



World Vegetable Center

ANNUAL REPORT 2021



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Published by

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WorldVeg Publication: 22-1045
ISBN: 92-9058-235-9

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Cover photo

Ms. Krum Sahray at the WordVeg research and training station in Kamphaeng Saen, Thailand conducts manual pollination of bitter gourds to support the Center's cucurbit breeding program. *Photo:* Sorawit Limsiriwat/WorldVeg

Suggested citation

World Vegetable Center. 2022. Annual Report 2021. World Vegetable Center, Shanhua, Taiwan. Publication 22-1045. 83 p.

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Foreword from the Director General

2021 was the UN declared “International Year of Fruits and Vegetables” (IYFV). For WorldVeg it was of course a very busy year, still largely influenced by the COVID-19 pandemic. Our primary focus continued to be on health and safety of staff and families. By the end of 2021, all project activities had resumed.

The IYFV started well with the first All Africa Summit on traditional African vegetables (“Power on Your Plate”) organized by the WorldVeg team in Arusha, Tanzania, in collaboration with CAB International (CABI), the Global Alliance for Improved Nutrition (GAIN) and USAID. More on this on pages 30-31. Throughout the year, WorldVeg was very much present on social media and contributed to the UN Food Systems Summit (UNFSS), the World Food Prize Borlaug International Dialogue, and the Tokyo Nutrition for Growth Summit. In the regions, WorldVeg staff contributed to and organized special events to celebrate this special year.

Under the umbrella of the Association of International Research and Development Centers for Agriculture (AIRCA), WorldVeg published two briefing papers for the UNFSS, highlighting priorities for food systems research and action, and the need to safeguard and use fruit and vegetable biodiversity. More on these papers on pages 8-9.

Food safety concerns are often an important barrier to increasing vegetable consumption. A pilot study focusing on pesticide residues, heavy metals, and foodborne pathogens funded by the Asian Development Bank in Dhaka, Bangladesh and Hanoi, Vietnam revealed that market infrastructure in both cities is insufficient and overall hygiene is poor. Foodborne pathogens were a particular concern for leafy vegetables. More on this on pages 45-46.

Our Research Infrastructure Modernization Project (RIM project) switched gear with the start of the fourth, last, and largest contract: construction of new research facilities at our headquarters in Shanhua, Taiwan. However, the project also suffered delays and rapidly rising costs because of the COVID-19 pandemic. We are very grateful that Taiwan's Executive Yuan decided in July to approve a revised budget and implementation plan. The duration of the RIM project was extended until 12 December 2023 with an additional budget of NTD 142,116,000 (about US\$ 5.1M, page 11). Our RIM-funded field phenotyping facility at WorldVeg headquarters in Taiwan enabled detailed characterization of a core collection representing the global diversity of cultivated pepper comprising 300 accessions in terms of heat stress tolerance (page 50).

Another solanaceous crop - tomato - is a key ingredient of many popular dishes in West Africa. Well-adapted and locally-bred disease resistant and heat tolerant tomato varieties are needed for both the fresh and processing markets. Facilitated by WorldVeg and in collaboration with a local seed company and the West African Centre for Crop Improvement (WACCI), three multi-disease resistant and high yielding tomato hybrids were released in Ghana (pages 48-49).

2021 was the year that enabled WorldVeg and partners to place the 'Big 3' projects in Africa ('Veggies for Planet & People', 'SAFEVEG West Africa', and the Taiwan-Africa Vegetable Initiative') firmly on the rails. For details on TAVI see page 15. This entailed a great team effort, involving WorldVeg staff and partners in both Africa and Asia. I am grateful to all who made this happen.

WorldVeg staff also engaged with One CGIAR scientists to work on their new research portfolio, attempting to integrate vegetables from a food systems perspective, across regions and science areas. By the end of the year, WorldVeg was tentatively involved in 9 out of a first set of 33 "One CGIAR initiatives", however a lot of uncertainty remained. We look forward to helping to catalyze a transformative change in the new One CGIAR research portfolio towards nutritious foods, like vegetables.

All Board meetings and our Global R&D Week were again held virtually in 2021. The Board added one new member to the team: Victor Ajieroh, a Nigerian national and a food security and nutrition specialist with 20 years of experience in policy and development programming in sub-Saharan Africa. We look forward to working with Victor.

We are once more very grateful for the generous support of our funders listed on pages 70-71, enabling us to contribute to healthier lives and more resilient livelihoods around the world. It was a great pleasure for me to meet with some of these funders, other partners and the WorldVeg teams in Benin, Mali, Tanzania and Kenya in the second half of the year, after a long absence due to COVID-19. I sincerely hope to be able to continue with such working visits in 2022. A special thanks also to all WorldVeg staff for the hard work done in 2021, despite the huge challenges the pandemic has imposed upon all of us.

-- Marco Wopereis

TIMELINE

01 JANUARY

The inception meeting for the “Veggies for Planet and People” project funded by IKEA Foundation was held from 12–13 January in Nairobi, Kenya.

The 2nd Pumpkin Open Field Day was held on 25 January at the WorldVeg ESEA Research & Training Station, Kasetsart University Kamphaeng Saen Campus in Thailand.

From 25 to 28 January, the first all Africa Summit “Power on Your Plate: Diversifying Food Systems with African Traditional Vegetables to Increase Health, Nutrition and Wealth” was held at the Gran Melia Hotel, Arusha, Tanzania. There were about 175 in-person participants; 312 registered online. More than 10,000 people viewed the Summit during the live Facebook feed. Board Chair JJ Chen addressed the Summit during the closing ceremony.



02 FEBRUARY



A groundbreaking ceremony was held on February 1 to mark the start of the construction of WorldVeg new research facilities, Taiwan, as part of the Research Infrastructure Modernization (RIM) project, funded by the Council of Agriculture, Taiwan.

The official launch of the “SAFEVEG-West Africa” project funded by the European Union and the Netherlands took place on 5 February in Cotonou, Benin.



Representatives from the World Food Programme (WFP), WorldVeg, school directors, school canteen managers, and mayors from participating communities gathered on 18 February in Cotonou, Benin to launch

“NUTRIFOOD”, a project funded by UK Research and Innovation (UKRI) - Biotech and Biological Sciences Research Council (BBSRC), focusing on promoting nutritious vegetables through education and gardening in schools and communities.

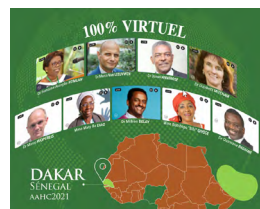


The inception meeting for the “Veggies for Planet and People” project, funded by the IKEA Foundation, was held from 23–24 February in Addis Ababa, Ethiopia.

WorldVeg attended the National Horticulture Fair at the Indian Institute of Horticultural Research (IIHR), Bengaluru from February 7–10, an event that attracted 75,000 in-person participants and in total 1.7 million people.

03 MARCH

On 18 March 2021, WorldVeg and partners organized the SAFEVEG National project planning meeting in Mali.



On 29–31 March 2021, Marco Wopereis and Sognibé N'Danikou S. gave keynote presentations at the 4th All Africa Horticultural Congress, Dakar, Senegal, along further WorldVeg presentations.

04 APRIL



A farmers' field day was organized by WorldVeg and Tomato Jos Farming and Processing Company on 14 April in Kaduna State, Nigeria and funded by FCDO.

Enabling Impact and Healthy Diets Flagship Leader Pepijn Schreinemachers addressed the Second International Congress of Biological Control (ICBC2) held virtually from 26-30 April, highlighting misuse of pesticides in Asia's vegetable sector.

The World Vegetable Center Board of Directors convened their 59th Meeting via videoconference on 28 April.

From 29 to 30 April, WorldVeg Regional Director for West and Central Africa, Victor Afari-Sefa, participated in the AfDB/IFAD sponsored High Level Virtual Dialogue on "Feeding Africa: Leadership To Scale Up Successful Innovations".

05 MAY

The Asia and Pacific Seed Association (APSA)-WorldVeg Vegetable Breeding Consortium Annual Workshop was held virtually on 11 May. A total of 208 participants from 30 companies and WorldVeg met online for discussions and intensive seminars on the Center's breeding work and other research.

On 13 May, WorldVeg co-hosted a UN Food Systems Summit (UNFSS) Independent Dialogue entitled "Should Thailand have a National Vegetable Policy?" with Thailand's Bureau of Foreign Agricultural Affairs (BOFAA) and the Thai Health Promotion Foundation (ThaiHealth). Delphine Larrousse and Jody Harris contributed as speakers and moderators of the national event attended by 270 participants.

A Center-Commissioned External Review on WorldVeg's Research and Development Programs officially started on May 13, chaired by Prof. Rodomiro Ortiz, Professor at the Swedish University of Agricultural Sciences. The Review was conducted entirely virtually and reported to the WorldVeg Board of Directors in their 2021 end-of-year full Board meeting.

06 JUNE

On 21 June, Director General Marco Wopereis addressed a meeting convened by FCDO and other funders and One CGIAR partners on the perspective of a Global Vegetable Research Initiative.

On 28 June, Srinivas Ramasamy, Safe and Sustainable Value Chains Flagship Leader, contributed to the UNFSS Independent Summit Dialogue "Towards Safe Food, Nutritious Diets, and Resilient Food Systems" organized by the Asian Development Bank and the International Fund for Agricultural Development. More than 190 participants from 30 countries joined the event.

07 JULY

On 19 July, 178 accessions of traditional African vegetables collected as part of the CoA/MOFA Taiwan funded "Taiwan-Africa Vegetable Initiative" (TAVI) by the University of Abomey-Calavi (UAC) in Cotonou, Benin were handed over to West and Central Africa Regional Director, Victor Afari-Sefa, by Prof. Enoch Achigan-Dako of UAC.



The 7th Bitter Gourd Open Field Day was held on 30 July at the WorldVeg ESEA Research & Training Station, Kasetsart University Kamphaeng Saen Campus, Thailand.

08 AUGUST

On 9 August, Director General Marco Wopereis gave a keynote presentation on “Vegetable food systems innovations for healthier diets” during the Annual Conference of the American Society for Horticultural Science, Annual Conference, in Denver, USA.

On 19-20 August, WorldVeg conducted a training program on GAP and Pests & Diseases Management for Tomato, Legumes and Brassicas under the BMZ funded Grow Against the Flow project in Cambodia. A total of 53 plant protection practitioners from the National Agricultural Research and Extension System, Academia, Private Sector and NGOs were trained.



09 SEPTEMBER



8 September saw the visit of Her Excellency Catharina Geertuida Maria Tjoelker-Kleve, Ambassador of the Netherlands to Benin to the WorldVeg Regional Office in Benin.

The 2021 Africa Vegetable Breeding Consortium (AVBC) annual workshop was held on 21-22 September online and at the WorldVeg Eastern and Southern Africa campus in Arusha, Tanzania. A total of 40 exclusive lines of African eggplant, amaranth, mungbean, peppers, pumpkin and tomato were shown in demonstration trials.



Under the umbrella of the Association of International Research and Development Centers for Agriculture (AIRCA), WorldVeg staff contributed two position papers to the UN Food Systems Summit held on September 23 in New York: “Fruits and vegetables for healthy diets: priorities for food system research and action”, led by Lead Specialist on food systems, Jody Harris, and “Safeguarding and using fruit and vegetable biodiversity” led by WorldVeg’s Genebank manager, Maarten van Zonneveld.

On 6 October, Director General Marco Wopereis gave a keynote presentation during the 50th Anniversary Symposium of the Food and Fertilizer Technology Center (FFTC) on “Circular Approaches to Transition to Sustainable Agro-food Systems”, held in Taipei, Taiwan.

On 7 October, India’s Honorable Union Minister for Finance Mrs. Nirmala Sitharaman visited WorldVeg-led activities within the framework of the World Bank funded APART project in Assam State. Honorable Chief minister of Assam, Shri Hemanat Biswah Sharmah was also present.

11 NOVEMBER

12 DECEMBER

13 October saw the launch of the CoA/MOFA Taiwan-funded “Taiwan Africa Vegetable Initiative” (TAVI) in Eswatini, attended by 56 participants. The Minister of Agriculture of Eswatini, the Principal Secretary of the Ministry of Education and Training, and the Counselor Minister of the Embassy of Taiwan in Eswatini expressed their support and endorsed the project during the event.



On 21 October, WorldVeg and Crop Trust hosted a virtual side event for the World Food Prize Borlaug International Dialogue titled: “Use it or lose it: A 10-year Global rescue plan for fruit and vegetable biodiversity”.

Tomato breeder Mathieu Ayenan presented improved varieties, tomato grafting and zero energy cooling chambers as technologies ready for upscaling during the West Africa Technology Fair in Dakar, Senegal held on 25-29 October and organized by CORAF and the African Development Bank.

On 4 November, Peter Hanson, WorldVeg Global Plant Breeder and Lead Scientist, received the Most Influential Plant Breeding Researcher (Public Sector) Recognition Award from the Asia and Pacific Seed Association (APSA).

The 2021 Global R&D Week was held virtually on 8-11 November to engage WorldVeg staff from around the globe in planning and team building activities for the coming year.



The Southeast Asia Vegetable Symposium 2021 (SEAVEG 2021) “Vegetables for Resilience and Healthy Diets” was held in Yogyakarta Indonesia from 18-20 November. WorldVeg’s postdoctoral scientist plant pathology, Lourena Arone Maxwell received the Outstanding Oral Presentation Award for her research on seedling methods to screen for biocontrol against bacterial wilt. Director General Marco Wopereis gave a keynote presentation on “Vegetable research matters for Southeast Asia”.

The WorldVeg Board of Directors held its 60th meeting online from 1-2 December.



On 6 December, Marco Wopereis presented on “Moving forward: Fruits and vegetables research and action priorities for sustainable, healthy and equitable development” during a side event organized by the Japan International Research Center for Agricultural Sciences (JIRCAS) for the Nutrition for Growth Summit, Tokyo, Japan.

On 8-9 December, WorldVeg staff (Pepijn Schreinemachers, Delphine Larrousse and Somchit Pruangwitayakun) participated in the “Virtual Regional Consultation on Engaging with Academia and Research Institutions to Support Family Farmers and Food System Transformation during and Post COVID-19 Pandemic in Asia”, in Bangkok, Thailand, and presented on “Home gardens for resilient local food systems”.



The International Conference on “Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21)” was held from 14-16 December at the ICAR-Indian Institute of Vegetable Research (ICAR-IIVR), Varanasi, Uttar Pradesh, India and saw strong participation by WorldVeg staff.



WorldVeg Deputy Director General, Dr. Yann-Rong Lin received the Agricultural Academic Award from the Agricultural Association of Taiwan for her outstanding achievements and contributions to the field of crop genetics and molecular breeding. She was recognized for her work as a food and agriculture research scientist as well as an esteemed educator and lecturer at the prestigious National Taiwan University.



WorldVeg and the UN Food Systems Summit



UNITED NATIONS
FOOD SYSTEMS
SUMMIT 2021

- In 2021, the **United Nations Food Systems Summit** (UNFSS) served as a historic opportunity to empower all people to leverage the power of food systems to drive recovery from the COVID-19 pandemic and launch new actions to achieve all 17 Sustainable Development Goals (SDGs) by 2030.
- WorldVeg contributed to **Action Tracks 1, 2 and 5** to ensure that vegetables were explicitly included in the Summit's 'game-changing' ideas, and synthesized three 'system-level' game-changers:
 - 'valuing vegetables both financially and socially';
 - 'collective action through diversifying food system decision-making'; and
 - 're-shaping agricultural investments to better reflect healthy diets'.



- As Research Partners of the Scientific Group for the Food Systems Summit 2021, WorldVeg in collaboration with other member organizations of the Association of International Research and Development Centers for Agriculture (AIRCA) led the publication of **two research briefs** for the UNFSS:
 - The first brief, entitled ***'Fruits and Vegetables for Healthy Diets: Priorities for Food System Research and Action'***, states that fruits and vegetables are unaffordable for many, with 3 billion people around the world unable to afford diverse healthy diets. The authors propose to address the issue of low fruit and vegetable consumption through a set of 'push', 'pull' and 'policy' actions.
 - The second brief, entitled ***'Safeguarding and Using Fruit and Vegetable Biodiversity'***, warns that declining biodiversity limits options for a sustainable, healthy food supply. The authors propose a 10-year rescue plan for protecting genetic resources and ensuring fruit and vegetables can fulfill their increasingly prominent role in a new global research and development agenda emphasizing nutrition and healthy diets alongside climate action, safeguarding biodiversity, ending poverty, and improving livelihoods.

Both papers will be published as separate chapters in a book entitled 'Science and Innovations for Food Systems Transformation' in 2022 as well as in a special UNFSS issue in the journal Global Food Security, emphasizing the links between biodiversity and dietary diversity.

- WorldVeg contributed to the **UNFSS Independent Summit Dialogue** 'Towards Safe Food, Nutritious Diets, and Resilient Food Systems' organized by the Asian Development Bank (ADB) and the International Fund for Agricultural Development (IFAD), on 28 June 2021. Srin Ramasamy (WorldVeg SSVV Flagship Leader) presented WorldVeg activities in Asia and the Pacific in the session titled "Towards Balanced, Healthy and Nutritious Food". More than 190 participants from 30 countries joined the event.
- In Thailand, WorldVeg worked closely with the Thai Bureau of Foreign Agricultural Affairs (BOFAA) and the Thai Health Promotion Foundation (ThaiHealth) to co-host the UNFSS Independent Dialogue on May 13, 2021 titled ***"Should Thailand have a National Vegetable Policy?"*** attended by 270 participants. Delphine Larrousse, WorldVeg ESEA Regional Director, opened the event with the Deputy Permanent Secretary, Ministry of Agriculture and Cooperatives of Thailand, and Jody Harris, WorldVeg Lead expert, Food Systems, gave a keynote presentation on Vegetable Food Systems for Healthy Diets. WorldVeg continued to contribute to further dialogues in the country, including "Reshaping Thailand's readiness to Encourage Vegetable and Fruit Intake as National Agenda" which culminated in the Thai government announcing that "food security and nutrition and safe and sufficient consumption of fruits and vegetables is a national agenda". The Thai government is now considering putting the issue into the Thirteenth National Economic and Social Development Plan, which is a significant policy move in support of the livelihoods of vegetable producers and the health of the Thai population.



Progress with the RIM project in Taiwan



The **Research Infrastructure Modernization (RIM)** project is a massive infrastructure investment in the Center's headquarters, the first of its scale since the Center's establishment in the 1970s. A vision initially developed in 2016 and gradually shaped into a four-year construction proposal throughout 2017, **RIM** officially came into being in 2018 when a grant of NT\$ 660 million (about US\$ 22 million) was approved by Taiwan's **Executive Yuan** to support its realization.

Progress since 2018 can be summarized as follows:

- **2018:** Hired **EDS International** to design and supervise constructions (SC-340-03), procured high-throughput field phenotyping scanner from **Phenospex** (PO-RIM-2018-01).
- **2019:** Installed the field scanner on Field #35 and enabled research to generate valuable results, contracted with **AD Engineering** for overhauling electric cabling (SC-340-07) and landscape (SC-340-10), contracted with **De-Yuan Construction** for building two controlled-environment greenhouses (SC-340-06).
- **2020:** Completed all construction designs, contracted with **Ding Chuang Construction** for building the new lab (SC-340-11), contracted with **Jien-An Horticulture Facility** for turning the original GMO greenhouse into a shared space (SC-340-12) among many minor works for the screenhouses.



- 2021: Completed and accepted most works, continued with new lab construction, and contracted with **Zheng-Zung Civil Engineering** for repairing farm road in the greenhouse area (SC-340-20), contracted with **Feng-Ming Civil Engineering** for building a warehouse (SC-340-21).

The outbreak of COVID-19 in 2020 has impacted many industries on a global scale. The Center's modernization construction also suffered from lack of labor and rising costs, the combination of which pushed back the overall schedule and rendered the original budget insufficient.

Therefore, with the help of Council of Agriculture, the Center submitted a request of project change to the Taiwan Executive Yuan. This request was approved, and the RIM Project was extended by two years until December 31, 2023 with an additional NT\$142 million (about US\$5.1 million).



Veggies 4 Planet & People (V4P&P)

DONOR	IKEA Foundation
BUDGET	€ 6 million
DURATION	5 years, 1 Jul 2020 – 30 Jun 2025
PROJECT LOCATIONS	Ethiopia and Kenya
PROJECT MANAGER	Ralph Roothaert

Poverty rates in Ethiopia and Kenya remain high despite their impressive economic growth in recent years. A quarter of the Ethiopian population and a third of the Kenyan live below national poverty lines. High unemployment rates and low incomes in the rural areas have stimulated rural-urban migration, especially among youth. Mean levels of vegetable consumption in sub-Saharan Africa are the lowest of any region in the world.



