



World Vegetable Center

# ANNUAL REPORT 2020





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Published by

**World Vegetable Center**

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WorldVeg Publication: 21-1034

ISBN: 92-9058-233-2

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## **Cover photo**

A young farmer in Assam, India produces healthy tomato seedlings in a plug tray, a simple but effective tool to raise sturdy young plants. *Photo: Souradeep Acharjee*

## **Suggested citation**

World Vegetable Center. 2021. Annual Report 2020. World Vegetable Center, Shanhua, Taiwan. Publication 21-1034. 73 p.



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# Foreword

2020 was an extraordinarily difficult year. Some of us lost a dear family member or friend because of the COVID-19 pandemic. Many people lost their jobs, income, or were separated for a long time. WorldVeg's primary focus has been to ensure the health and safety of its staff and families.

We were very fortunate that the pandemic was kept at bay in Taiwan. We adopted center-wide and project-specific business continuity planning, became accustomed to virtual ways of communication, and rolled out COVID-19 precautionary measures across regional centers, inspired by the Taiwan example. Although this turned out to be quite effective, we really missed the face-to-face interactions with our partners, and welcoming visitors, colleagues, and students to our offices and project sites.

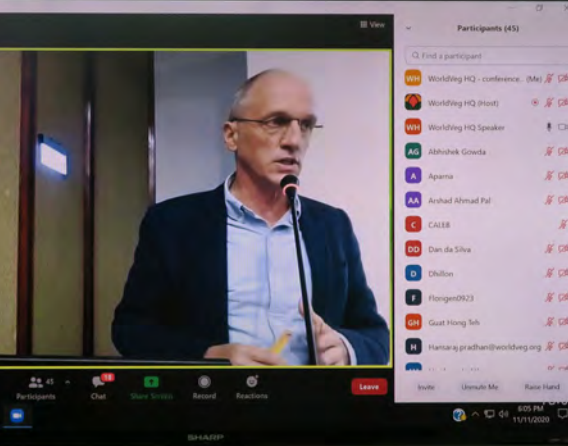
Before the pandemic began to spread worldwide, WorldVeg attended the 2020 Svalbard seed summit and seed deposit ceremony at the Svalbard Global Seed Vault in Norway on February 25. We deposited more than 700 samples of 23 vegetable species in this memorable event.

We established a COVID-19 Task Force early April to plan responses to the pandemic through distribution of seed kits with sturdy, rapid growing vegetable varieties, and to conduct strategic research to understand the pandemic's effects on food systems in Africa and Asia.

WorldVeg staff in collaboration with national partners and nongovernmental organizations distributed seed kits of fast-growing, nutritious vegetable varieties to thousands of vulnerable households in Benin, Mali, Philippines, Taiwan, Tanzania and Thailand; see page 55 ("From vulnerable to resilient") and elsewhere in this report.

WorldVeg researchers in collaboration with project partners in India analyzed the devastating effect COVID-19 had on vegetable farmers across the country. More than 80% of farms reported a decline in sales, and 62% of surveyed households experienced disruptions to their diets; see page 13 ("Disrupting food systems on the sub-continent").

Three consecutive surveys on the effect of the pandemic on the vegetable seed sector in Asia were conducted in the period April – August in collaboration with the Asia & Pacific Seed Association. Companies reported a substantial decline in seed demand and problems acquiring import and export permits, finding



freight solutions, and difficulties with seed storage at the port of entry and seed distribution in the destination country.

Despite the difficulties, WorldVeg started up the Veggies 4 Planet & People project in July—a five-year € 6M project funded by the IKEA Foundation to engage women and youth in vegetable production and distribution networks in Ethiopia and Kenya; more on this project on page 36.

In November, WorldVeg added another large project to its sub-Saharan Africa activities, a five-year € 11.8M project funded by the European Union and The Netherlands' Ministry of Foreign Affairs entitled "Safe locally-produced vegetables for West Africa's urban consumers"(SAFEVEG). This project aims to reduce undernourishment and improve income and productivity of small-scale vegetable producers in Benin, Burkina Faso, and Mali. The project will benefit vegetable consumers and producers in the target countries, and provide numerous opportunities for young agricultural college and university graduates to work in the vegetable sector. More on this project on page 36.

The modernization of our research facilities at WorldVeg HQ (through a generous grant from the Taiwan Council of Agriculture) continues to make good progress, with two top-notch controlled environment facilities for research on insect pests and disease pressure in vegetables about to be completed. Our high-throughput field phenotyping system installed in 2019 is providing valuable data and is fully booked for the next few years. Read more on page 7 ("The RIM Transformation") and page 43 ("Red hot chili peppers").

This year, we also gained better insight into the huge impact four mungbean varieties developed by WorldVeg and released in Myanmar by the Department of Agricultural Research have had, with economic gains of US\$ 1.4 billion from 1980 to 2016. The benefits from this work will continue well into this decade. More on the billion-dollar bean on page 51.

All Board meetings and our Global R&D Week were held virtually in 2020. During our November board meeting, we said goodbye to Dr. Chi-Chung Chen from Taiwan and Mr. Shigehiro Nishiumi from Japan. I would like to sincerely thank them for their dedication and contributions to WorldVeg.

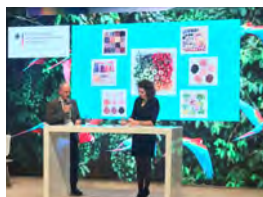
We are once more very grateful to the generous support of our funders listed on page 29, enabling us to contribute to healthier lives and more resilient livelihoods around the world.

**-- Marco Wopereis**  
*Director General*

# TIMELINE

01 JANUARY

The **International Mungbean Improvement Network (IMIN)** received the 12th annual Illumina Agricultural Greater Good Initiative Grant for generating genomic resources for mungbean breeding at the Plant and Animal Genome Conference, 11-15 January in San Diego, USA.



WorldVeg Director General Marco Wopereis was among the 2,000 people representing research, politics, business, and civil society at **International Green Week**, 16-18 January in Berlin, Germany. In interviews Marco emphasized the need to change diets, reduce waste and increase productivity to feed and nourish a growing population.

A field of 190 elite tropical pumpkin lines bred for virus and disease resistance with fruit shapes and colors for different market segments were on view for plant breeders during **Pumpkin Open Field Day**, 22 January, at the WorldVeg Research and Training Station, Kasetsart University - Kamphaeng Saen, Thailand.

02 FEBRUARY

Representatives from the **World Bank/State of Maharashtra Agribusiness and Rural Transformation Project (SMART)** visited WorldVeg South Asia in Hyderabad, India on 3 February to discuss opportunities for collaboration.

On February 3, surveyors began taking measurements for new landscaping at WorldVeg HQ; on February 12, contractors set up a table with fruit and candles to appease the Earth God during excavation. Part of the **Research Infrastructure Management (RIM) Project**, the new green space will integrate vegetables, flowers, trees, and a lotus pond.

More than 700 samples of 23 vegetables species were sent for storage to the Svalbard Global Seed Vault in Norway on 5 February. WorldVeg has about 24% of its collection duplicated and stored in the vault. WorldVeg DG Marco Wopereis spoke about the **importance of genebanks to address malnutrition and climate change** at a gathering on 25 February in Longyearbyen.



03 MARCH



WorldVeg and the Taiwan Agricultural Research Institute (TARI) hosted a **Field Demonstration of Vegetable Cultivars from Taiwan and Trade Fair** on 3 March at the WorldVeg Research and Training Station, Kasetsart University - Kamphaeng Saen, Thailand to demonstrate vegetable varieties from Taiwan seed companies and foster collaboration between seed companies in Taiwan and Thailand.

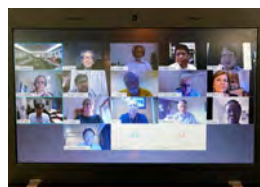
WorldVeg staff participated in the Special Interest Group on Vegetables and promoted the Africa Vegetable Breeding Consortium during the **2020 African Seed Trade Congress (AFSTA)** 3-6 March in Livingstone, Zambia.

On 20 March, students at Parakou University, Benin won a **Food Systems Caravan** award from the Swiss Agency for Development and Cooperation (SDC) to grow WorldVeg amaranth and other traditional vegetables on the campus experimental farm.

04 APRIL

WorldVeg formed a **COVID-19 Task Force** in early April to plan active responses to alleviate disruptions in food access and to conduct strategic research to understand the pandemic's effects on food systems.

**Research** by WorldVeg socio-economists revealed **COVID-19 pandemic-related disruptions** on the movement of people and goods also constricted the international seed trade in Asia. Vegetable production, trade and consumption were particularly affected due to vegetables' seasonal nature, high labor requirements, perishability, need for proper storage, and distribution logistics.



The World Vegetable Center **Board of Directors** convened their 57th Meeting via videoconference on 29 April, checking in from Australia, Philippines, USA, Malaysia, UK, India, Zimbabwe, Thailand, Germany, Canada, Japan and Taiwan.



## 05 MAY

WorldVeg launched a **webpage for new vegetable gardeners**: <https://avrdc.org/grow-vegetables/>



On 29 April, hundreds of pepper seedlings were set out in the **Phenospex phenotyping field** and scanned with 3D imaging devices three times a day as they flowered and fruited to assess the diversity of the WorldVeg Capsicum core collection in a project funded by the EU Horizon 2020 project G2P-Sol.

The **Asia and Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium Annual Workshop** went virtual on 12 May, as COVID-19 underlined the need to invest in how we produce, process and distribute nutrient-dense vegetables. Nearly 200 participants from 33 companies met online for discussions and intensive seminars on the Center's breeding work and other research.



Despite a heavy downpour, more than 85 people from 14 Taiwan seed companies, 4 universities, 9 research institutions and government agencies, and the press gathered at WorldVeg HQ on 21 May for the **6th Annual Field Demonstration of Vegetable Breeding Research** to view the performance of WorldVeg chili and sweet peppers, dual-purpose tomato, pumpkin, and bitter melon lines.

On 28 May, WorldVeg announced that 12 vegetable varieties—including 9 traditional vegetables—were registered in **Cameroon's official catalog of varieties**.

## 06 JUNE



The first shipment of **pandemic-relief seed kits** containing seed of six fast-growing, nutritious traditional vegetables was sent on 4 June for distribution to 1,020 families vulnerable to the impact of COVID-19 in southwestern Luzon, the Philippines with support of the Ministry of Foreign Affairs (MOFA) Taiwan.

Staff from WorldVeg Eastern and Southern Africa demonstrated how to make **sack gardens** and **distributed seed kits** to urban youth on 5 June during activities hosted by two Arusha, Tanzania organizations, Jobortunity and Future Stars.

On 12 June, WorldVeg provided **400 seed kits** of rapid-growing nutritious vegetables for World Vision to distribute to vulnerable families in the Tainan, Taiwan area.

The WorldVeg East and Southeast Asia team presented **200 seed kits** on 17 June to Thai City Farm, an organization promoting home gardens in Bangkok, Thailand.

A new **5-year partnership agreement** signed on 26 June between WorldVeg, the Tanzania Horticultural Association (TAHA), COLEACP, and the Nelson Mandela African Institution of Science and Technology to bridge the practical skills gap in horticulture for youth in East Africa.



Framing of the new **insectary and virology greenhouses** began in June at WorldVeg HQ, part of the RIM Project.

07 JULY



Enabling Impact Flagship Leader Pepijn Schreinemachers discussed the **impact of home and school gardens in Nepal on children's food choices** during Agriculture, Nutrition, and Health Academy Week, 30 June – 2 July, convened by IMMANA (Innovative Methods and Metrics for Agriculture and Nutrition Actions).

On 1 July, WorldVeg virtually launched **Veggies 4 Planet & People (V4P&P)**, a five-year project funded by the IKEA Foundation to engage women and youth in vegetable production and distribution in Ethiopia and Kenya.

WorldVeg Eastern and Southern Africa welcomed Tanzania's Deputy Minister of Agriculture, the **Hon. Hussein Mohamed Bashe** to the Arusha campus on 2 July.

From July 6-9, regional directors Victor Afari-Sefa and Kabirou N'diaye participated in a meeting of the new **Food Systems Resilience Program (FSRP)** in West Africa funded by the World Bank.

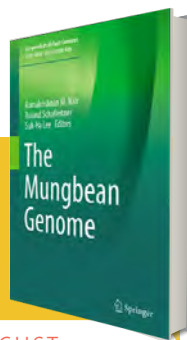
WorldVeg Regional Director for South Asia, Ramakrishnan Nair, participated in a webinar on **'Can Vegetable Farming Help to Fight Climate Change?'** hosted by East West Seed India on 13 July.

**Tanzania's Ministry of Agriculture (MOA)** and the World Vegetable Center (WorldVeg) signed a new memorandum of understanding (MOU) on 20 July 2020 to improve research and development of vegetable crops, enhance nutrition, and increase food security in the country.



WorldVeg West and Central Africa – Coastal & Humid Regions Office, in collaboration with ProCaR and Benin's Ministry of Agriculture, Livestock and Fisheries, distributed **seed kits** on 28 July to 420 farmers participating in the PADMAR project at Grand Popo, Benin.

08 AUGUST



**The Mungbean Genome**, a book edited by Ram Nair, Roland Schafleitner and Suk-Ha Lee, published by Springer, was officially presented in a virtual book launch on 12 August organized by WorldVeg South Asia.

The Honorable Minister of Agriculture for Benin, **Mr. Gaston Dossouhou**, and Benin's Secretary-General of Agriculture, **Dr. Françoise Assogba-Komla**, visited WorldVeg West and Central Africa Coastal & Humid Regions office in Cotonou on 19 August.

**Nane Nane (8-8)**, an annual agricultural exhibition held on 8 August, recognizes the important contribution of farmers to Tanzania's economy. The WorldVeg Eastern and Southern Africa team participated in 8-8 events at Bariadi in Simiyu Region and in Zanzibar to demonstrate the benefits of traditional African vegetables for nutrition and a healthy economy.



09 SEPTEMBER

On 2 September, WorldVeg Regional Director for West and Central Africa – Dry Regions, Kabirou N'diaye, handed over 150 **group seed kits** to the National Director of Agriculture in Mali for farmers' groups to reach thousands of families affected by the pandemic.

WorldVeg and the African Seed Trade Association hosted a virtual workshop for **African Vegetable Breeding Consortium** members on 7 September, emphasizing the importance of research for Africa's seed companies to thrive.

WorldVeg DG Marco Wopereis participated in a panel on "The Key Role of SMEs in Serving Urban Food Markets" during the **2020 African Green Revolution Forum** virtual summit, 7 September.

From 24-26 September WorldVeg showcased new heat-tolerant sweet pepper, seed multiplication partnerships with local farmers, disease-resistant cucurbits and more at the **2020 Taiwan Innotech Expo** in Taipei.

Hundreds of improved bitter melon breeding lines/F1 hybrids were in the spotlight during **Bitter Melon Open Field Day**, 30 September, at the WorldVeg Research & Training Station, Kasetsart University – Kamphaeng Saen campus, Thailand.

## 10 OCTOBER

"The Billion-dollar Bean" gave top billing to **mungbean** during a World Food Prize side event webinar on 12 October.

Researchers running a **tomato grafting trial** for the Grow Against the Flow project at Kbal Koh Vegetable Research Station in Cambodia feared the worst when flood waters inundated their field in mid-October. They were delighted to discover that all the grafted tomato plants survived the flood.



WorldVeg HQ welcomed **Richard Soong**, Chairman of Chi Mei Frozen Foods Co., Ltd., and his team to campus to get acquainted and explore opportunities for collaboration.

The Eastern and Southern Africa office celebrated **World Food Day**, 16 October, by inviting 100 students, farmers, extension workers, government officials, and journalists to tour the research farm in Arusha.

## 11 NOVEMBER

DG Marco Wopereis presented remarks on "Pursuing green growth of the vegetable sector in low-income countries" during the **2020 International Agriculture Innovation Conference (IAIC 2020)** Virtual Event on 7 November.

