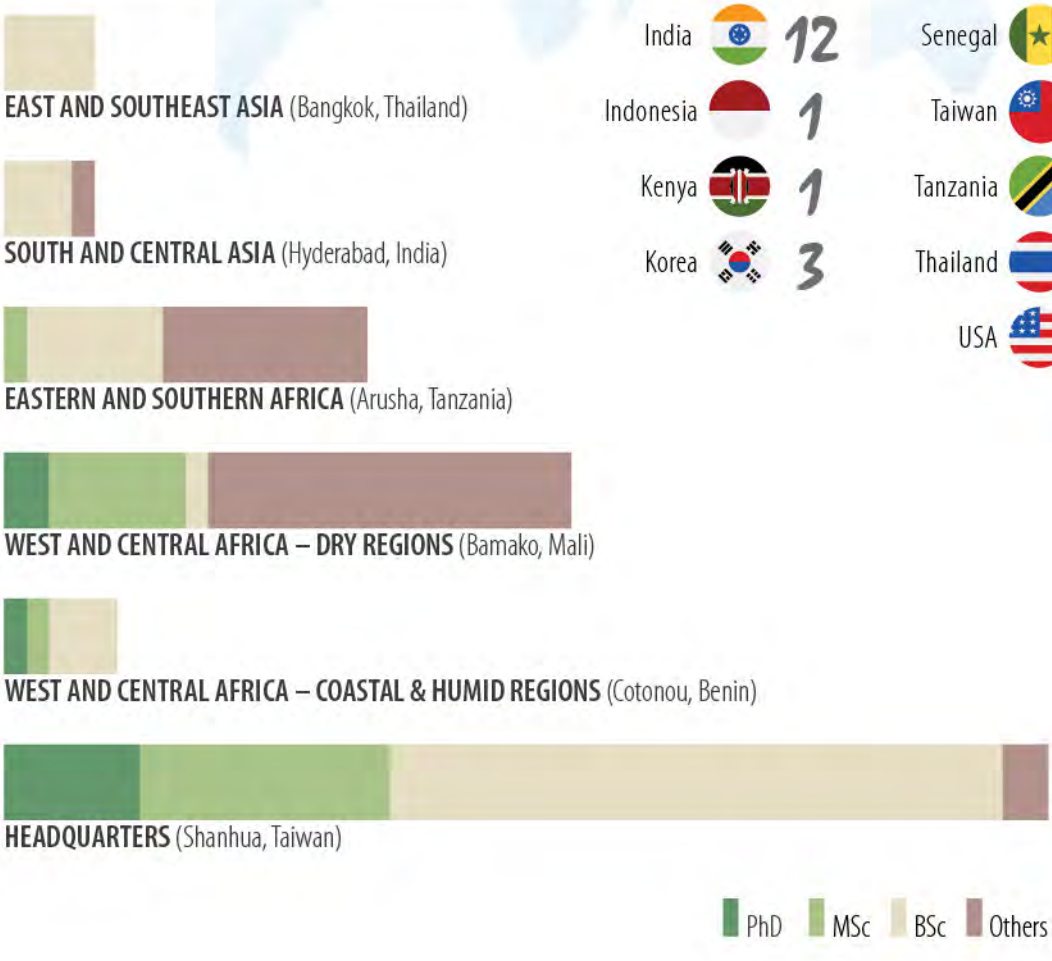
STUDENT INTERNS

In 2019, WorldVeg hosted 100 student interns from 17 countries

By Country

Benin	5	Malaysia	2
Ethiopia	1	Mali	25
France	1	Nepal	2
Germany	1	Pakistan	1
India	12	Senegal	1
Indonesia	1	Taiwan	21
Kenya	1	Tanzania	16
Korea	3	Thailand	4
		USA	3

