FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Feed the Future Innovation Lab for Horticulture

Annual Report 2022–2023

Cooperative Agreement No. 7200AA21LE00003

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HORTICULTURE
INNOVATION LAB

UC DAVIS
UNIVERSITY OF CALIFORNIA

HORTICULTURE INNOVATION LAB

ANNUAL REPORT 2022–2023

OCTOBER 31, 2023

This publication is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of the Horticulture Innovation Lab and do not necessarily reflect the views of USAID or the United States Government.

COVER PHOTO

Student with vegetable seedlings in a greenhouse nursery on the campus of Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Nairobi, Kenya. Horticulture Innovation Lab photo by Heather Hayashi.

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The Feed the Future Innovation Lab for Horticulture at the University of California, Davis (UC Davis) works with and promotes local leadership in communities across the globe to advance horticultural and social innovations for nutritional and financial security. Initiated in October, 2021 with a base $15 million investment from U.S. Agency for International Development (USAID) the Horticulture Innovation Lab is a five-year program and is the second competitive Feed the Future Horticulture Innovation Lab awarded to UC Davis. The competitive award for the Horticulture Innovation Lab was first received in 2009 when USAID selected UC Davis to lead a $14.6 million, five-year program (then called the Horticulture Collaborative Research Support Program, or Horticulture CRSP). The university was awarded a subsequent five-year phase for the Horticulture Innovation Lab ending in 2019 for $18.75 million.

The program team and its projects work with low-resourced farmers and their communities to improve horticultural value-chain systems. Improving livelihoods—through higher profits and diversified, nutrient-rich diets—is a primary goal for the Horticulture Innovation Lab's research efforts around the world. The program's work will be guided by ensuring gender equity, youth empowerment, improved nutritional outcomes, improving information access, targeting innovative technologies and increasing research capacity.

Horticulture Innovation Lab projects will span the value chain of fruit and vegetable production, from seed systems to postharvest processing. Through partnerships and collaborative research, the program also aims to build the capacity of researchers, institutions and farmers to advance horticultural science.

MANAGEMENT ENTITY

The Horticulture Innovation Lab Consortium is managed by a team in the UC Davis College of Agricultural and Environmental Sciences, under the Department of Plant Sciences and the International Programs Office.

Members of the management entity:

- Erin McGuire, Director
- Archie Jarman, Associate Director
- Lydiah Maranga, Program Officer
- Katie Schroeder, Financial Officer
- Heather Hayashi, Communications Manager
- Michel Kabirigi, Post-Doctoral Researcher
- Siobhan Rubsam, Graduate Student Researcher
- Kristen Becker, Graduate Student Researcher
- Kat Gregerson, Graduate Student Researcher
- Max Luepke, Undergrad Assistant

As part of this Management Entity Team, Consortium Specialists consistently engage with the Management Entity. Specialists include:

- Christine Stewart, Nutrition Specialist
- Hilary Proctor, Youth Specialist
- Janelle Larson, Gender Specialist

In addition to the U.S. management team, the Horticulture Innovation Lab works with Regional Hub managers from each of the four focus regions to provide on-the-ground monitoring and coordination of projects and trainings. Regional Hub Managers include:

- West Africa:
    - Dr. Naalame Amissah
    - Dr. Freda E. Asem
- East Africa:
    - Dr. Peninah Mueni Yumbya
    - Dr David Sarfo Ameyaw
    - Annsofie Misiani
- Central America:
    - Julio Lopez
    - Dr. Celia Trejo Ramos
    - Patricia Arce
- South Asia:
    - Krishna Sapkota

CONSORTIUM AND SCALING PARTNERS

Along with Consortium Specialists, the Consortium consists of Partners that are recognized as global experts in horticulture research and related fields. Partners include:

- Florida Agricultural and Mechanical University
- Michigan State University
- Texas A&M University
- World Vegetable Center

Along with Partners and Specialists, the Consortium also includes Scaling Partners that have experience with broad dissemination of innovations. Scaling Partners include:

- Cultivated New Frontiers in Agriculture
- International Fertilizer Development Center

TECHNICAL AND/OR ADVISORY COMMITTEE INFORMATION

The Horticulture Innovation Lab's International Advisory Board (IAB) is the program's senior advisory council. The IAB ensures that Horticulture Innovation Lab priorities are met and integrated for maximum effectiveness. The IAB helps set priorities and ensure that USAID, Global Horticulture Assessment and Horticulture Innovation Lab objectives are met.

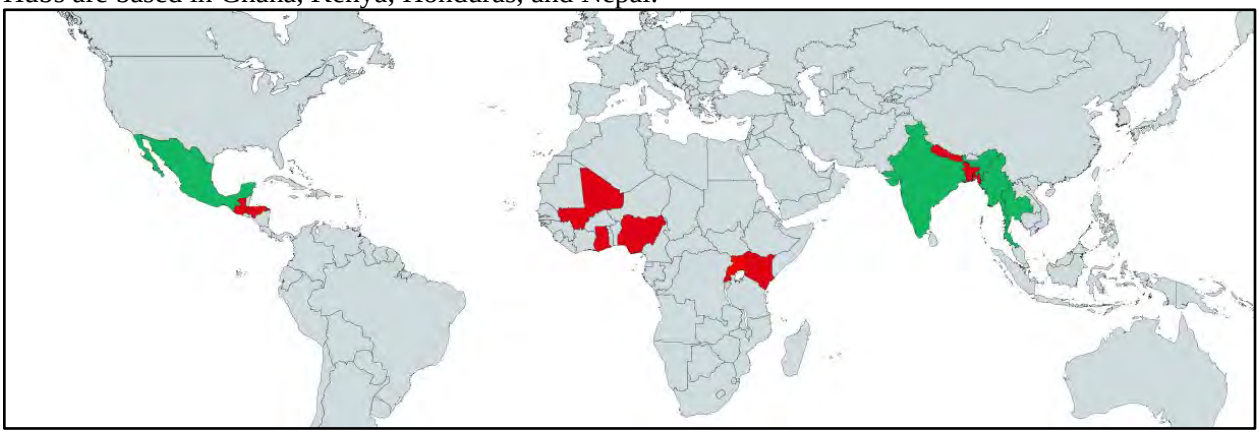
Members of the Horticulture Innovation Lab International Advisory Board:

- Daniel Bailey, U.S. Agency for International Development (ex-officio), Agreement Officer Representative
- Kathleen (Katya) Doherty, Cultivating New Frontiers in Agriculture, Principal, Program Development
- Maria Ester Bucaro, Counterpart International, Regional Program Director
- Rafael Flor, Bill and Melinda Gates Foundation, Senior Program Officer
- Anna Lartey, University of Ghana, Professor of Nutrition
- Hazel Malapit, International Food Policy Research Institute, Senior Research Coordinator
- B. Jan Middendorf, Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification at Kansas State University, Associate Director

- Latha Nagarajan, International Fertilizer Development Center, SOILS Consortium Director
- Kushal Naharki, Youth Ambassador - Nepal
- Mary Ann Sayoc, East West Seed, Public Affairs Lead
- Lusike Wasilwa, Kenya Agricultural & Livestock Research Organization, Director of Crop Systems

LOCATIONS OF WHERE WE WORK

In FY2023, the Horticulture Innovation Lab funded research projects in ten Feed the Future countries: Honduras, Guatemala, Mali, Ghana, Nigeria, Kenya, Uganda, Rwanda, Nepal, and Bangladesh. Regional Hubs are based in Ghana, Kenya, Honduras, and Nepal.