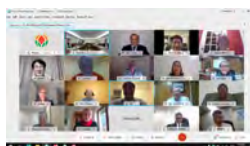
**Gerald Kusaya**, Permanent Secretary, Ministry of Agriculture, Tanzania, visited WorldVeg Eastern and Southern Africa in Arusha on 7 November.

On 9 November, Marco Wopereis delivered a plenary speech on "Rethinking food systems for a post-COVID19 world" at **Agriculture and Beyond, 2nd University Consortium Faculty Forum** organized by the Southeast Asian Regional Center for Graduate Studies and Research in Agriculture (SEARCA) and the College of Bioresources and Agriculture, National Taiwan University in Taipei, Taiwan.



**2020 Global R&D Week** (9-12 November) went virtual to engage WorldVeg staff from around the globe in planning and team building activities for the coming year.

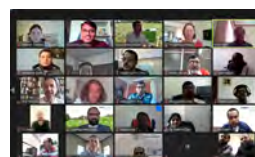
Japan International Research Center for Agricultural Sciences (JIRCAS) President **Masa Iwanaga**, who also serves as Vice Chair of the WorldVeg Board of Directors, and WorldVeg Director General Marco Wopereis joined a panel discussion on international collaboration in agricultural research for the post COVID-19 global food system held on 10 November 2020 as part of the **JIRCAS International Symposium 2020 50th Anniversary Program**.



The **WorldVeg Board of Directors** held its 58<sup>th</sup> meeting online from 18-19 November.

## 12 DECEMBER

The WorldVeg East and Southeast Asia team showcased tomato and pumpkin grafting, integrated pest management, and bitter melon and pumpkin breeding activities at the annual **Kaset Fair** at Kasetsart University - Kamphaeng Saen campus from 1-10 December.



WorldVeg and the Syngenta Foundation for Sustainable Agriculture conducted the International Mungbean Improvement Network's **Demand-Led Breeding Workshop** on 8-9 December; more than 60 breeders and researchers from 20 countries participated in the virtual training and discussion.









## *A vibrant new hub for research and open science takes shape at WorldVeg HQ.*

Two new glasshouses sparkle under silver shade cloth while contractors put the finishing touches on their interiors, which will house future research on insects and viruses. It's one more step forward in the **Research Infrastructure Modernization (RIM)** project, which continues to transform the 50-year-old WorldVeg headquarters campus with new equipment, new buildings, and new surroundings.

Officially launched in 2018, RIM has already changed the way WorldVeg works: A high-throughput field phenotyping system installed in 2019 now generates valuable research results on peppers, mungbean, okra, and amaranth. The replacement of aging underground electrical cabling in 2020 with more efficient, higher capacity lines connected by three new high voltage switchgear stations supports new growth chambers and faster data transfer. The new controlled-environment entomology and virology greenhouses are well underway, and the shape of the new Front Court garden landscape, with demonstration beds, a water feature, cafeteria terrace, pedestrian pavement, greenery, and a new entrance with guardhouse and flagpoles evolves daily.

RIM is supported by a US\$ 22 million grant from Taiwan. We expect top-notch researchers to be in the building sometime in late 2022, devising experiments to discover, investigate and explore with the latest equipment and amenities.

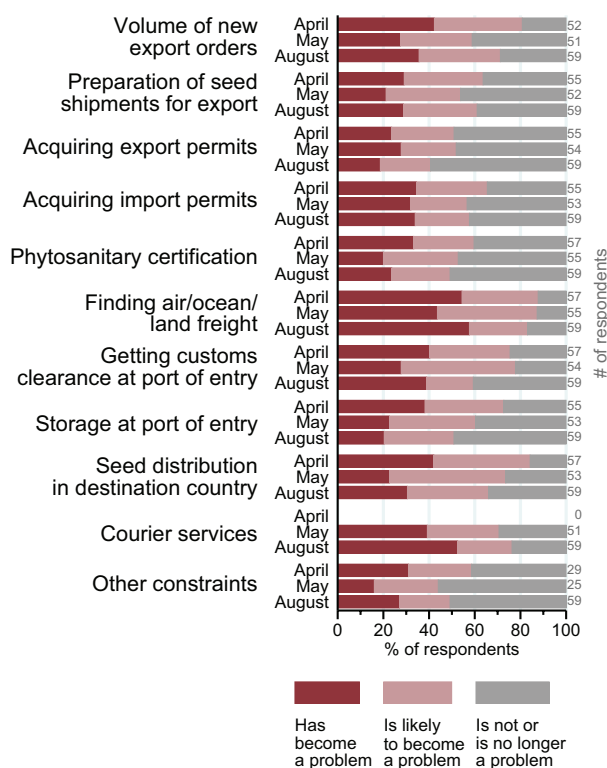


*The Asia-Pacific Seed Association (APSA) and WorldVeg surveyed seed producers to illuminate the impact of the COVID-19 pandemic on seed trade in the region.*

# SEED SYSTEMS AFFECTED BUT NOT DEFEATED

COVID-19 severely restricted international traffic in the Asia and Pacific region. This disruption affected the transport of sowing seed, which relies on an efficient system of production, inspection, and delivery to distributors and ultimately to farmers. The study assessed the impact of COVID-19 on demand for various types of seed, the effect on business operations (shipments, inputs, labor, finance), and international trade (permits, custom procedures, freight).

In August 2020, 73% of respondents reported a negative effect on vegetable seed demand—higher than in May 2020, when 65% of respondents indicated a



negative impact. Lockdowns substantially impacted seed companies' business operations, with 91% of the respondents reporting difficulties in international seed shipments in August (the same as in May). Furthermore, 62% reported problems with domestic seed shipments, 64% in obtaining inputs to their seed factories, and 75% in securing labor for seed production and processing.

Disruptions to seed systems can have severe consequences for food and nutrition security. The WorldVeg/APSA study aimed to gauge the effects of COVID-19 on the seed sector in the Asia-Pacific region, monitor for changes and trends to anticipate extraordinary challenges, and thus devise coping strategies moving forward.

Interestingly, several seed companies reported an increase in sales of home garden seed packs. Twelve respondents said their companies donated home garden seed packs to the general public as part of government- and NGO-led COVID-19 relief efforts. Home gardening is an important coping strategy for many households to deal with the hardship and uncertainty caused by the COVID-19 pandemic. To alleviate the situation for farmers and communities, WorldVeg also mobilized small packages of easy to grow, nutritious, short-duration vegetables to promote vegetable gardening and assist people in building long-term resilience in the Asia-Pacific region and around the world.

READ MORE: <https://avrdc.org/asia-pacific-seed-trade-on-long-road-to-recovery/>.





## East and Southeast Asia

Activities were conducted in **Cambodia, Laos, Myanmar, Philippines, South Korea, Thailand, and Vietnam.**

### Cambodia

- The project “**Angkor SALAD: Geodata for sustainable vegetable farming**” funded by the Netherlands Space Office developed a mobile phone app that makes data easily accessible to farmers. The app provides advice on irrigation, fertilization, crop planning, market information, and Khmer good agricultural practices (GAP) compliance.
- The project “**Grow Against the Flow: Scaling off-season vegetable innovations** to improve incomes and nutrition in Cambodia and Lao PDR” funded by the German government (BMZ) started on 1 January 2020. WorldVeg collaborated with biopesticide distributors and linked them with retailers and farmers. The project provided training on off-season vegetable production and established trials of tomato grafting, yard-long bean and brassica crops.
- The project “**Teach and Text: Combining on-farm demonstration and phone messaging to scale vegetable integrated pest management (IPM) in Cambodia**” funded by BMZ promoted safer and more sustainable pest management practices in Cambodia and tested the potential of cellphone-based messages. The endline survey in May 2020 was conducted via phone because of the COVID-19 pandemic.

### Thailand

- WorldVeg evaluated IPM packages against leafhopper and whitefly on eggplant by using trap crops (cotton, okra, sunflower), yellow sticky traps, and biopesticides under laboratory and field conditions at the Kamphaeng Saen Research & Training Station. Researchers also screened 10 resistant pepper varieties against *Pepper yellow leaf curl virus* under controlled conditions.

### South Korea

- WorldVeg Korea Office conducted “Regional adaptability evaluation of WorldVeg germplasm of pepper and tomato accessions” in Jeonju using 15 pepper and 5 tomato accessions in 2020, funded by the Rural Development Administration (RDA).
- The office coordinated a virtual training program on viral diseases and their control in peppers and tomatoes as part of the AFACI-RDA project “Development of pepper and tomato breeding technology in Asia.”

### Global food systems studies

- With the new Lead Expert - **Food Systems** coming on board in February 2020, an initial activity was to undertake a systematic **scoping review** of published research covering the areas of vegetables, food systems, and diets in LMICs. This review helped identify gaps to be filled with future work and has contributed to discussions with funders and academic collaborators.
- Researchers in the region developed a **food systems assessment approach** that can be used in multiple contexts to understand how vegetable food systems impact healthy diets and trade-offs with other food system outcomes.





## Events

- **Pumpkin Open Field Day:** On 22 January 2020, WorldVeg displayed 190 elite tropical pumpkin lines of different market segments possessing inbuilt tolerance to multiple viruses and powdery mildew at the WorldVeg Research and Training Station in Kamphaeng Saen, Thailand. The event was attended by 51 representatives from the private seed industry.
- **Field Demonstrations of Vegetable Cultivars** from the Taiwan Agricultural Research Institute (TARI) were held on 3 March 2020 at the WorldVeg Research and Training Station. There were 40 participants from seed companies, Asia-Pacific Association of Agricultural Research Institutions (APAAARI), Taipei Economic and Cultural Office in Thailand, Kasetsart University, and farmers. Varieties displayed came from Taiwan seed companies and included 44 cherry tomato varieties, 28 cauliflower varieties, and 22 sweet corn varieties.
- **APSA/WorldVeg Vegetable Breeding Consortium Annual Workshop:** Nearly 200 participants from 33 companies and WorldVeg met online for discussions and intensive seminars on breeding work and other research on 12 May 2020.
- **Bitter Gourd Open Field Day:** Held on 30 September 2020 at the Kamphaeng Saen Research & Training Station and attended by 14 representatives of local seed companies. Due to COVID-19 travel restrictions, international companies were given a virtual demonstration of the bitter gourd trials.
- **International Mungbean Improvement Network:** Online training was held on demand-led breeding, which was organized by the Syngenta Foundation for Sustainable Agriculture.
- **Kaset Fair:** In December 2020, WorldVeg collaborated with the Tropical Vegetable Research Center during Kaset Fair, a large agriculture exhibition hosted by Kasetsart University - Kamphaeng Saen, Thailand campus, and provided short on-site training courses on insect traps and vegetable grafting.

## Activities related to the COVID-19 pandemic

- To help mitigate the effects of the COVID-19 pandemic, WorldVeg distributed **vegetable seed kits** around the world. In **Thailand**, WorldVeg collaborated with “Thai City Farm” to share seed kits with families in Bangkok whose livelihoods were affected by COVID-19. In the **Philippines**, WorldVeg partnered with the government to distribute seed kits as part of the “Plant-Plant-Plant” countrywide initiative.
- In collaboration with the **Asia & Pacific Seed Association (APSA)**, WorldVeg conducted an online survey of seed companies in Asia in April, May and August 2020 to understand the **impact of COVID-19 on the seed sector** in the region. Companies reported declines in demand, problems acquiring import/export permits, finding freight solutions, and difficulties with seed storage at the port of entry and seed distribution in the destination country. Three blogs were published with the results.
- To understand the **impact of COVID-19 on vegetables in food systems for healthy diets**, WorldVeg researchers studied vegetable farmers’ diets and livelihoods in India. They published several blogs analyzing the pandemic’s effect on vegetable food systems and healthy diets.



# DISRUPTING FOOD SYSTEMS ON THE SUBCONTINENT

Disruption to food systems and impacts on livelihoods and diets have been brought into sharp focus by the COVID-19 pandemic. WorldVeg conducted a study in four Indian states (Andhra Pradesh, Assam, Jharkhand, and Karnataka) to find out if vegetable farmers were being affected by the lockdown measures.

More than 80% of farms reported some decline in sales, and over 20% of farms reported devastating declines. The downward pressure on prices was significant, which resulted in a notable reduction in income for farmers. According to the WorldVeg study, farm income dropped for 90% of farms, and by more than half for 60% of those reporting.

The pandemic lockdowns affected diets as well. About 62% of surveyed households reported disruptions to their diets. Although 80% of households were able to continue consuming staple foods, significant declines in consumption were reported for fruit and animal source foods other than dairy in approximately half of the households.

Vegetable consumption fell in almost 30% of households—but vegetables were also the only food group in which consumption increased for some, in about 15% of households. Our data suggested higher vulnerability of female farmers in terms of both livelihoods and diet.

Farm size in part determined how a farm household fared in the pandemic. Farms of different sizes may require different types of support to continue to function. Farms reported diverse coping strategies to maintain sales, though





*A study of farm households in India  
points to pandemic-related problems.*

often with negative implications for reported incomes. The ability to consume one's own produce may be somewhat protective of diets when other routes to food access fail.

The impact of COVID-19 and subsequent policy responses on both livelihoods and diets in horticultural households risks rolling back the impressive economic and nutrition gains India has seen over the past decade. Food systems, particularly those making available the most nutrient-dense foods, must be considered in ongoing and future government responses.



## South and Central Asia

Activities were undertaken in **India, Bangladesh, Pakistan, and Tajikistan.**

### India

- WorldVeg South Asia distributed 35 tomato, 15 pepper, six cucumber, seven bitter gourd, 18 mungbean, and 15 vegetable soybean **breeding lines** and six vegetable cowpea and eight yard-long bean **accessions** to public sector (ICAR-IARI-New Delhi, KAU-Kerala, SKUAST-Kashmir, BCKV-West Bengal) and private sector (Indo-American Hybrid Seeds, VNR Seeds Pvt. Ltd., Daftari Seeds Pvt. Ltd., Nethra Crop Science Pvt. Ltd., Mahalakshmi Seeds, and Kartik Bio Seeds) partners.
- In the APART Project** in Assam, improved production guides, illustrated crop manuals, and leaflets were prepared for vegetables (brinjal, cabbage, cauliflower, tomato and pumpkin) and pulses (blackgram, lentil and garden pea) and shared with implementing partner agencies.
- A WorldVeg team assessed eight **nursery entrepreneurs** in Assam and submitted a report to the State Department of Horticulture and Food Processing, wrote a strategic plan and draft business plan to guide the establishment of vegetable nurseries, prepared a nursery training manual, and conducted an online refresher training session for the World Bank-funded APART Project.
- In the **JOHAR Project** in Jharkhand, 39 vegetable demonstrations were conducted for priority vegetables (bitter gourd, tomato, chili, eggplant, cabbage, cauliflower, green pea, okra, pepper and watermelon) across the project areas. Seventy master training programs on package of practices (POPs) and 46 nursery training sessions were provided to 4000 participants (1390 men and 2610 women) in project districts. The project team provided technical advice to 204 farmers through digital modes (WhatsApp, mobile phone) during the COVID-19 restrictions.
- Onion value chain improvements** in Odisha included activities such as production demonstrations in all six project districts: 249 during *Kharif* (wet summer) and 361 during *Rabi* (dry winter) seasons. Eight training cum demonstration programs for onion production and postharvest technologies were conducted for 142 participants (110 men and 32 women).
- Odisha Livelihood Mission Project** activities included 140 GAP demonstrations of chili, eggplant and tomato; 58 onion crop demonstrations; and 39 tomato mulching demonstrations across all three project districts in the state.
- WorldVeg **open pollinated (OP) tomato** lines evaluated at Assam Agricultural University (AAU) showed AVTO 1424 recorded the highest yield of 40 t/ha, whereas India's first triple disease resistant tomato hybrid 'Arka Rakshak' recorded 33 t/ha. **Pumpkin** line AVPU 1392 evaluated at AAU produced the highest yield of 55 t/ha, whereas the popular hybrid variety 'Arjuna' produced 45 t/ha. **Garden pea** varieties were evaluated in rice fallow cultivation; the yield of 'Kashi Sambridhi' (1511 kg/ha) was the highest, followed by 'Kashi Udai' and 'Kashi Ageti'.
- Off-season cauliflower production**, conducted under low tunnel conditions in Assam, showed that 2-4 t higher yield per hectare (6-11% increase) was obtained in tunneled plants, especially with 'Megha' and 'Gauri' varieties, as compared to uncovered, open-field conditions.