By WorldVeg Office



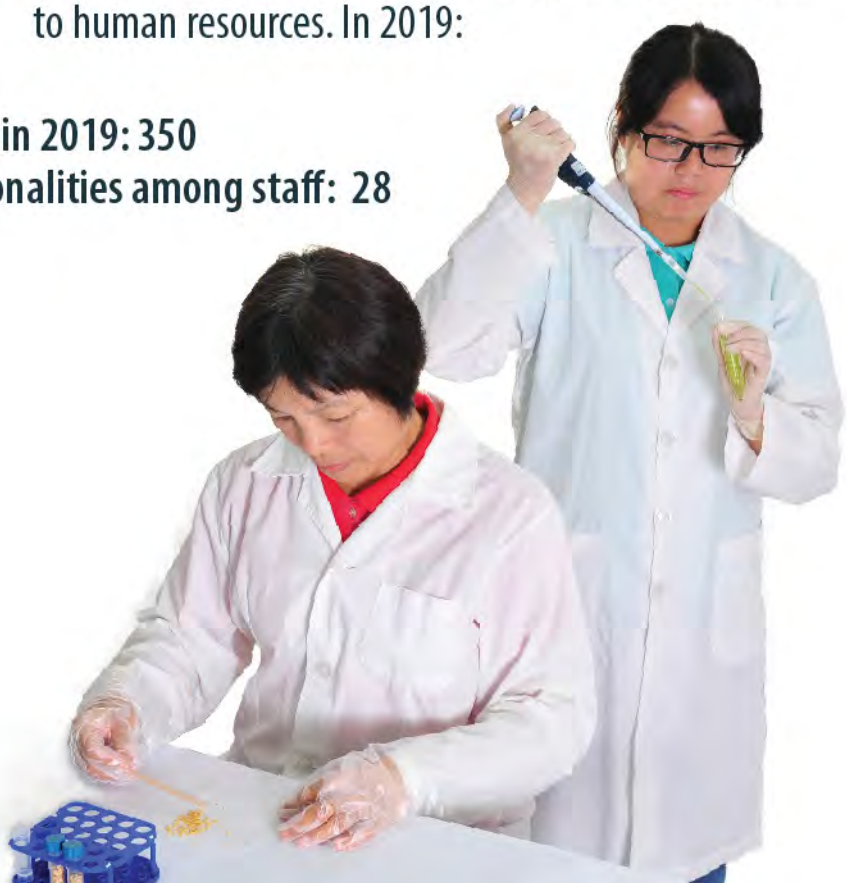
46%
of WorldVeg staff were **women**

16%
of staff recruited internationally were **women professionals**

CORNUCOPIA OF TALENT

WorldVeg values diversity among staff, teams and partners—it is the foundation of our approach to human resources. In 2019:

Number of staff in 2019: 350
Number of nationalities among staff: 28

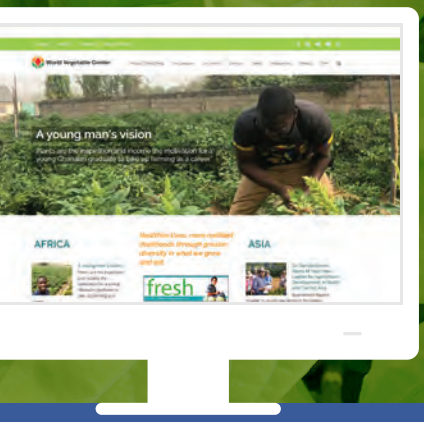


Board of Directors

NAME	COUNTRY	APPOINTED
Dr. Junne-Jih Chen – Board Chair	Taiwan	Apr 2011
Dr. Masa Iwanaga – Vice-Chair	Japan	Apr 2016
Dr. Chi-Chung Chen	Taiwan	Feb 2018
Dr. Myoung-Rae Cho	Korea	Aug 2017
Mr. George Culaste	Philippines	Nov 2017
Dr. Richard Ellis	UK	Apr 2017
Dr. Julie Howard	USA	Apr 2017
Dr. Marlis Lindecke	Germany	Jun 2015
Mr. Gordon MacNeil	Canada	Apr 2016
Dr. Bonnie McClafferty	USA	Dec 2017
Mr. Shigehiro Nishiumi	Japan	Nov 2017
Dr. Gordon Rogers	Australia	Nov 2019
Dr. Lindiwe Sibanda	Zimbabwe	Nov 2018
Dr. Anand Kumar Singh	India	Nov 2019
Dr. Chongrak Wachrinrat; Dr. Buncha Chinnasri	Thailand	Feb 2016
Dr. Dennis Wang	Taiwan	Feb 2018
Dr. Marco Wopereis, ex-officio member	The Netherlands	Apr 2016
Terms concluded in 2019		
Ms. Cathy Reade	Australia	Nov 2019
Ms. Ndidi Nwuneli	Nigeria	Dec 2019

COMMUNICATING with the world

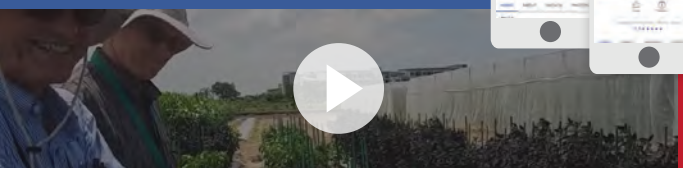
The World Vegetable Center reaches out through various media to engage people everywhere in the effort to diversify diets, improve nutrition, and strengthen economies with vegetables. In 2019:



Monthly unique visitors to worldveg.org: **24,000+**
Subscribers to Fresh, the WorldVeg newsletter: **8,856**

Facebook followers: **19,877**

Twitter followers: **6,343**
(@go_vegetables)



WorldVeg YouTube channel: **5,880**

Media mentions: **221**,
including reports by BBC News, National Public Radio (NPR) USA, NOVA, TalkAfrica, Food Tank, HortiDaily, Medium

Visitors: More than **1670 visitors from 72 countries** toured WorldVeg headquarters and regional offices to learn about our research and projects, and see WorldVeg improved varieties, traditional vegetable and new technologies in our Demonstration Gardens.

IN PERSON

WorldVeg staff highlighted R&D activities at these and other exhibitions and conferences in 2019:

E.A.T. Food Forum :::: 12-13 June, Stockholm, Sweden
Tokyo International Conference on African Development (TICAD 7) :::: 28-30 August, Tokyo, Japan
African Green Revolution Forum :::: 3-6 September, Accra, Ghana
Taiwan Innotech Expo :::: 27-29 September, Taipei, Taiwan
World Food Prize Borlaug International Symposium :::: 16-18 October, Des Moines, Iowa USA
Asian Development Bank 2019 Rural Development and Food Security Forum :::: 28 October, Manila, Philippines
23rd Annual Seed & Seedling Festival :::: 23 November, Xinhua, Taiwan
2019 Asian Seed Congress :::: 25-29 November, Kuala Lumpur, Malaysia
Open Day 2019 :::: 14 December, WorldVeg HQ, Taiwan

FINANCE

	WorldVeg	CGIAR recommended range
Cash management on restricted operations*	0.28	less than 1
Adequacy of reserves	109 days	75-90 days
Short-term solvency	124 days	90-120 days

2019 Revenues (in '000 USD)		
Unrestricted grants	8,617	39%
Restricted grants	13,280	60%
Other revenues	341	1%
Total	**22,238**	100%