Enabling Vegetable Business Development in East Africa

How does the project address the problem?

The project contributes to enhanced youth employment, healthier ecosystems, and better nutrition through increased vegetable production and trade using the following approach:

- Enabling young people to produce and sell a diverse range of vegetables, particularly traditional African vegetables in effective value chains. The project trains, builds capacity, mentors and links youth to service providers such as finance, input suppliers and traders.
- Establishing Vegetable Business Networks (VBNs) with existing- or newly established groups to link farmers to consumers through vegetable traders built on stable business relationships aimed at quality and fairness. The role of women and youth in VBNs is being particularly promoted.
- Sustaining VBNs through mentoring and coaching, support in marketing, and linking them to similar youth platforms for mutual learning and support.
- Introducing improved/new regenerative production technologies to restore, maintain or improve the health of the soil, reduce production costs, reduce postharvest losses, and enhance product quality.
- Promoting the consumption of vegetables among consumers and promoting the program to policy makers and other stakeholders to increase visibility and widen support and allow replication of the model.



Local production of safe vegetables for West African consumers

SAFEVEG

DONOR	European Commission and (EC) Netherland Directorate General for International Cooperation (DGIS)
BUDGET	EC: € 7,8M and DGIS: € 4,0M (total of € 11,8 M)
DURATION	November 2020 - 2025
PROJECT LOCATIONS	Benin, Burkina Faso and Mali
PROJECT MANAGER	Edmond Totin
PARTNERS	CIRAD (France), University of Wageningen (Netherlands)

In West Africa, there is a growing urban demand for safe and high-quality vegetables. Still, the vegetable systems face serious challenges, including low productivity due to poor quality seed systems, post-harvest losses, relatively limited investments in storage and processing facilities, inadequate market infrastructure and climate challenges. SAFEVEG aims to promote innovative approaches and generate evidence-based information for increased vegetable production and consumption. In addition, it will enable increased use of sustainable agricultural and post-harvest practices, strengthen vegetable businesses networks and the capacity of national agricultural research systems in Benin, Burkina Faso, and Mali.

How does the project address the problem?

- SAFEVEG assumes that developing a competitive vegetable sector requires both supply and demand interventions. Therefore, the project uses a market-oriented approach - vegetable business networks - to channel innovations that increase vegetable production in West Africa. Its business model offers new opportunities to transform the livelihoods of youth and women.
- SAFEVEG is stimulating the supply of quality seed, a major barrier to vegetable production in West Africa. In addition, the approach creates conditions for vegetables to be more accessible, affordable and acceptable to consumers. The SAFEVEG actions will strengthen vegetable business networks (VBNs) through coaching and capacity building on the market side. This will connect farmers to consumers and reduce post-harvest losses through greatly improved synergies between supply and demand.
- On the policy side, SAFEVEG will mainstream an equity approach that promotes an effective engagement of different social groups, mainly youth and women, in vegetable production, processing and trade. The project activities will also generate information about the opportunities and challenges in the vegetable sector and generate evidence for the impact of vegetable interventions.

Taiwan-Africa Vegetable Initiative

TAVI

DONOR	Taiwan Council of Agriculture and the Ministry of Foreign Affairs
BUDGET	TWD 195 million
DURATION	3 years, January 2021 - December 2023
PROJECT LOCATIONS	Eswatini, Tanzania, Benin, Madagascar
PROJECT MANAGER	Maarten van Zonneveld
PARTNERS	Ministry of Agriculture (Eswatini), National Plant Genetic Resources Center (Tanzania), FOFIFA and University of Antananarivo (Madagascar), and University of Abomey Calavi (Benin)

Sub-Saharan Africa faces a “triple burden” of malnutrition with 30% of children under 5 being stunted, 49% of women of reproductive age suffering from anemia, and overweight and obesity affecting 28% of adults. At the same time, climate change and a rapidly growing young population challenge governments across the region to meet the nutritional needs of their populations. Nutrient-dense African vegetables can make an important contribution to diversifying the food system with climate-resilient and nutritious food products. However, access to these vegetables is limited because of lack of awareness of their nutritional benefits, and sub-optimal seed supply and vegetable production technologies.

How does the project address the problem?

- TAVI aims to stimulate supply and demand of African vegetables to create strong and resilient foundations for healthy and sustainable food systems in the region.
- In Eswatini TAVI supports the National School Feeding Program (NSFP) to improve child and household nutrition. This includes the establishment of school and home gardens to promote vegetable consumption among school children and their families.
- TAVI connects champion farmers to schools to supply nutrient-dense African vegetables for nutritious and diverse school meals. These champion farmers have traditionally maintained African vegetables and thus are forerunners in the supply of these vegetables.
- TAVI will rescue genetic resources of African vegetables through germplasm collection of at least 4,800 landraces and crop wild relatives from 25 species in four hotspots of vegetable biodiversity in Africa: Eswatini, Tanzania, Benin, and Madagascar. Targeted vegetables include vegetable amaranth, African eggplant, roselle, jute mallow, Ethiopian mustard, okra, and spider plant.
- To safeguard the seed accessions and make them available for breeding, TAVI is upgrading the genebanks of Eswatini’s National Plant Genetic Resources Centre (NPGRC) and WorldVeg’s Regional Office for Eastern and Southern Africa in Tanzania.



A TREASURE TROVE FOR DIVERSE DIETS AND A HEALTHY PLANET



African vegetable biodiversity presents an opportunity to improve people's diets with nutritious and tasty food plants that are adapted to harsh climate conditions and connected to people's roots. This biocultural heritage, however, is underutilized and threatened. WorldVeg scientists and partners identified 422 African vegetables and six hotspots of vegetable biodiversity in sub-Saharan Africa: West Tropical Africa in Ghana, Togo and Benin; Cameroon, Ethiopia, Tanzania, Madagascar, and Eswatini. The diversity of the majority of these vegetables is poorly conserved in genebanks while many vegetable landraces and wild relatives are under threat of extinction because of changing diets, land-use change, climate change, among other pressures.

With support of the Taiwan Africa Vegetable Initiative (TAVI) and the UK Darwin Initiative, WorldVeg accelerated the rescue, conservation, and use of African vegetable biodiversity in collaboration with key partners in four of the six hotspots: the Ministry of Agriculture in Eswatini, the National Plant Genetic Resources Center of Tanzania, the National Center of Applied Research and Rural Development (FOFIFA) and the University of Antananarivo in Madagascar, and the University of Abomey-Calavi in Benin.

In 2021, these organizations visited farmer communities across their countries and collected seed of 3,600 vegetable landraces and wild relatives in line with national biodiversity laws. This is part of a larger aim to rescue by 2025 at least 15,000 threatened landraces and wild relatives of 25 African vegetables across sub-Saharan Africa (SSA) with high potential for nutrition and income generation. Research teams in Benin and Madagascar also documented traditional knowledge of the people who cultivate and harvest these vegetables to learn best ways to grow and prepare these foods and rescue this knowledge before it disappears.

To properly store the seed of the rescued landraces and wild relatives for current and future generations in SSA and globally, construction plans have been made to upgrade the regional vegetable genebank of WorldVeg in the Eastern and Southern Africa office in Tanzania and to convert the National Plant Genetic Resources Centre of Eswatini into a regional center for vegetable germplasm conservation and use in Southern Africa. Construction starts in 2022 with support of TAVI.

Seed samples that are already safeguarded in the Worldveg genebank in Tanzania are characterized and evaluated to select promising materials for breeding programs and home and school gardens in SSA countries. In 2021, 352 accessions of amaranth and jute mallow were agronomically characterized to select promising materials, and 14,273 seed kits with 163,653 seed samples were sent to Eswatini, Benin, Botswana, Djibouti, Ghana, Kenya, Madagascar, Mali, Senegal, and Tanzania for school and home garden establishment and citizen science with farmers.

In Madagascar, FOFIFA used these seed kits and local varieties to successfully establish biodiversity-rich school gardens in eight primary schools to teach children and their families about the relevance of African vegetables for diets, identity, and biodiversity. The World Food Programme (WFP) and the Food and Agriculture Organization (FAO) endorsed this approach during the first national school garden workshop held in Madagascar, and that was organized by FOFIFA and WorldVeg in November 2021. Already two NGOs and three local governments are interested in using the seed rescued in Madagascar to establish biodiversity-rich gardens in other schools.

FOFIFA and WorldVeg are working with the Ministries of Education and Agriculture to engage with more NGOs and local governments that are interested in adopting this approach and access seed.

In Eswatini, WorldVeg and the Ministries of Education and Agriculture are now taking up the lessons learned from Madagascar and other school garden projects. So far, eight primary schools have been selected to pilot a farm-to-school program where champion farmers supply these schools with fresh produce to improve child nutrition. To date, 120 extension officers of the Ministry of Agriculture and local NGOs strengthened their capacity to support these champion farmers and schools, and 3,000 rural households in production and processing of African vegetables.

These activities do not stand alone. The Power on your Plate All-Africa Summit, organized by WorldVeg in Tanzania in January 2021, connected researchers, practitioners, and policy makers who all care about mainstreaming African vegetables for people and planet. More than 100 persons from 14 African countries participated in the first TAVI vegetable genetic resource course held online in November 2021. These events nurture a Pan-African movement to rescue, conserve, and use African vegetable biodiversity.

The World's largest public Vegetable Genebank

Safety back-up. Seed samples of a total of 11,771 germplasm accessions were sent for long-term back up to the Svalbard Global Seed Vault, 10,590 safety duplicates were prepared for shipment to the RDA-Korea genebank. In addition, seed samples of 1,608 accessions have been deposited at the genebank of the Taiwan Agricultural Research Institute.





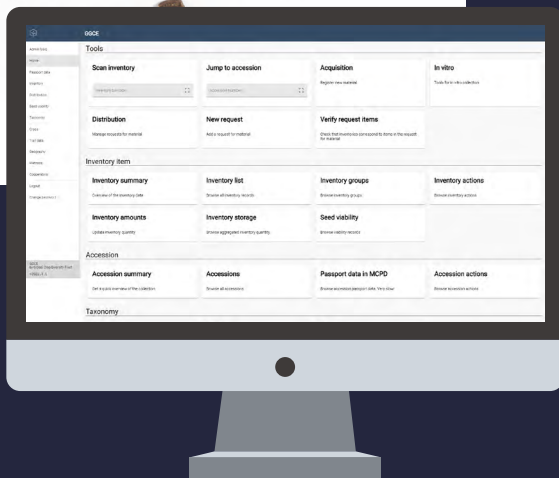
Germplasm regeneration. In total, 2,649 accessions have been successfully regenerated by the WorldVeg genebank teams in Taiwan and Tanzania, seed companies, and WorldVeg breeding programs.

Capacity building. The 1st pan-African vegetable genetic resources course was organized with 101 participants from 14 African countries and Taiwan with support of the Taiwan-Africa Vegetable Initiative.

A global conservation strategy for crops in the Cucurbitaceae family has been published (<https://worldveg.tind.io/record/74399/>). This strategy was led by the Global Crop Diversity Trust in collaboration with WorldVeg and others.

Monitoring. A dashboard has been established in the genebank in Taiwan to track real-time temperature and relative humidity in the cold and drying chambers, and the genebank seed lab.

Information. A new germplasm information system, Grin-Global Community Extension, has been implemented with support of the Crop Trust (genebank.worldveg.org). This system allows to provide better service to seed requesters, improves the genebank's seed inventory, and streamlines genebank operations in Taiwan and Tanzania under one system.





COVID-19 IMPACTS ON HEALTHY DIETS IN ASIA

The COVID-19 pandemic amplified existing nutrition challenges especially among marginalized groups. Healthy diets based on diverse plant-based foods are already inaccessible for 3 billion people globally, and shocks such as COVID-19 exacerbate this problem. This study asked: what were the consequences for healthy diets through policy, economic and social lenses?

In the ASEAN region, food systems in different countries have been affected very differently by the pandemic, and governments have made different decisions on how to support populations to eat healthily. With support from Taiwan's Ministry of Foreign Affairs, WorldVeg ESEA researchers examined the effect of COVID-19 on healthy diets at different levels of the food system in Thailand and the Philippines. These two ASEAN countries had different rates of COVID-19 infection, different socio-political contexts, and different policy responses to the pandemic; but both had poor rates of vegetable consumption even before the pandemic.

Using policy review and in-depth interviews with policy actors, researchers in this first study mapped new or adapted policies during the pandemic in each country, finding that policy to mitigate the impacts of the virus and of government 'lockdown' policies on food were in three main categories: Keeping food flowing, such as through dispensations on transport, shop opening and flow of goods; stimulating the economy broadly, including through national tourism or international loans; and most policy by far was in the area of social protection, largely through either extensions to existing social protection systems, or one-off or multiple cash grants to specific

groups. Crucially, written food policy didn't change as a response to Covid; what changed was short-term legislation addressing specific parts of the food system, in response to local perception of need.

Focusing on Bangkok and Manila, the second study looked at food prices, and modeled how common reductions in income would affect people's ability to buy the diet recommended by each government's dietary guidelines. Food price data from each country show that the initial lockdown had no effect on the price of vegetables in Bangkok, and the overall cost of the recommended diet declined a little, by 3%; while in Manila, COVID-19 resulted in a slight increase in the cost of vegetables and fruit of 7%; but the overall cost of the recommended diet did not change. So, the cost of food was not hugely affected by Covid in these cities; what was affected was people's ability to afford it. In our findings, almost all households in Bangkok could, in principle, meet the minimum cost of the recommended diet before the COVID-19 pandemic, but 40% in Manila already could not, amounting to 5.4 million people when extrapolated to the whole of Manila. As formal unemployment jumped in both countries, and informal workers were hit hard by lockdowns (using an estimated 20% contraction of the household food budget), the minimum cost could not be met by 14% of the sample in Bangkok (2.3 million people if extrapolated to the whole city population); and an additional 15% of people in Manila (almost 2 million additional people). Some people lost more than 20% of their income through Covid, so these are conservative estimates. With the government relief funds provided during COVID-19, the minimum cost of the recommended diet would, in principle, be affordable to almost everyone in Bangkok, assuming that the relief funds were spent evenly over the year and other costs did not increase. In Manila, the population unable to afford the minimum cost during COVID-19 would reduce by only 5%. So, affordability of diets was a key issue in both cities, but in Manila, the social security provided by the government did not go far enough to protect recommended diets.

The third study spoke to people sampled from population groups known to be marginalized in Philippines or Thailand societies: groups such as migrant workers, those living in slum areas, and informal food system workers. This is work in progress, but initial themes coming out included strong feelings of uncertainty and anxiety; cramped households and burdens of caring responsibilities and illness, but opportunities for mutual support through shared wages; limited incomes and lost jobs, and the importance of social protection but also its limits; physical food access restrictions of lockdown alongside reduced affordability; changes in habits such as choosing longer-life rather than fresh products, and more home cooking but often only one meal per day; and stories of community sharing and adapting. Some very powerful stories of COVID-19 disruption to healthy diets, and how people coped, which we are now analyzing in-depth.

COVID-19 was not the first shock to food systems and healthy diets, and it will not be the last. The learning from this set of studies can inform policy and practice to mitigate the effects of future shocks on healthy diets, and point to ways to create more resilient food systems. These include the importance of social protection measures in maintaining healthy diets through food system shocks; the importance of understanding and addressing the needs of the most marginalized populations; and the need to consider and plan for food system shocks even in the good times.



East and Southeast Asia

Thailand

- The **Global Cucurbit Breeding program** is based at ESEA research station in Kamphaeng Saen, Thailand hosted by Kasetsart University with funding from the private seed sector, MAFF Japan and RDA Korea. It conducts multi-location trials in virus hotspots in Thailand, India, Myanmar, and Vietnam.
- Promising **bitter melon** selections in S5 generation of recurrent selection program were identified and advanced to S6 generation through inbreeding (controlled hand pollination), for next seasons' evaluation through plant to progeny row plots.
- 30 WorldVeg F1 hybrids of **pumpkin** were selected in Observational Yield Trials (OYT) based on fruit yield, flesh thickness, high beta-carotene content, and resistance to begomoviruses and data were shared with the stakeholders.
- WorldVeg **pumpkin** line AVBG1426 resistant to multiple viruses was released and the data published in peer-reviewed SCI indexed international journal.
- 240 **Luffa** breeding lines were evaluated and 188 selections for begomovirus and downy mildew resistance completed and selected resistant plants advanced to next generation (S5) through inbreeding (controlled hand pollination).
- WorldVeg evaluated the potential of entomopathogenic nematodes and biopesticides against **brassica** flea beetles (*Phyllotreta striolata* and *P. chotanica*) on choy sum in hot, wet and dry seasons in Thailand.
- A study published in the journal Agricultural Systems compared 25 countries in Asia in terms of response and resilience of agrifood systems to the **COVID-19 pandemic**. WorldVeg and Kasetsart University worked together to conduct the Thailand component of this study. Overall, the study concluded that Asian farming and food systems were quite resilient during the COVID-19 pandemic. Irrigated wheat-based systems were most strongly affected by the pandemic while hill mixed systems showed to be the most resilient.

Thailand and the Philippines

- A project aiming to understand the **effects of COVID-19** on healthy diets in Thailand and the Philippines has assessed changes in food policy and in the cost and affordability of healthy diets, and has been funded for a second year by the Taiwanese Government to understand community perspectives on the impact of the pandemic (see pages 20-21).

Vietnam and Bangladesh

- A study was conducted on the **food safety** situation in the fruit and vegetable value chains in Hanoi, Vietnam and Dhaka, Bangladesh. Commissioned by the Asian Development Bank, it identified key food safety challenges as well as entry points for improvement.



Myanmar

- WorldVeg cooperated with the Plant Protection Division, Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Myanmar to study the occurrence of South American Tomato Leaf Miner, *Tuta absoluta* in Southern Shan State.
- WorldVeg **bitter gourd** lines AVBG1301 and AVBG1304 and WorldVeg **pumpkin** line AVPU1502 were released and registered with National Seed Corporation, Myanmar by the Department of Agricultural Research, Myanmar under the name Yezin Bitter gourd – 1, Yezin Bitter gourd – 2, and Yezin Pumpkin – 1, respectively.

Cambodia

- In 2021, WorldVeg and its partners promoted the adoption of **off-season technologies** (seed, protected cultivation, integrated pest management and water-saving technologies) through training and on-farm demonstrations reaching at least 15,750 smallholder farmers. This work is conducted as part of the project “Grow Against the Flow: Scaling off-season vegetable innovations to improve incomes and nutrition in Cambodia and Lao PDR”, funded by BMZ Germany.
- WorldVeg completed the implementation of the Angkor SALAD project and launched an Application for Geo Data for Water and Agriculture together with local partners. **The Angkor SALAD App** includes: irrigation advice, fertilizer advice, crop planning advice, market information, and Khmer GAP compliance.
- Analysis of data obtained from a cluster randomized control trial was done in Cambodia to test the hypothesis that **text messages**, either used as a stand-alone method or combined with demonstrations and training, can help to promote the use of IPM practices among vegetable farmers. The results show that text messages or demonstrations and training alone did not affect IPM adoption, but when combined, they increased IPM adoption by 20%. However, this combination increased the number of pesticide sprays by 23%. This suggests that text messages can reinforce demonstrations and training, but not substitute for them.

Korea

- Hosted and supported by RDA Korea, WorldVeg Korea Office (WKO) conducted regional adaptability evaluation of 20 accessions of WorldVeg germplasm (**tomato** 5 lines, **pepper** 15 lines).
- WKO conducted training to 13 **AFACI** member countries (Bangladesh, Bhutan, Cambodia, Indonesia, Kyrgyz Republic, Laos, Mongolia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand, Vietnam) in **pepper and tomato** breeding technology, mostly implemented virtually due to COVID.



East and Southeast Asia

- Through the KoRAA project (Korea RDA Alumni Association), WKO provided training to Asian countries in vegetable production with a focus on demonstrating **smart farms** from Korea (46 participants from 9 countries in 2021 – Bhutan, Indonesia, Laos, Mongolia, Pakistan, The Philippines, Sri Lanka, Thailand, Vietnam).