- WorldVeg and the Syngenta Foundation for Sustainable Agriculture organized a workshop on **Demand-Led Breeding (DLB)** through the ACIAR-funded International Mungbean Improvement Network (IMIN) on 8-9 December 2020. More than 80 mungbean researchers from 20 countries in Asia and Africa came together virtually for brainstorming on DLB approaches for market segmentation and to design mungbean product profiles for major mungbean growing countries.
- Large **community-level IPM demonstrations** were carried out for five vegetable (tomato, eggplant, cabbage, cauliflower and pumpkin) and three pulse (black gram, lentil and pea) crops in Assam. The IPM demonstrations were shown to reduce pesticide use by 33-72%, and except trap crops, all the IPM technologies were adopted by more than 50% of the beneficiary farmers.
- New **climate-resilient technologies** such as tomato production under minimum tillage conditions to utilize rice fallows in Assam showed that the farmers were able to generate an additional income of ₹ 7,000-₹ 24,000 (~USD 95.00 - 330.00).
- WorldVeg provided training on the grading, sorting, packing and handling of the vegetables as part of **good handling practices** (GHP) to 970 beneficiaries (396 men and 574 women) through 36 training events in Jharkhand, India.

### Tajikistan

- **Cherry tomato** production in greenhouses in the Khatlon region delivered impressive results: Yields of the tiny tomatoes were 33-45% higher compared to traditional tomato varieties. **Daikon** (winter radish) was introduced for the first time in Tajikistan; the highest yield of 26.5 t/ha was recorded with 'Siroagari' under open field conditions. Greenhouse cultivation of **broccoli** with drip irrigation led to a yield increase of 20% over existing farmer practices.
- An **integrated pest management** (IPM) package for tomato leaf miner (*Tuta absoluta*) was piloted in greenhouses and in open field conditions in Jaloliddin Balkhi district. Yields of IPM fields were higher (18-35%) with 54% increased net income compared to farmers' practice. The IPM strategy was disseminated to different stakeholders through training events.
- With the Institute of Horticulture and Vegetable Growing, two **mungbean** lines 'Marvori' (VC 1178A) and 'Muattara' (VC 6173B6) were submitted to the State Variety Trial Commission. Both these lines recorded higher yields (4%-80% increase) compared to the local check 'Tojiki 1'.
- In collaboration with the Republican National Center for Genetic Resources (RNCGR) of the Tajik Academy of Agricultural Sciences, **urdbean** line VI032468, which performed well in three different agroecological zones, was identified for promotion during 2021 and also for submission to the State Variety Trial Commission.



# AFRICAN EGGPLANT ATTRACTS DAIRY COWS

The Kombani Farmers' Group in Zanzibar earns substantial income producing and selling African eggplant. Led by Ali Pandu, a young farmer from Wete district, northern Pemba, the 10-member group started growing African traditional vegetables after receiving training in good agricultural practices and marketing provided by the INSIST (Improving Nutrition Status and Income Sustainably through African Traditional Vegetables) project. INSIST is led by WorldVeg with a grant from the USAID-funded Mboga na Matunda / Feed the Future initiative.

Kombani has three acres of land, which sat fallow for many years. They had water near their land, but they lacked production skills and advice. After the INSIST training, members were motivated to start producing African eggplant on a half-acre plot. Early in August 2020, the INSIST team linked the group with the Zanzibar Economic Empowerment Fund (ZEEF) to apply for a loan. Kombani secured a TZS 2,000,000 (~USD 860) loan to purchase inputs and equipment, including a water pump and water pipes.

By adopting improved production techniques, they were able to produce more than 130 buckets of African eggplant. At the time they started harvesting the price per bucket was TZS 6,000 (~USD 2.60). By November 2020, they had earned TZS 820,000 (~USD 350), and put part of the income toward repaying about 30% of their total loan.

Kombani members discovered that well-tended African eggplant is a prolific producer. In December, they harvested a total of 65 buckets, sold at an average of TZS 6,500 (~USD 2.80) per bucket, which earned them TZS 422,500 (~USD 180.00 USD). Harvesting continued; they sold 53 buckets in January 2021 at an average of TZS 7,000 (~USD 3.02) per bucket. Over seven months, Kombani earned TZS 1,613,500 TZS (~USD 700) from their half-acre of eggplant. By February 2021, the group was able to repay 51% of the loan.





In February, the group decided to invest in an additional acre of watermelon production. The watermelon crop is still maturing, and the group prepared another half-acre for planting tomato in late May. They plan to cultivate short-maturing watermelon before venturing into tomato production after the heavy rain season. Thanks to their initial investment, they have stable irrigation facilities (water source, water pump, water pipes, and a dam constructed for temporary storage of water).

The effort and enthusiasm of the Kombani Farmers' Group did not go unnoticed. The group recently received support from the government in the form of two dairy cows. Five young people with an interest in dairy have now joined the group. With 15 dedicated members, the Kombani Farmers' Group expects to make excellent progress in integrated vegetable-dairy production in the years ahead.

*How training in production of a traditional African vegetable brought prosperity—and dairy—to a farmers' group in Zanzibar.*



## Eastern and Southern Africa

**Activities** were conducted in three countries: **Kenya, Madagascar, and Tanzania.**

### **Tanzania**

- The WorldVeg Eastern and Southern Africa **genebank** in Arusha continued germplasm acquisition, characterization, regeneration, and distribution to partners. A total of 93 pumpkin and okra accessions were acquired from Zambia and Nigeria, and 202 and 420 accessions were characterized and regenerated, respectively.
- The genebank distributed 2,166 **seed samples** of 37 breeding lines and seven accessions to Tanzania and Madagascar development partners. A total of 113 lines and 21 accessions were distributed to seed enterprises and research institutions in Kenya, Uganda, France, Netherlands, Zimbabwe and Nigeria, while 49 lines and four accessions were sent to WorldVeg offices in Benin and Taiwan for research.
- **Amaranth and African eggplant breeding** continued at WorldVeg Eastern and Southern Africa with evaluation of fixed lines and segregating populations, and scaling activities. Sixty-six F<sub>6</sub> segregating amaranth lines were evaluated for desirable agronomic/horticultural traits for improved vegetable and seed yields. One hundred F<sub>4</sub> segregating African eggplant lines of different populations were evaluated for generation advance. A total of 46 amaranth breeding lines were evaluated for improved vegetable and seed yields, grain size (1000 grain weight) and earliness.
- Five **amaranth** varieties released in Tanzania were evaluated for their performance under two planting-harvesting methods: (1) direct broadcast sowing followed by once-over harvest by uprooting, (2) transplanting seedlings raised in trays followed by multiple leaf harvests.
- Eight **African eggplant** entries were evaluated for drought tolerance in pot experiments maintained at 30% irrigation demand in a screenhouse in Tanzania.
- **Seed** of 46 African eggplant and 20 amaranth lines was increased for use in research programs and distribution to scaling and research partners. Seed of eight entries was provided to one project partner and another 29 entries to another project partner.
- Four **amaranth** lines were characterized in a distinctness, uniformity and stability (DUS) test for submission to the Tanzania Official Seed Certification Institute (TOSCI) for possible release. Two promising **mungbean** lines were submitted to TOSCI for possible release as commercial varieties in 2021.
- At a **mungbean business workshop** in Mtwara, 30 mungbean farmers became members of the Tanzania Pulse Network (TPN) and signed purchasing agreements (non-binding) with a company, Elements Export. The farmers are expected to supply 60 t of mungbean by May 2021.
- **Campaigns** aimed at alleviating malnutrition and associated effects have been conducted via mass media and events (Radio 5, SUA TV, Radio Channel Ten, World Food Day, National Agricultural Show ('NaneNane') in Tanzania.
- Four African nightshade and two Ethiopian mustard varieties were introduced to Africa RISING project partners in Tanzania via **seed kits**. Kit recipients were also given training on seed production.





- Analysis of mungbean grain **micronutrient** (iron and zinc) content was conducted.
- Fifty-one mungbean lines were screened for their **soil micronutrient** uptake ability and resistance to biotic and abiotic stresses.
- A total of 1,577 people (58% farmers and 42% extensionists) from the Lake, Western, Eastern, Northern and Southern zones of Tanzania benefited from training in mungbean agronomy, IPM and value addition through activities funded by a **Foreign, Commonwealth and Development Office (FCDO)** project.
- **Scaling activities** distributed seeds of one African eggplant variety, one African nightshade, two Ethiopian mustard and four amaranth varieties to 879 farmers (388 female and 491 male) in 20 villages (16 in Kilimanjaro region and 4 in Arusha region), and in 24 Streets of Dar es Salaam, Tanzania in collaboration with District Agricultural Offices and the Tanzania Agricultural Research Institute - Mikocheni, with support of UK aid and the Amazing Amaranth project. A total of 100 people, including farmers, extensionists and researchers, participated in a field day organized in Dar es Salaam.
- More than 6,700 **individual insect samples** collected from three sites were sorted and identified into five orders. The samples are being sorted out to group them into possible parasitoids (wasps), predators (mirids), and to understand their effect on *Tuta absoluta*.
- **Home garden** and **agribusiness** training activities in Zanzibar, Tanzania reached 3,372 farmers on commercial production of African traditional vegetables; 3,983 farmers and community members on nutritional benefits; and 1,666 farmers on vegetable marketing.
- Partnerships with Kibo Seed and East African Seed aim to develop **seed systems** for African traditional vegetables in Zanzibar to improve farmers' access to quality seed.
- Workshops on **seed systems for African traditional vegetables** were held on the islands of Pemba and Unguja in Zanzibar. A total of 40 agrodealers, representatives from seed companies and NGOs, government officials, and extensionists reviewed WorldVeg research and made recommendations for strengthening the system. Meetings on each island brought together vegetable producers and buyers to **improve marketing linkages** for traditional vegetables. Booths for National Farmers' Day exhibitions in Pemba and Unguja highlighted the importance of GAPs, marketing strategies, and **entrepreneurship** for traditional vegetable production; 1,897 people visited the booths.

### Madagascar

- Under the **Darwin Project**, a total of 14 lines of amaranth, African nightshade, African eggplant, Ethiopian mustard and pumpkin were evaluated on-farm and on-station in Itasy and Antsirabe regions in collaboration with national partner FOFIFA in Madagascar. Four African nightshade and two Ethiopian mustard varieties were introduced to project partners, and kit recipients were given training on seed production.

# SEEDING UPTAKE OF SMALL-SCALE IRRIGATION IN MALI

Small-scale irrigation is expensive for many farmers in Mali and smallholder farmers producing staple food crops may not easily be able to make such an investment. More profitable crops, such as vegetables, offer a better opportunity to invest in irrigation and improve farm incomes.

However, Malian farmers have limited opportunities to take up production of vegetables due to an underdeveloped seed sector in the country. Currently, vegetable seed production is often restricted to the wet season because of lack of irrigation technologies. Seed companies and cooperatives have low technical capacity in variety development and quality seed production, face difficulties accessing finance, and lack suitable equipment for seed processing and packing. As a result, many vegetable farmers use costly imported seed rather than locally produced seed.

To strengthen local vegetable seed production, the USAID Feed the Future Innovation Lab for Small Scale Irrigation (ILSSI) and the World Vegetable Center trained 20 staff of vegetable seed companies and seed cooperatives in Mali on how to strengthen seed production. The training was held at the WorldVeg West and Central Africa – Dry Regions Office in Samanko, near Bamako, from 16-20 November 2020. Twenty staff of fourteen seed companies and cooperatives participated in the workshop. Participants came from diverse regions of Mali including Kayes, Sikasso, Koutiala, Koro, and Bamako.

WorldVeg Regional Director Mamadou Kabirou Ndiaye welcomed participants. He discussed the challenges vegetable producers face in Mali and West Africa as well as the opportunities available for those willing to adopt irrigation for vegetable production.



*Getting access to more and better vegetable seeds is an opportunity for smallholder farmers in Mali to grow high-value crops and improve their diets, incomes, and ability to adopt small-scale irrigation.*

The five-day training combined classroom teaching with hands-on sessions. Resource persons came from WorldVeg and the Institute of Rural Economy (IER). Topics covered vegetable breeding, including different crossing methods; seed legislation; seed production methods; crop management; and management of soil fertility, pests, and diseases. Pros and cons of different irrigation methods were explored.

Training participants were very satisfied with the course and hoped for a future opportunity to receive follow-on training. Given the high interest among vegetable seed producers in the training, a second course has been scheduled for 22-26 March 2021.



## West and Central Africa – Dry Regions

Activities were conducted in **Mali** and **Ghana**.

### Ghana

- Two **shallot** lines ('Saboula jaba' and 'N'galamanjan') with yield higher than 40 t/ha were identified over two years and proposed for registration in Mali.
- Pre-basic **mother bulb production** of Cameroon onion 'Goudami' was conducted in Samanko, Mali in the dry season under the PADFA project.
- For the Africa RISING project, dry season activities were conducted in Ghana and Mali from October 2019 to September 2020. Activities involved **vegetable variety and disease screening trials**, agronomic and postharvest activities in Ghana's Upper East and Northern Regions and in the districts of Bougouni and Koutiala in Mali.
- **Field days** for vegetable training were organized in the Northern Region of Ghana and at Nyangua and Tekuri in the Upper East Region of Ghana on 3-4 April 2020 to give lead and non-lead farmers the opportunity to participate in variety selection and to promote information and knowledge sharing.
- Varietal trials on tomato, pepper and onion were conducted in five lead farmers' hubs in two communities (Tekuri and Nyangua). **Seed kits** were distributed to 150 (102 men; 48 women) lead and non-lead farmers within Gia, Bonia and Doku communities who implemented variety demonstrations on their own farms.

### Mali

- For the Africa RISING Project, varietal trials on **tomato**, **African eggplant**, **vegetable cowpea**, and **onion** were conducted in two technology parks (Madina and Nampossela); 188 farmers benefited from training on good agricultural practices in Bougouni and Koutiala; 175 farmers conducted field variety demonstrations with 150 farmers participating in organoleptic tests on vegetable cowpea varieties versus green bean; 58 farmers were trained and successfully implemented sack gardens in their homes; and 83 farmers were trained on postharvest storage and food processing.
- Under the Massachusetts Institute of Technology (MIT) project, a total of 37 (76% women) farmers, clay pot makers and sellers, vegetable sellers, extension officers and consumers in Mopti region were trained on assembling, using and maintaining **clay pot coolers** to improve vegetable storage.

### Ghana & Mali

- 16 accessions of pepper and 24 tomato accessions from WorldVeg were screened in replicated trials for identification of **new sources of resistance** to major virus, bacteria and pests prevailing in Ghana and Mali.
- In Ghana and Mali, **zero-energy cooling chamber** technologies were effective in reducing yield losses of tomato variety 'Keneya' by 3 times compared to 'Bebiyereye.' Tomato variety 'Bebiyereye' was discovered to be a variety with long shelf life.





# AN HOUR WITH THE MINISTER



*Benin's Minister for Agriculture,  
the Hon. Gaston Dossouhou,  
visits WorldVeg in Cotonou.*

WorldVeg recognizes the importance of local connections and partners—the essential links in-country and on the ground that allow us to work together toward building healthier lives and more resilient livelihoods for farmers, their families, and consumers.

So it was with great pleasure that the WorldVeg West and Central Africa Coastal & Humid Regions team welcomed the Honorable Minister of Agriculture for Benin, **Mr. Gaston Dossouhou**, and Benin's Secretary-General of Agriculture, **Dr. Françoise Assogba-Komla** for a visit on 19 August 2020.

WorldVeg Regional Director **Dr. Victor Afari-Sefa** and **Dr. Manuel Tamo**, Country Representative for the International Institute of Tropical Agriculture (IITA), which hosts WorldVeg in Benin, greeted Mr. Dossouhou and Dr. Assogba-Komla.