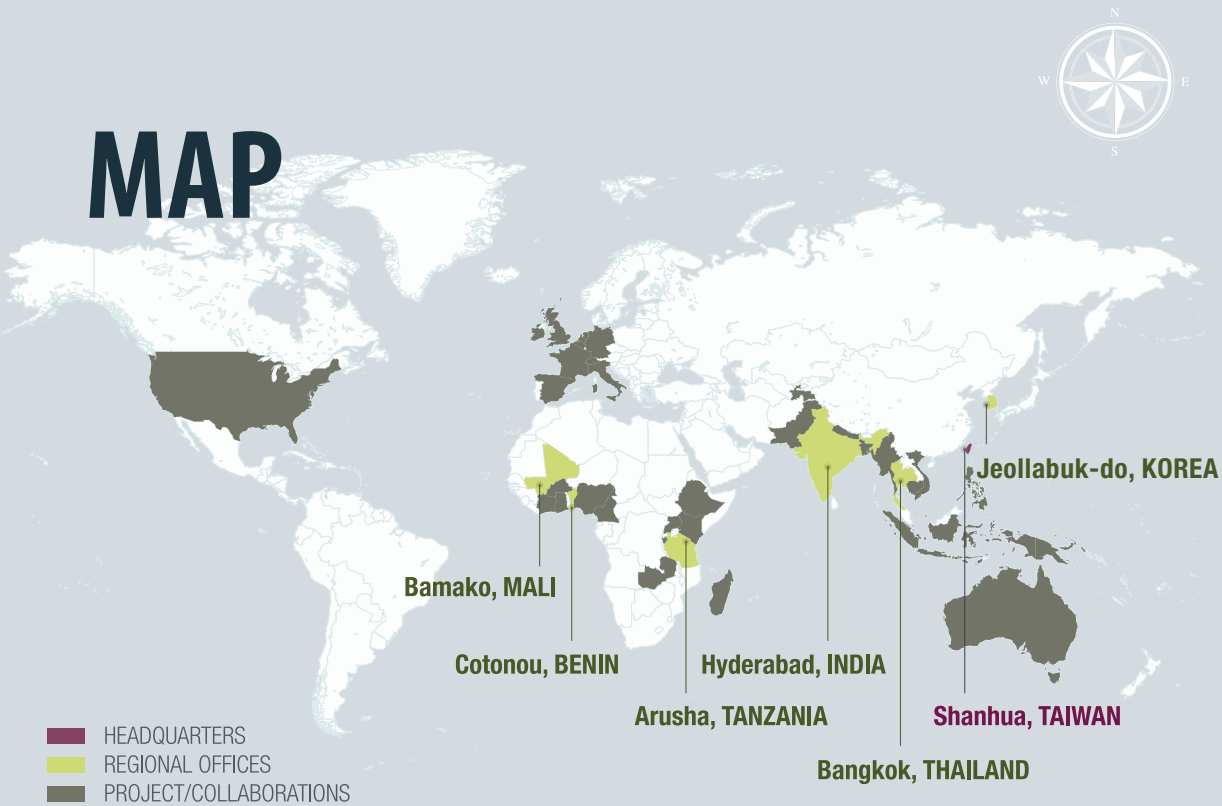
Unrestricted Grants

Republic of China (Taiwan)	4,586
UK Department for International Development (UK/DFID)	2,649
United States Agency for International Development (USAID)	825
Australian Centre for International Agricultural Research (ACIAR)	303
Thailand	145
The Philippines	50
Korea	50
Japan	8
Sub-total	***8,617***
Other revenues	341
Total	**8,957**

Restricted Grants

Republic of China (Taiwan)	4,117
United States Agency for International Development (USAID)	3,417
Republic of Germany / BMZ / GIZ	1,194
UK Department for International Development (UK/DFID)	1,062
Private seed sector companies; Asia and Pacific Seed Association (APSA)	667
Australia/Australian Centre for International Agricultrual Research (ACIAR)	459
State Governments of India	348
Korea / Rural Development Administration (RDA)	268
Others (projects with expenses less than 200K USD)	1,749
Sub-total	***13,280***
Total Revenues	**22,238**