Regional initiatives

- Feedback data collected from 34 consortium members in Asia showed that 86 varieties of **tomato, pepper, pumpkin and bitter gourd** sold by seed companies were developed from WorldVeg breeding lines. The report estimated that consortium members sold 24.7 tons of seed of WorldVeg-related varieties in 2020 -- enough to plant 171,000 hectares and benefit 490,500 smallholder farmers. Tomato and chili pepper contribute to most of the impact while the impact of bitter gourd is rapidly increasing as 13 seed companies are currently using WorldVeg bitter gourd lines and hybrids in their breeding programs.
- The APSA-WorldVeg Vegetable Breeding Consortium had **38 seed company members** in 2021, slightly down from 44 members in 2020. The reduction in membership is likely because of the COVID-19 pandemic.
- 7 new powdery mildew and begomovirus resistant **bittergourd** F1 hybrids were released to APSA-WorldVeg Consortium members and 5 begomovirus resistant **pumpkin** F1 hybrids were released to Africa Vegetable Breeding Consortium (AVBC) members.
- An **online home garden toolbox** was launched in June 2021 (<https://toolbox.avrdc.org/>). The toolbox contains facilitator guides and crop growing guides using participatory hands-on learning methods tailored to home gardeners in low- and middle-income countries (pages 54-55).





BITTER GOURDS IN THE AIR

The “Jharkhand Opportunities for Harnessing Rural Growth” Project (JOHAR) is a World Bank funded and dedicated livelihood intensive project being implemented in Jharkhand by the Jharkhand State Livelihood Promotion Society (JSLPS) under the aegis of the Department of Rural Development, Government of Jharkhand, India. The Project strives to enhance and diversify household incomes through high-value agriculture for targeted beneficiaries by leveraging the competitive advantage of the local climate and by bringing a systematic approach to diversification, high-productivity production systems, increasing linkages to higher-value markets, and promoting rural entrepreneurship. Since April 2018 WorldVeg has been an active Technical Support Agency in the project.

During 2018 and 2019, WorldVeg had prepared Package of Practices (POP) of main crops of Jharkhand and provided it to our partners. Demonstration plots were established in villages with the farmers interested in following the POP of crops. Training of Trainers (ToT) is conducted at three crop stages (before sowing/transplanting, 30 days after sowing/transplanting and 60 days after sowing/transplanting). Half day classroom training is followed by practical training cum exposure visit to WorldVeg demonstration plots. WorldVeg field staff provide training and technical advice to the farmers about Good Agricultural Practices like use of compost, importance of soilless seedlings, proper spacing of crops, crop specific fertilizer dose and time of application of these fertilizers, foliar spray of micronutrients, staking in tomato, trellising of cucurbits, and safety measures while using pesticides.

Smt Yashoda Devi, who is from Changani village, Bero block in Jharkhand, is a hardworking and dedicated farmer. She and her husband have been cultivating vegetables for many years. During May 2020, Smt Yashoda was one of the participants in the training conducted by the WorldVeg team on the benefits of vertical trellising and on the WorldVeg POP guidelines. After the training, she was very excited to put the techniques into use on her farm.

Smt Yashoda decided to cultivate bitter melon as per WorldVeg POP during the rainy season (transplanting during June) in 2021. This would fetch good returns by cultivating crops in the off season. She knew that the price of bitter melon would increase by a lot during the off season. Before that she used to cultivate few plants in her home garden by erecting them individually on dried bushes of other plants or sometimes letting them to trail on the ground. In her village, farmers used to grow bitter melon during the spring season (main season- march sowing/transplanting) and they let the plants trail on the ground only.

Recommended nutrient management included use of compost, and foliar spray of secondary nutrients (Ca and Mg) and micronutrients (Fe, Zn and B). Integrated Pest Management (IPM) included use of sticky traps for the management of sucking pests and pheromone traps for the management of fruit fly. Prophylactic spray schedules with safe pesticides were provided for disease and pest management. Smt Yashoda was not aware of use of soilless seedling, importance of spacing of crop (90 x 45 cm), weed control at regular intervals, irrigation provided based on the soil moisture estimation and on vertical trellising. With proper spacing and by following correct IPM and nutrient management, her bitter melon crop started performing well. Passer-bys were stunned to see the fruits dangling in the air, rather than lying on the ground. Smt obtained approximately 450 kg/0.04 ha (30% increase) with a net profit of USD 520/0.04 ha.

Smt Yashoda is now determined to use trellises for the bitter melon vines. This same methodology was adopted in Charima village of Bero block by farmer Mr. Biseswar Minz. He is a true motivator among his fellow farmers and is helping to spread the message to other areas. During 2021, training was provided to 4130 farmers (2272 women and 1858 men) covering 41 blocks in 14 districts. There is huge potential to replicate vertical trellising of bitter melon cultivation in other states like Odisha, Bihar and Chhattisgarh.



South and Central Asia

- **APART Project:** Open pollinated (OP) **tomato** line AVTO1424 showed higher resistance to bacterial wilt, late blight and heat in the hot-wet season in Assam, India. Similarly, **pumpkin** line AVPU1391 performed better in Assam conditions. **Minimum tillage** was successfully demonstrated in six selected districts under the supervision of respective Krishi Vijyan Kendras at Khumtai, Nalbari, Nagaon, Kokrajhar, Jorhat and Cachar, at three farmers' fields in each district. Positive economic gains were obtained in all locations (except in Kokrajhar) ranging from 2.11 to 3.86 Indian rupees for every rupee invested using minimum tillage, whereas this was only 1.81 to 3.47 rupees following traditional practice. The number of irrigations with minimum tillage was on average only 2.7 as compared to traditional practice. Production cost with minimum tillage was reduced along with higher yield and extended growth duration. During 2021, training was provided on Climate Resilient Technologies - 3914 (2524 men and 1390 women), Integrated Pest Management – 197 (139 men and 58 women), Minimum tillage – 211 (152 men and 59 Women), Rain shelter – 6 (4 men and 2 women), OP Seed production – 324 (213 men and 111 women) and Nursery – 50 (41 men and 9 women).
- **JOHAR Project:** Crop demonstrations were conducted during the spring season for **bitter melon, watermelon and muskmelon**. Benefit to Cost ratio (B:C) was highest (2.0) for watermelon. During *kharif* season demonstrations of chilli, brinjal, tomato, okra, cabbage, cauliflower, cucumber and bitter melon were taken up in five districts of Jharkhand, India. Highest B:C ratio (3.6) was found for cucumber. In the *rabi* season, 33 demonstration plots were conducted for cabbage, pea and broccoli. In the spring season, **intercropping** of cowpea with bitter melon (B:C ratio 1.5) and in *kharif* season bitter melon intercropped with radish (B:C ratio 1.8) and bitter melon with cauliflower (B:C ratio 2.26) were particularly promising. Training on vegetable grafting was imparted to nursery entrepreneurs, involving 83 men and 82 women participants. In 2021, training on GAP was provided to **4130 farmers (2272 women and 1858 men)** covering 41 blocks in 14 districts.
- **Onion value chain improvement project in Odisha state:** Introduction of **climate smart GAP and IPM packages** increased the yield of onion varieties by a factor 2.5 to 2.7 as compared to average yield in the state (i.e. about 11 t/ha). Forty demonstrations for improved onion storage technologies were conducted for dry winter season onions in India. The beneficiary farmers were able to store onions for 3-4 months, and then sell the stored onions @ ₹35-50/kg (4-5 times higher) compared to ₹6-10/kg during the main season and storage losses reduced to 5-7% from 25-35%. In addition, 11 existing onion storage structures were upgraded and 3 new storage structures were installed. The state government is currently **scaling out 540 onion storage structures** across the state.



- In 2021, 36 training programs on **nursery management, GAP and IPM** were conducted for **985 participants** (692 men and 293 women); 28 training/ demonstration events for harvesting, curing, sorting, and grading of onions were conducted for 210 farmers (109 men and 101 women) and 16 exposure visits to WorldVeg demonstrations were conducted for 161 farmers (121 men and 40 women) across the project locations.
- **Odisha Livelihood Mission Project (OLM):** Three low cost **solar dryers** were installed and 10 training/ demonstrations were conducted for 188 farmers (82 men and 106 women) across the project locations. To create awareness among the farmers, 12 training/demonstration events on GHPs (harvesting, sorting, grading and packing) of different vegetables were organized for 80 farmers (38 men and 42 women) across the project locations. In addition, 74 training/demonstration programs on soil-less nursery, easy planter, GAPs, IPM, mulching were conducted for **1041 participants (628 men and 413 women)** across the project areas.

International Mungbean Improvement Network (IMIN2):

- Thirteen mungbean accessions including VI003534 BG, VI004743 AG, VI003493 BG, VI002529 B-BL, V VI004045 A-DGM, VI003337 BR from 42 mini-core collection showed **resistance to anthracnose** under natural disease pressure in India. In addition, five mungbean accessions (VI003534 BG, VI005022 BG, VI003882 A-BLM, VI001403 BR, and VI003470 BG) showed **resistance to powdery mildew** in India.
- Selected mini-core collection (155) and improved lines (72) lines were screened for **thrips resistance** at two different locations: Hyderabad and Punjab during Spring, 2021. In Hyderabad location, 10 accessions (VI000736 AG, VI001124 AG, VI001221 AG, VI001244 AG, VI001535 BG, VI002647 AG, VI003534 BG, VI003925 B-BLM, VI003954 BG, VI004954 BG) showed resistance to both seedling and flower thrips; while, only one accession (VI001268 BG) showed resistance to both seedling and flower thrips in Punjab.
- Among selected 110 mini-core accessions, 30 accessions showed **resistance to cowpea aphids** during the *Kharif* season, 2021. Out of 30 accessions, 10 (VI000736 AG, VI001124 AG, VI001221 AG, VI001244 AG, VI001535 BG, VI002647 AG, VI003534 BG, VI003925 B-BLM, VI003954 BG, VI004954 BG) accessions consistently showed resistance response against cowpea aphid incidence for three years (2017,2020,2021).
- Field characterization of the WorldVeg **Horse gram core collection** (300 accessions) (October sown) was conducted at Hyderabad as part of the Department of Biotechnology, Government of India project.



POWER ON YOUR PLATE SUMMIT

The International Year of Fruits and Vegetables (IYFV 2021) started off with a bang through the first All Africa 'Power on Your Plate Summit' dedicated to traditional African vegetables (TAVs). The event was held in the week of January 25 in Arusha, Tanzania. The topic was thoroughly explored with 64 scientific presentations covering six subject areas. There were about 175 in-person participants in Arusha; 312 registered online participants, and another 200 people following activities through the WHOVA conference app. More than 10,000 people viewed the Summit during the live Facebook feed. All Summit presentations, including the panel discussions and our Board Chair's closing remarks, are available on the Power on Your Plate YouTube channel.

The main 10 takeaways from the "Power on Your Plate Summit"

1. Consumption of TAVs is on the decline on the African continent because of changing diets towards more processed and westernized foods.
2. TAV diversity is threatened because of diet homogenization, food production homogenization and urban migration. There is an urgent need to conserve and document vegetable land races, their wild relatives and traditional knowledge of these vegetables before they are lost.
3. TAVs are generally very rich in micronutrients and sturdier than global 'exotic' vegetables and are an affordable way to meet the micronutrient needs of a rapidly growing African population.
4. TAVs can provide significant opportunities to create employment and income in particular for women and youth, diversify diets, and diversify farming systems thereby contributing to increased resilience to climate change.



5. To realize the potential of TAVs in Africa, there is a need to work simultaneously on the '3 Ps' of TAVs: pulling demand for TAVs, pushing supply of TAVs, and providing enabling policy and governance for TAVs.
6. On the push (or supply) side, innovative approaches are needed to expand availability and affordability of TAVs. This will involve strengthening of formal and informal seed systems and introduction of 'green' agricultural practices to guarantee food safety, diversify the TAV species that are grown and marketed, raise yields and extend growing seasons in a sustainable manner. There is also scope to reduce post-harvest losses by introducing processing technology, shorter supply chains and appropriate market storage space for vegetable vendors.
7. On the pull (or demand) side, innovative approaches are needed to stimulate the acceptability and accessibility of TAVs as part of healthy foods. Establishment of trust and traceability relationships and short connection lines between producers and consumers can address food safety concerns. Information campaigns can raise interest in traditional vegetables. Such campaigns must emphasize taste, cultural value and ease of preparation besides nutritional, health and environmental benefits.
8. On the policy (or governance) side, promotion of TAVs must occur within local, national and regional initiatives to reduce malnutrition and create employment opportunities, and ensure crucial buy-in from policy- and decision-makers. Government policies supporting public procurement of TAVs for school feeding programs and other public food programs are expected not only to raise demand, but also to address several of the sustainable development goals at once, including SGDs 1, 2, 3, 13 and 15 among others.
9. The enormous diversity of TAVs offers farmers and processors great market opportunities. There is a need to identify 'local favorites' that best fit local agro-ecosystems and diets.
10. A far greater proportion of national, regional and global R&D efforts must be dedicated to nutritious food, and in particular TAVs.



Eastern and Southern Africa

Kenya, Ethiopia

- A total of 129 **Vegetable Business Networks (VBN)** were identified and engaged in the V4P&P project. A total of 96 business coaches were trained on regenerative agriculture and business skills. A total of 1640 VBN members (829 in Ethiopia and 811 in Kenya) and 23 non-VBN members were fully trained, with 41% of those trained in Ethiopia and 29% of those in Kenya being young people.
- **Baseline studies** were conducted using formal questionnaires involving 404 households in Kenya and 430 households in Ethiopia; a specific study focusing on establishing a baseline on soil health was conducted in Ethiopia (soil samples were collected from 72 households) and in Kenya (155 households).
- Curricula and materials were developed for **training of trainers events** focusing on: production systems, climatic niches, vegetable varieties, regenerative agriculture, seed production, soil management, crop establishment, water management, post-harvest management, business skills, value chain development, gender tools, and farm economics.
- Both countries used **learning sites and demonstration sites** to carry out the training activities. A total of 81 learning sites (31 in Ethiopia, 50 in Kenya) and 3 demonstration sites (2 in Ethiopia, 1 in Kenya) were established. Learning sites were used to provide practical training to VBN members while the demonstration sites were used to showcase different crop varieties and cutting edge horticultural technologies. Seed used for the training activities were imported to Ethiopia from WorldVeg Tanzania, and sourced locally from seed companies in Kenya.
- The **Greener Greens** project leverages on the main vegetable producing regions in Central Kenya, which have multiple marketing channels targeting Nairobi markets. The entry point of the project's interventions is through Vegetable Business Networks (VBNs) who will be trained on agroecological approaches as well as linked with stakeholders in the food system to ensure adoption and consistency in implementing these approaches.

Tanzania

- A new germplasm information system, **Grin Global Community Extension**, has been installed with support of the Crop Trust to integrate and streamline WorldVeg genebank operations in Tanzania and Taiwan.
- As part of the TAVI project, preparations have started to **modernize the WorldVeg genebank in Tanzania** following international standards. Construction is expected to be completed in 2022.
- 867 seed samples from 30 genera and 3 regions were collected by National Plant Genetic Resource Center in Tanzania (NPGRC).
- 654 genebank accessions were regenerated while 352 accessions were characterized. This includes the whole amaranth collection (265 accessions) of the **Tropical Agricultural Research and Education Center (CATIE)** in Costa Rica to assist CATIE and for further research and evaluation at the ESA station.



- 2,135 new accessions (eggplant, Jute mallow, okra, amaranth, cowpea, bottle gourd, pumpkin, tomato, African nightshade, and pepper) were acquired from Benin, Cameroon, Costa Rica and Taiwan.
- Nearly 900 accessions were collected in Tanzania by NPGRC in collaboration with WorldVeg.
- 34 unique lines and 115 unique accessions were distributed for research purposes in Tanzania, Kenya, Benin, Mali, Botswana, Djibouti, Ghana and Senegal.
- **15,210 seed kits** were distributed in Tanzania, Eswatini, Benin and Madagascar.
- 109 F5 segregating African eggplant lines obtained from different populations were evaluated. Single plants were selected for generation advance. Five promising African eggplant from 27 entries were retained for further evaluation of horticultural traits.
- 96 F7 segregating amaranth lines were evaluated for desirable agronomic and horticultural traits. 39 F1 hybrid amaranth lines from one population were evaluated for seed yield and other traits of interest. Of these, 15 lines with desirable traits were retained for generation advance for OPVs development. In addition, nine amaranth entries were evaluated for heat tolerance.
- Three amaranth lines were submitted to **Tanzania Official Seed Certification Institute (TOSCI)** for Distinctiveness Uniformity and Stability (DUS) tests and possible release as commercial varieties. A promotion campaign was undertaken in five regions to promote the five recently released amaranth varieties. Some 5000 farmers were given small packets of seed for further evaluation and adoption.
- Akeri, Madiira 1, Madiira 2, Nguruma and Poli amaranth varieties were evaluated under two sowing-harvesting methods for marketable surplus in two locations in Tanzania. Likewise seeds for 11 amaranths and 11 African eggplant entries including 4 African nightshade and 2 Ethiopian mustard varieties were increased for use in research programs and distribution to partners and/or farmers.
- The Tanzania National Performance Trial Technical committee finalized the performance assessment of two WorldVeg mungbean lines (AVMU 1601 and AVMU 1693) and recommended their release as commercial varieties in early 2022.

Madagascar

- A total of 1,012 seed samples of 30 species from 8 regions were collected by the National Center for Applied Research on Rural Development (FOFIFA) and the University of Antananarivo.
- WorldVeg and the FOFIFA established **biodiversity-rich school gardens in eight primary schools** to teach children and their families about the relevance of African vegetables for diets, identity, and biodiversity, with support of the UK Darwin Initiative. The World Food Programme (WFP) and the Food and Agriculture



Eastern and Southern Africa

Organization (FAO) endorsed this approach during the first national school garden workshop held in Madagascar. Several NGOs and local governments expressed interest to establish biodiversity-rich gardens in other schools. FOFIFA and WorldVeg are working with the Malagasay Ministries of Education and Agriculture to scale this approach and enhance access to seed for healthy foods.

Eswatini

- A genebank design has been developed to modernize the National Plant Genetic Resources Center following international standards and to integrate the national herbarium with the national genebank. Construction starts in 2022.
- A total of 101 teams and individuals from 14 African countries and Taiwan participated in the first Pan-African vegetable genetic resources course. The course was held online and the overall rating by participants was 4.5 on a scale of 5.
- WorldVeg prepared and shipped 5,120 seed kits with 11 African vegetable varieties for Eswatini home and school gardens and so far 2,635 kits were distributed to community members across the country through 8 organizations working with farmers. The beneficiaries were identified using agreed selection criteria.
- Forty-three participants from nine non-governmental and governmental organizations participated in the training-of-trainer event for production of traditional vegetables.
- Eight schools across all four regions in Eswatini were identified by the Ministry of Education and Training to pilot home grown school feeding in 2022. Approximately 3,600 pupils will participate in the pilot feeding program.
- Demonstration gardens with all 11 vegetable varieties promoted in Eswatini have been established in seven locations: Malkerns Research Station, the Wellness Centre in Manzini; Amitofo Care Centre; Buka Neighbourhood Care Point; Mahamba Community Garden, Bulembu Community Garden and Mananga Training Centre. Vegetables from existing demo sites were harvested and were prepared by cooks to determine acceptability or preference among children and colleagues. The vegetables performed well with the exception of tomatoes which were affected by tomato blight while African nightshade was attacked by aphids. More adaptability tests for the various vegetables are currently being undertaken at the Research Station at Bigbend.





HEALTHIER SCHOOL MEALS IN BENIN

Vitamin A Deficiency is widespread in low-income countries and prevalent in sub-Saharan Africa, with 83% of children aged 2 to 5 years suffering from this deficiency. This results in malnutrition, 500,000 cases of blindness, and 1.25 million deaths annually. The region has a high prevalence of both undernutrition and of overweight, obesity, and diet-related noncommunicable diseases in the same population: the scourge known as the “double burden” of malnutrition.

The UK-funded NUTRIFOOD project aims to allow local institutions to take a giant step toward reversing this situation by identifying new nutrient-dense food and vegetable varieties as well as food processing methods that retain and enhance nutrients. Promoting nutrition through education and gardening in schools and communities will put this new knowledge into practice.

The NUTRIFOOD project was launched on 18 February in Cotonou, Benin by representatives from the World Food Programme (WFP), WorldVeg, school directors, school canteen managers, and mayors from participating communities.

School gardens are one of the tools NUTRIFOOD will use to break the cycle of malnutrition plaguing many schoolchildren in Benin. The NUTRIFOOD team works with school administrators, parents and students to establish gardens in ten pilot schools in Mono, Atlantique and Ouémé departments. In addition to producing food, the gardens are used as teaching platforms.