Agronomist **Judith Honfoga** briefed them on WorldVeg activities in the country, Training and Outreach Assistant **Azoma Komla** led the group through the seed storage and drying rooms, and Plant Breeding Researcher **Herbaud Zohoungbogbo** guided all on a field tour of the campus.

Minister Dossouhou appreciates the importance of vegetables for a healthy agricultural economy and a healthy populace. In July, he distributed WorldVeg home garden seed kits for families affected by the COVID-19 pandemic in Grand Popo, Benin.



## West and Central Africa – Coastal & Humid Regions

Activities were conducted in **Benin, Cameroon, Ghana** and **Nigeria**. The Cameroon liaison office was closed at the end of the year.

### Benin

- WorldVeg and the University of Abomey-Calavi tested a set of new **bacterial wilt-resistant** WorldVeg lines. Resistance levels were high and several lines (AVTO1955-9, AVTO1955-10, AVTO1955-15, AVTO1955-22 AVTO1955-3, AVTO1955-11 and AVTO1955-20) produced a fruit type preferred in Benin.
- In collaboration with the IFAD-funded ProCaR/PADMAR project, WorldVeg distributed 420 vegetable **seed kits** to farmers in 27 municipalities of Benin affected by the COVID-19 pandemic in July.
- On September 7, WCA-CH hosted the 2nd annual **Africa Vegetable Breeding Consortium (AVBC)** workshop online, with 12 participants from 4 private seed companies. Ten amaranth lines and seven African eggplant lines were evaluated.
- A **needs assessment study** showed seed companies located and/or operating in Africa are diverse in terms of size, crop portfolios, and research capacity. The study contributed to a new membership model for AVBC, which will tailor benefits and services to specific capacity building needs/priorities.
- KAFACI-RDA (South Korea) contracted WorldVeg to moderate its **horticulture project** entitled “Enhancement of tomato and onion production in Africa for maximum sustainable yield” in 17 African countries from 2020-2025.

### Cameroon

- Twelve vegetable varieties, including 9 traditional vegetables, were registered in Cameroon's **official catalog of varieties**: Amaranth: AC-NL and AM-KNGN; African eggplant: RVI 00002245 (DB 3); Jute mallow: UG, IP 2, Aziga and Bafia; Okra: RVI 00001416 (PI 496946); African nightshade: TzSMN 55-3; Tomato: AVTO 9601 (CLN 1462 A), AVTO 9604 (CLN 1464 A) and AVTO 9605 (CLN 1464 B).
- Yield of African nightshade grown in soil amended with **biochar** from peanut shells, corn cobs, and rice husks combined with chicken manure was assessed in Cameroon's dry region. The peanut shell and corn cob mixtures produced the highest total yield (34-36 t/ha), with peanut shells preferred due to competition for corn cobs as firewood and scarcity of rice husks. A total of 153 participants (119 women and 34 men) were trained in biochar production.
- Under a UNICEF-funded project in Cameroon, a survey assessed **infant and young child indicators** among children aged 6-23 months in the target district. More than 125 trainers, including public-sector staff, were trained in Water, Sanitation & Hygiene (WASH) behavior change communication and Infant and Young Children Feeding (IYCF) practices. The project sensitized 22,529 individuals (18,786 females and 3,743 males) on IYCF practices and the importance of vegetables for human nutrition through the project's breastfeeding support groups.





## Ghana

- On-station **tomato and chili trials** were conducted in Nigeria (Ibadan and Kaduna) and Ghana (Navrongo). Tomato (hybrid and inbred) yields of the Kaduna trial ranged from 29.0–56.9 t/ha with an average yield of 39.6 t/ha. Highest yielding hybrids included 'Mona F1' (Nova Genetic), AVTO1871 and AVTO1864 (WorldVeg), and 'Percheron F1' (SeedCo).
- Four WorldVeg **tomato hybrids** (CLN4330, CLN4333, CLN4335, CLN4344) performed well in trials conducted by Agri-Commercial Services Ltd., Ghana. WorldVeg arranged with I&B Seeds, India to produce seed of the hybrids for additional trials. WorldVeg, Agri-Commercial Services, and the University of Ghana (via WACCI) discussed a formal collaboration for the release of these hybrids.
- **Dry season** activities in Ghana involved variety, disease screening, agronomic and postharvest trials in the Upper East and Northern Regions. Tomato, pepper and onions were trialed in five lead farmers' hubs within two communities to evaluate farmer- and market-preferred varieties.
- Application of **animal manure (compost)** either alone (5 t/ha) or in combination with NPK (15-15-15) at half the recommended rate significantly increased tomato yield (19-23 t/ha) in northern Ghana, suggesting there is no need for heavy use of inorganic fertilizer alone.
- WorldVeg and commercial tomato (24) and pepper (16) lines/varieties were tested for **disease resistance** and general performance in Mali and Ghana. Virus diseases and early blight (*Alternaria tomatophila* or *A. solani*) caused problems; AVTO1704 was most resistant/tolerant to disease and AVTO1706 most susceptible in Mali, with no significant differences between lines/varieties in Ghana.

## Nigeria

- A **rainy season chili trial** was conducted in Ibadan, including commercial hybrids and inbred lines from WorldVeg. Yields ranged from 2.2-24.5 t/ha with AVPP9905 (WorldVeg) as the highest yielding and 'Demon F1' (East-West Seeds) was the highest yielding hybrid. Future on-station and on-farm trials will emphasize habanero pepper types in response to strong West African market preference. WorldVeg recently launched a habanero breeding program targeting West Africa.
- On-farm trials of **tomato and habanero peppers** were launched in Kaduna, Nigeria, starting in late 2019 and continuing into 2020. Featured tomato hybrids included 'Padma F1' (East-West Seeds), 'Jarrah' (Rijk Zwaan), 'Cobra 26' (Technisem-Novagenetic) and check 'Rio Grande'. Featured habanero hybrids included 'Áfadja' and 'Lengai' from Rijk Zwaan. At a field day hosted by Tomato Jos Ltd., 478 farmers and local authorities discussed the tomato varieties; farmers noted that large fruit size was preferred and would be welcome in future trials.

# FUNDING PROGRESS, SUSTAINING SOLUTIONS

## STRATEGIC LONG-TERM FUNDING



## PROJECT FUNDING



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

We recognize donors who have provided US\$ 100,000 or more to further the Center’s work during 2020.





# Strengthening partnerships with the private seed sector

Seed companies are WorldVeg's essential partners to ensure seed of our improved breeding lines with drought and heat tolerance, resistance to major pests and diseases and other important traits reaches vegetable producers of all sizes, from home gardeners to commercial growers. To more closely collaborate with these vital partners in the vegetable value chain, WorldVeg established two vegetable breeding consortia, one for Asia and one for Africa.

## **Asia Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium**

The APSA-WorldVeg Vegetable Breeding Consortium was established in 2017 with 19 members, expanded to 33 members in 2018, 43 members in 2019 and 44 members in 2020. Seed companies participating in the consortium get early access to new breeding lines and the opportunity to interact with WorldVeg scientists on upstream research. The annual workshop in 2020 was held virtually with nearly 200 participants. "The online workshop was very insightful," said a consortium member. "The knowledge and experiences shared by all the scientists was helpful for our future breeding programs and I really appreciate the efforts taken to connect with us in the time of big crisis to humanity." Said another member: "This was a good platform to know about availability and usage of genetic resources in future breeding programs. WorldVeg experimented a lot to discover new resistance sources, making it easy for seed industry and farmers to gain more income and lead to increased vegetable consumption." In 2020, a total of 55 exclusive lines of tomato, pepper, bitter melon and pumpkin were made available to all consortium members and 382 packets of seeds distributed. In addition, three special projects for pumpkin breeding, *Chilli veinal mottle virus* (ChiVMV), and Chilli leaf curl disease (ChiLCD) were successfully launched and jointly funded by 27 consortium companies from 10 countries.

## **Africa Vegetable Breeding Consortium (AVBC)**

The Africa Vegetable Breeding Consortium was established in 2018 with 9 members in 2019, and dropped to 6 members in 2020. To promote and increase AVBC's visibility in Africa, membership fees will be waived in 2021-2022. The AVBC 2020 virtual workshop was held on 8 September 2020, attended by 12 participants from 4 seed companies. A total of 53 exclusive lines of African eggplant, amaranth, mungbean, onion, peppers, pumpkin and tomato were made available to all AVBC members and 113 packets of seeds distributed.

Partnership is a long-term investment toward impact. Seed consortia provide a platform for action to work together and develop collaborations that will deliver results for farmers and consumers.



# ships ector



## APSA-WorldVeg Vegetable Breeding Consortium

Acscn HyVeg Pvt. Ltd., India  
Advanta Seed (United Phosphorus Limited Group), India  
Bhn Seed, USA  
Certus Seeds Pvt. Ltd., Pakistan  
CKD Seeds & Fertilizer, Pakistan  
Chakra Seeds (Bharat Nursery Pvt. Ltd.), India  
Chia Tai Co., Ltd., Thailand  
Chung Kuan Seed Co., Ltd., Thailand  
Clover Seed Co., Ltd., Hong Kong  
Comienzo Agri Science Ltd., India  
East-West Seed International Ltd., Thailand  
Flotech Seeds Co., Ltd., Thailand  
HM.Clause (Thailand) Co., Ltd., Thailand  
I & B Seeds Pvt. Ltd., India  
Indo-American Hybrid Seeds Pvt. Ltd., India  
Kalash Seeds Pvt. Ltd., India  
Kaneke Seeds Co., Ltd., Japan  
Kaveri Seed Co., Ltd., India  
Known-You Seed Co., Ltd., Taiwan  
Landmark Agro Seeds Pvt. Ltd., Sri Lanka  
Laxmi Inputs, India  
Loc Troi Joint Stock Company, Vietnam  
Mahyco 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  
Nu Genes Pvt. Ltd., India  
Nunhems BV, Netherlands  
Nuziveedu Seeds Ltd., India  
Onesh Agri Pvt. Ltd., Sri Lanka  
PT. East West Seed Indonesia, Indonesia  
Rallis India Limited, India  
Rijk Zwaan, Netherlands  
Sakata Seed Corporation, Japan



Seedworks International Pvt. Ltd., India  
 Semillas Fito India Pvt. Ltd., India  
 Shriram Bioseed Genetics, India  
 Sing-Flow Seed Co., Ltd., Taiwan  
 Syngenta India Ltd., India  
 Takii & Co., Ltd., Japan  
 Tokita Seed India Pvt. Ltd., India  
 Welcome Crop Science Pvt., Ltd., India  
 Your Chain Seed Co., Ltd., Taiwan

### **Africa Vegetable Breeding Consortium**

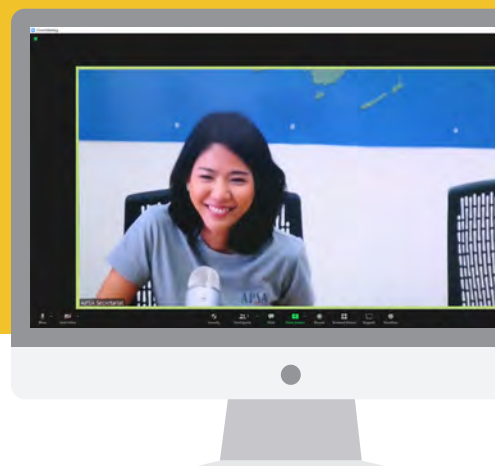
Bakker Brothers Seeds, Netherlands  
 Kamano Seed, Zambia  
 Nova Genetic, France  
 Premier Seed Nigeria Ltd., Nigeria  
 SeedCo International Ltd., Botswana  
 Rijk Zwaan Afrisem Ltd., Tanzania

### **Contributors: Pumpkin Breeding Project (July 2020 – June 2023)**

Acasen HyVeg Pvt. Ltd., India  
 Chung Kuan Seed Co., Ltd., Thailand  
 CKD Seeds & Fertilizer, Pakistan  
 Comienzo Agri Science Ltd., India  
 Flotech Seeds Co., Ltd., Thailand  
 Kalash Seeds Pvt. Ltd., India  
 Kaneko Seeds Co., Ltd., Japan  
 Landmark Agro Seeds Pvt. Ltd., Sri Lanka  
 Onesh Agri Pvt. Ltd., Sri Lanka  
 Sakata Seed Corporation, Japan  
 HM.CLAUSE (Vilmorin & Cie), France

### **Contributors: Chilli veinal mottle virus (ChiVMV) project (July 2020 – June 2022)**

Advanta Seed (United Phosphorus Limited Group), India  
 Chia Tai Co., Ltd., Thailand  
 CKD Seeds & Fertilizer, Pakistan  
 Clover Seed Co., Ltd., Hong Kong  
 HM.CLAUSE, France  
 Mahyco Pvt. Ltd., India  
 Nunhems BV, Netherlands  
 Takii & Co., Ltd., Japan





## Contributors: Chilli leaf curl disease (ChiLCD) project (July 2020 – June 2023)

Advanta Seed (United Phosphorus Limited Group), India  
 Chia Tai Co., Ltd., Thailand  
 CKD Seeds & Fertilizer, Pakistan  
 Clover Seed Co., Ltd., Hong Kong  
 East-West Seed International Ltd., Thailand  
 I & B Seeds Pvt. Ltd., India  
 Indo-American Hybrid Seeds Pvt. Ltd., India  
 Known-You Seed Co., Ltd., Taiwan  
 Mahyco Pvt. Ltd., India  
 Nunhems BV, Netherlands  
 Nuziveedu Seeds Ltd., India  
 PT. East West Seed Indonesia, Indonesia

Rallis India Limited, India  
 Rijk Zwaan Breeding B.V., Netherlands  
 Syngenta India Ltd., India  
 Takii & Co., Ltd., Japan  
 Welcome Crop Science Pvt. Ltd., India

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

All Lucky Seed Co., Ltd.  
 Known-You Seed Co., Ltd.  
 Mu-Zi-Li Farm  
 Sing-Flow Seed Co., Ltd.  
 Suntech Seed Co., Ltd.  
 Your Chain Seed Co., Ltd.



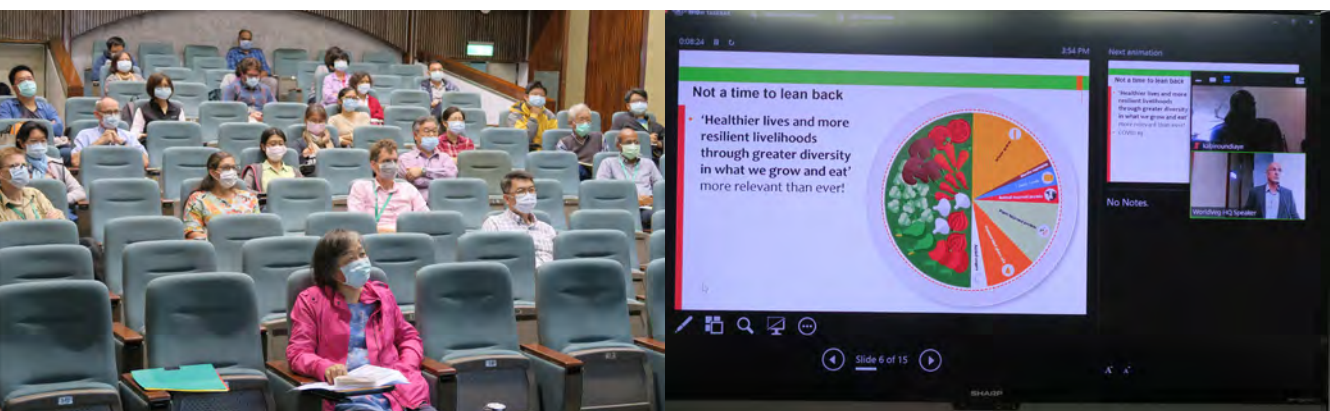


# GLOBAL R&D WEEK

Although WorldVeg researchers are no strangers to (plant) viruses, the human kind threatened to put a damper on the 2020 edition of Global R&D Week. Normally, R&D Week is a time for staff from all regions in Asia and Africa to convene at headquarters for spirited discussions, lively exchanges of new ideas, good times and camaraderie. With the COVID-19 pandemic underway, we shifted to an online event, with daily three-hour sessions spread out from 9-12 November 2020.