Countries where the Horticulture Innovation Lab has awarded research projects are in solid red, and green are countries with DryCard activities only.

LIST OF PROGRAM PARTNERS

United States – Cultivating New Frontiers in Agriculture; Florida Agricultural and Mechanical University; Institute for Global Nutrition, University of California, Davis; International Fertilizer Development Center; Making Cents International; Michigan State University; Pennsylvania State University; Texas A&M University

Bangladesh - Bangladesh Agriculture University

Ghana – University of Ghana; Ofori Agrochemical Services (DryCard Entrepreneur); CSIR Food Research Institute;

Guatemala – EarthEmpower (DryCard Entrepreneur); Acceso; Universidad del Valle

Honduras - Pan-American Agricultural School, Zamorano, The Pennsylvania State University

India - Vivia Foundation (DryCard Entrepreneur)

Kenya – International Center for Evaluation and Development (ICED); Kenya Agriculture and Livestock Research Organization; Jomo Kenyatta University of Agriculture and Technology; GROOTS Kenya, BetterCrops Ltd. (DryCard Entrepreneur)

Mali - University of Sciences and Techniques and Technologies, Bamako

Mexico – EarthEmpower (DryCard Entrepreneur)

Myanmar – Myanmar Innovative Life Sciences (DryCard Entrepreneur)

Nepal –Agriculture and Forestry University; Forum for Rural Welfare and Agricultural Reform for Development; R&D Innovative Solutions (DryCard Entrepreneur); Welthungerhilfe Nepal; Nepal Agricultural Research Council;

Nigeria – Willow Foundation (DryCard Entrepreneur); Obafemi Awolowo University

Rwanda – Development Solutions Consulting (DryCard Entrepreneur);

Taiwan – World Vegetable Center

Tanzania –Market Infrastructure, Value Addition and Rural Financial Services (DryCard Entrepreneur)

Thailand –Go Organics (DryCard Entrepreneur)

Uganda –Mwino Group (DryCard Entrepreneur); Muni University

ACRONYMS

AFU Nepal–Agriculture and Forestry University Nepal

AGRF–Africa Green Revolution Forum

AIVs- African Indigenous Vegetables

AOR–Agreement Officer's Representative

ASD- Anaerobic Soil Disinfestation

BAU- Bangladesh Agricultural University

BEO–Bureau Environmental Officer

BIFAD- Board for International Food and Agricultural Development

CIAT- International Center for Tropical Agriculture

CEP–Critical Engagement Projects

DDL–Development Data Library

EMMP–Environmental Management and Mitigation Plan

ERT- Embedded Research Translation

FAMU–Florida Agricultural and Mechanical University

FDGs- Focus Group Discussions

FORWARD–Forum for Rural Welfare and Agricultural Reform

FRESH- Fruits and Vegetables for Sustainable and Healthy Diets

FTF–Feed the Future

GSR–Graduate Student Researcher

IAB–International Advisory Board

ICED–International Center for Evaluation and Development

IITA- International Institute for Tropical Agriculture

ICT–Information Communication Technology

JKUAT–Jomo Kenyatta University of Agriculture and Technology

KALRO–Kenya Agricultural and Livestock Research Organization

KII- Key Informant Interviews

MILS–Myanmar Innovative Life Sciences

MORE–Market-Oriented Research for Empowerment

NARC- Nepal Agricultural Research Council

NHTS- National Horticulture Traceability System

OAU- Obafemi Awolowo University

PAC- Project Advisory Committee

PAR- Participatory Action Research

PERSUAP–Pesticide Evaluation Report and Safe User Action Plan

PI- Principal Investigator

PPE- Personal Protective Equipment

RFA- Request for Application

RFP–Request for Proposal

SOW- Scopes of Work

TOR- Terms of Reference

UC Davis–University of California Davis

UEI–Unique Entity Identifier

USAID–US Agency for International Development

VACS- Vision for Adapted Crops and Soils

WUR–Wageningen University and Research

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

FY2022-2023 has been a dynamic, collaborative, and formative year for the Horticulture Innovation Lab.

A total of 15 projects were successfully awarded by the Horticulture Innovation Lab during the reporting period, with 93% of sub-awarded funds going to academic institutions based in West and East Africa, Central America and South Asia. These research projects focus on integrated pest management strategies, soil health, increased production, and postharvest loss. They also have strong social components concerning market access, nutrition, increased biodiversity, and are gender-responsive. Together they represent a significant investment in innovative research and development endeavors, aimed at enhancing horticulture practices and outcomes in each region, with global implications. To this end, the Horticulture Innovation Lab hosted its inaugural annual meeting, bringing together Principal Investigators (PIs), Co-PIs, the International Advisory Board, consortium partners, and specialists. This gathering fostered collaborative discussions and the sharing of expertise, contributing to the Lab's thought leadership in the field.

The Lab has been a proponent of the local-led development model, and this philosophy was emphasized through various presentations and discussions. This approach is deeply embedded in our systems-based and inclusive approach to Lab management. Notably, our regional hub managers have taken on increasingly prominent roles in global-facing events, underscoring the Lab's dedication to empowering local stakeholders. Moreover, the Lab has actively engaged with CGIAR on scaling initiatives, with a specific emphasis on gender and socially differentiated scaling. These partnerships continue to evolve, strengthening our efforts to promote sustainable horticultural practices.A highlight of the year was the visit of Cary Fowler to the University of California, Davis, where he discussed "The Vision for Adapted Crops and Soils" programs. This dialogue reaffirmed the Lab's dedication to African Indigenous Fruit and Vegetable crops, which have been a longstanding focus of our research efforts.

Highlights from the Management Entity and Regional Hub Managers this year are:

- Development of impact pathway, an evaluation method that can be applied to all ILs
- Results from informal market study in Nigeria
- Forthcoming white paper on African Indigenous Vegetables
- Initial results of Innovation Network study that contributes to understanding of effective innovation networks
- Postharvest side-event at the All-African Postharvest Conference
- Publication of review of postharvest innovations for small-scale farmers
- GenderUp scaling tool workshops and trainings held
- Locally led request for applications and awarding of twelve locally led regional projects
- Successful award of buy-in opportunity for work in Guinea Bissau
- Regional Hub in Central America held a postharvest short course with stakeholders from horticulture sector

As Chair of the FTF innovation Labs the Horticulture Innovation Lab team organized two significant conferences during the reporting period. The first conference took place in Nairobi, where 100 USAID staff, FTF Innovation Labs, and regional experts and stakeholders convened to deliberate on climate change adaptation and mitigation, this also included a focus on local-led development strategies. The second conference occurred in Washington, DC, focusing on the critical aspects of gender research within agricultural research for development.

As we look ahead to the coming year, we are poised to establish robust partnerships and initiate research projects in the countries where we operate. As initial research results emerge, the Lab will further solidify systems for information dissemination, application, and the connection of relevant lessons.