In the first year, school gardens were implemented in 10 schools in southern Benin in collaboration with WFP. WorldVeg also provided training courses for school canteen cooks and community mothers on good cooking practices of leafy vegetables. The training was done through videos, poster visualization, and culinary demonstrations. A total of 417 persons including 349 women (83%) and 69 men (17%) attended the training courses, including cooks, NGO staff, and parents of students.

As a result, primary school children of the 10 schools (2,995 students, 48% girls) are now able to eat well diversified vegetables (i.e., amaranth, celosia, African eggplant leaves, jute mallow, okra, tomato, pepper, pumpkin, mungbean) produced in the schools and community gardens on a daily basis.

One of the schools (the Goulo Sodji primary school, located in the municipality of Zè) is particularly successful and this prompted WFP to invite the First Lady of Burundi, Mrs Angeline Ndayishimiye during her working visit to Benin to undertake a tour of the garden and community as part of her program. A mobile phone service provider has funded modernization of the kitchen and school canteen of the Goulo Sodji primary school, further boosting the confidence of school children and underlining the importance and contribution of school gardens to enhance nutrition and learning in schools.



West and Central Africa

Benin, Burkina Faso and Mali

- An in-country planning meeting for the **SAFEVEG** project with all partners was organized after the project launch in each country to identify key collaboration partners.
- The **diagnostic phase** for all work packages started to identify main constraints and opportunities to enhance vegetable consumption and production, and reduce postharvest losses:
 - A literature search was conducted on accessibility and acceptability of vegetables and related food safety concerns. A long list of potential interventions to promote vegetable consumption and a list of possible indicators were established.
 - Production systems and postharvest handling and processing practices were assessed in two agro-ecological zones in Benin and Mali.
 - Seed producer assessments were completed to guide focus of seed production training.
 - Food system policy and strategies were documented in the three focus countries to analyze how these encourage or discourage vegetable-rich diets and to assess coherency of the policy environment.
- A total of 20 **Vegetable Business Networks (VBNs)** were selected, and 10 coaches were engaged in Benin. The 10 business coaches were trained on technical aspects of vegetable production, business skills, and functional capacity development.
- Training modules were developed focusing on vegetable breeding for improved nutrient content and quality, vegetable breeding for disease and insect resistance, multi-location variety evaluation, participatory breeding methods, statistical methods for plant breeding, soil fertility management, crop establishment.
- On-station variety trials focusing on climate-resilience for **tomato, chili, habanero, amaranth and okra** were completed in Mali and southern Benin.
- Rainy season multilocation variety trials were implemented at the WorldVeg research station in Samanko, Mali.
- A brief video documentary was developed, highlighting the project's theory of change and expected deliverables.

Mali

- A total of 367 onion accessions were transferred from HQ to Mali.
- Six new adapted **shallot varieties** registration trials were conducted for the second year. Varieties Sabalibougou and G'Ngalamandian were the best performers.
- As part of a collaborative project with the Institut d'Économie Rural (IER), funded by the Islamic Development Bank, four **evaporative cooling device** designs with



optimized performance were identified. These devices extended the shelf-life of vegetables by 50% to 600%. A training guide in English, French, and Bambara was developed and about 350 people (pot makers, producers, vegetable vendors and consumers) were trained. In a post-training survey, 26 out of 33 respondent persons reported that they started using clay pot coolers since the training and are seeing significant benefits.

- Through the USAID funded **Africa RISING** project, field days for **vegetable post harvest management, soil fertility management and disease screening** were organized for 499 farmers including 394 women in Bougouni and Koutiala. Disease screening trials involving 24 different accessions of tomatoes and 16 accessions of pepper were conducted as well.
- 51 farmers including 42 women from Bougouni and Koutiala implemented sack gardening in their homes to improve vegetable consumption and improve household nutrition. Ten bags and four vegetable crops (**tomato, amaranth, carrot and onion**) varieties were provided to each farmer.
- A total of 25kg of seeds of 227 samples of 8 vegetable species including **pepper, onion, tomato, okra, amaranth, African eggplant, roselle and Corchorus** were distributed to beneficiaries in Mali, Senegal, Burkina Faso, Tanzania, Niger, Benin, Ghana, Djibouti and Kenya.
- From 21 to 26 March, staff from seed enterprises, individual seed producers and students (23 participants, 6 women) were trained during 5 days on vegetable **seed production** techniques as a contribution to the USAID-funded **Innovation Lab for Small-Scale Irrigation** in Mali.

Benin

- 250 farmers in urban and peri-urban areas of southern Benin adopted elite lines of **amaranth** through the BMZ - funded **Choose, Grow Thrive**.
- More than 525 farmers (40% women) participated in field days and participatory varietal selection of **3 tomato, 3 chili pepper, 3 habanero pepper, 2 okra and 1 amaranth** lines within the framework of the IFAD funded PADMAR project in Benin.
- Good postharvest management practices were disseminated to 398 beneficiary value chain actors (37% women), notably, the **Zero Energy Cooling Chamber (ZECC) and plastic crating** for tomato to reduce postharvest losses in selected vegetable production areas of southern Benin.
- Twenty-four **habanero** varieties were screened for best performance and high yield evaluation in Benin with four best-bet lines (i.e VI047123, AVPP1503, AVPP1922, AVPP1929) identified for promotion and dissemination to farmers.
- As part of the IFAD-funded **PADMAR** ("*Projet d'appui au développement du maraîchage au Bénin*") project supporting the development of the horticultural sector in Benin, 4 demonstration fields were established to showcase the



West and Central Africa

performance of elite varieties of **tomato, chili and habanero peppers, okra and amaranth** to farmers. Six field days were organized with over 500 farmers resulting in participatory selection of best performing varieties: AVTO1955-15, CLN4066G and CLN2498D for tomato; AVPP1111, AVPP9905, AVPP1346 for chili pepper; AVPP1929, AVPP1922, AVPP1503 for habanero; AVOK1504 and KONNI for okra and AM-NKGN was selected for amaranth.

- As part of the FCDO-funded Africa project, 24 **habanero** varieties were evaluated to select the best varieties for promotion in Benin. VI047123, AVPP1503, AVPP1922, AVPP1929 were observed as the best performing varieties, yielding 19.0 t/ha; 13.6 t/ha; 11.4 t/ha; and 10.1 t/ha respectively).

Benin and Mali

- As part of the BMZ-funded '**Choose Grow Thrive**' project, a portfolio of **9 amaranth lines, 10 okra lines** and 6 jute mallow lines has been established for testing through **citizen science** trials. 250 farmers (36% women) are involved in Grand-Popo, Cotonou, Abomey-Calavi, Dangbo, Porto-Novo et Sèmè-Podji districts. Agro-morphological and viscosity characterization of the okra lines identified three promising lines (i.e Sassilon, AVOK1504 and Konni). In Mali, 250 farmers (94% women) are involved in Koulikoro, Sikasso and Bougouni. From the preliminary results of amaranth citizen science trials, Madira 1, Madira 2, Akeri and IP-5-Sel are so far the most preferred varieties and lines by farmers, and the major traits considered are marketability, yield and taste.
- During the rainy season, 300 on-farm **amaranth** trials were conducted in Mali. Seed multiplication of traditional vegetables (**okra, amaranth, corchorus**) was initiated.

Ghana and Nigeria

- Three WorldVeg **tomato hybrids** were released in southern Ghana in collaboration with the West Africa Centre for Crop Improvement (WACCI) of the University of Ghana and Agri-Commercial Services Limited (ACSL), a private seed company and commercial farm. This is the first release of local hybrid tomato seeds in Ghana.
- A **grafting efficacy test** on bacterial wilt incidence in tomato production showed that Hawaii7996 and PADMA F1 are good rootstocks under Tounvi a highly susceptible local variety of tomato (Hawaii7996/Tounvi: 6% and PADMAF1/Tounvi: 9% of wilting) while the control Tounvi/Touvi showed 78% of wilting.
- Two high performing **tomato hybrids** developed by seed companies (Mona F1 and DIVA F1 respectively from NovaGenetic and East-West Seed) and two high performing habanero pepper varieties (Avenir F1 and Red Piquante were tested under on-farm conditions in Ghana and Nigeria.



- A **farmers field day with 574 participants** was organized in Kaduna state, Nigeria in collaboration with Tomato Jos Farming and Processing Company on 14 April. **Forty tomato commercial hybrids** and selected WorldVeg breeding lines were evaluated in an on-station trial.
- Through the USAID-funded Africa RISING project, four **tomato** lines (AVTO1716, AVTO1706, AVTO1464 and AVTO1707) and two **pepper** lines (AVPP0002 and AVPP9703) were better adapted in northern Ghana and provided a higher yield (up to 26 t/ha in tomatoes, and 9 to 10 t/ha in peppers).
- One hundred farmers from 20 communities in north Western Ghana received elite varieties of **tomato, hot pepper, onion and head cabbage** (from a private seed company in Taiwan) along with technical backstopping from WorldVeg for conducting field variety trials under a GIZ-Ghana funded project.
- Through the USAID-funded Africa RISING project, field days for **vegetable post harvest management, soil fertility management and disease screening** were organized for 102 farmers including 48 women at Doku in the Northern Region and Nyangua and Bonia in the Upper East Region. Disease screening trials involving 24 different accessions of tomatoes and 16 accessions of pepper were conducted at Bonia in the Upper East Region of Ghana.
- A survey on assessing the **inclusiveness of women and youth** within the vegetable production value chain to enhance vegetable production among smallholder farmers was completed in March 2021. The surveys were conducted in fifteen (15) communities from a total of four hundred respondents within the Northern, Upper East and Upper West Region.
- Training sessions on **good agricultural practices and integrated pest management** in vegetables were implemented for 150 farmers (48 women). A further 90 farmers (38 women) were trained in ZECC construction using local materials in the Upper East and Northern Regions of Ghana. The shelf-life of tomatoes was prolonged from 5 to 10 days using the ZECCs.
- The RDA Korea-funded “Enhancement of tomato and onion production in Africa for maximum sustainable yield” project involves 16 countries in sub-Saharan Africa. Monitoring visits were undertaken to 3 project countries (Ghana, Nigeria and Kenya).



TACKLING *TUTA ABSOLUTA*, A NEW THREAT TO TOMATO PRODUCTION IN ASIA

Tomato is an important vegetable crop worldwide with an annual production of 181 million tons from an area of 5.03 million ha. Asia is the top producer sharing about 52% global acreage and 62% global production. Tomato production is constrained by several abiotic and biotic stresses. The South American tomato leaf miner, *Tuta absoluta*, which is endemic to South America has recently emerged as a major invasive pest, constraining tomato production in Europe, Africa and Asia. Although it has been reported in South Asia during 2014-2017, Central Asia during 2017-2018 and recently in China and Taiwan, it has not been reported from Southeast Asia.

Preliminary surveys conducted on tomato crops in Myanmar suggested the presence of *T. absoluta* in Southern Shan State, but there was no official survey conducted until the end of 2019. Hence, WorldVeg in collaboration with the Plant Protection Division, Ministry of Agriculture conducted a survey to confirm the presence of *T. absoluta* in Myanmar. The presence of *T. absoluta* was observed in the Southern Shan State, which is the largest tomato production area in Myanmar, where tomato is cultivated in two different ways (floating and land cultivation). The highest *T. absoluta* infestation was recorded at Kalaw with 82% damage, followed by Inle Lake (i.e., floating cultivation) (20%) and Pin Ta Ya (10%). Similarly, monitoring studies using pheromone traps were also conducted in spring 2021 in Southern Taiwan, since *T. absoluta* was reported to occur in Central Taiwan in mid-2020. The results confirmed the occurrence of *T. absoluta* in Southern Taiwan and the pheromone traps trapped a maximum of 420 moths/trap/week during April-May 2021.



Due to the lack of information on the effectiveness of different bio-pesticides in the newly invaded regions such as South Asia, WorldVeg conducted a study in controlled as well as field conditions to identify most effective bio-pesticides that could be included as components in integrated pest management (IPM) packages for *T. absoluta*. It found that bio-pesticides, especially neem and *B. thuringiensis* formulations reduced *T. absoluta* infestation similar to the chemical pesticides, without affecting the yield. Subsequently, an IPM package including microbial pesticides, neem products and a chemical pesticide was evaluated in multi-location trials through participatory approaches in 2018 and 2019. The performance of the IPM package was similar to the Farmers' practice (calendar based application of chemical pesticides) in reducing *T. absoluta* infestation, without any compromise in the marketable yield. In fact, the excessive spraying of chemical pesticides in the Farmers' practice led to an increase in the protection cost, which was nearly two times higher than that of the IPM package. Thus, the IPM package has been found to be effective and economical in managing invasive *T. absoluta* on tomato in India.

Considering the speed of spread and extent of losses in Asia, it will not be possible for a single organization to address *T. absoluta*. Hence, WorldVeg has established an alliance under the existing ASEAN-AVRDC Regional Network for Vegetable Research and Development (AARNET), which secured a project on improved coordination and strengthened capacity to deal with the invasive *T. absoluta* in mainland Southeast Asia, with National Parks Board of Singapore as the proponent, which has been financed by the JAPAN ASEAN Integration Fund - Emergency Economic Assistance Related to Financial Crises in the ASEAN Region. The project will enhance diagnostic and monitoring capacity of the research and extension personnel and quarantine agencies to improve phytosanitary and quarantine measures in ASEAN member states to recognize and monitor *T. absoluta*, besides introducing management strategies should the pest arrive. The management strategy is primarily based on the IPM package, which has been proven effective and economical in managing invasive *T. absoluta* on tomato at pilot sites in South Asia.



Safe and Sustainable Value Chains

- About 200 farmers have adopted **composting** in their vegetable production in Kenya. In addition, more than 30 farmers in Ethiopia have started using bio-slurry and vermicompost to improve their soil fertility. About 100 farmers in Kenya have adopted growing **companion crops** such as spring onions, Mexican marigold and coriander to repel insect pests from their vegetable farms. Fifty learning sites in Kenya and 31 in Ethiopia have been established to demonstrate regenerative agricultural practices in vegetable production.
- A mixture of ½ recommended dose of **organic manure** (5 t/ha) and ½ recommended dose of NPK provided the highest tomato (var. Pectomech) yield (27 t/ha) in northern Ghana. However the yield did not differ significantly between manure (16 t/ha) and NPK application (18 t/ha) alone.
- 60 demonstrations of **mulching** in tomatoes were conducted in Odisha, India, which increased the yield by 20-25% compared to the conventional practice (without mulching). Mulching also reduced soil compaction and erosion, weeds and labor costs, while conserving soil moisture. Mulching and use of **Zai pits** (small basins in which the seeds/seedlings are planted) to conserve soil moisture has been adopted in Machakos County, which is a semi-arid area in Kenya. About 200 farmers have adopted mulching in their vegetable production in Kenya.
- **Minimum tillage** cultivation of tomatoes in rice fallows of Assam, India reduced the number of irrigation (2.7 times) compared to the traditional practice (4.5 times). The cost benefit ratio of minimum tillage was higher (3.14) than the traditional method (2.85). 25 demonstrations on drip irrigation in onion production are being conducted in Odisha, India.
- WorldVeg surveyed and confirmed the presence of **Tuta absoluta** in major tomato production systems in Myanmar by the end of 2019. The pest has also been monitored with pheromone traps in Taiwan, and trapped up to 420 moths/trap/week in 2021.
- A quantitative PCR (qPCR) assay for screening mungbean genotypes against **dry root rot** (DRR) caused by *Macrophomina phaseolina* that provides a precise fungal load present in the plant was developed. A rapid biocontrol and resistance screening method using seedlings at their first stages of growth (7-10 days) was optimized for bacterial wilt in tomato and pepper.
- Ten distinct *Colletotrichum* species associated with sweet pepper **anthracnose** were identified in samples collected from Taiwan by multiple-locus phylogeny, and *Colletotrichum scovellei* is most prevalent in the open field, whereas *Colletotrichum fruticola* in protected cultivation. About 79% of the late blight disease samples collected from tomato during 2019-2021 in Taiwan are *Phytophthora infestans* race T1,2,3. A majority (87.5%) of bacterial spot disease samples from tomato in Taiwan are *Xanthomonas perforans* (Xp) race T4.



- The **begomovirus** isolates from sweet pepper in Taiwan are highly diverse, with DNA-A sequence identity ranging from 72.4% to 99.8% among the isolates, while polerovirus isolates are highly identical with nucleotide sequence identity of 95.5%-99.7%.
- Two tomato germplasm accessions (VI037869 from Ecuador and VI044915 from Peru) and breeding line CLN4197AD showed resistance/tolerance to **Tomato chlorosis virus** (ToCV) in Taiwan. One tomato accession VI007032 and two lines BL1231 and BL1233 showed resistance/tolerance to **bacterial spot** (*X. perforans* race T4). Five squash breeding lines (18ZP3204-1, 19ZY3091-1, 18PR3071-1, 18PR3188-2, and 18PR3118-5) possessed the resistance/ tolerance to **Papaya Ringspot Virus** (PRYL96).
- Progenies of three tomato accessions (VI034868, VI048634, and VI048662) with resistance to root-knot nematode and tolerance to short-term waterlogging also showed resistance to **bacterial wilt**. Four *Solanum torvum* S1 accessions (VI034868-S1, VI048634-S1, VI055486-S1, VI048662S1) displayed tolerance to bacterial wilt caused by Pss97 (eggplant strain), which can be used as rootstock in tomato grafting. Twelve hybrid lines (F1) of 5 eggplant rootstocks (VI041809A, VI041943, VI041945, VI041979A, and VI041984) showed resistance to 2 strains viz., Pss97 (eggplant strain) and Pss4 (tomato strain) causing bacterial wilt.
- The *Talaromyces* spp. has been identified as the effective **biocontrol agent** against bacterial wilt when combined with a partially resistant variety of tomato (L180). It also reduced the disease severity for Fusarium wilt and Southern blight in tomatoes.
- **IPM packages** for tomato, eggplant, cabbage, cauliflower and pumpkin have been scaled out through 122 demonstrations in Assam, India. Adoption of IPM led to significant yield increase over the control plots. The highest yield increase was observed in pumpkin (188%) followed by cauliflower (160%), with the lowest being eggplant (10%).
- Introduction of **climate resilient GAP packages** for tomato, pumpkin, cabbage, cauliflower and eggplant through 170 on-farm demonstrations led to a substantial yield increase (21-43%), while reducing pesticide sprays by 44-51% in Assam, India.
- 90 demonstration trials on **safer and off-season vegetable production** of tomato, yard-long bean and leafy brassicas have been implemented in Cambodia. Using the application of GAP packages on tomato, African nightshade and Ethiopian mustard, over 95% of target farmers increased yield and 100% farmers reduced pesticide use in Tanzania. A total of 10,690 farmers have adopted climate-smart GAP packages for various vegetable crops in Cambodia, Laos, India, Tajikistan, Kenya, Ethiopia, Tanzania and Mali.
- **Food safety risks** along the Horticulture value chains were assessed in Bangladesh and Vietnam. Consumers in Hanoi and Dhaka buy most of their fruit



Safe and Sustainable Value Chains

and vegetables from traditional wet markets, and the produce sold in these markets are not certified and not traceable to farms. Sample analysis showed that 31% of the mustard green samples collected from farmers' fields in Vietnam had *E. coli* loads above maximum permissible levels and this was 67% for wholesale markets and 82% for retail markets. 5% each mustard green and cucumber samples had pesticide residues above permissible levels. No samples had heavy metals and nitrate concentrations above maximum permissible levels.

- WorldVeg installed three low cost **solar dryers** and 10 training/ demonstrations were conducted on the use of solar dryers for drying vegetables in Odisha, India. Farmers were able to sell the dried produce for 2-3 times higher price than the fresh produce.
- **Zero energy cooling chambers (ZECC)** were found to extend the shelf-life of tomatoes to 9 days compared to 6 days in control in Ghana and Mali. A total of 12,650 beneficiaries have been trained on good handling practices and post-harvest management of vegetables in India, Ethiopia, Kenya, Ghana and Mali.
- Three vegetable **value chain studies** (integrating Tajikistan into the global mungbean value chain; vegetable value chain analysis for traditional African vegetables in Kenya; value chain/market systems development study for the horticulture sector in Zanzibar) were completed.
- A total of 111 **vegetable business networks (VBNs)** have been established in Ethiopia and Kenya.