MAP



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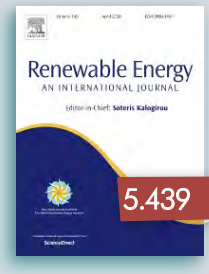
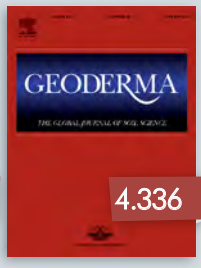
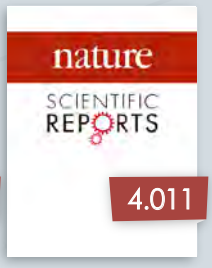
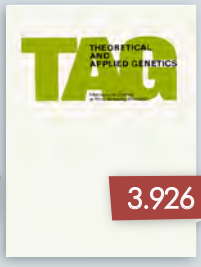
RESEARCH
FOR DEVELOPMENT

TOP 10 journals according to impact factor









2019 Publications

Journal articles w/impact factor (47)

1. Ali, A.; Rakha, M.; Shaheen, F.A.; Srinivasan, R. 2019. Resistance of certain wild tomato (Solanum spp.) accessions to Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) based on choice and no-choice bioassays. FLORIDA ENTOMOLOGIST. 102(3):544-548.
2. Ayenan, M.A.T.; Danquah, A.; Hanson, P.; Ampomah-Dwamena, C.; Sodedji, F.A.K.; Asante, I.K.; Danquah, E.Y. 2019. Accelerating breeding for heat tolerance in tomato (Solanum lycopersicum L.): An integrated approach. AGRONOMY. 9(11):720.
3. Baliki, G.; Brück, T.; Schreinemachers, P.; Uddin, Md. N. 2019. Long-term behavioural impact of an integrated home garden intervention: evidence from Bangladesh. FOOD SECURITY. 11(6):1217-1230.
4. Barchenger, D.W.; Yule, S.; Jeeatid, N.; Lin, S.-W.; Wang, Y.-W.; Lin, T.-H.; Chan, Y.-L.; Kenyon, L. 2019. A novel source of resistance to Pepper yellow leaf curl Thailand virus (PepYLCThV) (Begomovirus) in chile pepper. HORTSCIENCE. 54(12):2146-2149.
5. Bhavana, P.; Singh, A.K.; Kumar, R.; Prajapati, G.K.; Thamilarasi, K.; Manickam, R.; Maurya, S.; Choudhary, J.S. 2019. Identification of resistance in tomato against root knot nematode (Meloidogyne incognita) and comparison of molecular markers for Mi gene. AUSTRALASIAN PLANT PATHOLOGY. 48(2):93-100.
6. de Sousa, K.; van Zonneveld, M.; Holmgren, M.; Kindt, R.; Ordoñez, J.C. 2019. The future of coffee and cocoa agroforestry in a warmer Mesoamerica. SCIENTIFIC REPORTS. 9:8828.
7. Depenbusch, L.; Klasen, S. 2019. The effect of bigger human bodies on the future global calorie requirements. PLoS ONE. 14(12):e0223188.
8. Dhillon, N.P.S.; Sanguansil, S.; Srimat, S.; Laenoi, S.; Schafleitner, R.; Pitrat, M.; McCreight, J.D. 2019. Inheritance of resistance to cucurbit powdery mildew in bitter gourd. HORTSCIENCE. 54(6):1013-1016.
9. Dinssa, F.F.; Hanson, P.; Ledesma, D.R.; Minja, R.; Mbwambo, O.; Tilya, M.S.; Stoilova, T. 2019. Yield of vegetable amaranth in diverse Tanzanian production environments. HORTTECHNOLOGY. 29(4):516-527.
10. Gonzalo, M.J.; Díaz, A.; Dhillon, N.P.S.; Reddy, U.K.; Picó, B.; Monforte, A.J. 2019. Re-evaluation of the role of Indian germplasm as center of melon diversification based on genotyping-by-sequencing analysis. BMC GENOMICS. 20:448.
11. Kessy, R.; Ochieng, J.; Afari-Sefa, V.; Chagomoka, T.; Nenguwo, N. 2019. Solar dried vegetables in rural Tanzania: awareness, perceptions and factors affecting purchase decisions. ECONOMIC BOTANY. 72:367-379.
12. Kessy, R.F.; Ochieng, J.; Afari-Sefa, V.; Chagomoka, T.; Nenguwo, N. 2018. Solar-dried traditional African vegetables in Rural Tanzania: Awareness, perceptions, and factors affecting purchase decisions. ECONOMIC BOTANY. 72(4):367-379.
13. Kudryavtseva, N.; Havey, M.J.; Black, L.; Hanson, P.; Sokolov, P.; Odintsov, S.; Divashuk, M.; Khrustaleva, L. 2019. Cytological evaluations of advanced generations of interspecific hybrids between Allium cepa and Allium fistulosum showing resistance to Stemphylium vesicarium. GENES. 10(3):195.
14. Kunwar, S.; Hsu, Y.-C.; Lu, S.-F.; Wang, J.-F.; Jones, J.B.; Hutton, S.; Paret, M.; Hanson, P. 2019. Characterization of tomato (Solanum lycopersicum) accessions for resistance to phylotype I and phylotype II strains of the Ralstonia solanacearum species complex under high temperatures. PLANT BREEDING. Online.
15. Lee, J.; Jang, S.; Ryu, S.; Lee, S.; Park, J.; Lee, S.; An, G.; Park, S.K. 2019. Impaired plastid ribosomal protein L3 causes albino seedling lethal phenotype in rice. JOURNAL OF PLANT BIOLOGY. 62(6):419-428.
16. Malapit, H.; Quisumbing, A.; Meinzen-Dick, R.; Seymour, G.; Martinez, E.M.; Heckert, J.; Rubin, D.; Vaz, A.; Yount, K.M. 2019. Development of the project-level Women's Empowerment in Agriculture Index (pro-WEAI). WORLD DEVELOPMENT. 122:675-692.