II. FOCUS COUNTRY KEY ACCOMPLISHMENTS

In FY2023, the Horticulture Innovation Lab worked with its consortium and Regional Hub Managers to set regional research priorities and communities of focus for research projects. Requests for Applications (RFAs) were developed in FY2023 and close to 125 applications were received across four regions - East Africa, West Africa, South Asia, and Central America. As a result of this process, twelve regional projects were awarded, which are all led by locally-based institutions.

In May, FY2023, the Horticulture Innovation Lab held its annual meeting. Hosted by the Regional Hub in East Africa, the International Center for Evaluation and Development (ICED), this meeting gathered for the first time the Lab's project principal investigators (PIs) to share with the consortium, the Horticulture Innovation Lab's International Advisory Board (IAB), and with each other in depth presentations on the purpose, methods, and objectives of their research projects. Additionally, this meeting provided an opportunity for the management entity to conduct important onboarding activities with the PIs in person.

Below is a description of the country-level research activities that have occurred in FY2023 as the projects are ramping up.

Guatemala: Two projects conducting research in climate smart agriculture in the Guatemalan highlands were contracted in FY2023. The projects are led by Universidad del Valle and Acceso. Participatory research approaches will be used in the projects to develop and validate appropriate agricultural technologies adapted to climate change for small scale producers. In FY2023, monitoring, evaluation, and learning systems were designed, integrating strategic planning and monitoring indicators. Furthermore, a strategy to establish a research center, as well as an initial design, that will be a central hub for trainings and technology dissemination in Guatemala have been developed.

Honduras: A fellowship project led by Zamorano University supporting Honduran graduate students to conduct horticulture research was initiated in FY2023. The target is for four students during FY2024 (2 men and 2 women) to receive two leadership courses and will have the opportunity to interact with producers and researchers to enhance their professional profile, along with receiving seed funding to conduct thesis research. Additionally, the Regional Hub, based at Zamorano University, has established connections with project PIs in Guatemala and assisted with onboarding of projects. The Regional Hub Managers also held a short training in postharvest management that was attending by stakeholders in the horticulture sector in Honduras.

Mali and Ghana: Two projects led by University of Ghana were contracted in FY2023 that will both be conducting research in Mali and Ghana. Inception workshops and initial survey design were completed in FY2023 for projects that will: conduct research in youth engagement with indigenous vegetables; research necessary input supply chains to support indigenous vegetable production; develop an accessible database of indigenous fruit and vegetables in West Africa; strengthen indigenous fruit and vegetable seed production systems; and identify nutrient-rich, climate-resilient high-yielding indigenous vegetable genotypes for production among small-scale producers. Additionally, the Horticulture Innovation Lab's Regional Hub at the University of Ghana has effectively supported project PIs in Ghana and Nigeria, participated in horticulture-related conferences, and have played a critical role in an associate award

starting in FY2024 from the USAID Mission in Senegal to strengthen the horticulture sector in Guinea Bissau. Specifically, the Regional Hub Managers presented at the 4th All Africa Postharvest Congress in Ethiopia. Finally, the DryCard entrepreneur in Ghana, Ofori Agrichemicals, continued as a vendor of the technology in FY2023.

Nigeria: In FY2023, a project engaging youths in the production of indigenous fruits and vegetables was successfully contracted after delays with receiving a Unique Entity Identifier (UEI). Led by Obafemi Awolowo University, in FY2023 the research team identified fields in southern Nigeria for seed production of indigenous fruits and vegetables, and protocols were developed for soil, crop, and nutrition components. Additionally, in FY2023, research activities led by Wageningen University and Research (in a project examining the motivations of informal, mid-stream actors in horticulture value chains) completed its data collection and data analysis. Finally, the DryCard entrepreneur in Nigeria, Willow Foundation, continued to make sales of the technology in FY2023.

Kenya: Three Horticulture Innovation Lab projects are in Kenya. Led by ICED, the first research project is examining the cost-benefits of integrating horticulture into staple crop production in Kenya and was contracted in FY2023. The project has developed an extensive survey the project team will conduct in early FY2024. A second project led by Jomo Kenyatta University of Agriculture and Technology (JKUAT) and GROOTS Kenya, researching the trade-offs (income, gender equity, household nutrition) of long versus short horticulture value chains (short being 1 or less intermediaries) held inception workshops and designed the survey that will be used to collect data from stakeholders in these value chains in FY2023. This project will also examine the extent information communication technologies (ICTs) are being used in these value chains. The third research project is being led by the Kenya Agriculture and Livestock Research Organization (KALRO) that is researching African indigenous vegetables (marketing and how to reduce postharvest losses) was awarded in FY2023, but has run into contracting delays. This project will be contracted in early FY2024. The Regional Hub in East Africa, led by the ICED, hosted the Horticulture Innovation Lab's annual meeting in Nairobi and has supported PIs with the initiation of project activities and has presented at horticulture-related conferences. Specifically, the East Africa Regional Hub Manager, Dr. Penina Yumbya, organized and hosted a side-event on indigenous vegetables at the 4th All Africa Postharvest Congress in Ethiopia. Finally, the DryCard entrepreneur in Kenya, BetterCrops Ltd., continued to make sales of the technology in FY2023.

Nepal and Bangladesh: In FY2023, three new research projects were contracted in Nepal, with one of those projects also having activities in Bangladesh. First, a project led by Forum for Rural Welfare and Agricultural Reform for Development (FORWARD) Nepal is researching approaches that empower the youth entrepreneurs by promoting appropriate horticulture interventions which will promote employment and income opportunities. In FY2023 this project established institutional collaborations among partners and collaborators, recruited project staff including, and designed a survey questionnaire assessing agricultural land and fruit orchard leasing mechanisms, local and regional markets, and household data (youth aspiration, income needs and livelihood assessment). Second, a project researching how to reduce soilborne pathogens in tomato and pepper value chains in Nepal and led by the Nepal Agricultural Research Council (NARC), established a project advisory committee, held inception workshops, conducted participatory research-oriented trainings, and initiated pathogen surveys on field sites in FY2023. This project has also conducted initial research in determining the effects of various treatments for soil disinfestations. The third project contracted in FY2023 and led by Agriculture and Forestry University (AFU), Nepal and Bangladesh Agricultural University (BAU), focuses on enhancing peri-urban and urban production of horticulture crops in Nepal and Bangladesh. This project, in FY2023, identified possible study sites in three different cities of Bangladesh to conduct the project activities and two horticulture resource centers in Makwanpur and Kapilbastu districts in Nepal. The Regional Hub Manager, based at FORWARD Nepal, in FY2023 collaborated with PIs to help advance project activities and has networked well with organizations in Nepal and the USAID Mission. Finally, the DryCard entrepreneur in Nepal, R&D Innovative Solutions, continued as a vendor of the technology in FY2023.

Uganda: In FY2023, the initial design of baseline studies, workshops, and field visits for a project awarded in FY2023 and led by Muni University were completed. The project will use participatory research methods to reduce postharvest losses and build market connections for small-scale horticulture producers in the West Nile region of Uganda. Twenty-three potential farmer groups across six districts have been selected to conduct participatory research and the development of a baseline tool to understand gender preferences in terms of crops grown and pre- and postharvest technologies is underway. Additionally, the DryCard entrepreneur in Uganda, the Mwino Group, continued to make sales of the technology in FY2023.