THE FIRST COMMERCIAL TOMATO HYBRIDS "MADE IN WEST AFRICA"

Tomato is an indispensable ingredient of popular dishes in West Africa, such as jollof rice, diverse soups and stews that are consumed daily. Although tomato production in Ghana has intensified in recent years, it falls far short of domestic demand. Ghana produces on average 510,000 tons of tomato per year and imports up to 7,000 tons per month of fresh tomato from neighboring countries, along with 27,000 tons of processed tomato from China and Europe for producing ketchup, puree, paste, powder and juice. Average tomato yield in Ghana is 8 tons/ha versus 21 tons/ha in India and 63 tons/ha in the Republic of Korea. The low productivity is due to a combination of poor management practices and the use of unadapted, disease susceptible tomato varieties bred in temperate countries. Ghanaian farmers require heat tolerant, multiple disease resistant varieties that produce high yields of firm fruit for the fresh market and for processing as well.

In 2018, Benin-based WorldVeg scientists Victor Afari-Sefa, Peter Hanson, and Herbaud Zohoungbogbo visited Agri Commercial Services, a commercial farm and tomato processing facility in Wenchi Ghana. Managing Director, Kwabena Adu-Gyamfi explained



that the Wenchi factory had processed up to 100 tons of fresh tomatoes per day from 2004-2009, but factory operations had ceased due to insufficient tomato supplies. As a result of the visit and with support from FCDO, WorldVeg Benin provided seed of seven multiple disease resistant dual purpose tomato hybrids suitable for fresh market and processing to Agri-Commercial Services and two other Ghanaian private seed companies for local trials. By September 2019, Agri-Commercial Services had evaluated the WorldVeg hybrids along with many local and introduced commercial hybrids: WorldVeg hybrids AVTO1866, AVTO1870, and AVTO1871 stood out for foliar disease resistance, high yield, and acceptable fruit size. Mr. Kwabena had ambitions not only to produce fruit, but also seed of the hybrids and avail them commercially to the farmers of Ghana and neighboring countries.

The next step towards commercialization of the hybrids was official variety release, a rigorous process requiring trials of the hybrids along with check varieties in different locations in Ghana, and clear evidence that these varieties are superior in terms of yield, adaptation, and fruit qualities compared to previously released cultivars. In 2020, Mr. Kwabena enlisted the technical assistance of Drs. Leander Dede Melomey and Agyemang Danquah of the West African Centre for Crop Improvement (WACCI), University of Ghana, to facilitate the multilocation trials and other steps in the variety release process. In October 2020, WorldVeg, Agri-Commercial Services and WACCI established a formal collaboration to release and scale seed production of the varieties. By October 2021, hybrids AVTO1866, AVTO1870 and AVTO1871 were released in the southern sector of Ghana with local names of 'Ante Dede', 'Legon Tomato', and 'Tomato Queen', respectively. WorldVeg has provided the parental lines needed to produce the hybrid for seed multiplication to WACCI and Agri-Commercial Services is initiating certified seed production and training of producers in the second quarter of 2022 for the first commercial tomato hybrids produced in Ghana.



Vegetable Diversity and Improvement

• **Vegetable biodiversity**

The **GRIN-Global database** application has been adopted to manage seed and information of the vegetable germplasm conserved in the WorldVeg genebanks. A monitoring dashboard has been established to track real-time temperature and relative humidity in cold and drying chambers as well as in seed preparation and cleaning rooms of the genebank at WorldVeg headquarters to enhance the security of the seed storage and handling facilities.

In 2021, a total of 11,771 germplasm accessions were sent for long-term back up from WorldVeg to Svalbard, and more than 9,000 safety duplicates were prepared for shipment to the genebank of the Rural Development Administration (RDA, Korea). By today, 33% of the WorldVeg germplasm collection is **security duplicated** at RDA and 45% is deposited in the Svalbard Global Seed Vault, Norway.

A total of **2,957 new accessions of traditional African vegetables** were collected in 2021 in vegetable biodiversity hotspots in Sub-saharan Africa.

• **New traits for breeding**

Growth, health and yield of 300 accessions of a **pepper core collection** were investigated over two hot seasons and one cool season at WorldVeg headquarters. Vegetative traits were measured by three-dimensional laser scanning using a **high throughput field phenotyping system**, and generative traits, such as pollen number and activity, were assessed by **impedance flow cytometry**. Variations of heat stress responses were detected in the germplasm and **heat tolerant accessions** were identified. Among others, pollen activity, biomass accumulation and leaf angle change were found associated with yield maintenance under elevated temperatures.

Three-dimensional laser scanning was also applied to measure variation of the **response to flooding in an okra core collection** of 100 accessions over two seasons. Germplasm that maintained growth under flooding or recovered rapidly after flooding has been identified.

• **Tomato breeding**

The first **tomato hybrid varieties “Made in West Africa”** were approved for commercialization in Ghana. The multi-disease resistant hybrids have been developed by WorldVeg, seed of the parental lines is produced locally by the West Africa Centre for Crop Improvement (WACCI), and the local seed company Agro-Commercial Services produces and commercializes the hybrid seed.

A tomato F6 multiparent advanced generation intercross (**MAGIC**) **population combining heat stress tolerance with fruit quality and multiple disease resistances** was phenotyped for heat-related traits including pollen viability, stigma exertion, fruit-set and other traits with the purpose to map QTLs underlying



heat tolerance and boost tolerance levels. Tainan DARES is evaluating the MAGIC population in the greenhouse to begin a genomic selection program.

- **Pepper breeding**

746 WorldVeg-developed hot and sweet pepper lines were distributed to >25 different countries across Asia, Africa, Europe, North America and Central America.

Five newly developed **habanero** lines were identified as promising in Benin, combining high fruit quality with tolerance to abiotic and biotic stresses. The WorldVeg habanero line AVPP1929 was selected after multi-location and multi-year trials for release in Benin through the National Institute for Agricultural Research.

WorldVeg **chili hybrids** AVPP1245, AVPP2049, AVPP2050, AVPP2051, AVPP2052, and AVPP2053 outperformed commercial hybrid checks in Myanmar and Vietnam and showed potential for scaling. The F₁ hybrid chili AVPP1245 was selected by one of the major private sector seed companies in Bangladesh for release and scaling.

- **Cucurbit breeding**

WorldVeg **bitter gourd lines** AVBG1301 and AVBG1304 and WorldVeg **pumpkin line** AVPU1502 were **released and registered** with the National Seed Corporation in **Myanmar** under the name Yezin Bitter gourd – 1, Yezin Bitter gourd – 2, and Yezin Pumpkin – 1, respectively. Seven **new powdery mildew and begomovirus resistant F₁ bitter gourd hybrids** were released to APSA-WorldVeg Consortium members and five **begomovirus resistant pumpkin F₁ hybrids** were released to Africa Vegetable Breeding Consortium (AVBC) members.

- **Legume breeding**

The **WorldVeg mungbean minicore** collection has been successfully screened by the “Institute Germplasm Identification Committee” (IGIC) of ICAR (India) for accessions with resistance to **Mungbean Yellow Mosaic Disease**, one of the key constraints of mungbean production in South Asia. The resistant accessions will be registered as unique germplasm with the National Bureau of Plant Genetic Resources (NBPGR). In other screening accessions resistant to anthracnose, seedling and flower thrips and cowpea aphids were detected.

In India, two **mungbean breeding lines** have been selected for advanced varietal trials in the All India Coordinated Trials. In Bangladesh, three mungbean breeding lines with higher yields compared to the check variety BARImung 6 were included in regional yield trials. Seven WorldVeg mungbean lines and two high yielding mungbean minicore accessions were selected in Myanmar for further testing before potential release.



Vegetable Diversity and Improvement

- **Traditional Vegetables**

A high quality **whole genome sequence of *Amaranthus tricolor*** has been produced in collaboration with JIRCAS, Japan.

The **WorldVeg amaranth core collection** comprising 4 amaranth species (*A. cruentus*, *A. hypochondriacus*, *A. caudatus* and *A. dubius*) was shared with the International Center for Biosaline Agriculture (ICBA) for evaluation in Bhutan, Laos, Mozambique, Togo, Tunisia, Egypt, Uzbekistan and at the ICBA headquarters in Dubai.

Eight amaranth entries were grown for display to African Vegetable Consortium (AVBC) member companies in Tanzania and were evaluated for seed yield and other traits. Two amaranth lines were submitted to the Kenyan Plant Health Inspectorate service (KPHIS) and three lines were forwarded to the Tanzania Official Seed Certification Institute (TOSCI) for Distinctiveness Uniformity and Stability (DUS) tests and possible release as commercial varieties.

Seven **African eggplant** entries were grown for display to African Vegetable Breeding Consortium (AVBC) member companies, and evaluated for fruit yield and other traits.



Establishing Your Garden

Building Healthy Soils

Planting Your Garden

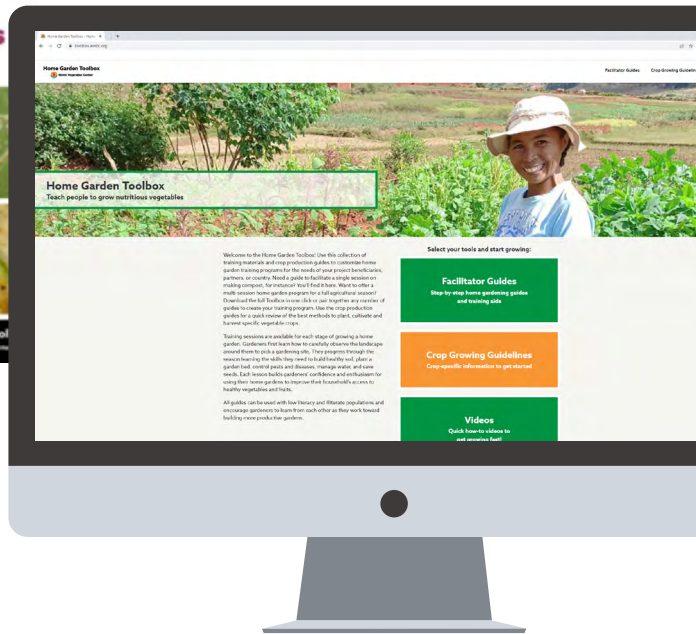
Understanding and Making Compost



TRAINING MADE EASY THROUGH THE NEW HOME GARDEN TOOLBOX

Many people—rich and poor, young and old, rural and urban—have taken up home gardening during the COVID-19 pandemic. Growing your own vegetables, fruits, herbs and spices can contribute to healthier eating habits, but also to personal joy, a sense of purpose during times of hardship, and biodiversity conservation, among several other documented benefits. Gardening is not difficult, but training can strengthen people’s ability to deal with common challenges such as poor soil conditions, water shortages, and pests and diseases.

WorldVeg has developed a standard set of straightforward-to-use materials to support home garden training programs in low- and middle-income countries. This [Home Garden Toolbox](#) is based on participatory adult learning methods suitable for people with low literacy skills. It was developed by a team of external consultants led by Lauren Pincus with content provided by Elin Duby, Sheena Shah and Archie Jarman and Evan Clayburg doing the graphical design. The toolbox is organized in 10 Facilitator Guides (subdivided into 21 training sessions, each about 3 hours long), 10 Crop Growing Guides, and a growing number of short instructional videos.



Gardeners first learn how to carefully observe the landscape around them to pick a gardening site. They progress through the seasons and learn the skills they need to build healthy soil, plant a garden bed, control pests and diseases, manage water, and save seeds. Each lesson builds gardeners’ confidence and enthusiasm for using their home gardens to improve their household’s access to healthy vegetables and fruits.

All the training guides build on principles of agroecology. For instance, the guide on pests and diseases asks gardeners to collect insects from their garden and group them into insect pests and beneficials. Insect pests are then separated into ‘piercing/sucking pests,’ ‘defoliators/chewing pests,’ and ‘borers,’ and the facilitator explains how to prevent or control each category of insect pest. Gardeners also learn about the role of beneficial insects (natural enemies, pollinators) and flowering plants that can attract them. This knowledge is not just useful for pest management in gardens, but could equally be applied to farmers’ fields. The high diversity of plants grown in a home garden also helps to demonstrate how plant diversity promotes beneficial organisms including pollinators. The small scale of home gardens therefore enables experimentation and learning, which can help farmers to innovate.

Because home gardening is directly linked with nutrition, it also includes a module on healthy eating, with the aim to promote the consumption of a wide range of nutritious local vegetables, fruits and herbs, thereby contributing to transforming food habits and increasing the use of plant biodiversity.

The toolbox is available in English and can be used or adapted to any location, context and language. All materials of the Home Garden Toolbox are publicly available and any organization can use them in their current form or adapt them as needed.



Healthy Diets

- The **online home garden toolbox** was launched in June 2021 (<https://toolbox.avrdc.org/>). The toolbox contains facilitator guides and crop growing guides using participatory hands-on learning methods suitable tailored to home gardeners in low-and middle-income countries. In addition, about 10 home gardens demonstration videos were created on topics such as how to grow vegetables from plant cuttings, how to make a keyhole garden, and how to make vermicompost. Videos were distributed through social media and are available on YouTube.
- A study was conducted on the **effects of Covid-19** on healthy diets in Thailand and the Philippines. Funded by the Taiwan Ministry of Foreign Affairs, it assessed changes in food policy and in the cost and affordability of healthy diets. It found that Covid exacerbated policy issues existing before the pandemic, particularly around policy implementation; and that while the cost of a healthy diet declined in Thailand and rose in the Philippines, affordability dropped for low-skilled workers in both countries due to unemployment and livelihood disruption. This is now being followed up in a second phase, to understand the lived experience of food system change for marginalised populations in each country.
- Two **research briefs** were contributed to the UN Food Systems Summit (UNFSS) Scientific Committee, titled "Fruits and vegetables for healthy diets: Priorities for food system research and action" and "Safeguarding and using fruit and vegetable biodiversity." These were then combined into a journal article for a special issue on the UNFSS in the journal Global Food Security.
- A study published in the journal Global Food Security and written in the context of the Drivers of Food Choice Program, compared **12 global nutrition initiatives** in terms of recommended actions to achieve sustainable healthy diets. Led by Ligia I. Reyes at the Arnold School of Public Health at the University of South Carolina, the study showed that most strategies target changing food environments, but fewer target changing individual food choice and very few deal with sustainability. It concludes that food choice and sustainability need to be allocated more attention.
- A study published in the journal Agricultural Systems and led by John M. Dixon at the Australian National University and University of Queensland, compared 25 countries in Asia in terms of response and resilience of agrifood systems to the COVID-19 pandemic. WorldVeg and Kasetsart University worked together to conduct the Thailand component of this study. Overall, the study concluded that Asian farming and food systems were quite resilient during the **Covid-19 pandemic**. Irrigated wheat-based systems were most strongly affected by the pandemic while hill mixed systems showed to be the most resilient.
- In cooperation with the World Food Programme in Benin, and funded by UK Research and Innovation (UKRI), WorldVeg led the establishment of 10 **school vegetable gardens** reaching 2996 elementary students (1564 boys and 1432 girls) plus 50 school cooks and 170 teachers and community members. Students,



teachers and school garden committee members were trained in production practices of fruit and traditional leafy vegetables, and basic water, sanitation and hygiene (WASH) and nutrition concepts. School cooks were trained in proper harvesting, preparation, and cooking of vegetables to retain nutrients.

- In Madagascar the **Darwin Initiative project** supported the establishment of 8 school gardens and trained 96 students (12 per school) and 16 school teachers. School children and their teachers received nutrition education and vegetable production training to grow 12 varieties of traditional African vegetables. Eight school cooks received training on how to optimally prepare the vegetables.
- In total 5,347 samples were received for **nutrition analysis** in the WorldVeg nutrition laboratory in 2021. This included 123 tomato, 3,564 tomato flower, 119 hot / sweet pepper, 288 pepper leaves, 1,139 mungbean, 12 amaranth and 102 other vegetables from WorldVeg HQ (e.g. SSVV and VDI), other regions (e.g. Uganda, Myanmar, Kenya, Tanzania and Bangladesh) and Taiwan Hualien-DARES, and 10,687 analysis data points were completed.
- A systematic scoping review was published in the journal Food and Nutrition Bulletin, assessing how studies of food systems for healthy diets have addressed the role of vegetables in low- and middle-income countries. In reviewing 1,383 articles, the paper identified key gaps in terms of country contexts, parts of the food system, types of vegetables, and aspects of diets covered in the literature, to shape WorldVeg strategy going forward.

**HEALTHY DIET:
"SHOULD THAILAND
HAVE A NATIONAL
VEGETABLE POLICY?"**

THURSDAY, 13 MAY 2021
TIME: 08:30 - 12:45 HRS.
(GMT + 7)
VIA ZOOM APPLICATION

NATIONAL DELEGATE CONFERENCE
MR. NARINAY CHANDANANON
SECURITY FURNISHMENT - SUPPLY
MINISTRY OF AGRICULTURE, FISH AND COOPERATIVES DEVELOPMENT

CHAIRMAN / SPEAKER
DR. VANIDA KIRKHIDDHETCI
DIRECTOR OF FOREIGN AGRICULTURAL AFFAIRS, MOAC

SPEAKER
DR. PAKSIY SACONTAM
ASSISTANT CEO AND ACTING DIRECTOR OF OPERATIONS
FOUNDATION OF WELL-BEING THAI HEALTH PROMOTION
FOUNDATION (THAIHEALTH)

SPEAKER
MR. ANONAN ADTHALIMORNOY
SENIOR PROFESSIONAL AGRICULTURAL RESEARCH OFFICER
DEPARTMENT OF AGRICULTURE (DOA)

REGIONAL LEADER FOR EAST AND SOUTHEAST ASIA
WORLD VEGETABLE CENTER (WORLDEVEG)

SPEAKER / FACILITATOR
DR. JOEY HARRIS
GLOBAL FOOD SYSTEMS EXPERT, WORLDEVEG

SPEAKER
ASSOCIATE PROFESSOR SIBBYA PORNCHINDO
INSTITUTE FOR POPULATION AND SOCIAL
RESEARCH (IPSR), MAHIDOL UNIVERSITY

SPEAKER / FACILITATOR
MR. BRAPAB JONTASERONG
EXPERT IN VEGETABLE PROMOTION AND NUTRITION
DEPARTMENT OF AGRICULTURAL EXTENSION (DOAE)

FOR REGISTRATION



ENABLING VEGETABLE SEED COMPANIES TO GROW AND FLOURISH IN AFRICA

Much of the vegetable seed used by farmers in sub-Saharan Africa, particularly of economically important crops such as tomato, onion, cabbage, carrot and chili pepper, is imported from Europe and Asia rather than produced locally. Imported seed is expensive and performance is variable. Local production of quality vegetable seed could benefit farmers, but a private vegetable seed sector that develops own locally-adapted varieties has been slow to develop. One important reason for this is that local seed laws and regulations have not created strong incentives to invest in local breeding and seed production of vegetables. A study by New Markets Lab and World Vegetable Center looked into this by comparing written seed laws and regulations across 13 countries in sub-Saharan Africa and complementing this with interviews of public and private sector stakeholders.



The study finds that seed laws and regulations in sub-Saharan Africa are not generally conducive for the vegetable seed sector to develop. Countries have taken a government-centered approach to seed quality control with a focus on seed of staple food grains, but without recognizing that these rules may not be suitable for vegetables or that government agencies have little capacity to apply these rules properly to vegetables.

For instance, nearly all countries require new vegetable varieties to undergo stringent multi location testing to prove that their agronomic performance is superior to those of existing varieties in the market—a test called “Value for cultivation and use (VCU)”. While this may be useful to compare yields of rice or maize varieties, quality attributes of vegetables are a lot more complex with taste, shape, color, texture, or shelf-life, which cannot be easily compared in a conventional field trial. Vegetable crops are therefore not normally subjected to VCU testing following international good practice; yet most African countries require it nevertheless. This delays the variety release process and increases the cost to local seed companies, while most countries do not require VCU trials and variety registration for imported seed.

The study therefore concluded that governments can enable the development of locally-adapted varieties by exempting vegetable varieties from mandatory VCU trials. It also identified several other regulatory changes that would create a more enabling environment such as giving up government monopolies over early generation vegetable seed production; creating easily accessible online and up-to-date national variety catalogs for vegetables; introducing alternative systems for seed quality control than state-controlled seed certification; and harmonizing regional trade regulations for vegetable seed. Introducing these changes requires the vegetable seed sector to be explicitly recognized in national seed policies, which is not currently the case. The benefits of doing this will be increased incomes for smallholder farmers and other value chain actors and more available and affordable vegetables for consumers at large.