17. Malini, P.; Srinivasan, R.; Schafleitner, R.; Muthukalingan, K. 2019. Pheromone-binding proteins based phylogenetics and phylogeography of Maruca spp. from Asia, Africa, Oceania, and South America. ECOLOGY AND EVOLUTION. 9(16):9239-9272.

18. Muthoni, F.K.; Odongo, V.O.; Ochieng, J.; Mugalavai, E.M.; Mourice, S.K.; Hoesche-Zeledon, I.; Mwila, M.; Bekunda, M. 2019. Long-term spatial-temporal trends and variability of rainfall over Eastern and Southern Africa. THEORETICAL AND APPLIED CLIMATOLOGY. 137(3-4):1869-1882.

19. Nair, R.M.; Giri, Rajkumar R.; Boddepalli, V.N.; Prasad, K.V.S.V.; Devulapalli, R.; Blümmel, M. 2019. Variation in grain yield, fodder quality and animal intake in two dual purpose legume crops: Mungbean and vegetable soybean grown in semi-arid tropical India. LEGUME RESEARCH. Online.

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21. Ndindeng, S.A.; Wopereis, M.; Sanyang, S.; Futakuchi, K. 2019. Evaluation of fan-assisted rice husk-fueled gasifier cookstoves for application in sub-Sahara Africa. RENEWABLE ENERGY. 139:924-935.

22. Nguyen, T.D.; Jang, S.; Soh, M.-S.; Lee, J.; Yun, S.D.; Oh, S.A.; Park, S.K. 2019. High daytime temperature induces male sterility with developmental defects in male reproductive organs of Arabidopsis. PLANT BIOTECHNOLOGY REPORTS. 13(6):635-643.

23. Nordey, T.; Davrieux, F.; Léchaudel, M. 2019. Predictions of fruit shelf life and quality after ripening: Are quality traits measured at harvest reliable indicators? POSTHARVEST BIOLOGY AND TECHNOLOGY. 153:52-60.