Rwanda: In FY2023, research activities examining the informal horticulture sector in Rwanda were led by Wageningen University and Research. Data collection and data analysis of surveys distributed to plastic crate adopters in Rwanda were completed in FY2023.

United States: The Horticulture Innovation Lab had the honor of hosting State Department Special Envoy, Dr. Cary Fowler, Jefferson Fellow, Dr. John Leslie, and Agreement Officer Representative (AOR), Daniel Bailey, at UC Davis. The visit provided an opportunity for the three Innovation Labs at UC Davis to share with Dr. Fowler their research activities and learn more about the Vision for Adapted Crops and Soils (VACS) program. The visit included a tour of the Horticulture Innovation Lab's Demonstration Center. In FY2023, the Demonstration Center also attracted informative tours to various academic courses on campus and international researchers (including the Mandela Fellows) visiting the campus.

III. RESEARCH PROGRAM OVERVIEW AND STRUCTURE

The Horticulture Innovation Lab recognizes there are many challenges that limit further development of the horticulture sector. The Horticulture Innovation Lab's strategic approach to research is to ground-truth these challenges and also learn about opportunities within the four selected regions, highlighting local stressors that impact the horticulture sector, and brainstorm solutions through the methodical and intentional gathering of insights from local experts. The Horticulture Innovation Lab, in collaboration with local stakeholders, has prioritized those areas of greatest need and potential impact and empower local experts - that will be globally supported by experts within the Horticulture Innovation Lab consortium - to conduct research to improve the horticulture sector and to develop appropriate, affordable, and scalable technological solutions. Additionally, there are important research topics in the social science area, such as understanding the drivers of fruit and vegetable consumption, testing models and understanding the constraints for youth/women/disadvantaged group engagement in horticulture, that are integral within the Horticulture Innovation Lab research strategy.

The Horticulture Innovation Lab's consortium consists of consortium partners World Vegetable Center, Texas A&M University, Michigan State University, and Florida Agricultural and Mechanical University. Additionally, the Innovation Lab has specialists in Gender (Dr. Janelle Larson from Penn State University), Making Cents International (Hillary Proctor), and the Institute for GLobal Nutrition (Dr. Christine Stewart). Additionally, Cultivating New Frontiers in Agriculture (CNFA) and the International Fertilizer Development Council (IFDC) are scaling partners.

There are two types of research projects in the Horticulture Innovation Lab portfolio that are locally led, globally supported. First, regional research projects address specific priority areas and communities of foci set by local expertise and stakeholders. The regional priorities are:

West Africa

- **Priority:** Improve the affordability and availability of healthy diets - in particular, consumption of indigenous horticulture crops.
- **Community of Focus:** Women small-scale farmers involved in rural and or urban agriculture.

East Africa

- **Priority:** To reduce post-harvest losses; and enhanced marketing and market access of vegetables.
- **Community of Focus:** Rural small-scale women farmers.

South Asia

- **Priority:** To increase fruit and vegetable production efficiency.
- **Community of Focus:** Youth from marginalized communities.

Central America

- **Priority:** Determine appropriate technologies for climate smart agriculture.
- **Community of Focus:** Small and medium producers, young mothers in rural areas.

The other projects are classified as critical engagement projects and are smaller-scale, targeted research projects addressing the Innovation Lab's internal cross-cutting themes, and have research deliverables that will inform the activities of the broader, regional research projects. There are two critical engagement projects - one in Kenya examining trade-offs in short and long value chains, the other in Nigeria and Rwanda researching the informal horticulture value chains.

The Horticulture Innovation Lab's locally led, systemic approach to its research program is buttressed by the Innovation Lab's four Regional Hubs. These Regional Hubs are based at University of Ghana for West Africa, the International Center for Evaluation and Development in Kenya for East Africa, FORWARD Nepal for South Asia, and Zamorano University in Honduras for Central America. In practice, this locally led approach has manifested as twelve of its fourteen total projects being led by locally or regionally-based organizations and PIs. The Innovation Lab believes that a locally led, globally supported strategy builds long-term healthy entrepreneurial and expert eco-systems, regional technical expertise and thought leadership, and creates academic networks that can be engaged during regional crises. Additionally, locally led research builds regional and systemic resiliency, and contributes to an overarching goal of social transformation, increased incomes and improved nutrition. Finally, we anticipate that this research program approach will generate context specific solutions from research, produce technologies and practices that are relevant, and can be more responsive to changes on the ground. As a framework for this approach, please see the framework in Figure 1.

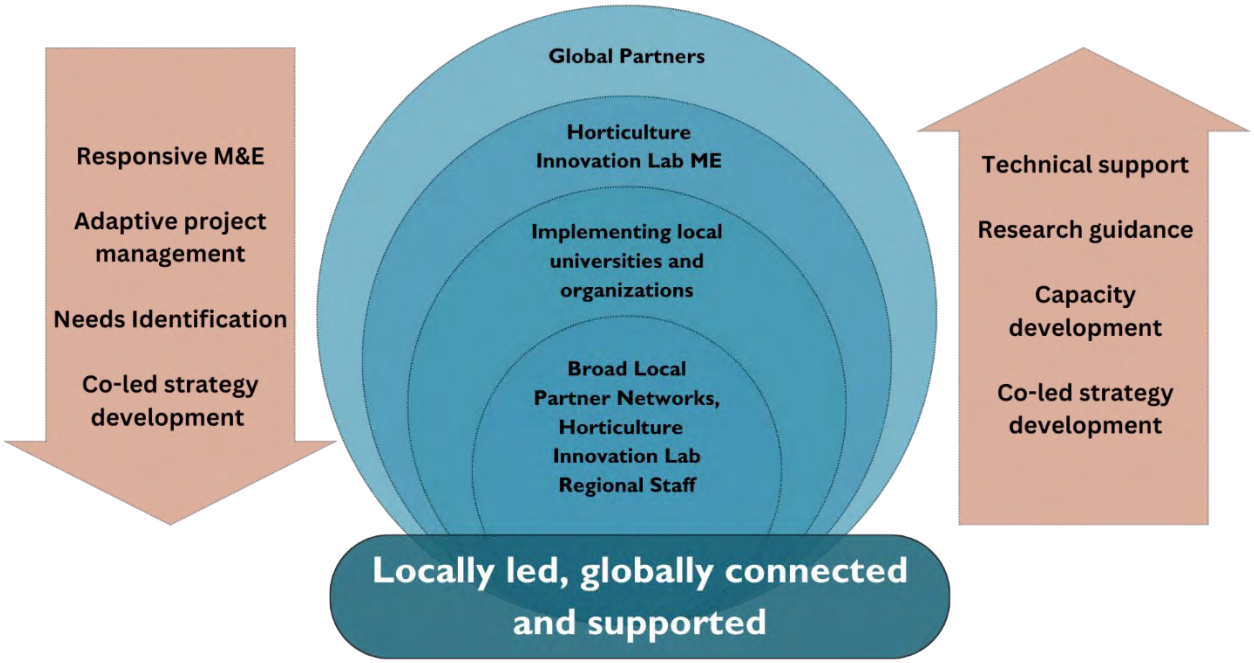


Figure 1 Framework for locally led, globally supported research program.