Enabling Impact

- A study was conducted on the **food safety** situation in fruit and vegetable value chains in Vietnam and Bangladesh. Commissioned by the Asian Development Bank, it identified key food safety challenges as well as entry points for improvement. One of the key findings is the importance of organizing farmers into producer groups to facilitate the adoption of good production and postharvest practices.
- The BMZ-funded project **“Teach and text”** tested the hypothesis that phone-based text messages, either used as a stand-alone method or combined with demonstrations and training, can promote IPM adoption among vegetable farmers in Cambodia. The results showed that text messages and training/ demonstration implemented as stand-alone interventions did not improve IPM adoption, but when combined, they increased IPM adoption by 20%. However, this combination also increased the frequency of pesticide spraying by 23%.
- The Asia & Pacific Seed Association (APSA)-WorldVeg **Vegetable Breeding Consortium** had 38 seed company members in 2021. The annual workshop was held virtually on 11-12 May 2021 and attracted 208 participants representing 31 member seed companies to discuss and deliberate on the consortium’s vegetable R&D progress.
- APSA and WorldVeg monitored the effects of the **COVID-19 pandemic** on the seed sector in the Asia and Pacific region. Previous surveys were conducted in April, May and August 2020 and a fourth survey was conducted in May 2021. The results showed that seed business operations have continued to improve across all aspects, but challenges persist particularly to the international seed trade.
- Feedback data collected from 34 vegetable seed companies in Asia that are members of the WorldVeg-APSA Vegetable Breeding Consortium showed that 86 commercial varieties of tomato, pepper, pumpkin and bitter melon currently sold in Asia contain germplasm developed by WorldVeg. The report estimated that consortium members sold 24.7 tons of seed of WorldVeg-related varieties in 2020 -- enough to plant **171,000 hectares and benefit 490,500 smallholder farmers**. Tomato and chili pepper contributed to most of the impact while a rapid increase in the impact of bitter melon was observed.
- The **Africa Vegetable Breeding Consortium (AVBC)** increased from 9 seed company members in 2019 and 6 members in 2020 to 23 members in 2021. Membership fees were waived for 2021 and 2022 and the consortium was actively promoted to seed companies in Africa. Another 23 organizations (universities, public research organizations, NGOs) became associate members. The annual workshop was held in Arusha, Tanzania on 21 September as a hybrid (physical and online) event.
- WorldVeg and New Markets Lab reviewed laws and regulations governing the private vegetable seed sector in 13 countries of sub-Saharan Africa. It found that **seed laws and regulations in sub-Saharan Africa are not generally conducive for the vegetable seed sector** to develop. Results were presented at the Annual Congress of the African Seed Trade Association on 28 September 2021.



- A study published in the journal *Agronomy*, and funded by UK aid, described the mechanisms by which **COVID-19** has affected smallholder vegetable farmers in two northern states of Nigeria. Farmers reported challenges in accessing farm inputs and storing and selling fresh vegetables. The study concluded that vegetable processing and storage could help to sustain vegetable supplies during the Covid-19 pandemic, but individual farmers may not be able to afford these and would require government help.
- The use of **digital monitoring and data collection** tools was further expanded. For instance, the project “Safe Locally-Produced Vegetables for West Africa’s Consumers” (SAFEVEG) set up a monitoring dashboard to track progress; while the project “Veggies 4 Planet & People” used Akvo Flow to collect regular monitoring data from Vegetable Business Networks; and several other projects used various digital tools to collect survey data.
- A new impact assessment study was initiated to assess the impact of **vegetable business networks (VBNs) and agroecological practices** in Kenya and Ethiopia. Baseline surveys were successfully completed in both countries using face-to-face interviews.
- Baseline surveys were conducted to assess the impact of **off-season vegetable production** in Cambodia and Laos as part of the BMZ-funded Grow Against the Flow project. Data were collected using a phone-based survey method as the Covid-19 pandemic prevented face-to-face interviews.
- A study was conducted on the effects of the **COVID-19** pandemic on the livelihoods and diets of vegetable farmers in five states of India. Data were collected through a phone-based survey, which was a repeat of a survey conducted in 2020. The results showed that 60% of farmers reported a reduction in vegetable production in the past year and over 80% reported reduced consumption of at least one food group. Difficulty accessing inputs such as seeds/ seedlings and reduced household spending were associated with decreased vegetable production. Households that received government Covid-19 support, borrowed money and had home gardens were observed to consume more vegetables than other households.
- A study on the **vegetable seed sector in India** was initiated to map its evolution and contributions to farmer livelihoods and diets. Several in-depth interviews have been completed with private seed companies, and field visits for farmer interactions to understand their experiences with the private seed sector had begun. However, further data collection had to be put on hold because of the Covid-19 pandemic in India.
- The knowledge management system (titled ‘**HARVEST**’) was further populated with library data. The system, launched in December 2017, gives WorldVeg staff better access to research outputs as well as project reports, protocols, and original research data. The system had 59,573 records by January 2022 and there were 110,919 downloads for 2021 as a whole.



Seed companies of all sizes are WorldVeg's essential partners in ensuring seeds of our improved breeding lines with drought and heat tolerance, resistance to major pests and diseases and other important traits reach vegetable producers, from home gardeners to smallholder farmers to large-scale commercial growers. To more closely collaborate with these important 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, 44 members in 2020, and 38 members in 2021. Seed companies participating in the consortium get early access to newly developed lines and the opportunity for professional interaction with WorldVeg researchers, evaluate the field trials,

discuss emerging challenges and explore solutions. The annual workshop in 2021 was held virtually with 208 participants.

"The online workshop was very informative. I am so glad to see the tremendous progress on white fly & anthracnose resistance introgression in tomato & hot pepper", said a consortium member. "The knowledge shared on this platform was very useful for us to plan the breeding strategies and I am very happy to be part of it", said another consortium member. Another participant remarked: "We received a lot of very important information for our future breeding activities. It was a very successful program and I wish WorldVeg to continue such a program in the future".

In 2021, a total of 34 exclusive lines of tomato, pepper and bitter melon were made available to all consortium members and 3562 packets of seeds distributed. In addition, a research project entitled "Heat stress tolerance of tomato & pepper" was successfully launched and jointly funded by 14 consortium companies from nine countries.



SEED CONSORTIA



Africa Vegetable Breeding Consortium (AVBC)

The AVBC was initiated in 2018 as a joint initiative of the World Vegetable Center and the Africa Seed Trade Association (AFSTA). The Consortium promotes the development of a strong vegetable seed sector in Africa, supporting small, regional and international companies. AVBC subscription fees have been suspended in 2021 and 2022 thanks to the generous support of the FCDO and USAID. In 2021, two AVBC membership categories were established:

Full members are seed companies that are current AFSTA members and engaged in vegetable breeding. There were 23 full members in 2021 from 14 countries.

Associate members include universities, NARS, NGO's and do not need to be AFSTA members

but must be engaged in vegetable breeding, variety testing, or seed production. In 2021, AVBC counted 23 Associate members from 10 countries.

The 2021 AVBC annual workshop was held on 21-22 September 2021 online and at the WorldVeg Eastern and Southern Africa campus in Arusha, Tanzania, attended by more than 65 participants. Access to improved breeding material is a major benefit of AVBC membership and a total of 40 exclusive lines of African eggplant, amaranth, mungbean, peppers, pumpkin and tomato were shown in demonstrations trials and open to visits on day 2 of the Arusha workshop.

Partnership is a long term investment toward impact. The seed consortia provide a platform for action to work together for a greater impact in a faster time.



APSA-WorldVeg Vegetable Breeding Consortium

- Certus Seeds Pvt. Ltd., Pakistan
- Chakra Seeds (Bharat Nursery Pvt. Ltd.), India
- Chia Tai Co., Ltd., Thailand
- Clover Seed Co., Ltd., Hong Kong
- Comienzo Agri Science Ltd., India
- East-West Seed International Ltd., Thailand
- Enza Zaden India Pvt. Ltd., India
- Feltrin Sementes Ltda, Brazil
- Gemini Seeds Pvt. Ltd., India
- Genting Green Sdn Bhd, Malaysia
- HM. CLAUSE India Pvt. Ltd., India
- I & B Seeds Pvt. Ltd., India
- Kalash Seeds Pvt. Ltd., India
- Kaveri Seed Co., Ltd., India
- Landmark Agro Seeds Pvt. Ltd., Sri Lanka
- Mahindra Agri Solutions Ltd., India
- Mahyco Pvt. Ltd., India
- Monsanto Holdings Pvt. Ltd., India
- Monsoon Foods, India
- Namdhari Seeds Pvt. Ltd., India
- Nath Bio-Genes (I) Ltd., India
- Nong Woo Bio, South Korea
- Nongwoo Seed India Pvt. Ltd., India
- Nova Genetic, France

- Nunhems India Pvt. Ltd., India
- Nuziveedu Seeds Ltd., India
- Onesh Agri Pvt. Ltd., Sri Lanka
- PT. BISI International Tbk, Indonesia
- PT. East West Seed Indonesia
- Rallis India Ltd., India
- Rijk Zwaan India Pvt. Ltd., India
- Seedworks International Pvt. Ltd., India
- Shriram Bioseed Genetics (A Division of DSCL), India
- Sing-Flow Seed Co., Ltd., Taiwan
- Syngenta India Ltd., India
- Takii & Company, Ltd., Japan
- Tokita Seed India Pvt. Ltd., India
- Your Chain Seed Co., Ltd., Taiwan

Africa Vegetable Breeding Consortium

- Agri Commercial Services Ltd. (ACSL), Ghana
- Agriseeds (subsidiary of Morabit Holding Group), Morocco
- Bakker Brothers Seeds, Netherlands
- Bayer East Africa Ltd., Kenya
- Continental Seeds, Kenya
- East African Seed Co., Ltd., Kenya
- East West Seed International, Tanzania
- EPAM (Enterprise et Promoteur de produits Agricoles Modernes), Burkina Faso
- EPC-SAC sarl (Entreprise e production et de commercialisation de



STRENGTHENING PARTNERSHIP WITH THE PRIVATE SEED SECTOR

semence ameliorée et certifiée), Burkina Faso
 FAGRI SARL, Burkina Faso
 FASO KABA SRL, Mali
 Indo-American Hybrid Seeds, India
 Kamano Seed, Zambia
 Meru Agro-Tours & Consultants Co. Ltd., Tanzania
 Neema Agricole du Faso (NAFASO SA), Burkina Faso
 Nova Genetic, France
 Premier Seed Nigeria Limited, Nigeria
 Rijk Zwaan Afrisem Ltd., Tanzania
 SeedCo International Limited, Zimbabwe
 Simlaw Seeds Company Ltd., Kenya
 Syngenta Seeds B.V., Netherlands
 Victoria Seeds Ltd., Uganda
 Zamoho, Mali

Contributors: Heat stress tolerance of tomato & pepper (HST) Project (August 2021 – July 2024)

Bioseed Research India
 Chia Tai Co., Ltd., Thailand
 East West Seed International Ltd., Thailand
 Genting Green Sdn Bhd, Malaysia
 HM. CLAUSE S.A.S, France
 I & B Seeds Pvt. Ltd., India
 Monsanto Company and Monsanto Holdings Pvt. Ltd., India

Nath Bio-Genes (I) Ltd., India
 Nova Genetic, France
 Nunhems Netherlands BV
 Onesh Agri Pvt. Ltd., Sri Lanka
 PT. East West Seed Indonesia
 Takii & Company, Ltd., Japan
 Your Chain Seed Co., Ltd., Taiwan

Taiwan companies/agricultural research institute in-kind contribution: multiplying WorldVeg germplasm

All Lucky Seed Co., Ltd.
 Known-You Seed Co., Ltd.
 Seven Stars Seed Co.
 Sheng Nong Seed Co., Ltd.
 Suntech Seed Co., Ltd.
 Telome Seedlings Co., Ltd.
 Your Chain Seed Co., Ltd.
 Taiwan Seed Improvement and Propagation Station



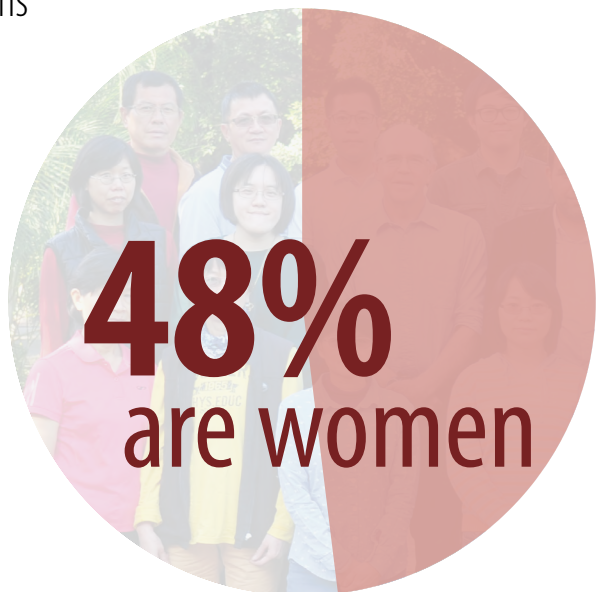
A MULTIPLICITY OF TALENTS, SKILLS AND VIEWPOINTS

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

Number of staff in 2021: **347**

Number of nationalities among staff: **27**

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





🔊 Unmute ▾ 📹 Start video ▾ 📄 Share 📄 Record 🗣️ ⋮ 🔴 ×

👤 Participants 💬 Chat ⋮

Board of Directors

NAME	COUNTRY	APPOINTED
Dr. Junne-Jih Chen, <i>Board Chair</i>	Taiwan	Apr 2011
Dr. Masa Iwanaga, <i>Vice-Board Chair</i>	Japan	Apr 2016
Dr. Victor Ajieroh	Nigeria	Dec 2021
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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
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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, <i>ex-officio member</i>	The Netherlands	Apr 2016
Mr. Akira Yokochi	Japan	Sep 2020

FINANCE

	WorldVeg	CGIAR recommended range
Cash management on restricted operations*	0.16	less than 1
Adequacy of reserves	112 days	75-90 days
Short-term solvency	136 days	90-120 days

2021 Revenues (in '000 USD)

Unrestricted grants	6,401	25%
Restricted grants	18,719	73%
Other revenues	379	1%
Total	25,499	100%

Unrestricted Grants

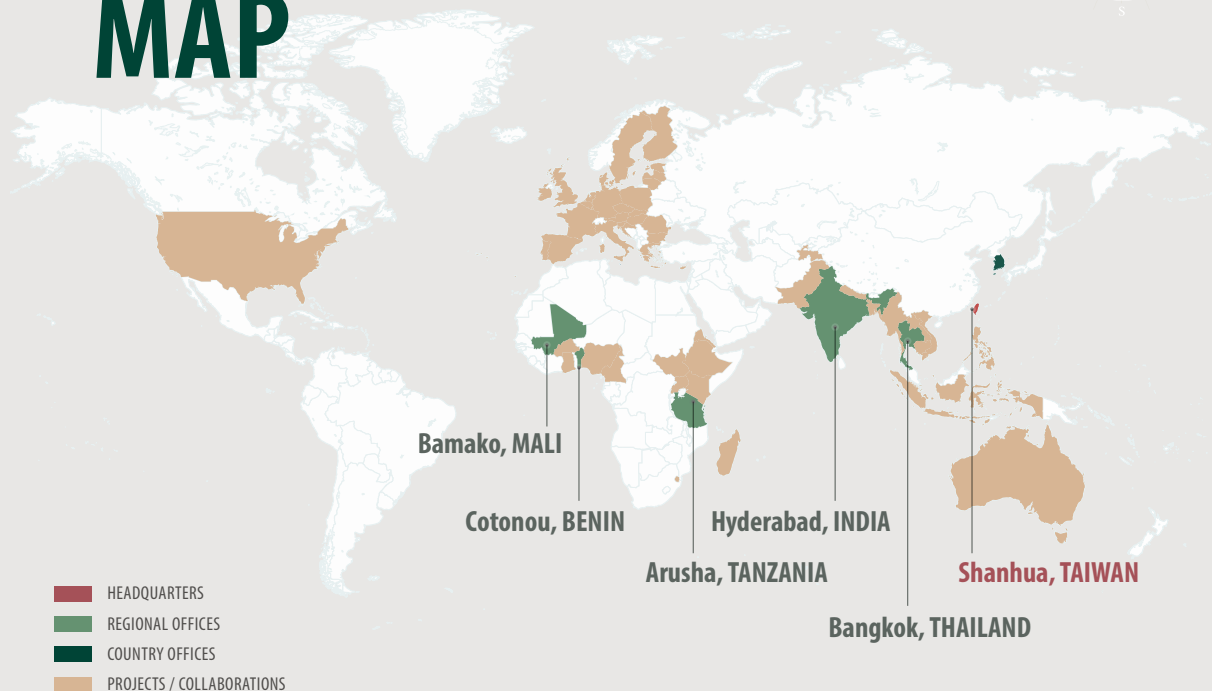
Republic of China (ROC)	5,034
UK Foreign, Commonwealth & Development Office (FCDO)	-
United States Agency for International Development (USAID)	850
Australian Centre for International Agricultural Research (ACIAR)	326
Thailand	136
Korea	50
Japan	5
The Philippines	0
Sub-total	6,401
Other revenues	379
Total	6,780

Restricted Grants

Republic of China (Taiwan)	9,566
UK Foreign, Commonwealth & Development Office (FCDO)	1,607
IKEA Foundation	1,411
The Netherlands (MOFA) and European Union	1,245
Republic of Germany / BMZ / GIZ	1,191
Private seed sector companies; Asia and Pacific Seed Association (APSA)	693
Australia/Australian Centre for International Agricultural Research (ACIAR)	513
Korea / RDA	402
United States Agency for International Development (USAID)	388
State Governments of India	336
Others (projects with expenses less than 200K USD)	1,369
Sub-total	18,719
Total Revenues	25,499



MAP



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MALI
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West and Central Africa – Coastal & Humid Regions

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

GENEREROUS and VISIONARY

STRATEGIC LONG-TERM
FUNDING



PROJECT FUNDING



ASIAN DEVELOPMENT BANK



Japan-ASEAN Cooperation



Australian Government

Australian Centre for
International Agricultural Research



सत्यमेव जयते

विज्ञान एवं
प्रौद्योगिकी मंत्रालय
MINISTRY OF
SCIENCE AND
TECHNOLOGY



Department
for Environment
Food & Rural Affairs



Foreign, Commonwealth
& Development Office

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

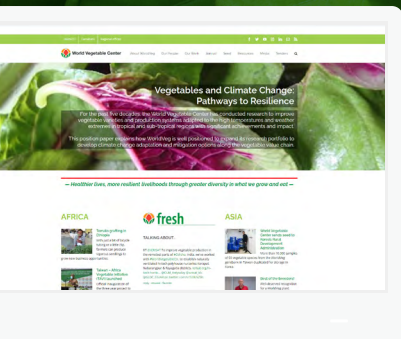
We recognize those donors that provided US\$ 100,000 or more to further the Center’s work during 2021.



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 2021:

Monthly unique visitors to worldveg.org: **31,000+**
Subscribers to Fresh, the WorldVeg newsletter: **9,731**



facebook followers: **28,637**

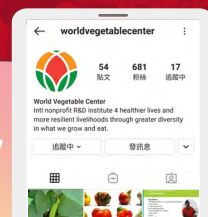
LinkedIn followers: **14,513**



WorldVeg  YouTube channel: **9,700**

twitter followers: **10,186** (@WorldVegCenter)

Instagram followers: **1,027**



Media mentions: **304**.

Visitors: More than **675 visitors from 36 countries** toured WorldVeg headquarters and regional offices to learn about our research and projects, and see WorldVeg improved varieties, traditional vegetables and new technologies in our Demonstration Gardens.

WorldVeg contributed to the International Year of Fruits and Vegetables in 2021:



INTERNATIONAL YEAR OF
FRUITS AND VEGETABLES
2021

22

Facebook posts

100+

Twitter tweets

50+

Instagram posts

100+

#ShowUsYourGarden!