Flagship members briefed colleagues on their progress and an advanced draft of the 2021-2025 Operational Plan was reviewed. Staff learned about two new WorldVeg projects: Veggies 4 Planet & People and SAFEVEG: Safe locally-produced vegetables for West Africa's urban consumers. Panel discussions explored on-farm diversification using landraces versus improved varieties, agroecological approaches to vegetable production, and the Africa Vegetable Breeding Consortium. During a session on COVID-19 in the regions, staff proposed activities to address the impact of the pandemic on small-scale farmers and their families.

Updates on work procedures and opportunities to learn best practices for project financial management, human resources, and communications are a regular feature of the event—as is a photo competition to highlight some excellent images taken throughout the year. The winners by popular vote: Sheela Mahato (1st place), Sorawit Limsiriwat (2nd place) and Souradeep Acharjee (3rd place). In lieu of the usual sweaty football match, an online typing competition pitted the fastest fingers around the globe in a race for glory. WorldVeg legal consultant Guat Hong Teh in Malaysia sped past the pack to win the 2020 Golden Finger Award.



## Meet the Top 2

*Two significant new projects took flight in late 2020, both in Africa*

### ***Veggies 4 Planet & People (V4P&P) (Kenya and Ethiopia)***

Veggies 4 Planet & People, funded by the IKEA Foundation, aims to establish 200 vegetable business networks (120 in Kenya, 80 in Ethiopia) to engage an estimated 4000 women and youth in market activities to improve their livelihoods and diets. V4P&P will engage 'business champions' to guide the formation of Vegetable Business Networks of women and youth as they pursue collective action in vegetable production and marketing in urban and peri-urban areas. V4P&P places special emphasis on regenerative agricultural technologies including biochar, compost, green manures, crop rotation and beneficial microbes to nourish the soil and reduce or eliminate the use of chemical fertilizers and pesticides.

### ***SAFEVEG: Safe locally-produced vegetables for West Africa's urban consumers (West Africa)***

SAFEVEG, funded by the European Union and the Netherlands, seeks to create a vegetable sector innovation axis (Benin / Burkina Faso / Mali) that will allow for expansion to other countries in the Economic Community of West African States (ECOWAS). The axis will link the World Vegetable Center's regional research centers in Benin and Mali with national research centers in the three countries, supported by expertise from CIRAD (France) and Wageningen University (Netherlands). The project will benefit vegetable consumers and producers in the target countries, and provide opportunities for young agricultural college and university graduates to build resilient livelihoods and improve the nutritional quality of diets in the region.





Figure 1: (right) The MK1c unit (size: h33 x l142 x w118 mm) currently on hire from Taiwan Nanopore and (left) an annotated picture of the MinION flow cell that fits inside the MK1c.

# PROPER IDENTIFICATION

Plant pests and diseases are spreading and evolving rapidly as climate change and globalization alter agriculture. As WorldVeg moves into new territories and introduces different crops (e.g. mungbean into Africa), plant pathologists and entomologists have found new tools to keep pace with the pests.

Traditional methods used to identify viruses and fungal or bacterial pathogens are time-consuming and require skilled local labor to properly process. When diseased leaf or fruit samples from new crops or territories were returning negative identifications with the available tools, researchers knew it was time to innovate for a more accurate view.

To ID samples faster and with greater accuracy, the WorldVeg pathology group collaborated with the UK Food & Environment Research Agency (FERA) and University of Newcastle on two small BBSRC-funded projects to use high-throughput sequencing (HTS) to identify virus sequences present in samples of chili pepper, eggplant, okra and tomato from Mali and Ghana. Samples from plants with virus-like symptoms were sent to FERA where the RNA was extracted separately from each sample, pooled and bar-coded according to collection host and location. The data were used to create HTS libraries that were sequenced in an Illumina MySeq sequencer. The sequence reads were passed through a bioinformatics pipeline and checked against the BLASTn nucleotide database, which revealed the presence of 22 different viruses and two viroids, several of which were novel or had not been detected in these areas before (Table 1). Based on the sequences obtained, RT-PCR primers were developed to allow detection of the novel or previously un-encountered viruses and back-testing of the individual samples to determine the prevalence of some of these potentially important novel viruses.

The MySeq sequencing proved to be expensive and the assembly and processing of the short sequence reads required considerable time and skill, so the WorldVeg pathology group turned to the Oxford Nanopore MinION portable real-time sequencer to produce longer virus sequence reads requiring less complex bioinformatics at a lower cost. Because all new MinION units had been diverted to laboratories sequencing SARS-CoV-2 from COVID-19 samples, the virology group borrowed an older MinION model from a distributor in Taiwan and was able to hire a Nanopore MK1c, which combines a MinION and small processor for immediate base-calling in one unit (Figure 1). Work to establish the optimum nucleic acid extraction and library preparation conditions is ongoing.

## High-throughput sequencing (HTS) delivers essential details on plant viruses and diseases.

This system already has identified previously undetected DNA alpha satellites in association with *Mungbean yellow mosaic virus* and *Mungbean yellow mosaic India virus* (both DNA Begomoviruses) in mungbean samples from India, and has identified for the first time in cowpea the Polerovirus 2 (RNA Luteoviridae) in WorldVeg trials in Uganda. The system is capable of rapidly detecting and identifying both RNA and DNA viruses, and has the potential to detect and identify other microbial plant pathogens and endophytes, as well as phyllosphere- and rhizosphere-associated insects, mites, algae and nematodes quickly and cheaply for more systematic surveys of individual diseases or pests. In the future, the MK1c may be used to sequence whole genomes of plant pathogenic bacteria, fungi, nematodes, or insect pests.

Table 1. Virus and viroid sequences detected by HTS from samples of four crop species collected in Mali

Virus	Genus or Family	PEPPER	EGGPLANT	OKRA	TOMATO
African eggplant (yellowing) virus	Polerovirus	✓	✓		
Bell pepper endornavirus (Seed)	Endornavirus	✓			
Capsicum frutescens endornavirus 1 (Seed)	Endornavirus	✓			
Cotton leaf curl (alpha and beta satellite)	Geminiviridae / satellite			✓	
Cotton yellow mosaic virus	Begomovirus			✓	
Cytorhabdovirus (new)	Cytorhabdovirus		✓		
Chrysovirus (new) (Fungus-infecting)	Alphachrysovirus		✓		
Leviviridae (new) (infecting bacterial endophyte?)	bacteriophage	✓			
Okra leaf curl virus	Begomovirus			✓	✓
Okra leaf curl virus beta satellite	Geminiviridae / satellite			✓	
Okra yellow crinkle virus (& alpha satellite)	Begomovirus & satellite			✓	
Peanut clump virus M	Pecluvirus	✓			
Pepper cryptic virus 1 (Seed?)	Deltapartitivirus	✓			
Pepper Enamovirus	Luteoviridae	✓			
Pepper leafroll virus	Begomovirus	✓			
Pepper vein yellows virus	Polerovirus	✓		✓	
Pepper veinal mottle virus	Potyvirus		✓		
Pepper yellow vein Mali virus	Begomovirus	✓			✓
Pepper yellow vein virus	Begomovirus	✓	✓		✓
Potato spindle tuber viroid (Seed)	Pospiviroid	✓	✓		
Southern tomato virus (Seed)	Amalgavirus				✓
Tomato apical stunt viroid (Seed)	Pospiviroid	✓			✓
Tomato chlorosis virus	Crinivirus		✓		✓
Olive mild mosaic virus	Alphanecrovirus?		✓		

Virus or viroid names followed by “(seed)” are often seed-borne. The detected new Chrysovirus is likely to have been infecting a commensal, endophytic, or plant pathogenic fungal species, while the new Leviviridae bacteriophage may have been present in a commensal, endophytic, or plant pathogenic bacterial species. Although the sequencing was from extracted RNA, several Begomovirus (DNA virus) sequences were detected and identified.





## Safe and Sustainable Value Chains

- WorldVeg used **high-throughput sequencing (HTS)** technologies for initial identification/diagnosis of plant viruses in crops and locations where we have little or no prior information: 22 viruses and 2 viroids from tomato, eggplant, pepper and okra fields in Mali (MySEQ-UK); mungbean begomoviruses and alpha satellites in Punjab (India) and Bean common mosaic virus, Cucumber mosaic virus, and cowpea polerovirus-2 in mungbean in Uganda (MinION-Taiwan).
- **Virus disease surveys** of sweet pepper in Eastern and Central Taiwan showed Begomovirus, potyviruses and Polorovirus as most prevalent; CMV, Tospovirus and Tobamovirus infection were not significant. Polorovirus is more prominent in Eastern Taiwan and requires further identification to assess yield effects and search for resistance.
- Field survey for **bacterial spot** in Taiwan revealed that 93% was caused by *Xanthomonas perforans* (Xp), 5% by *X. euvesicatoria* (Xe) and 2% by *X. vesicatoria* (Xv); all Xp strains from *Capsicum* spp. are race P0 and are less aggressive than the various races (P1, P3, P7, P8) of Xe.
- Characterization of **Colletotrichum gloeosporioides** complex associated with sweet pepper anthracnose in Taiwan revealed that *C. fructicola* was the most prevalent, followed by *C. siamense*.
- **Cucurbit gummy stem blight** isolates were identified as either *Stagonosporopsis cucurbitacearum*, *S. citrulli*, or *S. caricae* and highly aggressive isolates, Phoma39 and Phoma33 of *S. citrulli* were selected for disease resistance screening in Taiwan.
- At WorldVeg HQ in Taiwan, routine **testing of seed lots** (504), seedlings (14,398), grow-outs (1,940 seedlings of 220 accessions) and BAPHIQ seed-lots (78) for Pospiviroids for national and international distribution showed a decline in Pospiviroid levels over the last few years.
- A new growth room pathogenicity/resistance **screening protocol** adapted for tomato target spot (*Corynespora cassiicola*) includes tomato lines with different levels of resistance/susceptibility and can differentiate between *C. cassiicola* isolates.
- Three infectious clones of **Lisianthus enation leaf curl virus (LELCV)**, an emerging Begomovirus becoming important in tomato in Taiwan were constructed and found infectious by inoculation in tomato and tobacco and will be useful for maintaining pure cultures of the virus for resistance/tolerance screening.
- Tomato VI037301 (*Solanum peruvianum*) showed potentially greater resistance/tolerance to **tomato chlorosis virus** – Taiwan (ToCV; *Crinivirus*) than 3 commercial lines and 27 other GRSU lines. Although all of the plants of VI037301 tested positive for ToCV, 37.5% of the plants remained symptomless.
- The selfed progenies of 29 ***S. peruvianum*** accessions that showed some resistance to TSWV or CaCV (Taiwan strains) in 2019 showed high resistance to TSWV in 2020. None of the *S. lycopersicum* or *S. galapagense* retained their putative resistance after selfing.
- Twenty three out of 100 accessions of ***S. pimpinellifolium*** continued to show good resistance to *X. perforans*, strain Xvt314 (race T4, Taiwan).



- Through recurrent selection and selfing, *S. pimpinellifolium* accessions VI005797 and VI029740 showed stable resistance/tolerance to *Ralstonia solanacearum* **bacterial wilt** phylotype II (Pss1632), and VI029740 showed resistance/tolerance to both phylotype II strains (Pss1632 and Pss1587), but all were susceptible to *R. pseudosolanacearum* phylotype I strains in Taiwan.
- Of 43 tomato F<sub>5</sub> populations with different **black leaf mold** (BLM; *Pseudocercospora fuligena*) resistance QTL combinations screened in Jan & Oct 2020, only those carrying all 4 resistance QTLs showed good BLM resistance in Taiwan.
- All ten **tomato hybrids** from Taiwan's Hualien District Agricultural Research and Extension Station (DARES) containing *Ph-3* (screened in Oct. 2020) showed resistance to *Phytophthora infestans* isolate Pi-39A (race T1,2).
- Four WorldVeg **Cucurbita moschata** breeding lines (18ZY3015-6, 18ZP3204-1, 19ZY3091-1 & 19ZY3093-2) showed potentially greater resistance to a new, more aggressive Taiwan strain (PRYL96) of papaya ringspot virus (PRSV; Potyvirus) than the other 26 lines and commercial varieties tested.
- Twenty-three advanced **mungbean** lines showed high resistance to bruchids with no adult emergence and no seed weight losses in Taiwan. The line AVMU1618 showed only 3% adult emergence and 4% seed weight loss, compared to the susceptible line Tainan No. 5 with 77% adult emergence and 99% seed weight loss.
- Five **carrot** lines (N4, N9, Brasilia, Danvers, and Nantes) showed flowering and seed production under hot weather conditions in India and Taiwan. Since Brasilia matures early with high root production, it can be introduced for root and seed production in the tropics.
- S<sub>1</sub> progenies of four *S. torvum* lines (VI048606-S<sub>1</sub>, VI048634-S<sub>1</sub>, VI048659-S<sub>1</sub>, and VI048662-S<sub>1</sub>) showed significantly fewer number of **root-knot nematode** (RKN) galls in Taiwan. Although the *S. torvum* accessions supported the RKN, they possessed a high level of tolerance for RKN infection. These accessions can be used as rootstocks for grafting against RKN. Five S<sub>1</sub> progenies of five *S. torvum* lines (VI047629-S<sub>1</sub>, VI048606-S<sub>1</sub>, VI048634-S<sub>1</sub>, VI048659-S<sub>1</sub>, and VI048662-S<sub>1</sub>) showed high level of tolerance for short-term **waterlogging**, and can be used as rootstocks for managing waterlogging.
- None of the S<sub>1</sub> progeny of *S. torvum* accessions that showed some waterlogging and root knot nematode resistance in 2019 showed resistance to **bacterial wilt** Pss97 or Pss 4 in 2020 in Taiwan.
- The S<sub>3</sub> generations of four **eggplant** accessions (VI041809A, VI041943, VI041945, and VI041984) previously shown to have good bacterial wilt resistance and grafting compatibility showed good resistance or tolerance to *R. pseudosolanacearum* (phylotype I) strain Pss97 (Taiwan eggplant strain) under controlled conditions in Taiwan.



## Safe and Sustainable Value Chains

- There was no difference in marketable yield of tomatoes produced in **colored net-houses**, white net-houses and the open field in 2020 in Taiwan, although higher marketable yield in colored net-houses was recorded in 2018. Ratio of marketable yield to total yield was higher in colored net-houses compared to open field conditions. Tomato produced in colored net-houses had significantly higher color index and lycopene concentration, and vitamin C was higher in both open field conditions and colored net-houses compared to white net-houses.
- Highest yield of 217 t/ha was harvested from the **cherry tomato** variety 'Tainan-Yasu No. 19' compared to the traditional tomato hybrid 'Wolverine F1' with 150 t/ha in greenhouse conditions. Average yield of cherry tomato compared to traditional tomato was 45% higher in Tajikistan.
- White and black **shade nets** reduced leafhopper incidence on tomatoes in Mali, but there were high numbers of whiteflies with both shade nets as well as open fields. Virus disease incidence was significantly higher in open field production than on tomatoes inside net-houses. Yield of tomato ('Icixina') was higher (14.2 t/ha) in the white shade net-house compared to tomatoes grown under the black shade net-house (8.9 t/ha) and in the open field (9.7 t/ha).
- Shortest developmental time (3-5 days faster) for **fall armyworm**, *Spodoptera frugiperda*, was recorded on corn and cabbage, compared to tomato in Taiwan. Oviposition period was 30-40% longer in cabbage and soybean compared to the artificial diet. Fecundity in soybean, cabbage, and tomato was 5-fold higher compared to the artificial diet. However, adult females are reluctant to lay eggs in vegetable crops compared to corn.
- More than 3,000 **arthropods** were collected from three tomato production sites (Ngarenanyuki, WorldVeg, and TARI Tengeru) in Tanzania. The majority of the insects were identified as Arachnida (24%), Hemiptera (20%), Hymenoptera (18%), Diptera (14%), and Coleoptera (9.7%). Most effective natural enemies for the invasive *Tuta absoluta* will be identified from this pool.
- The introduction of climate resilient **good agricultural practices (GAPs)** led to a substantial yield increase in tomato, eggplant, cabbage, cauliflower, pumpkin, garden pea, black gram and lentil in Assam, India. A maximum of 55% yield increase was recorded for black gram, whereas at least 20% yield gain was documented for all the other crops. The benefit cost (B:C) analysis revealed that the highest return (₹11) was realized from pea cultivation, for every rupee invested.
- Six **crop decision trees** (cabbage, bitter gourd, yard-long bean, cucumber, eggplant, and okra) were developed and validated in Cambodia.
- In Tanzania, more than 21,234 farmers and extension personnel were trained on different aspects of **vegetable GAP** (mulching, composting, grafting, IPM, cropping systems, etc.).
- 15 different **evaporative cooling devices** (clay pots, plastic buckets, metal buckets) were evaluated for improving the shelf-life of amaranth, spinach, and cowpea leaves in Bamako, Mali. Clay pots kept inside plastic containers significantly reduced the weight loss of the vegetables and prolonged shelf-life compared to the plastic and metal containers.