IV. THEORY OF CHANGE AND IMPACT PATHWAY

The overall focus on local researchers addressing local challenges and opportunities while promoting inclusion generates sustained impacts beyond the life of the Innovation Lab for Horticulture award and is central in the Horticulture Innovation Lab's Theory of Change. This approach will lead to outcomes such as increased financial capacity and entrepreneurship, long-term degree attainment, empowered regional leadership, well-connected market systems, and institutional development. Ultimately, the outcomes of these activities will contribute to developing capacity of local networks and building resilient horticulture management systems, improved community nutrition, inclusive and profitable market systems, and gender equity, youth engagement and social inclusion. See diagram below which visualizes the Horticulture Innovation Lab's Theory of Change.

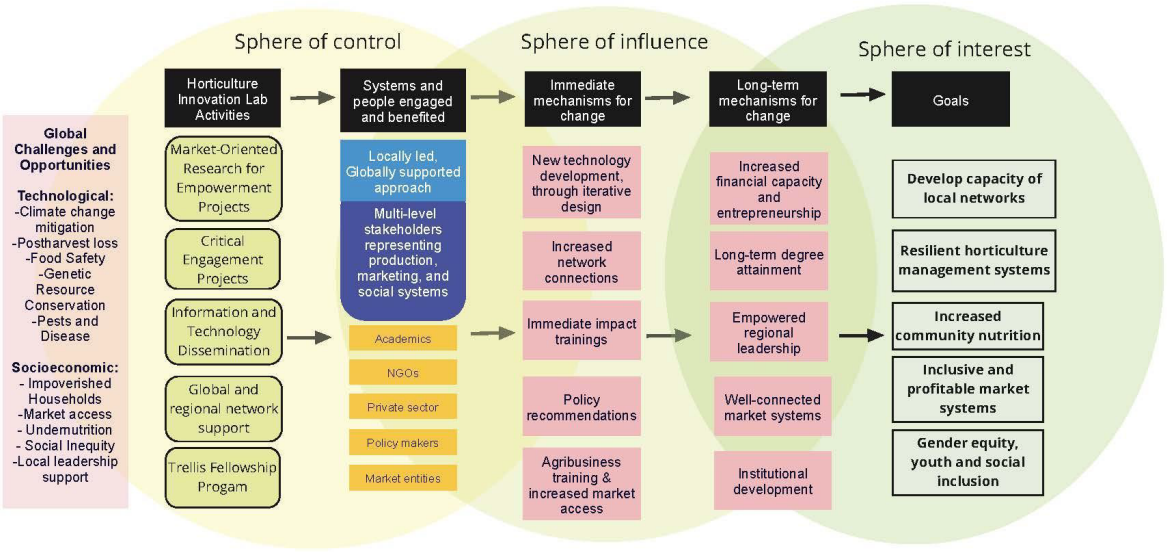


Figure 2 Feed the Future Innovation Lab for Horticulture Theory of Change

The Innovation Lab's programmatic impact pathway includes both downstream and upstream impacts. Visualized in Figure 3, the Horticulture Innovation Lab's locally led research, grounded in an inclusive and systems-based approach, follows an impact pathway of locally determined key challenges, locally generated knowledge and innovation, and finally locally diffused adoption of advanced technologies (including practices). Initially feeding this pathway are key objectives of collaborative research, capacity strengthening, local-leadership, and innovation network building. The upstream impacts from this programmatic impact pathway include increased local leadership and strengthened network capacity which directly affect downstream impacts (positive development outcomes) that are the Feed the Future three objectives.

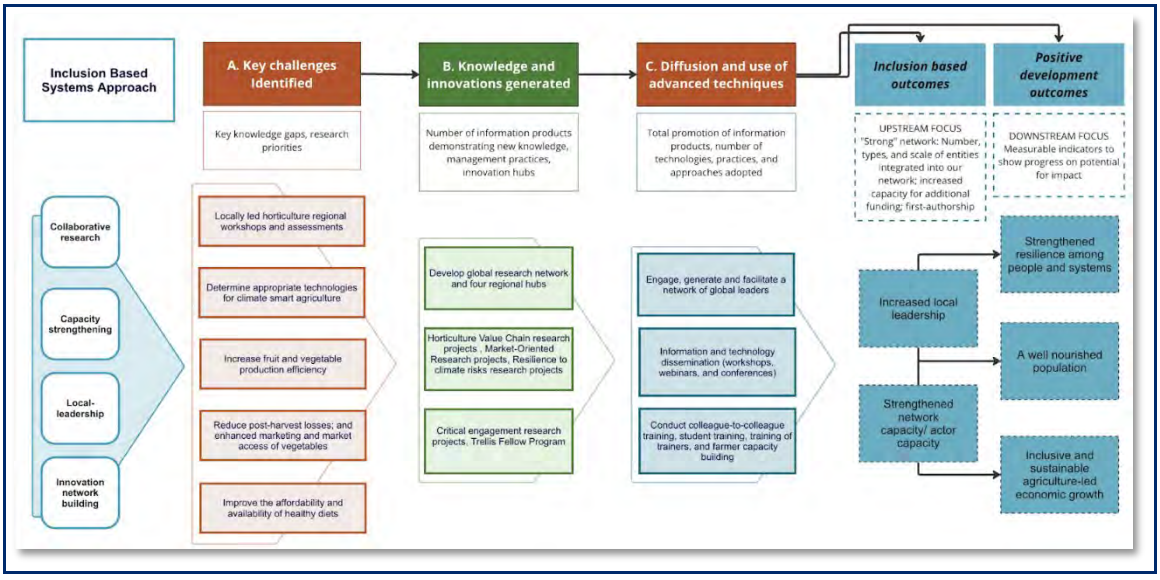


Figure 3 Horticulture Innovation Lab programmatic level impact pathway

At a project level, the impact pathway (Figure 4.) originates from challenges locally identified along with focus communities, then regions broken down by country. In terms of potential impact, the pathway is further delineated into project area foci which are then aligned with Feed the Future objectives. Although all projects are research focused and contain capacity strengthening, project area foci are classified between those that are strengthening collaborative research through the network and connectivity of research teams either across organizations or within organizations, and then those research projects that are more predominantly aligned to strengthen capacity of end-users.