24. Ochieng, J.; Knerr, B.; Owuor, G.; Ouma, E. 2019. Food crops commercialization and household livelihoods: Evidence from rural regions in Central Africa. AGRIBUSINESS. Online.

25. Ochieng, J.; Schreinemachers, P.; Ogada, M.; Dinssa, F.F.; Barnos, W.; Mndiga, H. 2019. Adoption of improved amaranth varieties and good agricultural practices in East Africa. LAND USE POLICY. 83:187-194.

26. Othim, S.T.O.; Ramasamy, S.; Kahuthia-Gathu, R.; Dubois, T.; Ekesi, S.; Fiaboe, K.K.M. 2019. Effects of host age and density on the performance of Apanteles hemara (Hymenoptera: Braconidae), a larval endoparasitoid of Spoladea recurvalis (Lepidoptera: Crambidae). JOURNAL OF ECONOMIC ENTOMOLOGY. 112(5):2131-2141.

27. Othim, S.T.O.; Srinivasan, R.; Kahuthia-Gathu, R.; Dubois, T.; Ekesi, S.; Fiaboe, K.K.M. 2019. The effects of pest-resistant amaranth accessions on the performance of the solitary endoparasitoid Apanteles hemara (Hymenoptera: Braconidae) against the amaranth leaf-webber Spoladea recurvalis (Lepidoptera: Crambidae). ENVIRONMENTAL ENTOMOLOGY. 48(1):163-172.

28. Pincus, L.; Croft, M.; Roothaert, R.; Dubois, T. 2018. African indigenous vegetable seed systems in Western Kenya. ECONOMIC BOTANY. 72(4):380-395.

29. Priya, M.; Dhanker, O.P.; Siddique, K.H.M.; HanumanthaRao, B.; Nair, R.M.; Pandey, S.; Singh, S.; Varshney, R.K.; Prasad, P.V.V.; Nayyar, H. 2019. Drought and heat stress-related proteins: an update about their functional relevance in imparting stress tolerance in agricultural crops. THEORETICAL AND APPLIED GENETICS. 132(6):1607-1638.

30. Priya, M.; Sharma, L.; Kaur, R.; Bindumadhava, H.; Nair, R.M.; Siddique, K.H.M.; Nayyar, H. 2019. GABA (γ-aminobutyric acid), as a thermo-protectant, to improve the reproductive function of heat-stressed mungbean plants. SCIENTIFIC REPORTS. 9:7788.

31. Priya, M.; Sharma, L.; Singh, I.; Bains, T.S.; Siddique, K.H.M.; HanumanthaRao, B.; Nair, R.M.; Nayyar, H. 2019. Securing reproductive function in mungbean grown under high temperature environment with exogenous application of proline. PLANT PHYSIOLOGY & BIOCHEMISTRY. 140:136-150.

32. Saito, K.; Vandamme, E.; Johnson, J.-M.; Tanaka, A.; Senthilkumar, K.; Dieng, I.; Akakpo, C.; Gbaguidi, F.; Segda, Z.; Bassoro, I.; Lamare, D.; Gbakatchetche, H.; Abera, B.B.; Jaiteh, F.; Bam, R.K.; Dogbe, W.; Sékou, K.; Rabeson, R.; Kamissoko, N.; Mossi, I.M.; Tarfa, B.D.; Bakare, S.O.; Kalisa, A.; Baggie, I.; Kajiru, G.J.; Ablede, K.; Ayeva, T.; Nanfumba, D.; Wopereis, M.C.S. 2019. Yield-limiting macronutrients for rice in sub-Saharan Africa. GEODERMA. 338:546-554.

33. Schreinemachers, P.; Ouedraogo, M.S.; Diagbouga, S.; Thiombiano, A.; Kouamé, S.R.; Sobgui, C.M.; Chen, H.-P.; Yang, R.-Y. 2019. Impact of school gardens and complementary nutrition education in Burkina Faso. JOURNAL OF DEVELOPMENT EFFECTIVENESS. 11(2):132-145.