- In Tanzania, WorldVeg is working with Agroxy Tanzania to establish a **digital platform** for mungbean market information and online trade. Tanzania Pulse Networking, a partnership to address mungbean market obstacles, also was established.
- Regular **marketing training** was offered to 1,343 individuals in Zanzibar. WorldVeg facilitated two traditional vegetable producer/buyer meetings to create market linkages. Research was conducted on traditional vegetable crop seed and distribution with agro-dealers and seed companies. Two workshops reached 41 agro-dealers, seed companies, and government officials.

A man with a mustache, wearing a white long-sleeved button-down shirt and light-colored trousers, stands in a field of chili pepper plants. The plants are green with many bright red chili peppers hanging from the stems. The background shows a clear blue sky and some distant trees and utility poles.

# RED HOT CHILI PEPPERS

More than 65% of chili pepper production occurs in Asia, with South and Southeast Asia being major production regions. In response to high temperatures, chili pepper, like other fruiting vegetables, tends to abort reproductive organs (buds, flowers, and young fruits) significantly reducing yield.

Sridhar Mannam is one of the many chili pepper farmers in Guntur district, Andhra Pradesh, India. Chili cultivars from Guntur district are renowned globally for their flavor and color. They are important ingredients in popular Indian dishes and are exported to Asia, Canada, and Europe. Increasing temperatures lower yields, shorten the production season, and reduce the quality of chili pepper. Smallholder chili farmers like Sridhar Mannam are particularly susceptible to losses in revenue due to the effects of climate change. Heat tolerant cultivars would provide farmers an effective strategy to mitigate the losses associated with climate change.

Breeding for heat tolerance has been a primary goal of the WorldVeg pepper breeding program since its inception 35 years ago. The focus of this research has almost exclusively been on studying the reproductive organs (pollen viability, stigma exertion, etc.), the most sensitive tissues of the plant. Conducting comparison trials between hot and cool seasons focusing on pollen traits is tedious, but has resulted in the development of several high performing heat tolerant sweet pepper

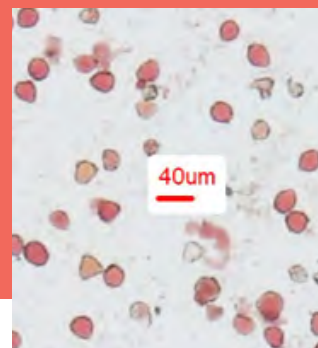


*High temperatures interfere with the ability of chili pepper to produce the fruit that adds heat and savor to dishes in Asia and beyond.*

varieties that were released in collaboration with Taiwan institutions. To increase efficiency in phenotyping for pollen traits in hot and sweet pepper, WorldVeg invested in an impedance flow cytometer (IFC). With the help of this technology, we were able to increase the throughput of our pollen evaluations 100-fold compared to traditional staining methods.

Climate change is caused by elevated levels of atmospheric carbon dioxide (CO<sub>2</sub>). CO<sub>2</sub> is also the substrate of photosynthesis, and elevated concentrations of this molecule have the potential to increase crop yields; however, the associated increase in temperatures affects a range of plant functions and can negate the CO<sub>2</sub> fertilization effect.

In 2020 WorldVeg conducted advanced phenotyping of the G2PSol *Capsicum* core collection, which was developed with funding from the EU Horizon 2020 program. Using the Phenospex field phenotyping platform, we captured an array of morphological traits during the hot and cool growing seasons, and were able to identify various vegetative traits—most notably changes in leaf angle—to be highly correlated with yield. This is the first time morphological traits associated with light interception and photosynthetic capacity have been studied in-depth in chili pepper and highlights the need to conduct future research in vegetables' reproductive response to high temperatures.







## Vegetable Diversity and Improvement

- **COVID-19 response:** 37,953 seed packs of 5,404 seed kits were distributed by four WorldVeg offices to local partners to strengthen local vegetable production during the COVID-19 pandemic.
- **Seed** of more than 2,647 genebank accessions was **regenerated** by the WorldVeg genebanks in Taiwan and in Tanzania, partly in collaboration with WorldVeg breeding teams and seed companies. A total of 115 **newly collected accessions** of eggplant wild relatives were acquired in collaboration with Royal Botanic Gardens, Kew, UK to close collection gaps for this gene pool.
- Seed of 2,528 breeding lines was **distributed to users** in 35 countries and seed of 3,200 genebank accessions was distributed to users in 28 countries. In addition, 1,630 genebank accessions were provided for internal use to WorldVeg researchers and breeders.
- Gap- and geospatial **analysis of diversity and distribution** were carried out to prioritize *ex situ* and *in situ* conservation interventions for a wide range of traditional African vegetable species as well as the wild relatives of *Vigna*, *Capsicum*, and *Cucurbita* spp.
- The WorldVeg mungbean team won the Illumina Agricultural Greater Good Award to sequence 1,200 WorldVeg mungbean accessions. The sequencing information will strengthen **genomics-assisted breeding** to generate disease resistant, high yielding and farmer-accepted mungbean varieties.
- The G2P-Sol *Capsicum* core collection was evaluated for **tolerance to heat stress** in field conditions. Crop performance was monitored using the Phenospex field phenotyping system and pollen activity was measured by high throughput impedance flow cytometry. Significant genotypic effects under heat were detected for a wide range of traits. In tomato, a multi-parent advanced generation intercross (MAGIC) population derived from eight heat tolerant founder lines was developed for use in heat stress tolerance research and breeding.
- In total 105 biodiverse okra (*Abelmoschus esculentus*) accessions and 2 check varieties were screened for **flooded tolerance** under hot conditions using the Phenospex field phenotyping system. Tolerant germplasm was identified for research and breeding.

### BREEDING

- **Tomato:** New bacterial wilt-resistant lines with good fruit and horticultural traits, as well as 'Great Pyramid' tomato lines combining various tomato yellow leaf curl disease resistance genes were made available to breeding consortia in Asia and Africa. Tomato line CLN3938A demonstrated good yields in trials conducted by NARS partners of an Asian Food and Agriculture Cooperation Initiative-funded project in Bangladesh, Kyrgyzstan, Laos, Mongolia and the Philippines. Backcross lines with high acylsugar contents were identified for developing insect resistant tomato lines.



- **Pepper:** New multiple disease resistant sweet and hot pepper lines were released to breeding consortia in Asia and Africa and chili pepper hybrids were evaluated in Myanmar and Vietnam to strengthen local breeding programs. Newly developed heat tolerant sweet pepper hybrids out-performed commercial hybrid varieties in terms of organoleptic, nutritional and yield traits in farmer fields in Taiwan.
- **Cucurbits:** Additional sources of cucurbit powdery mildew resistance were identified and fixed in bitter melon breeding lines. Pumpkin lines resistant to multiple virus diseases were developed and shared with partners. Bitter melon and pumpkin open field days at WorldVeg Thailand showcasing WorldVeg breeding materials attracted together more than 60 participants from seed companies.
- **Legumes:** The evaluation of the mungbean minicore collection was extended to seven countries in Africa. In Asia, mungbean accessions resistant to dry root rot (*Macrophomina phaseolina*), as well as urdbean and vegetable soybean resistant to yellow mosaic disease were identified. The *Mungbean Genome*, a book with editors from WorldVeg and the Seoul National University, Korea, and contributions from the global mungbean research community was published in August 2020.
- **Onion:** Field evaluation of WorldVeg onion materials identified materials preferred in Ghana and Mali. 3.3 kg of onion breeders' seeds of breeding lines and released varieties, as well as 106.6 kg of mother bulbs, were made available to the seed sector in Mali.
- **Traditional African vegetables:** A highly biodiverse MAGIC population derived from eight founder lines of two amaranth species was developed for research and breeding. In Africa, five amaranth lines with good vegetable quality and more than 1 t/ha seed yield were selected. Drought tolerant as well as bacterial wilt resistant African eggplant genotypes were identified. For 46 African eggplant cultivars breeder seed was increased for research and scaling. Seed of Ethiopian mustard, African nightshade, amaranth and African eggplant was distributed to 879 farmers in Tanzania.





# TINY, TASTY, AND PACKED WITH NUTRIENTS

The Khatlon region is well-known in Tajikistan for producing vegetables, especially early-season vegetables in high demand at markets across the country. **Ms. Adolat Berdieva**, an experienced household farmer in Madaniyat village, Jamoat “Vakhdati Milli” of Jayhun district, has been growing vegetables for more than 10 years—all by herself, as her husband was a migrant laborer in Russia.

In 2018, USAID’s Tajikistan Nutrition-Sensitive Vegetable Technologies Project, implemented by WorldVeg, started working with women’s groups in the region,



*Ms. Adolat Berdieva produces cherry tomato in a low-cost greenhouse she built herself. She's part of the effort to extend the growing season for fresh produce in Tajikistan and ensure nutritious vegetables are available and affordable for a large part of the year. With processing, the season can go on even longer.*

which is in part of USAID's Feed the Future Zone of Influence. Ms. Berdieva actively participated in farmer field days and training sessions hosted by the project. She received healthy cherry tomato seedlings from a vegetable seedling producer, Ms. Faizi Rustamova, who also was trained through the WorldVeg project.

Using locally available materials, Ms. Berdieva built a low-cost 180 m<sup>2</sup> greenhouse following a design shared by project staff. She planted cherry tomato (variety 'Tainan-Yasu No. 19' introduced from Taiwan) in the first half of February 2020 in her new greenhouse. Her first harvest of the tiny, tasty, nutrient-packed tomato fruit began in early May and continued through mid-September.

Being able to enjoy such a long growing season was a new experience for Ms. Berdieva and for Tajikistan as well. Generally, production of local tomato varieties lasts only through the middle of July.

Ms. Berdieva harvested 3,920 kg of cherry tomato from her greenhouse, and sold 2,900 kg to local markets at an average price of 5.00 Tajik somoni/kg, generating an income of 14,500 Tajik somoni (US\$ 1,405). The yield per cherry tomato plant was 4.9 kg or 21.7 kg/m<sup>2</sup>. The rest of the harvest the Berdieva family consumed, eating some fresh while canning and drying the remainder. With skills she learned during training on food processing, Ms. Berdieva and other project beneficiaries, especially women, made cherry tomatoes jam and pickles, and dried the fruit for longer storage. Ms. Berdieva's success has inspired her neighbors to grow cherry tomato in greenhouses using new vegetable production technologies.



## Healthy Diets

- A study was conducted on the **effects of COVID-19 on diets and livelihoods** of vegetable farmers in four regions of India. Data were collected by phone from May-June 2020. The study showed that COVID-19 significantly disrupted the diets and livelihoods of vegetable farmers and was one of the first empirical studies to show this.
- A **scoping literature review** was started on research publications with a focus on vegetables and healthy diets in a food systems context to systematically map existing work in the field and identify research gaps. The work was presented to a multi-donor meeting in October 2020 to help shape global investments in vegetable research.
- The “Amazing Amaranth” project, funded by the Federal Ministry of Economic Cooperation and Development (Germany) and implemented in Tanzania and Kenya, analyzed 148 **vegetable amaranth** samples for protein, calcium (Ca), iron (Fe), zinc (Zn) and oxalate levels. It showed a 2.5-fold variation in oxalate content, and 2.2, 3.7 and 7.4-fold variations in Ca, Fe and Zn content, respectively.
- The USAID/UNICEF-funded project in Cameroon “Improving diet diversity among children aged 0-23 months in Mokolo health district, the Far North region” showed that the promotion of **vegetable home gardening** is effective in complementing nutrition and health programming to improve infant and young children feeding (IYCF) practices. Project data showed that the share of children receiving a minimum acceptable diet improved from 31% to 42% among breastfed children, and from 15% to 26% for non-breastfed children.
- The project “Diversify and Improve Household Incomes and Tackle Malnutrition in Cocoa Communities through Vegetable Home Gardening”, funded by the private company Barry-Callebaut, trained over 200 **cocoa producing farm households** in home gardening in Cameroon and distributed 50 seed kits, with another 78 farmers receiving seed kits in Ghana.
- The project “Building momentum for traditional African vegetables in Madagascar”, funded by the Darwin Initiative, conducted a baseline study and trained 25 extension officers and 200 women farmers on the **nutritional benefits of traditional vegetables** in Itasy and Antsirabe regions, Madagascar. Five schools were selected for establishing a school garden in 2021.
- The USAID-funded project “Africa RISING” reached over 500 people with **nutrition awareness messaging** and **cooking demonstrations** in Karatu, Simiyu and Dar es Salaam, Tanzania.
- The USAID-funded project “Improving Nutrition Status and Income Sustainably through Traditional African Vegetables” (INSIST TAV) in Zanzibar, Tanzania ended on 30 September 2020. The project stimulated **demand for traditional vegetables** using farmer training and cooking shows (3,635 participants), radio and TV programs, nutrition sensitization sessions provided to pregnant and lactating women (628 participants), and public events organized by WorldVeg during World Food Day and Farmers’ Day (2,561 participants).
- The USAID-funded “Tajikistan Nutrition-Sensitive Vegetable Technologies Project” organized a **training event** titled “Cooking methods of new vegetables”, which was attended by 110 people, mostly women.



- The **WorldVeg nutrition laboratory** in Taiwan analyzed a total of 2,727 samples, include 125 samples of tomato, 86 samples of pepper, 799 amaranth, 200 okra, 1,027 mungbean and 490 other vegetables. A total of 10,851 analysis data points were completed—a 17% increase over 2019.





# THE BILLION-DOLLAR BEAN

Mungbean is generally considered a minor crop in most places. Globally, the crop is planted only on about 7.3 million hectares (rice, in comparison, is planted on 166 million hectares), and global production is about 5.3 million tons<sup>1</sup>. But not so in Myanmar, where mungbean is one of the country's most important crops supporting the livelihoods of about 637,000 smallholder farm households. Myanmar accounts for 30% of global mungbean production and is by far the largest exporter of this green bean. The crop fits well in the country's rice-based cropping systems and the output is largely sold to India rather than consumed in-country.

World Vegetable Center researchers began mungbean breeding activities in 1972. WorldVeg and the Department of Agricultural Research in Myanmar have been working together since the 1980s to introduce new varieties with higher yield, short maturity and better disease resistance—particularly to mungbean yellow mosaic disease. These improved varieties resulted from a long-term collaboration with national mungbean programs in India, Philippines, Thailand and Pakistan. There are nine improved mungbean varieties available in Myanmar, and five of these came from the WorldVeg program<sup>2</sup>. Jointly, these five varieties have been adopted on 77% of the country's mungbean area.

A study funded by the UK's Foreign, Commonwealth and Development Office (FCDO) and led by Teresa Sequeros, an independent consultant hired by WorldVeg, estimated the economic impact of these varieties for Myanmar<sup>3</sup>. The study used the economic surplus model—a well-established method to quantify the economic impact of agricultural technologies at the aggregate level. The results show that mungbean research and development (R&D) in Myanmar created total economic gains of USD 1.4 billion from 1980 to 2016. Of these gains, 95% accrued to smallholder farmers and 5% accrued to consumers in Myanmar (as most of the output is exported). Extending the analysis up to 2030, when the current varieties may be replaced by newer ones, suggests total economic gains of 3.7 billion.