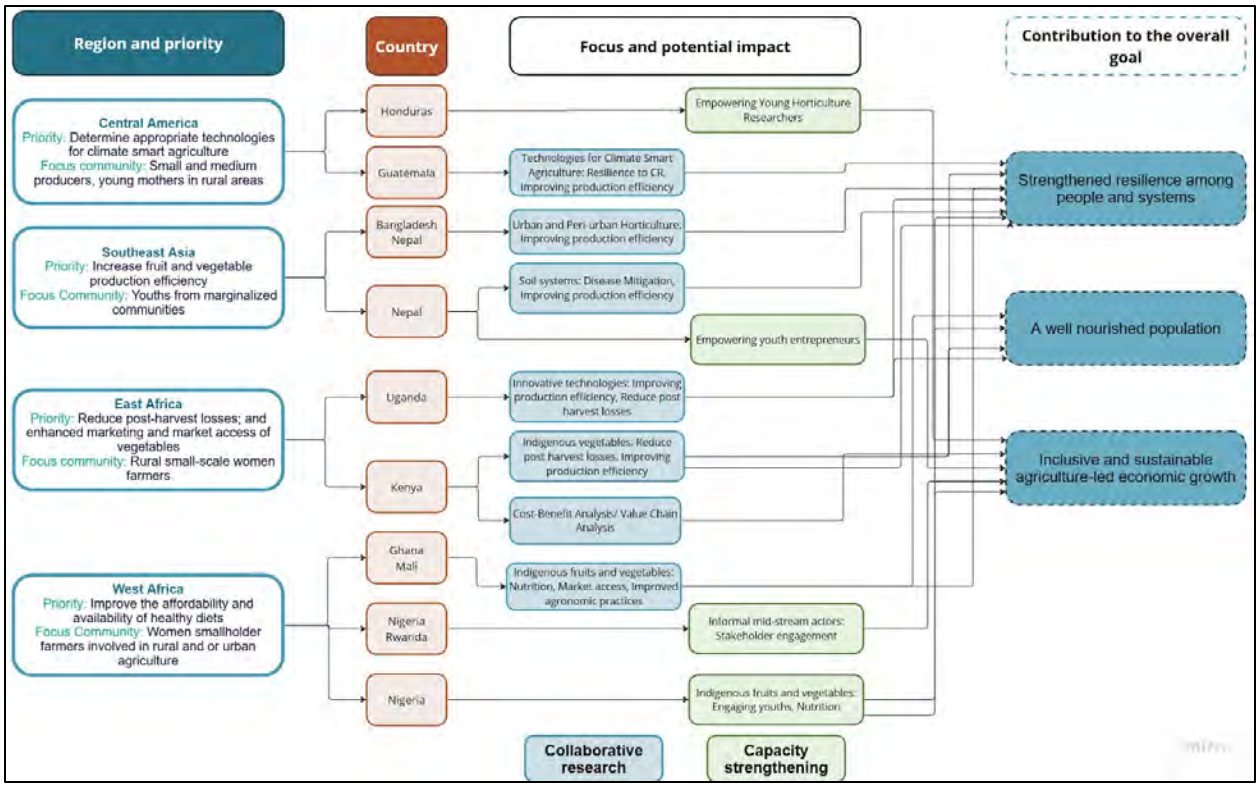


Figure 4 Project level impact pathway and how activities achieve Feed the Future priorities

Ultimately, as exhibited by both the programmatic and project-level impact pathways, the Horticulture Innovation Lab has aligned research activities to achieve Feed the Future's three objectives. Of course integrated into these pathways are also the Horticulture Innovation Lab's themes of empowering youth, improving community nutrition, building resilience, increasing gender equity, climate change mitigation/adaptation, and capacity strengthening. Specifically, in terms of gender equity, youth empowerment, and nutrition, the Horticulture Innovation Lab's specialists in these areas play a key role in assisting projects design and implement programs that address these thematic areas effectively. As part of this support, the specialists have formed in FY2023 affinity groups in these areas consisting of gender specialists, youth specialists, nutrition specialists, and monitoring and evaluation specialists from the projects.

V. RESEARCH PROJECT REPORTS

The Horticulture Innovation Lab is a global research network that works with and promotes local leadership to advance horticulture and social innovations to empower smallholder fruit and vegetable farmers to earn more income while better nourishing their communities. To support this goal, the Horticulture Innovation Lab has locally led, globally supported activities that include regional research projects (classified by regional priority area), critical engagement projects, internal scaling-oriented projects, and the Trellis Fellowship project.

I. IMPROVING THE AFFORDABILITY AND AVAILABILITY OF HEALTHY DIETS

PROMOTING OF FOOD AND NUTRITION SECURITY THROUGH INDIGENOUS FRUITS AND VEGETABLES IN GHANA IN MALI

Location: Ghana, Mali

Description: This project seeks to develop an accessible database of indigenous fruits and vegetables in West Africa to fill the existing use and nutrient knowledge gaps, strengthen indigenous fruit and vegetable seed production systems, identify nutrient-rich, and climate-resilient high- yielding indigenous vegetable genotypes for production among smallholder farmers in Ghana and Mali. There is a need for utilization of a consumer-led approach to promote consumption of indigenous fruit and vegetables, including development of innovative value-added products such as complementary foods, healthy-snacks and foods enriched with indigenous vegetables. Also, the project seeks to integrate education, health and agriculture to improve fruit and vegetable consumption behavior in communities, and enhance seed supply of indigenous fruit and vegetables.

Theory of Change: By researching indigenous vegetables and the supply chains/enabling environment needed for them, stakeholders can more effectively create food and nutrition security for their communities through the integration of indigenous vegetables.

Collaborators: University of Ghana, World Vegetable Center, and Council for Scientific and Industrial Research Institute, and the Savannah Agricultural Research Institute, Ghana

Achievements: In FY2023, the project team has developed data collection instruments (survey, questionnaire and interview guides) for profiling and consumer behavior study in regard to indigenous vegetables. Additionally, the project has coordinated with co-PIs to establish responsibilities to achieve project objectives. Finally, initial seed trials have been carried out in Ghana to help with the selection of Amaranth varieties for the project.

Capacity Building: The project is yet to carry out any capacity-building activity.

Lessons Learned: Over the course of the project, some of the lessons learned include;

1. Procurement processes take time to complete therefore the process should be started early
2. Request for funds and materials should start early to avoid project delays

Future Work: In FY2024, the project will initiate the profiling of indigenous fruits and vegetables in the sub-region. This will be carried out in at least six West African countries. Data collection (survey on consumer behavior and preferences & market research) will be carried out in FY2024 and the first year of field trials in Ghana and Mali will be completed.

Presentations and Publications: N/A

ENHANCING THE PRODUCTION AND CONSUMPTION OF AIVS TO IMPROVE DIETS IN GHANA AND MALI

Location: Ghana (Brong/Ahafo and Eastern), Mali (Koulikoro and Sikasso)

Description: This project will improve nutrition in Ghana and Mali through diet diversification by valorizing indigenous fruit and vegetables and promoting their consumption. The project will assess indigenous fruit and vegetable value chains to profile and identify cultural properties of indigenous fruits and vegetables to understand regional demand and supply, characterize them in terms of agronomic practices, nutritional composition, postharvest practices and value addition potential.

Theory of Change: Malnutrition and undernutrition are major issues for most countries in the world. Although fortification and biofortification programs have been developed, they have not been effective in low middle-income countries. Diets can be diversified and improved by researching nutrient composition of African indigenous vegetables, value chains, and methods for postharvest loss reduction. Promoting consumer awareness and demand for indigenous vegetables, will increase the production and consumption of nutritious indigenous vegetables .

Collaborators: University of Ghana, Young Professionals for Agricultural Development, Food Research Institute of the Council of Scientific and Industrial Research, University of Sciences and Techniques and Technologies, Bamako

Achievements: There have been three virtual meetings where team members have been working to put together the draft work plan for the next three years. This work plan will be shared with stakeholders in an inception workshop scheduled for October 25, 2023. Additionally, two graduate students have been recruited to join the team and have conducted a desk review on two of the four selected commodities (turkey berries and cocoyam leaves). The desk review report will form part of their literature review for their thesis and dissertation. Further, a consultant to conduct the value chain analysis on the four commodities has been identified and the contract is being developed. The instrument for data collection is also in its draft stage.