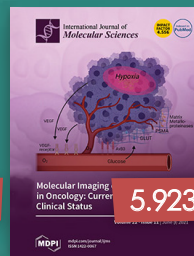
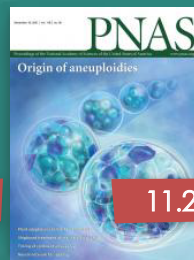
WORLD FOOD PRIZE FOUNDATION

Side event

RESEARCH FOR DEVELOPMENT



TOP 10 journals according
to impact factor



2021 Publications

Journal articles with impact factor (81)

1. Abang, A.F.; Srinivasan, R.; Hanna, R.; Fotso, A.K.; Kekeunou, S.; Tenkouano, A.; Bilong Bilong, C.-F. 2021. Productivity and resistance of okra (*Abelmoschus* spp.) to the cotton aphid *Aphis gossypii* Glover (Hemiptera: Aphididae) under tropical conditions. *INTERNATIONAL JOURNAL OF TROPICAL INSECT SCIENCE*. 41:197-208.
2. Adhikari, K.N.; Khazaei, H.; Ghaouti, L.; Maalouf, F.; Vandenberg, A.; Link, W.; O'Sullivan, D.M. 2021. Conventional and molecular breeding tools for accelerating genetic gain in faba bean (*Vicia Faba* L.). *FRONTIERS IN PLANT SCIENCE*. 12:744259.
3. Aski, M.S.; Rai, N.; Reddy, V.R.P.; Gayacharan; Dikshit, H.K.; Mishra, G.P.; Singh, D.; Kumar, A.; Pandey, R.; Singh, M.P.; Pratap, A.; Nair, R.M.; Schafleitner, R. 2021. Assessment of root phenotypes in mungbean mini-core collection (MMC) from the World Vegetable Center (AVRDC) Taiwan. *PLoS ONE*. 16(3):e0247810.
4. Ayenan, M.A.T.; Danquah, A.; Agre, P.A.; Hanson, P.; Asante, I.K.; Danquah, E.Y. 2021. Genomic and phenotypic diversity of cultivated and wild tomatoes with varying levels of heat tolerance. *GENES*. 12(4):503.
5. Ayenan, M.A.T.; Danquah, A.; Hanson, P.; Asante, I.K.; Danquah, E.Y. 2021. Identification of new sources of heat tolerance in cultivated and wild tomatoes. *EUPHYTICA*. 217:33.
6. Boni, S.B.; Mwashimaha, R.A.; Mlowe, N.; Sotelo-Cardona, P.; Nordey, T. 2021. Efficacy of indigenous entomopathogenic fungi against the black aphid, *Aphis fabae* Scopoli under controlled conditions in Tanzania. *INTERNATIONAL JOURNAL OF TROPICAL INSECT SCIENCE*. 41:1643-1651.
7. Buragohain, P.; Saikia, D.K.; Sotelo-Cardona, P.; Srinivasan, R. 2021. Evaluation of bio-pesticides against the South American tomato leaf miner, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) in India. *HORTICULTURAE*. 7(9):325.
8. Buragohain, P.; Saikia, D.K.; Sotelo-Cardona, P.; Srinivasan, R. 2021. Development and validation of an integrated pest management strategy against the invasive South American tomato leaf miner, *Tuta absoluta* in South India. *CROP PROTECTION*. 139:105348.
9. Carley, L.N.; Mojica, J.P.; Wang, B.; Chen, C.-Y.; Lin, Y.-P.; Prasad, K.V.S.K.; Chan, E.; Hsu, C.-W.; Keith, R.; Nuñez, C.L.; Olson-Manning, C.F.; Rushworth, C.A.; Wagner, M.R.; Wang, J.; Yeh, P.-M.; Reichelt, M.; Ghattas, K.; Gershenzon, J.; Lee, C.-R.; Mitchell-Olds, T. 2021. Ecological factors influence balancing selection on leaf chemical profiles of a wildflower. *NATURE ECOLOGY & EVOLUTION*. 5(8):1135-1144.
10. Dasgupta, U.; Mishra, G.P.; Dikshit, H.K.; Mishra, D.C.; Bosamia, T.; Roy, A.; Bhatil, J.; Priti; Aski, M.; Kumar, R.R.; Singh, A.K.; Kumar, A.; Sinha, S.K.; Chaurasia, S.; Praveen, S.; Nair, R.M. 2021. Comparative RNA-Seq analysis unfolds a complex regulatory network imparting yellow mosaic disease resistance in mungbean [*Vigna radiata* (L.) R. Wilczek]. *PLoS ONE*. 16(1):e0244593.
11. Depenbusch, L.; Farnworth, C.R.; Schreinemachers, P.; Myint, T.; Islam, M.M.; Kundu, N.D.; Myint, T.; San, A.M.; Jahan, R.; Nair, R.M. 2021. When machines take the beans: Ex-ante socioeconomic impact evaluation of mechanized harvesting of mungbean in Bangladesh and Myanmar. *AGRONOMY*. 11(5):925.
12. Depenbusch, L.; Schreinemachers, P.; Roothaert, R.; Namazzi, S.; Onyango, C.; Bongole, S.; Mutebi, J. 2021. Impact of home garden interventions in East Africa: Results of three randomized controlled trials. *FOOD POLICY*. 104:102140.
13. Dhillon, N.P.S.; Srimat, S.; Laenoi, S.; Bhunchoth, A.; Phuangrat, B.; Warin, N.; Deeto, R.; Chatchawankanphanich, O.; Jom, K.N.; Sae-tan, S.; Jang, S.-W.; Noh, H.; Schafleitner, R.; Chan, Y.-L.; Picó, B.; Sáez, C.; Kenyon, L. 2021. Resistance to three distinct Begomovirus species in the agronomical superior tropical pumpkin line AVPU1426 developed at the World Vegetable Center. *AGRONOMY*. 11:1256.

14. Dixon, J.M.; Weerahewa, J.; Hellin, J.; Rola-Rubzen, M.F.; Huang, J.; Kumar, S.; Das, A.; Qureshi, M.E.; Krupnik, T.J.; Shideed, K.; Jat, M.L.; Prasad, P.V. V.; Yadav, S.; Irshad, A.; Asanaliev, A.; Abugalieva, A.; Karimov, A.; Bhattarai, B.; Balgos, C.Q.; Benu, F.; Ehara, H.; Pant, J.; Sarmiento, J.M.P.; Newby, J.C.; Jules, P.; Tokuda, H.; Weyerhaeuser, H.; Digal, L.N.; Li, L.; Sarkar, M.A.R.; Abedin, M.Z.; Schreinemachers, P.; Grafton, Q.; Sharma, R.C.; Saidzoda, S.; Lopez-Ridaura, S.; Coffey, S.; Kam, S.P.; Win, S.S.; Praneetvatakul, S.; Maraseni, T.; Touch, V.; Liang, W.-L.; Saharawat, Y. S.; Timsi, J. 2021. Response and resilience of Asian agrifood systems to COVID-19: An assessment across twenty-five countries and four regional farming and food systems. *AGRICULTURAL SYSTEMS*. 193:103168.
15. Gatti, J.-L.; Belghazi, M.; Legeai, F.; Ravallec, M.; Frayssinet, M.; Robin, S.; Aboubakar-Souna, D.; Srinivasan, R.; Tamò, M.; Poirié, M.; Volkoff, A.-N. 2021. Proteo-transcriptomic analyses reveal a large expansion of metalloprotease-like proteins in atypical venom vesicles of the wasp *Meteorus pulchricornis* (Braconidae). *TOXINS*. 13(7):502.
16. Gillespie, S.; Harris, J.; Nisbett, N.; van den Bold, M. 2021. Stories of change in nutrition from Africa and Asia: an introduction to a special series in Food Security. *FOOD SECURITY*. 13(4):799-802.
17. Gore, P.G.; Das, A.; Bhardwaj, R.; Tripathi, K.; Pratap, A.; Dikshit, H.K.; Bhattacharya, S.; Nair, R.M.; Gupta, V. 2021. Understanding G × E interaction for nutritional and antinutritional factors in a diverse panel of *Vigna stipulacea* (Lam.) Kuntz germplasm tested over the locations. *FRONTIERS IN PLANT SCIENCE*. 12:766645.
18. Gyawali, P.; Hwang, S.-Y.; Sotelo-Cardona, P.; Srinivasan, R. 2021. Elucidating the fitness of a dead-end trap crop strategy against the Tomato Fruitworm, *Helicoverpa armigera*. *INSECTS*. 12(6):506.
19. Harris, J.; Huynh, P.; Hoa, T.N.; Nga, H.; Lan, T.M.; Le, D.T.; Phuong, H.N. 2021. Nobody left behind? Equity and the drivers of stunting reduction in Vietnamese ethnic minority populations. *FOOD SECURITY*. 13(4):803-818.
20. Hoshikawa, K.; Pham, D.; Ezura, H.; Schafleitner, R.; Nakashima, K. 2021. Genetic and molecular mechanisms conferring heat stress tolerance in tomato plants. *FRONTIERS IN PLANT SCIENCE*. 12:786688.
21. Hsieh, W.-H.; Chen, Y.-C.; Liao, H.-C.; Lin, Y.-R.; Chen, C.-H. 2021. High differentiation among populations of green foxtail, *Setaria viridis*, in Taiwan and adjacent islands revealed by microsatellite markers. *DIVERSITY*. 13(4):159.
22. Ibrahim, A.; Saito, K.; Bado, V.B.; Wopereis, M.C.S. 2021. Thirty years of agronomy research for development in irrigated rice-based cropping systems in the West African Sahel: Achievements and perspectives. *FIELD CROPS RESEARCH*. 266:108149.
23. Jang, S.; Cho, J.-Y.; Do, G.-R.; Kang, Y.; Li, H.-Y.; Song, J.; Kim, H.-Y.; Kim, B.-G.; Hsing, Y.-I. 2021. Modulation of rice leaf angle and grain size by expressing OsBCL1 and OsBCL2 under the control of OsBUL1 promoter. *INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES*. 22(15):7792.
24. Kang, Y.; Jang, S.-W.; Lee, H.J.; Barchenger, D.W.; Jang, S. 2021. Expression profiling of heat shock protein genes as putative early heat-responsive members in lettuce. *HORTICULTURAE*. 7(9):312.
25. Kang, Y.; Kim, M.; Shim, C.; Bae, S.; Jang, S. 2021. Potential of algae-bacteria synergistic effects on vegetable production. *FRONTIERS IN PLANT SCIENCE*. 12:656662.
26. Keding, G.B.; Gramzow, A.; Ochieng, J.; Laizer, A.; Muchoki, C.; Onyango, C.; Hanson, P.; Yang, R.-Y. 2021. Nutrition integrated agricultural extension: A case study in Western Kenya. *HEALTH PROMOTION INTERNATIONAL*. online.
27. Kelly, L.A.; Vaghefi, N.; Bransgrove, K.; Fechner, N.A.; Stuart, K.; Pandey, A.K.; Sharma, M.; Németh, M.Z.; Liu, S.-Y.; Tang, S.-R.; Nair, R.M.; Douglas, C.A.; Kiss, L. 2021. One crop disease, how many pathogens? *Podospaera xanthii* and *Erysiphe vignae* sp. nov. identified as the two species that cause powdery mildew of mungbean (*Vigna radiata*) and black gram (*V. mungo*) in Australia. *PHYTOPATHOLOGY*. 111(7):1193-1206.
28. Kim, Y.-C.; Kang, Y.; Yang, E.-Y.; Cho, M.-C.; Schafleitner, R.; Lee, J.H.; Jang, S. 2021. Applications and major achievements of genome editing in vegetable crops: A review. *FRONTIERS IN PLANT SCIENCE*. 12:688980.
29. Klippenstein, S.R.; Khazaee, H.; Vandenberg, A.; Schoenau, J. 2021. Nitrogen and phosphorus uptake and nitrogen fixation estimation of faba bean (*Vicia faba* L.) in Western Canada. *AGRONOMY JOURNAL*. accepted articles.

30. Kumawat, K.C.; Sharma, P.; Nagpal, S.; Gupta, R.K.; Sirari, A.; Nair, R.M.; Bindumadhava, H.; Singh, S. 2021. Dual microbial inoculation, a game changer? – Bacterial biostimulants with multifunctional growth promoting traits to mitigate salinity stress in spring mungbean. *FRONTIERS IN MICROBIOLOGY*. 11:600576.
31. Kundu, S.; Banna, M.H.A.; Sayeed, A.; Sultana, M.S.; Brazendale, K.; Harris, J.; Mandal, M.; Jahan, I.; Abid, M.T.; Khan, M.S.I. 2021. Determinants of household food security and dietary diversity during the COVID-19 pandemic in Bangladesh. *PUBLIC HEALTH NUTRITION*. 24(5):1079-1087.
32. Kuo, Y.-T.; Ishii, T.; Fuchs, J.; Hsieh, W.-H.; Houben, A.; Lin, Y.-R. 2021. The evolutionary dynamics of repetitive DNA and its impact on the genome
33. Larranaga, N.; van Zonneveld, M.; Hormaza, J.I. 2021. Holocene land and sea-trade routes explain complex patterns of pre-Columbian crop dispersion. *NEW PHYTOLOGIST*. 229(3):1768-1781.
34. Lee, H.J.; Lee, J.H.; Wi, S.; Jang, Y.; An, S.; Choi, C.K.; Jang, S. 2021. Exogenously applied glutamic acid confers improved yield through increased photosynthesis efficiency and antioxidant defense system under chilling stress condition in *Solanum lycopersicum* L. cv. Dotaerang Dia. *SCIENTIA HORTICULTURAE*. 277:109817.
35. Li, R.S.; van Zonneveld, M. 2021. Seed longevity of two nutrient-dense vegetables (*Amaranthus* spp.). *SEED SCIENCE AND TECHNOLOGY*. 49(1):25-31.
36. Lin, T.H.; Lin, S.W.; Wang, Y.W.; van Zonneveld, M.; Barchenger, D.W. 2021. Growing environment and heat treatment effects on intra- and interspecific pollination in chile pepper (*Capsicum* spp.). *AGRONOMY*. 11:1275.
37. Lin, Y.-P.; Mitchell-Olds, T.; Lee, C.-R. 2021. The ecological, genetic and genomic architecture of local adaptation and population differentiation in *Boechera stricta*. *PROCEEDINGS OF THE ROYAL SOCIETY B*. 288(1949):20202472.
38. Lozada, D.N.; Nunez, G.; Lujan, P.; Dura, S.; Coon, D.; Barchenger, D.W.; Sanogo, S.; Bosland, P.W. 2021. Genomic regions and candidate genes linked with *Phytophthora capsici* root rot resistance in chile pepper (*Capsicum annuum* L.). *BMC PLANT BIOLOGY*. 21:601.
39. Makinya, K.J.; Wagacha, J.M.; Odhiambo, J.A.; Likhayo, P.; Edoh-Ognakossan, K.; Tefera, T.; Abass, A.; Mutungi, C.M. 2021. The importance of store hygiene for reducing post-harvest losses in smallholder farmers' stores: Evidence from a maize-based farming system in Kenya. *JOURNAL OF STORED PRODUCTS RESEARCH*. 90:101757.
40. Manickam, R.; Chen, J.-R.; Sotelo-Cardona, P.; Kenyon, L.; Srinivasan, R. 2021. Evaluation of different bacterial wilt resistant eggplant rootstocks for grafting tomato. *PLANTS*. 10(1):75.
41. Martin, R.; Yous, S.; Korn, C.; Yous, S.; Pheng, S.; Rien, R.; Srinivasan, R. 2021. Management of Bean Flower Thrips (*Megalurothrips usitatus* Bagnall) in mungbean (*Vigna radiata* (L.) Wilczek) in North-west Cambodia. *GENERAL AND APPLIED ENTOMOLOGY*. 49:43-57.
42. Maxwell, L.A.; Callicott, K.A.; Bandyopadhyay, R.; Mehl, H.L.; Orbach, M.J.; Cotty, P.J. 2021. Degradation of aflatoxins B1 by atoxigenic *Aspergillus flavus* biocontrol agents. *PLANT DISEASE*. 105(9):2343-2350.
43. Mbogho, A.Y.; Mwashimaha, R.; Mbwambo, O.; Boni, S.B.; Yarro, J.; Nyundo, B.; Zalucki, M.P.; Srinivasan, R. 2021. Comparative effects of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) and *Crocidolomia pavonana* (F.) (Lepidoptera: Crambidae) on cabbage yield in Tanzania. *INTERNATIONAL JOURNAL OF TROPICAL INSECT SCIENCE*. 41(4):2733-2738.
44. Mekapogu, M.; Jung, J.-A.; Kwon, O.-K.; Ahn, M.-S.; Song, H.-Y.; Jang, S. 2021. Recent progress in enhancing fungal disease resistance in ornamental plants. *INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES*. 22(15):7956.
45. Mmbando, F.; Mbeyagala, E.; Binagwa, P.; Karimi, R.; Opie, H.; Ochieng, J.; Mutuoki, T.; Nair, R.M. 2021. Adoption of improved mungbean production technologies in selected East African countries. *AGRICULTURE*. 11(6):528.
46. Mwadzingeni, L.; Afari-Sefa, V.; Shimelis, H.; N'Danikou, S.; Figlan, S.; Depenbusch, L.; Shayanowako, A.I.T.; Chagomoka, T.; Mushayi, M.; Schreinemachers, P.; Derera, J. 2021. Unpacking the value of traditional African vegetables for food and nutrition security. *FOOD SECURITY*. 13(5):1215-1226.

47. Mwambi, M.; Bijman, J.; Galie, A. 2021. The effect of membership in producer organizations on women's empowerment: Evidence from Kenya. *WOMEN'S STUDIES INTERNATIONAL FORUM*. 87:102492.
48. Nair, R.M.; Giri, R.R.; Boddepalli, V.N.; Prasad, K.V.S.V.; Devulapalli, R.; Blümmel, M. 2021. Variation in grain yield, fodder quality and animal intake in two dual purpose legume crops: Mungbean and vegetable soybean grown in semi-arid tropical India. *LEGUME RESEARCH*. 44(2):207-214.
49. Nisbett, N.; Friel, S.; Aryeetey, R.; Gomes, F. da S.; Harris, J.; Backholer, K.; Baker, P.; Jernigan, V.B.B.; Phulkerd, S. 2021. Equity and expertise in the UN Food Systems Summit. *BMJ GLOBAL HEALTH*.
50. Nisbett, N.; Harris, J.; Backholer, K.; Baker, P.; Jernigan, V.B.B.; Friel, S. 2021. Holding no-one back: The Nutrition Equity Framework in theory and practice. *GLOBAL FOOD SECURITY*. 32:100605.
51. Nordey, T.; Boni, S.B.; Agbodzavu, M.K.; Mwashimaha, R.; Mlowe, N.; Srinivasan, R.; Deletre, E. 2021. Comparison of biological methods to control *Aphis fabae* Scopoli (Hemiptera: Aphididae) on kalanchoe crops in East Africa. *CROP PROTECTION*. 142:105520.
52. Nosaki, S.; Hoshikawa, K.; Ezura, H.; Miura, K. 2021. Transient protein expression systems in plants and their applications. *PLANT BIOTECHNOLOGY*. 38(3):297-304.
53. Ochieng, J.; Afari-Sefa, V.; Muthoni, F.; Kansime, M.; Hoeschle-Zeledon, I.; Bekunda, M.; Dubois, T. 2021. Adoption of sustainable agricultural technologies for vegetable production in rural Tanzania: trade-offs, complementarities and diffusion. *INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY*. Online.
54. Pandey, A.K.; Basandrai, A.K.; Basandrai, D.; Boddepalli, V.N.; Rathore, A.; Adapala, G.; Nair, R.M. 2021. Field-relevant new sources of resistance to anthracnose caused by *Colletotrichum truncatum* in a mungbean mini-core collection. *PLANT DISEASE*. 105(7):2001-2010.
55. Pandey, A.K.; Yee, M.; Win, M.M.; Lwin, H.M.M.; Adapala, G.; Rathore, A.; Sheu, Z.-M.; Nair, R.M. 2021. Identification of new sources of resistance to dry root rot caused by *Macrophomina phaseolina* isolates from India and Myanmar in a mungbean mini-core collection. *CROP PROTECTION*. 143:105569.
56. Parry, C.; Wang, Y.-W.; Lin, S.-W.; Barchenger, D.W. 2021. Reproductive compatibility in *Capsicum* is not necessarily reflected in genetic or phenotypic similarity between species complexes. *PLoS ONE*. 16(3):e0243689.
57. Priti; Mishra, G.P.; Dikshit, H.K.; Vinutha, T.; Tontang, M.T.; Stobdan, T.; Sangwan, S.; Aski, M.; Singh, A.; Kumar, R.R.; Tripathi, K.; Kumar, S.; Nair, R.M.; Praveen, S. 2021. Diversity in phytochemical composition, antioxidant capacities, and nutrient contents among mungbean and lentil microgreens when grown at plain-altitude region (Delhi) and high-altitude region (Leh-Ladakh), India. *FRONTIERS IN PLANT SCIENCE*. 12:710812.
58. Rane, J.; Raina, S.K.; Govindasamy, V.; Bindumadhava, H.; Hanjagi, P.; Giri, R.; Jangid, K.K.; Kumar, M.; Nair, R.M. 2021. Use of phenomics for differentiation of mungbean (*Vigna radiata* L. Wilczek) genotypes varying in growth rates per unit of water. *FRONTIERS IN PLANT SCIENCE*. 12:692564.
59. Raubach, S.; Kilian, B.; Dreher, K.; Amri, A.; Bassi, F.M.; Boukar, O.; Cook, D.; Cruickshank, A.; Fatokun, C.; Haddad, N.E.; Humphries, A.; Jordan, D.; Kehel, Z.; Kumar, S.; Labarosa, S.J.; Nguyen, L.H.; Mace, E.; McCouch, S.; McNally, K.; Marshall, D.F.; Mikwa, E.O.; Milne, I.; Odeny, D.A.; Plazas, M.; Prohens, J.; Rieseberg, L.H.; Schafleitner, R.; Sharma, S.; Stephen, G.; Tin, H.Q.; Togola, A.; Warschefsky, E.; Werner, P.; Shaw, P.D. 2021. From bits to bites: Advancement of the Germinate platform to support prebreeding informatics for crop wild relatives. *CROP SCIENCE*. 61(3):1538-1566.
60. Reddy, V.R.P.; Das, S.; Dikshit, H.K.; Mishra, G.P.; Aski, M.S.; Singh, A.; Tripathi, K.; Pandey, R.; Bansal, R.; Singh, M.P.; Gore, P.G.; Manjunatha, P.B.; Kothari, D.; Rai, N.; Nair, R.M. 2021. Genetic dissection of phosphorous uptake and utilization efficiency traits using GWAS in mungbean. *AGRONOMY*. 11(7):1401.
61. Reddy, V.R.P.; Dikshit, H.K.; Mishra, G.P.; Aski, M.; Singh, A.; Bansal, R.; Pandey, R.; Nair, R.M. 2021. Comparison of different selection traits for identification of phosphorus use efficient lines in mungbean. *PeerJ*. 9:e12156.
62. Reyes, L.I.; Constantinides, S.V.; Bhandari, S.; Frongillo, E.A.; Schreinemachers, P.; Wertheim-Heck, S.; Wall, H.; Holdsworth, M.; Laar, A.; Nguyen, T.; Turner, C.; Wellard, K.; Blake, C.E. 2021. Actions in global nutrition initiatives to promote sustainable healthy diets. *GLOBAL FOOD SECURITY*. 31:100585.