*Four mungbean varieties developed by the World Vegetable Center and released in Myanmar by the Department of Agricultural Research created economic gains of USD 1.4 billion from 1980 to 2016—and the benefits from this billion-dollar bean are expected to continue into the next decade.*

These economic gains were made possible by international donors and the Myanmar government, which invested about US\$ 5 million in mungbean R&D for Myanmar from 1980–2016. Calculations suggest that one dollar invested in mungbean R&D gave a mean return of 92 dollars until 2016, and will give a mean return of 181 dollars until 2030. This is an attractive return on investment for international donors, including FCDO and other long-term strategic donors of the Center.

However, the study also shows it took 20 years between the research investment and the start of impact—illustrating the fact that investments in agricultural research require a long-term, patient perspective. The varieties that made such large impact in Myanmar contained germplasm supplied by the national agricultural research programs of India, Pakistan, Thailand, the Philippines, and perhaps also other countries. The unconditional sharing of plant genetic resources between national agricultural research systems in Asia was a key contributor to the success of the mungbean breeding initiative. Future gains in mungbean breeding will continue to depend on this spirit of collaboration.

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- <sup>2</sup>Schreinemachers, P., Sequeros, T., Rani, S., Rashid, M.A., Gowdru, N.V., Rahman, M.S., Ahmed, M.R., Nair, R.M., 2019. Counting the beans: quantifying the adoption of improved mungbean varieties in South Asia and Myanmar. *Food Security* 11(3), 623–634. <https://doi.org/10.1007/s12571-019-00926-x>
- <sup>3</sup>Sequeros, T., Schreinemachers, P., Depenbusch, L., Shwe, T., Nair, R.M., 2020. Impact and returns on investment of mungbean research and development in Myanmar. *Agriculture & Food Security* 9(1), 5. <https://doi.org/10.1186/s40066-020-00260-y>





## Enabling Impact

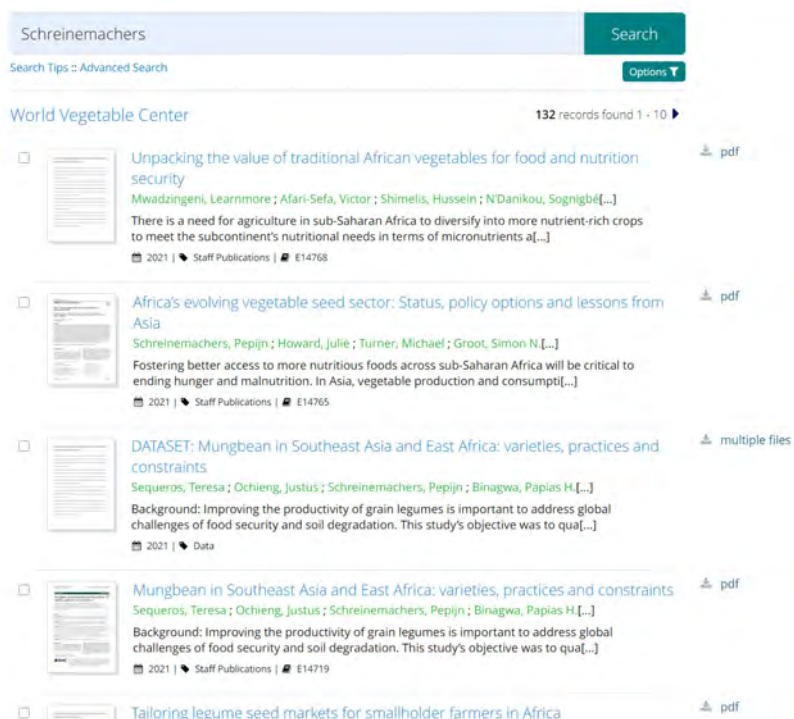
- The **Asia and Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium** expanded from 19 members in 2017 to 33 members in 2018, 43 members in 2019, and 44 members in 2020. The annual workshop was held virtually on 12 May 2020 with nearly 200 participants.
- The **Africa Vegetable Breeding Consortium (AVBC)** had six members in 2020 (3 less than 2019). Its workshop was held virtually on 7 September 2020. Memberships will be waived in 2021 to attract more companies to join.
- The **WorldVeg-Taiwan Seed Industry Exchange Platform**, launched in 2017 to promote and enhance the communication and interaction with Taiwanese seed companies, expanded to 122 individuals representing 85 companies, nurseries, and organizations. In 2020, 219 people joined germplasm regeneration-related activities, including germplasm multiplication training, experience sharing, and a field day of vegetable breeding research. Six companies assisted with seed multiplication and 17 announcements were shared with the platform.
- The **International Mungbean Improvement Network (IMIN)** expanded to 13 research organizations and seed companies from Asia and Africa.
- The **SAFEVEG** project (“Safe locally produced Vegetables for West Africa’s consumers”) started on 1 November 2020. Funded by the European Union and the Ministry of Foreign Affairs of the Netherlands, the 5-year project aims to reduce undernourishment, improve income and productivity of small-scale food producers—particularly women and youth, and expand sustainable land use in Benin, Burkina Faso, and Mali.
- A study on the likely effects of **introducing machine harvesting** in mungbean production in Bangladesh and Myanmar showed that mechanizing mungbean harvesting could adversely affect landless households for whom manual harvesting is an important source of income. It could particularly affect women with small children, as they cannot move easily to find other jobs. Gendered restrictions on women’s mobility and their role as family caregivers restrict their options for alternative work both locally and further away. The effects are likely to be particularly damaging in locations with low economic diversity and more restrictive gender norms.
- In collaboration with ASPA, a study was conducted on the **impact of the COVID-19 pandemic on the seed trade** in the Asia and Pacific region based on three rounds of surveys of seed company executives. It showed dramatic effects of the pandemic on the seed trade during April, somewhat of a recovery during May, but continued challenges in August.
- The BMZ-funded project “Teach and text: Combining on-farm demonstration and phone messaging to scale vegetable IPM in Cambodia” conducted its **endline survey** in May 2020. Because of the COVID-19 pandemic the data were collected as a phone survey.
- A **baseline study** was conducted among 500 households in 36 communities across ten local government areas in Kano and Kaduna states in northern Nigeria in September and October 2020. The data were collected by Sahel Consulting Agriculture & Nutrition Ltd. Part of the interviewed households will receive training in vegetable production by East-West Seed Knowledge Transfer and part will





not receive the training. A future follow-up study will quantify the impact of the training on the adoption of improved vegetable varieties and good agricultural practices and the associated improvements in farmers' livelihoods.

- Data were collected for a study on the development of the **vegetable seed sector** in Mali and the potential of irrigated seed production. WorldVeg hired consultant Dr. Siaka Dembélé to lead the study, an activity in the USAID Feed the Future Innovation Lab for Small-Scale Irrigation (ILSSI).
- A study on **chili pepper production** in Bogra District, Bangladesh, showed that all 260 farmers interviewed faced problems with chili anthracnose. Most had minimal knowledge about how the disease spreads in the field and how to control it with methods other than chemical pesticides. It is critical to strengthen the capacity of farmers in preventing and managing this disease.
- HARVEST, the WorldVeg **knowledge management system** (<https://worldveg.tind.io>) was further populated with documents and data. Launched in December 2017, HARVEST gives WorldVeg staff better access to research outputs, project reports, protocols, and original research data. The system had 59,198 records by December 2020 and there were 80,544 downloads from January-December 2020.



# FROM VULNERABLE TO RESILIENT

The COVID-19 pandemic exposed many weak links in the way food is produced, distributed, and consumed worldwide. Lockdowns restricted the movement of farm laborers and disrupted supply chains for seed, fertilizer, and other inputs. Markets continue to struggle with transport and delivery of fresh produce. Consumers who have seen their incomes shrink purchase less fresh fruit and vegetables, opting instead for cheaper, non-perishable food items—thus forgoing the essential nutrients fresh produce contributes to the family diet.

Yet global food systems have local elements capable of overcoming these systemic shortfalls. Individuals can and do make a difference when they grow some or even all of the vegetables their families consume.

**WorldVeg seed kits** with fast-growing, nutritious vegetable varieties are bringing a measure of resilience to thousands of households in Benin, Mali, Philippines, Taiwan, Tanzania, and Thailand.



## BENIN

The **Ministry of Agriculture, Livestock and Fisheries** distributed kits to 420 farmers and their families from 27 municipalities. Each kit contained seed of eight nutrient-dense, fast-growing vegetable crops: tomato, chili pepper, onion, okra (*févi*), amaranth (*fofotè*), African eggplant leaves (*gboma*), African basil (*tchiayo*), and jute mallow (*crincrin*).

## MALI

150 seed kits with okra, chili, African eggplant, Jute mallow (*zofon*) amaranth, and roselle (guinea sorrel) to supply 148 farmer and market gardening organizations were distributed by the **National Directorate of Agriculture**. The seed will benefit thousands of vulnerable families in Kayes, Koulikoro, Sikasso, Bougouni, Koutiala, Ségou, Mopti, and Bamako.

## PHILIPPINES

Seed kits containing amaranth, Malabar spinach, jute mallow, okra, mungbean, and kangkong were delivered to 1,020 families vulnerable to the impact of COVID-19 near the community of Los Baños in southwestern Luzon by the **Bureau of Plant Industry, Department of Agriculture, Philippines**. The kits were so popular, an additional 1500 were requested.

## TAIWAN

WorldVeg provided 400 seed kits of rapid-growing nutritious vegetables for **World Vision** to distribute to vulnerable families in the Tainan area; more than 2,010 children benefited from the seed kits.

“People have more nutritious, healthier diets when they can consume vegetables they have produced at home, and a home garden can help families overcome shocks.”

-- WorldVeg Director General Marco Wopereis

*With WorldVeg vegetable seed kits,  
families are growing their own nutrient-rich food for healthier diets.*

WorldVeg formed a COVID-19 Task Force in early April 2020 to plan active responses to alleviate disruptions in food access and to conduct strategic research to understand the pandemic's effects on food systems. Seed kits were at the top of the task force's list. To create the kits, WorldVeg staff reviewed available seed stocks, selected six to ten vegetable varieties for each specific country, and conducted germination tests to ensure the seed was viable. The kits contain seed of fast-growing, nutrient-rich traditional vegetables, such as okra, jute mallow, mungbean, kangkong, amaranth, and Malabar spinach, as well as booklets in local languages with planting instructions, crop management methods, nutrients, and ideas for food preparation for each crop.

National partners and nongovernmental organizations distributed the seed kits. They also are assisting WorldVeg researchers to prepare follow-up surveys to learn how the recipients used the kits. The information will help us understand practical constraints to home vegetable gardens and the social aspects of sharing seed and distributing surplus vegetables.



### TANZANIA

Staff from WorldVeg Eastern and Southern Africa shared their knowledge with 60 Tanzanian youth participating in skills training offered by two local organizations, **Jobortunity** and **Future Stars**. The WorldVeg team demonstrated how to make sack gardens and distributed seed kits to the youth, many of whom live in urban areas with limited space for growing vegetables. The **Agri Thamani Foundation** received 500 seed kits to use in school garden activities in Kagera, Geita, Tabora, Dodoma, Kigoma, and Tanga, Tanzania.

### THAILAND

The WorldVeg East and Southeast Asia team presented 200 seed kits to **Thai City Farm**, an organization promoting home gardens in Bangkok, Thailand. The kits are benefiting families across the city whose livelihoods have been affected by COVID-19; they are growing and eating their own vegetables, which has improved the nutritional quality of their diets and made them more resilient to market shocks. The kits contained nine species (roselle, wax gourd, tomato, pumpkin, sword bean, purple wing bean, chili pepper, butterfly pea, green wing bean) of seven different colors with seven unique nutrient profiles, as well as a booklet on how to save the seed of each species.



# BUILDING THE FOUNDATION FOR A CAREER

*Internships with WorldVeg lay the groundwork for a successful future in horticulture for development.*



**Inocent Ritte**, a Ph.D. student from Integrative Biosciences of Tuskegee University, Alabama, USA, did an internship in breeding and crop protection at WorldVeg Eastern and Southern Africa in Arusha, Tanzania from September 14 to November 13, 2020.

His breeding work involved analyzing data from a multilocation trial of cowpea (*Vigna unguiculata*) conducted in 2015. Sixteen entries were evaluated from the trials in three locations—Arusha (WorldVeg), Moshi, and Mbuguni. He observed that entry x location interactions were not significant for various traits, while differences among entries in each location were significant for some traits and locations. There is another year of data to be analyzed to prepare the results for publication.

On crop protection, Inocent worked on the initial identification of native biological control agents for thrips control. He participated in the culturing of two microorganisms—entomopathogenic bacteria (2 species) and fungi (3 species)—to generate a microbial stock suspension for testing the efficacy of the microorganisms for commercial-grade biopesticides to control thrips. The entomopathogenic bacterial species were *Bacillus thuringiensis* and *B. subtilis*; the fungi species were *Metarhizium anisopliae*, *Trichoderma asperellum*, and *Beauveria bassiana*. Inocent also participated in field sampling, culturing and sub-culturing of plant pathogens for morphological identification.

“My on-the-job-training experience with WorldVeg was vital in my career as an agricultural researcher and scientist,” Inocent said. “The lessons I learned have directly impacted my personal development in research, and I will apply them in my future positions towards serving communities.”



# Training Scholars

In 2020, WorldVeg hosted **70** interns  
(44 men and 26 women) from **10** countries