Capacity Building: The project has not been involved in any institutional or human capacity development activities within this reporting period.

Lessons Learned: No lessons learned in this current reporting period

Future Work: In FY2024, project activities will include profiling of the four selected indigenous fruits and vegetables including analyzing nutritional composition data developed into food composition tables, identifying the main nodes of the value chain for the selected commodities, and analyzing the dynamics of these connections with a keen focus on market and policy issues. Additionally, methods for improving the postharvest handling and preservation of indigenous fruits and vegetables will be analyzed in FY2024. This activity sets out to identify postharvest technologies that can extend the shelf life of indigenous fruits and vegetables. The final activity for FY2024 will involve the capacity strengthening of value chain actors.

Presentations and Publications: N/A

ENGAGING YOUTHS IN THE PRODUCTION OF INDIGENOUS VEGETABLES AND FRUITS IN NIGERIA

Location: Osun, Ondo, Oyo, Ekiti, and Ogun States in Nigeria

Description: This project will generate data to improve soil health and resilience and encourage youth in agriculture through indigenous vegetable and fruit production. Additionally, the project will establish gardening training programs in secondary schools on the indigenous vegetable and fruit value chain for in-school and out-of-school youths, using innovative good agricultural practices and climate-smart approaches to generate new knowledge critical to building the youth's entrepreneurial skills for livelihood and nutrition security from a gender perspective. Finally, the project will facilitate the availability and affordability of indigenous vegetable and fruit all-year-round.

Theory of Change: By researching youth engagement with school gardens focused on indigenous vegetables, and researching necessary input supply chains to support indigenous vegetable production, youth engagement in indigenous vegetable agriculture will increase and then this will reduce poor nutrition related outcomes among youths.

Collaborators: Obafemi Awolowo University (OAU); Utah State University.

Achievements: The project PI and Co-PI attended the Feed the Future Innovation Lab for Horticulture annual meeting in Nairobi, Kenya in May. At this meeting, the proposed project was successfully presented and defended before the panel of partners and board of consortium members gathered from around the world. In addition, the project team re-activated the OAU's UEI on SAM.gov. The team also identified seed production fields for indigenous fruits and vegetables, and planned and developed protocols for soil, crop, and nutrition components.

Capacity Building: No capacity strengthening activities occurred in FY2023.

Lessons Learned: One of the major lessons learned was the need to always keep an organization's UEI active on the SAM.gov platform! The OAU's UEI was inactive; and to get it reactivated was very difficult and complex. It took nearly six months before it was reactivated. This invariably slows down the process of signing contracts, and subsequent release of funds.

Future Work: Future work begins with the establishment of experimental sites at OAU, followed by processing of the Institutional Review Board approval with OAU. Then, study sites (communities and schools) will be selected across project target areas, and stakeholder engagement will be targeted within those areas. The project website will then be developed through registering its domain name, creating the mobile app framework, and gathering the required data to populate the database. The next phase is community entry and recruitment of study participants, which requires parental consent.

Presentations and Publications: N/A

II. REDUCING POSTHARVEST LOSSES AND ENHANCING MARKETING AND MARKET ACCESS OF VEGETABLES

DETERMINING THE COST BENEFIT OF INTEGRATING HORTICULTURE INTO STAPLE CROP PRODUCTION IN KENYA

Location: Kisii, Vihiga, and Machakos counties, Kenya

Description: This project will determine the cost-benefit of transitioning to horticultural production from production of staple crops for small-holder producers (especially females) in Kenya through trade-off and land-use analyses at the household and local level. Metrics include nutrition, economic, social, and production variables and will inform policy makers and small-scale female farmers on how to make a shift or diversify to vegetable production.

Theory of Change: The activities will enable the project to do several analyses that enable assessment of (i) costs and benefits of horticulture production relative to staple production, (ii) changes in land used for horticultural production, (iii) trade-offs – in terms of social and economic outcomes (e.g., income, employment, nutrition, and gender) – associated with shifting to horticulture production and (iv) local community or market responses to the shift to horticulture production. By doing so, the project builds our knowledge on small-holder farmer horticulture production to inform the design, testing and scale-up of sustainable horticulture production interventions, which further influences farmers adoption of horticulture production practices and promote policies for sustainable horticulture production.

Collaborators: International Center of Evaluation and Development, Kenya

Achievements: A thorough literature review on theories and gaps has been conducted to affirm the study. This was supported by a scoping study in the study counties of Vihiga, Muranga, and Kisii. During the mission, a preview of the cost and benefit streams of integrating horticulture with staples among smallholder women producers was gained. The relevant parameter pairs for smallholder decision-making in crop production have also been validated and different smallholder farm layouts observed. A sampling design has been developed where the specific enumeration areas (wards) with the potential to provide information of interest to the study within the study counties of Muranga, Kisii, and Vihiga counties have been identified. A draft of the questionnaire to be used during the data collection has been developed and scripted. It is now in the process of being refined through internal testing before being tested in the field. A field enumeration team based in each of the study counties has been identified based on training background, experience in data collection and familiarity with local languages. The research design targets women smallholder vegetable producers with the intended outcome reporting on the economic and nutritional impacts on this demographic group. During the scoping study, there was a key focus on the youth and they constituted 30% of the participants in focus group discussions. The data collection instruments constitute variables that will capture the nutritional benefits of integrating horticulture with staples. An approach that combines the cost of healthy diet and Dietary Quality Questionnaire have been exploited to support nutrition data production in the upcoming exercise.

Capacity Building: - ICED is collaborating with officers from the Ministry of Agriculture in the counties of Vihiga, Muranga, and Kisii.

Future Work: The data collection exercise will be done during this period. The exercise constitutes the physical data collection followed by 5 rounds of agile data to support real-time production and utilization data collection. Data will also be analyzed and a draft report will be prepared for discussion and improvement. The research output will be shared during the annual meeting and Evidence to Action conference.

Lessons Learned: The project has a key focus on collecting real-time data to minimize measurement errors. However, local contexts can change rapidly such as the onset of rains that trigger production activities. Flexibility and adaptability have therefore been crucial and our projects have been able to make adjustments in plans accordingly to achieve the objectives.