63. Schafleitner, R.; Lin, C.-Y.; Lin, Y.-P.; Wu, T.-H.; Hung, C.-H.; Phooi, C.-L.; Chu, S.-H.; Jhong, Y.-C.; Hsiao, Y.-Y. 2021. The World Vegetable Center okra (*Abelmoschus esculentus*) core collection as a source for flooding stress tolerance traits for breeding. *AGRICULTURE*. 11(2):165.
64. Schreinemachers, P.; Howard, J.; Turner, M.; Groot, S.N.; Dubey, B.; Mwadzingeni, L.; Chagomoka, T.; Ngugi, M.; Afari-Sefa, V.; Hanson, P.; Wopereis, M.C.S. 2021. Africa's evolving vegetable seed sector: Status, policy options and lessons from Asia. *FOOD SECURITY*. 13(3):511-523.
65. Schreinemachers, P.; Shrestha, R.M.; Gole, B.; Bhattarai, D.R.; Ghimire, P.L.; Subedi, B.P.; Brück, T.; Baliki, G.; Gautam, I.P.; Blake, C.E. 2021. Drivers of food choice among children and caregivers in post-earthquake Nepal. *ECOLOGY OF FOOD AND NUTRITION*. 60(6):826-846.
66. Senthilkumar, P.K.; Lin, M.-Y.; Chinniah, C.; Srinivasan, R.; Sotelo-Cardona, P. 2021. Effect of different colored net-house conditions on life table parameters of the diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), on broccoli (*Brassica oleracea* L. var. *italica*). *INTERNATIONAL JOURNAL OF TROPICAL INSECT SCIENCE*. 42:45-54.
67. Sheu, Z.M.; Chiu, M.H.; Kenyon, L. 2021. First report of *Podosphaera xanthii* causing powdery mildew on mungbean (*Vigna radiata*) in Taiwan. *PLANT DISEASE*. 105(6):1856.
68. Sikirou, R.; Dossoumou, M.E.; Honfoga, J.; Afari-Sefa, V.; Srinivasan, R.; Paret, M.; Bihon, W. 2021. Screening of *Amaranthus* sp. varieties for resistance to bacterial wilt caused by *Ralstonia solanacearum*. *HORTICULTURAE*. 7(11):465.
69. Sotelo Cardona, P.; Chuang, W.P.; Lin, M.Y.; Chiang, M.Y.; Srinivasan, R. 2021. Oviposition preference not necessarily predicts offspring performance in the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on vegetable crops. *SCIENTIFIC REPORTS*. 11:15885.
70. Souna, D.A.; Bokonon-Ganta, A.H.; Ravallec, M.; Alizannon, M.; Srinivasan, R.; Pittendrigh, B.R.; Volkoff, A.-N.; Tamò, M. 2021. Progeny fitness determines the performance of the parasitoid *Therophilus javanus*, a prospective biocontrol agent against the legume pod borer. *SCIENTIFIC REPORTS*. 11:8990.
71. Srinivasan, R.; Tamò, M.; Malini, P. 2021. Emergence of *Maruca vitrata* as a Major Pest of Food Legumes and Evolution of Management Practices in Asia and Africa. *ANNUAL REVIEW OF ENTOMOLOGY*. 66:141-161.
72. Tchokponhoué, D.A.; Achigan-Dako, E.G.; N'Danikou, S.; Nyadanu, D.; Kahane, R.; Odindo, A.O.; Sibiya, J. 2021. Comparative analysis of management practices and end-users' desired breeding traits in the miracle plant [*Synsepalum dulcificum* (Schumach & Thonn.) Daniell] across ecological zones and sociolinguistic groups in West Africa. *JOURNAL OF ETHNOBIOLOGY AND ETHNOMEDICINE*. 17:41.
73. Tchokponhoué, D.A.; N'Danikou, S.; Hotegni, N.V.F.; Nyadanu, D.; Kahane, R.; Odindo, A.O.; Achigan-Dako, E.G.; Sibiya, J. 2021. Use patterns, knowledge diversity and drivers for the cultivation of the miracle plant [*Synsepalum dulcificum* (Schumach & Thonn.) Daniell] in Benin and Ghana. *PLANTS*. 10(11):2253.
74. Tepe, J.; Benali, M.; Lemken, D. 2021. Consumer demand for novel fruit and vegetable products with extended shelf lives in East Africa: a multinational multi-product analysis. *PUBLIC HEALTH NUTRITION*. Online.
75. Tripodi, P.; Rabanus-Wallace, M.T.; Barchi, L.; Kale, S.; Esposito, S.; Acquadro, A.; Schafleitner, R.; van Zonneveld, M.; Prohens, J.; Diez, M.J.; Börner, A.; Salinier, J.; Caromel, B.; Bovy, A.; Boyaci, F.; Pasev, G.; Brandt, R.; Himmelbach, A.; Portis, E.; Finkers, R.; Lanteri, S.; Paran, I.; Lefebvre, V.; Giuliano, G.; Stein, N. 2021. Global range expansion history of pepper (*Capsicum* spp.) revealed by over 10,000 genebank accessions. *PNAS: PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA*. 118 (34): e2104315118.
76. van Zonneveld, M.; Kindt, R.; Solberg, S.Ø.; N'Danikou, S.; Dawson, I.K. 2021. Diversity and conservation of traditional African vegetables: Priorities for action. *DIVERSITY AND DISTRIBUTIONS*. 27(2):216-232.
77. Wang, S.-L.; An, H.R.; Tong, C.-G.; Jang, S. 2021. Flowering and flowering genes: From model plants to orchids. *HORTICULTURE, ENVIRONMENT, AND BIOTECHNOLOGY*. 62:135-148.
78. Yegbemey, R.N.; Ahihou, C.M. K.; Olorunnipa, I.; Benali, M.; Afari-Sefa, V.; Schreinemachers, P. 2021. COVID-19 effects and resilience of vegetable farmers in North-Western Nigeria. *AGRONOMY*. 11(9):1808.
79. Yule, S.; Htain, N.N.; Oo, A.K.; Sotelo-Cardona, P.; Srinivasan, R. 2021. Occurrence of the South American tomato leaf miner, *Tuta absoluta* (Meyrick) in Southern Shan, Myanmar. *INSECTS*. 12(11):962.

80. Zohoungbogbo, H.; Quenum, A.; Honfoga, J.; Chen, J.-R.; Achigan-Dako, E.; Kenyon, L.; Hanson, P. 2021. Evaluation of resistance sources of tomato (*Solanum lycopersicum* L.) to phylotype I strains of *Ralstonia solanacearum* species complex in Benin. *AGRONOMY*. 11(8):1513.
81. 이진형; 이희주; 위승환; 유인호; 여경환; 안세웅; 장윤아; 장성희. 2021. 고온, 건조 스트레스 조건에서 멜라토닌 경엽처리에 의한 배추의 생장 및 항산화효소 활성 증대. *HORTICULTURAL SCIENCE AND TECHNOLOGY*. 39(5):583-592.
Lee, J.; Lee, H.; Wi, S.; Yu, I.; Yeo, K.-H.; An, S.; Jang, Y.; Jang, S. 2021. Enhancement of growth and antioxidant enzyme activities on kimchi cabbage by melatonin foliar application under high temperature and drought stress conditions. *HORTICULTURAL SCIENCE AND TECHNOLOGY*. 39(5):583-592.

Journal articles (17)

1. Afele, J.T.; Dawoe, E.; Abunyewa, A.A.; Afari-Sefa, V.; Asare, R. 2021. Carbon storage in cocoa growing systems across different agroecological zones in Ghana. *PELITA PERKEBUNAN*. 37(1):32-49.
2. Ayenan, M.A.T.; Aglinglo, L.A.; Zohoungbogbo, H.P.F.; N'Danikou, S.; Honfoga, J.; Dinssa, F.F.; Hanson, P.; Afari-Sefa, V. 2021. Seed systems of traditional African vegetables in Eastern Africa: A systematic review. *FRONTIERS IN SUSTAINABLE FOOD SYSTEMS*. 5:689909.
3. Barchenger, D.W.; Ou, J.Y.; Lin, Y.C.; Hsu, Y.C.; Lu, S.F.; Chen, J.R.; Kenyon, L.; Hanson, P. 2021. Whole genome resequencing reveals novel loci associated with bacterial wilt resistance in tomato. *ACTA HORTICULTURAE*. 1316:49-52.
4. Bari, A.; Ouabbou, H.; Jilal, A.; Khazaei, H.; Stoddard, F.L.; Sillanpää, M.J. 2021. Machine learning speeding up the development of portfolio of new crop varieties to adapt to and mitigate climate change. *BIORXIV*. DOI: 10.1101/2021.10.06.463347.
5. Chen, W.Y.; Shih, S.L.; Hsieh, M.H.; Kenyon, L. 2021. Management of tomato viroids at World Vegetable Center headquarters. *ACTA HORTICULTURAE*. 1316:135-142.
6. Gela, T.S.; Bruce, M.; Chang, W.; Stoddard, F.L.; Schulman, A.H.; Vandenberg, A.; Khazaei, H. 2021. Genomic regions associated with chocolate spot (*Botrytis fabae* Sard.) resistance in faba bean (*Vicia faba* L.). *BIORXIV*. DOI: 10.1101/2021.11.22.469473.
7. Kenyon, L.; Chan, Y.L.; Lee, L.M.; Kuo, F.H.; Shih, S.L. 2021. Survey of viruses infecting tomato in Taiwan. *ACTA HORTICULTURAE*. 1316:107-112.
8. Kunwar, S.; Hsu, Y.C.; Lu, S.F.; Hanson, P. 2021. Evaluation of bacterial wilt resistance sources for presence of major resistance QTLs *Bwr-12* and *Bwr-6*, and as potential sources of new resistance QTLs. *ACTA HORTICULTURAE*. 1316:43-48.
9. Manga, L.A.A.; Kamga, R.T.; Bidogeza, J.-C.; Afari-Sefa, V. 2021. Dynamics and sustainability of urban and peri-urban vegetable farming in Yaoundé City, Cameroon. *AFRICAN JOURNAL OF AGRICULTURAL RESEARCH*. 17(10):1343-1359.
10. Manickam, R.; Rakha, M.; Chen, W.Y.; Nordey, T.; Dinssa, F.; Bihon, W.; Kamga, R.; Srinivasan, R. 2021. Vegetable grafting in promoting sustainable vegetable production in developing countries. *ACTA HORTICULTURAE*. 1302:21-32.
11. Roothaert, R.; Mpogole, H.; Hunter, D.; Ochieng, J.; Kejo, D. 2021. Policies, multi-stakeholder approaches and home-grown school feeding programs for improving quality, equity and sustainability of school meals in northern Tanzania. *FRONTIERS IN SUSTAINABLE FOOD SYSTEMS*. 5:621608.
12. Sequeros, T.; Ochieng, J.; Schreinemachers, P.; Binagwa, P.H.; Huelgas, Z.M.; Hapsari, R.T.; Juma, M.O.; Kangile, J.R.; Karimi, R.; Khaririyatun, N.; Mbeyagala, E.K.; Mvungi, H.; Nair, R.M.; Sanya, L.N.; Thi, T.L.N.; Phommalath, S.; Pinn, T.; Simfukwe, E.; Suebpongsang, P. 2021. Mungbean in Southeast Asia and East Africa: varieties, practices and constraints. *AGRICULTURE & FOOD SECURITY*. 10:2.
13. Shango, A.J.; Maswi, P.B. 2021. Nutritional aspects, pros and cons of nutrients-rich foods (fruits and vegetables) in response to stem cells transplantation. *JOURNAL OF EMBRYOLOGY & STEM CELL RESEARCH*. 5(2):000154.

14. Sotelo-Cardona, P.; Lin, M.-Y.; Srinivasan, R. 2021. Growing tomato under protected cultivation conditions: Overall effects on productivity, nutritional yield, and pest incidences. *CROPS*. 1(2):97-110.
15. Srinivasan, R.; Lin, M.-Y.; Wu, W.-Jen; Wang, H.-I.; Sotelo-Cardona, P. 2021. Evaluating the potential of protected cultivation for off-season leafy vegetable production: Prospects for crop productivity and nutritional improvement. *FRONTIERS IN SUSTAINABLE FOOD SYSTEMS*. 5:731181.
16. 장성희. 2021. 세계채소자원의 보존과 세계채소센터 유전자원센터. 세계 식품과 농수산. 2021:1. Jang, S. 2021. Conservation of global vegetable resources and World Vegetable Center- GRSU. *WORLD FOOD, AGRICULTURE & FISHERIES*. 2021:1.
17. 강석범; 양은영; 조명철; Tajima, T.; Lin, T.H.; Lin, S.-W.; Wang, Y.-W.; Yee, C.K.M.; Barchenger, D.; Schafleitner, R. 2021. 고추 침수 내성 자원 선발을 위한 생육 특성 조사. 韓國國際農誌. 33(2):180-188. Kang, S.-B.; Yang, Y.-Y.; Cho, M.-C.; Tajima, T.; Lin, T.H.; Lin, S.-W.; Wang, Y.-W.; Yee, C.K.M.; Barchenger, D.; Schafleitner, R. 2021. The evaluation of growth characteristics in chili pepper (*Capsicum* spp.) germplasm for selection of waterlogging tolerant lines. *Journal of the Korean Society of International Agriculture*. 33(2):180-188.

Books (3)

1. Amenu, K.; Bedasa, M.; Wamile, M.; Worku, H.; Kasim, K.; Taha, M.; Mego, L.; Dinede, G.; Ssemenda, J.N.; Grace, D.; Roesel, K.; Roothaert, R.; Knight-Jones, T. 2021. Qualitative assessment of chicken and vegetable value chains in Harar and Dire Dawa, Ethiopia: Food safety perspectives. Nairobi, Kenya; International Livestock Research Institute (ILRI). 73 p.
2. Dembélé, S.; Tignegre, J.-B.; Diarra, B.G. 2021. Development of the vegetable seed sector in Mali and opportunities for irrigated Seed production. Shanhua, Taiwan: World Vegetable Center. 40 p.
3. Ebert, A.W.; Drummond, E.B.M.; Giovannini, P.; van Zonneveld, M. 2021. A global conservation strategy for crops in the Cucurbitaceae family. Bonn, Germany: Global Crop Diversity Trust. 147 p.

Book chapters (1)

1. Rakha, M.; Prohens, J.; Taher, D.; Wu, T.-H.; Solberg, S.Ø. 2021. Eggplant (*Solanum melongena*, *S. aethiopicum* and *S. macrocarpon*) breeding. In: *Advances in plant breeding strategies: Vegetable crops: Volume 9: Fruits and young shoots.* / ed. by I-Khayri, J.M.; Jain, S.M.; Johnson, D.V. Cham, Switzerland: Springer. p. 163-203.

Acronyms

ACIAR	Australian Centre for International Agricultural Research
ACSL	Agri-Commercial Services Limited, Ghana
ADB	Asian Development Bank
AFACI	Asian Food and Agriculture Cooperation Initiative, Korea
AfDB	African Development Bank
AFSTA	African Seed Trade Association
AIRCA	Association of International Research and Development Centers for Agriculture
APART	Assam Agribusiness and Rural Transformation project, India
APSA	Asia and Pacific Seed Association
ARIAS	Assam Rural Infrastructure and Agricultural Services Society, India
ASEAN	Association of Southeast Asian Nations
AVBC	Africa Vegetable Breeding Consortium
BMZ	Federal Ministry for Economic Cooperation and Development, Germany
BOFAA	Bureau of Foreign Agricultural Affairs, Thailand
CATIE	Tropical Agricultural Research and Education Center, Costa Rica
CoA	Council of Agriculture, Taiwan
CORAF	West and Central Africa Council for Agricultural Research and Development
Crop Trust	Global Crop Diversity Trust, Germany
DUS	Distinctiveness Utility and Stability test
EI	Enabling Impact flagship
ESA	Eastern and Southern Africa
ESEA	East and Southeast Asia
FAO	Food and Agriculture Organization of the United Nations
FCDO	Foreign, Commonwealth & Development Office, UK
FFTC	Food and Fertilizer Technology Center, Taiwan
FOFIFA	National Center of Applied Research and Rural Development (FOFIFA), Madagascar
GAP	Good Agricultural Practices
GHP	Good Handling Practices
GIZ	Deutsche Gesellschaft für Internaitonale Zusammenarbeit
HARVEST	Holistic Access to Research on Vegetables, Societies and Technology
HD	Healthy Diets flagship
ICBC2	Second International Congress of Biological Control
ICAR	Indian Council of Agricultural Research
IFC	Impedance flow cytometry
IFAD	International Fund for Agricultural Development

IIVR	Indian Institute of Vegetable Research
IMIN	International Mungbean Improvement Network
IPM	Integrated Pest Management
JOHAR	Jharkhand Opportunities for Harnessing Rural Growth project, India
JPLS	Jharkhand State Livelihood Promotion Society, India
KoRAA	Korea RDA Alumni Association project
MAFF	Ministry of Agriculture, Forestry and Fisheries, Japan
MOFA	Ministry of Foreign Affairs, Taiwan
MOST	Ministry of Science and Technology, Taiwan
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
NPGRC	National Plant Genetic Resources Centre, Eswatini or Tanzania
NSFP	National School Feeding Program, Eswatini
OLM	Odisha Livelihood Mission project, India
OPV	Open pollinated variety
PoP	Package of Practices
R&D	Research and Development
RDA	Rural Development Administration, Korea
RIM	Research Infrastructure Modernization
SAFEVEG	Safe locally-produced vegetables for West Africa's consumers project
SDG	Sustainable Development Goal
SEAVEG	Southeast Asia Vegetable Symposium
SSA	Sub-Saharan Africa
SSVC	Safe and Sustainable Value Chains flagship
TOSCI	Tanzania Official Seed Certification Institute
TAVI	Taiwan – Africa Vegetable Initiative project
ToT	Training of trainers
UAC	University of Abomey - Calavi, Benin
UNFSS	United Nations Food Systems Summit
USAID	United States Agency for International Development
V4P&P	Veggies for planet and people project
VBN	Vegetable Business Network
VCU	Value for Cultivation and Use
VDI	Vegetable Diversity and Improvement flagship
WACCI	West African Centre for Crop Improvement, Ghana

WFP	World Food Program
WKO	World Vegetable Center Korea Office
WorldVeg	World Vegetable Center
ZECC	Zero Energy Cooling Chamber