Tanzania  **26**

Malaysia  **4**

USA  **2**

Japan  **1**

Mali  **17**

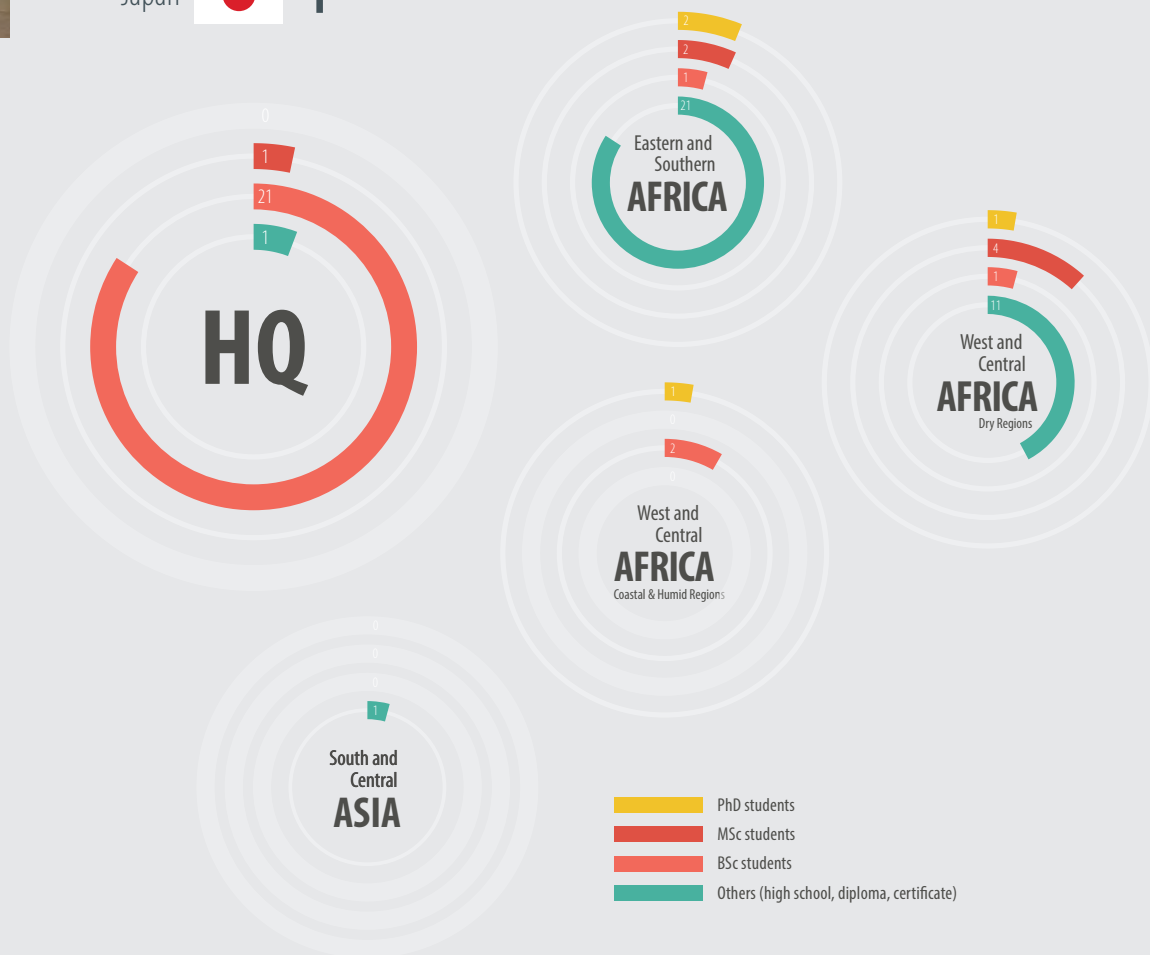
Benin  **3**

Haiti  **1**

Taiwan  **13**

Indonesia  **2**

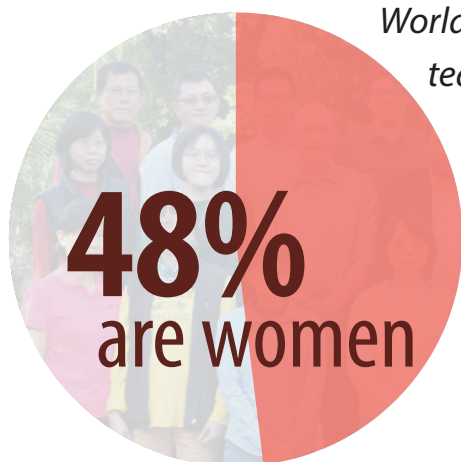
India  **1**





# A MULTIPLICITY OF TALENTS, SKILLS, AND VIEWPOINTS

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



Number of staff in 2020: **358**

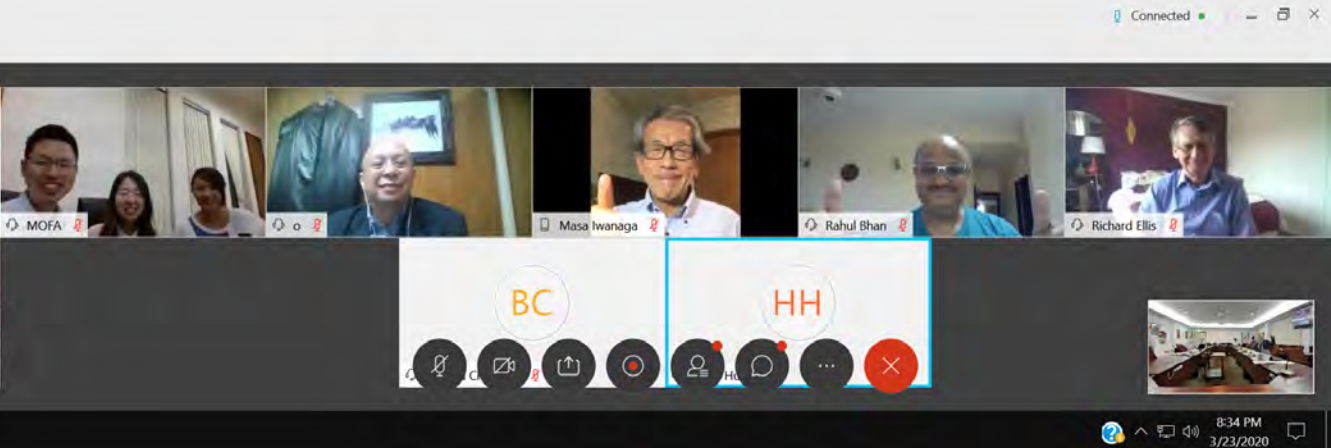
Number of nationalities among staff: **23**

Percentage of staff that are women: **48%**

Percentage of international recruitments that are  
women professionals: **25%**







# BOARD OF DIRECTORS

NAME	COUNTRY	APPOINTED
Dr. Junne-Jih Chen – Board Chair	Taiwan	Apr 2011
Dr. Masa Iwanaga – Vice-Chair	Japan	Apr 2016
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. Chung-Hsiu Hung	Taiwan	May 2020
Dr. Marlis Lindecke	Germany	Jun 2015
Mr. Gordon MacNeil	Canada	Apr 2016
Dr. Bonnie McClafferty	USA	Dec 2017
Dr. Gordon Rogers	Australia	Nov 2019
Dr. Lindiwe Sibanda	Zimbabwe	Nov 2018
Dr. Anand Kumar Singh	India	Nov 2019
Dr. Chongrak Wachrinrat	Thailand	Feb 2016
Dr. Dennis Wang	Taiwan	Feb 2018
Dr. Marco Wopereis, ex-officio member	The Netherlands	Apr 2016
Mr. Akira Yokochi	Japan	Sep 2020
Terms concluded in 2020		
Dr. Chi-Chung Chen	Taiwan	May 2020
Mr. Shigehiro Nishiumi	Japan	Sep 2020

# 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 2020:

Monthly unique visitors to [worldveg.org](http://worldveg.org): **24,000+**

Subscribers to Fresh, the WorldVeg newsletter: **9,922**

**facebook** followers: **22,991**

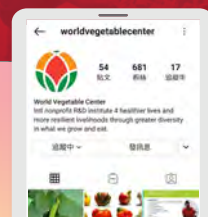
**LinkedIn** followers: **11,668**

**twitter** followers: **8,300** (@go\_vegetables)



WorldVeg  **YouTube channel: 8,000**

*Instagram* followers: **657**



Media mentions: **275**, including reports by National Public Radio (NPR) USA, IPP Media, The Hindu, Food Tank, HortiDaily, SeedQuest, Mali News, Manila Times, Science Magazine, Diplomat Magazine

Visitors: More than **712 visitors from 27 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.

WorldVeg staff highlighted R&D activities at these and other exhibitions and conferences in 2020:

## IN PERSON and ONLINE

**Gruene Woche (Green Week)** :::: 16-18 January, Berlin, Germany

**2020 Svalbard Seed Summit** :::: 25 February, Spitsbergen, Norway

**2020 African Seed Trade Congress (AFSTA)** :::: 1-5 March, Livingstone, Zambia

**Nane Nane (8-8)** :::: 1 August, Tanzania

**African Green Revolution Forum** :::: 7 September, online

**Taiwan Innotech Expo** :::: 24-26 September, Taipei, Taiwan

**World Food Prize Borlaug International Symposium** :::: 12 October, online

**2nd University Consortium Faculty Forum, National Taiwan University** :::: 9 November, Taipei, Taiwan

**JIRCAS International Symposium 2020 50th Anniversary Program** :::: 10 November, Tsukuba, Japan

**Kaset Fair** :::: 1-10 December, Kamphaeng Saen, Thailand

# Finance

2020 Revenues (in '000 USD)		
Unrestricted grants	7,602	35%
Restricted grants	13,708	63%
Other revenues	443	1%
<b>Total</b>	<b>21,753</b>	<b>100%</b>

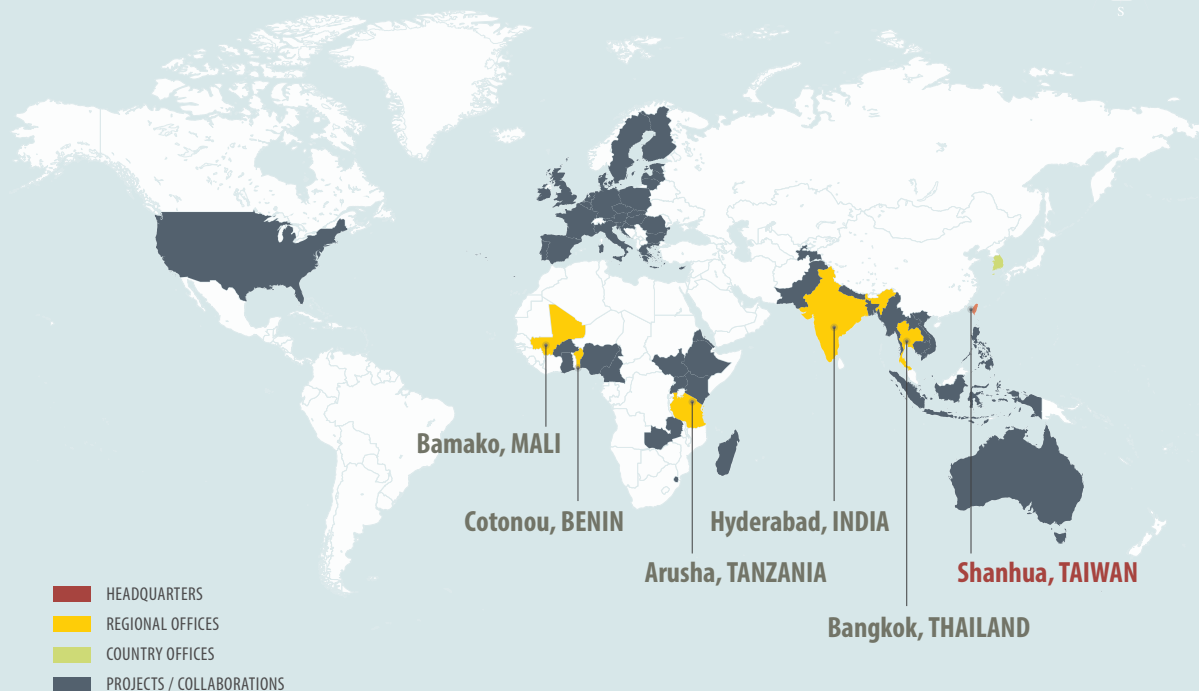
## Unrestricted Grants

Republic of China (ROC)	4,771
UK Foreign, Commonwealth and Development Office (FCDO)	1,510
United States Agency for International Development (USAID)	900
Australian Centre for International Agricultural Research (ACIAR)	273
Thailand	142
Korea	50
Japan	5
The Philippines	-50
<b>Sub-total</b>	<b>7,602</b>
Other revenues	443
<b>Total</b>	<b>8,044</b>

## Restricted Grants

Republic of China (Taiwan)	7,181
Federal Republic of Germany / BMZ / GIZ	1,351
UK Foreign, Commonwealth and Development Office (FCDO)	1,126
United States Agency for International Development (USAID)	794
Australia / Australian Centre for International Agricultural Research (ACIAR)	597
Private seed sector companies; Asia and Pacific Seed Association (APSA)	556
State Governments of India	407
Korea / RDA	330
Others (projects with expenses less than 200K USD)	1,367
<b>Sub-total</b>	<b>13,708</b>
<b>Total Revenues</b>	<b>21,753</b>





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### Eastern and Southern Africa

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### West and Central Africa – Dry Regions

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

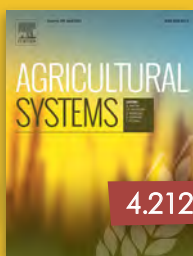
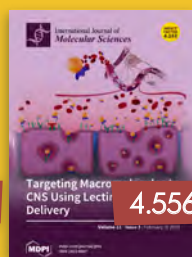
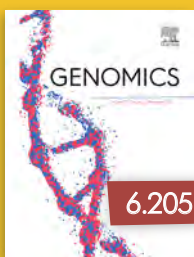
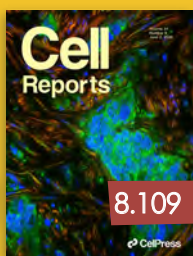
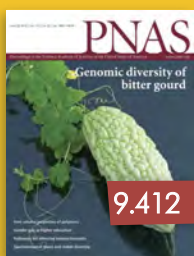
### West and Central Africa – Coastal & Humid Regions

IITA-Benin Campus 08  
BP 0932 Tri Postal, Cotonou,  
BENIN  
Tel: +229-6418-1313

# RESEARCH FOR DEVELOPMENT



**TOP 10** journals according  
to impact factor



**94%**

of WorldVeg journal articles  
published as **open access** in 2020

# 2020 Publications

## Journal articles with impact factor (63)

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# Acronyms

2DI	2 Degree Initiative
AAU	Assam Agricultural University
ACIAR	Australian Centre for International Agricultural Research
AFACI	Asian Food and Agriculture Cooperation Initiative
AFSTA	African Seed Trade Association
APAARI	Asia Pacific Association of Agricultural Research Institutions
APART	Assam Agribusiness & Rural Transformation Project
APSA	Asia & Pacific Seed Association
AVBC	Africa Vegetable Breeding Consortium
AVRDC	Asian Vegetable Research and Development Center
BAPHIQ	Bureau of Animal and Plant Health Inspection and Quarantine, Taiwan
BBSRC	Biotechnology and Biological Sciences Research Council, United Kingdom
BCKV	Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India
BIMAF	Biorisk Management Facility
BLM	Black leaf mold
BMZ	Federal Ministry for Economic Cooperation and Development, Germany
BPH	Best practice hubs
BW	Bacterial wilt
ChiLCD	Chilli leaf curl disease
ChiVMV	Chilli veinal mottle virus
COA	Council of Agriculture, Taiwan
COLEACP	Europe-Africa-Caribbean-Pacific Liaison Committee
DARES	District Agricultural Research and Extension Station
DLB	Demand-led breeding
DNA	Deoxyribonucleic acid
DUS	Distinctiveness, uniformity, and stability
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization of the United Nations
FCDO	Foreign, Commonwealth and Development Office, United Kingdom
FERA	Food & Environment Research Agency, United Kingdom
FOFIFA	National Center for Applied Research on Rural Development, Madagascar
FSRP	Food Systems Resilience Program
GAP	Good agricultural practices
GHP	Good handling practices
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLF	Global Landscapes Forum
HARVEST	Holistic Access to Research on Vegetables, Societies and Technology
HORTSON	Horticultural Association of Nigeria
HTS	High throughput sequencing
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFC	Impedance flow cytometry
IITA	International Institute of Tropical Agriculture

ILSSI	Feed the Future Innovation Lab for Small-Scale Irrigation
IMIN	International Mungbean Improvement Network
IPG	Improved production guides
IPM	Integrated pest management
IYCF	Infant and young children feeding
JOHAR	Jharkhand Opportunities to Harness Rural Growth
KAFACI	Korea-Africa Food & Agriculture Cooperation Initiative
KAU	Kerala Agricultural University
KU	Kasetsart University
LELCV	Lisianthus enation leaf curl virus
LMIC	Low- and middle-income countries
MAGIC	Multi-parent advanced generation intercross
MOFA	Ministry of Foreign Affairs, Taiwan
MoU	Memorandum of Understanding
NARS	National agricultural research system
NPR	National Public Radio, USA
OP	Open pollinated
PoP	Package of practices
PRSV	Papaya ringspot virus
QTL	Quantitative trait loci
RDA	Rural Development Administration, Korea
RIM	Research Infrastructure Modernization
RKN	Root-knot nematode
RNA	Ribonucleic acid
RNCGR	Republican National Center for Genetic Resources, Tajikistan
RSSC	Ralstonia solanacearum species complex
RT-PCR	Reverse transcription polymerase chain reaction
SDC	Swiss Agency for Development and Cooperation
SIGV	Special Interest Group on Vegetables
SKUAST	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Kashmir
TAHA	Tanzania Horticultural Association
TARI	Tanzania Agricultural Research Institute
TARI	Taiwan Agricultural Research Institute
TCDVd	Tomato chlorotic dwarf viroid
ToCV	Tomato chlorosis virus
TOSCI	Tanzania Official Seed Certification
ToT	Training of trainers
TPN	Tanzania Pulse Network
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WACCI	West African Centre for Crop Improvement
WASH	Water-sanitation-hygiene

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