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Acronyms

AARDO	Afro–Asian Rural Development Organization
AARNET	ASEAN-AVRDC Regional Network for Vegetable Research and Development
AAU	Assam Agricultural University
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AFACI	Asian Food and Agriculture Cooperation Initiative
AFC	Agriculture & Finance Consultants
AFSTA	African Seed Trade Association
AGRF	African Green Revolution Forum
AIT	American Institute in Taiwan
ANSAB	Asia Network for Sustainable Agriculture and Bioresources
APAARI	Asia Pacific Association of Agricultural Research Institutions
APART	Assam Agribusiness & Rural Transformation Project
APMAS	Andhra Pradesh Mahila Abhivruddhi Society
APSA	Asia & Pacific Seed Association
ATMA	Agricultural Technology Management Agency, Assam, India
ATS	All Terrain Services
AVBC	Africa Vegetable Breeding Consortium
AVRDC	Asian Vegetable Research and Development Center
AYT	Advanced yield trial
BBC	British Broadcasting Corporation
BMI	Body Mass Index
BMZ	Federal Ministry for Economic Cooperation and Development, Germany
BW	Bacterial wilt
CARI	Competitive African Rice Initiative
COA	Council of Agriculture, Taiwan
CONNECTED	Community Network for African Vector-borne Plant Viruses
DFAT	Department of Foreign Affairs and Trade, Australia
FAO	Food and Agriculture Organization of the United Nations
GAP	Good Agricultural Practices
GBS	Genotype by Sequencing
GFSS	Global Food Security Strategy, USAID
GIC	Green Innovation Center
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HARVEST	Holistic Access to Research on Vegetables, Societies and Technology

ICAR	Indian Council of Agricultural Research
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFC	Impedance flow cytometry
IFDC	International Fertilizer Development Center
IGZ	Leibniz Institute of Vegetable and Ornamental Crops
IITA	International Institute of Tropical Agricultural
IMIN	International Mungbean Improvement Network
IMMANA	Innovative Methods and Metrics for Agriculture and Nutrition Actions
IPM	Integrated pest management
ITCC	International Technology Cooperation Center
IVTC	International Vegetable Training Course
JKUAT	Jomo Kenyatta University of Agriculture and Technology
JOHAR	Jharkhand Opportunities to Harness Rural Growth
KU	Kasetsart University
MINAT	Ministry of Territorial Administration, Cameroon
MIT	Massachusetts Institute of Technology
MnM	Mboga na Matunda
MOFA	Ministry of Foreign Affairs, Taiwan
MoU	Memorandum of Understanding
NARC	Nepal Agricultural Research Council
NASTAG	National Seed Trade Association, Ghana
NBPGR	National Bureau of Plant Genetic Resources, India
NIHHS	National Institute of Horticultural and Herbal Science, Korea
NIHORT	National Horticultural Research Institute (Nigeria)
NPR	National Public Radio, USA
NPUST	National Pingtung University of Science and Technology, Taiwan
NTU	National Taiwan University
PoP	Package of practices
PVC	Polyvinyl chloride
PYT	Preliminary yield trial
QTL	Quantitative trait loci
RDA	Rural Development Administration, Korea
RIM	Research Infrastructure Modernization
SEAVEG	Southeast Asia Vegetable Symposium

SIGV	Special Interest Group on Vegetables
TAHA	Tanzania Horticultural Association
TARI	Tanzania Agricultural Research Institute
TARI	Taiwan Agricultural Research Institute
TASTA	Tanzania Seed Trade Association
TBS	Tomato bacterial spot
TICAD7	7th Tokyo International Conference on African Development
ToT	Training of trainers
TYLCV	Tomato yellow leaf curl virus
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USB	Universal serial bus
WASH	Water-sanitation-hygiene

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