DEVELOPING INNOVATIVE HORTICULTURE TECHNOLOGIES FOR IMPROVED INCOME AND LIVELIHOODS AMONG SMALL-SCALE WOMEN FARMERS IN UGANDA

Location: West Nile Region of Uganda.
Description: This project will develop innovative horticulture technologies for improved income and livelihoods among small scale women farmers in Uganda using the Embedded Research Translation (ERT) approach. All farmers and other stakeholders will be integrated early and throughout the research collaboration. Collaborative research is expected to improve household nutrition status of small-scale female farmers, and increase sale of vegetables by small-scale female farmers.
Theory of Change: The overall goal of this project is to increase financial independence and improve the livelihoods of small-scale women vegetable farmers. To achieve this goal, we will evaluate different agronomic practices for reduced loss; evaluate different postharvest practices for reduced loss in vegetables; and evaluate different marketing and market access strategies for vegetables by women farmers. This is expected to lead to improved household nutrition status; increased sales of vegetables; and increased household income status of small-scale women farmers.
Collaborators: Muni University; Omia Agribusiness Development Group; Arua District Government
Achievements: Three project members visited Nairobi, Kenya, to learn about three cost friendly cold storage technologies. The project team also identified 23 potential farmer groups across the six districts, and developed a baseline tool to understand gender preferences: in crops they grow (species and variety), and in preharvest and postharvest technologies. This data will allow them to craft targeted interventions in the next stages of intervention, especially for women. The team is also addressing youth empowerment, both within the project team and with their beneficiaries, through hiring 10 youth enumerators and two youth members of the core implementation team, collaborating with a private sector organization managed mainly by youth, and selecting youth farmer groups to work with. Finally, two team members conducted a training on proper nutrition through the consumption of horticultural products for breastfeeding mothers in Arua, one of the project districts. Trainings in the remaining five districts have been planned.
Capacity Building: The project hosted several trainings with team members this past year to boost capacity on topics that included: electronic tools such as Piestar, financial management, gender and nutrition, vegetable post-harvest handling, data collection and data quality management, willingness to pay for technologies, and cost friendly cold storage technologies.
Lessons Learned: From interacting with stakeholders, the team learned that the West Nile only contributes 28% of the horticultural products it consumes, which implies that the population in the area is not fully benefiting from the market in their vicinity. The proposed interventions would address this through increasing the share of local market farmers. In terms of land access, both women and refugees are limited in their ownership and control of agricultural land, and women are often not the ones making decisions in the household and on the farm. However, they are involved in farming associations, and while there are not many “female only” groups, their participation in mixed gender farming groups is relatively high (52%).
Future Work: First, in FY2024 the project plans to complete the baseline data collection, processing and analysis to reveal current status of pre-harvest management; namely, soil fertility management, pest and disease control, and soil and water conservation. The baseline data will also reveal postharvest technologies that address postharvest pest and disease management and extend the shelf life of vegetables. The team will also conduct a social network analysis to assess the status of vegetable marketing, transport and value addition technologies and actors. The project will then set up participatory trials to co-evaluate pre-harvest technologies, including vegetable varieties, soil fertility, pest, disease, and soil and water conservation technologies. From this data, the team will identify affordable technologies and will also co-evaluate postharvest pest and disease management. Finally, the project will also hold participatory meetings with women and men vegetable farmer marketing groups for collective bargaining, as well as outreach, and capacity strengthening.

ENHANCING PRODUCTIVITY, POST-HARVEST MANAGEMENT, AND MARKET ACCESS OF AIVS IN KENYA

Location: Kisii and Kakamega County, Kenya

Description: African indigenous vegetables (AIVs) play a critical role in food, nutrition and income security in Kenya. AIVs are rich in vitamins and minerals, and are widely consumed by those most vulnerable to food insecurity. Thus, they could diversify and complement staple-based diets since they are a cost-effective and sustainable source of micronutrients. However, the AIVs value chain remains fragmented without strong linkages between actors from inputs to production, marketing, and consumption. Production, which is primarily by smallholder women, is largely inefficient, where individual farmers produce small quantities for a market that is erratic, uncoordinated and often unrelated to demand. These issues lead to high transaction costs in AIVs marketing, which increase inefficiencies along the value chain, leading to low market performance and low social economic benefits. The overall goal of the project is to increase productivity, reduce post-harvest losses and enhance market access of AIVs for improved livelihoods of value chain actors, specifically smallholder women and youth farmers. The project team based in Kenya and the US will: 1. Establish, quantify and address critical sources of pre-harvest losses within the value chain to increase AIVs productivity, 2. Enhance post-harvest management, value addition and safety of AIVs to improve nutrition and dietary diversification in rural and urban households, 3. Strengthen linkages to input and output markets for smallholder farmers, specifically women and youths, and 4. Build capacity for smallholder farmers and cooperatives on climate-smart technologies, innovations and management practices. The project will be implemented in Kisii and Kakamega counties, where AIVs are an important enterprise for women. The project will build the capacity of local personnel by training graduate students and key stakeholders and increase incomes for smallholder women farmers and improve nutrition security for Kenyan households.

Theory of Change: If productivity and marketability of AIVs increases, and if AIVS are mostly produced by women, and if AIVs are nutritious can also be resilient in climate change, then research improving productivity (preharvest and postharvest) and marketability of AIVs will improve community nutrition and promote gender equity.

Collaborators: Kenya Agriculture Livestock Research Organization, University of Nairobi, North Carolina : State University

Achievements: This project has run into extensive administrative challenges to finalize the contracts. We hope early FY2024 this will be resolved. So far, this year, the project has collaborated with team members to start seed and fertilizer approval processes, presented material to Dr. Cary Fowler during a remote presentation, and at least stands prepared to get started immediately upon finalization of the contract and receipt of first payment.

Capacity Building: N/A

Lessons Learned: N/A

Presentations and Publications: N/A

III. INCREASE FRUIT AND VEGETABLE PRODUCTION EFFICIENCY

EMPOWERING YOUTH ENTREPRENEURS THROUGH APPROPRIATE HORTICULTURE INTERVENTIONS IN NEPAL

Location: Kapilvastu, Arghakhanchi, and Dang of Lumbini Province, Nepal.
Description: This project is designed to promote employment and income opportunities through the incubation of gender inclusive horticulture enterprises following the lean-startup approach. The major project interventions are to demonstrate the potential of horticulture technologies for sufficient family income and to formulate policies and guidelines which contribute to easy access to resources and funds to the youth. The developed and verified production schemes and postharvest technologies along with the successful models will be promoted across the country using professional platforms, integrating into government extension systems and the use of information communication technology.
Theory of Change: By empowering youth entrepreneurs through the promotion and incubation of gender-inclusive horticulture enterprises following the lean-startup approach, youth will be more engaged in horticulture and have sustainable livelihoods.
Collaborators: Forum for Rural Welfare and Agricultural Reform for Development (FORWARD), Nepal; Welthungerhilfe
Achievements: During this reporting period, the project established institutional collaboration among the partners and collaborators, recruited project staff including a project PI, and selected research sites. The project has also completed project inception workshops at three local levels and one provincial level, held orientation training for project staff, on-boarded project experts, and developed a questionnaire for mapping youth aspiration, income needs and livelihood assessment. The team then developed a questionnaire for assessing agricultural land and fruit orchard leasing mechanisms, conducted local and regional rapid market surveys, identified 420 youth for conducting an aspiration survey, and finally, initiated the household survey at the project sites.
Capacity Building: The project team (8 members total, 4 female and 4 male) attended an orientation in June on YUVA project objectives, planning, implementation approaches, major activities/methods, and reporting.
Lessons Learned: The local government should be onboarded into project activities from the very beginning, i.e. site selection, household identification for surveys, analysis of policy and programs through consultative meetings, and inception workshops at the local level to help build local ownership of the project. The local government supported our project by selecting research sites, information sharing (providing farmer group information) and facilitating organizing events like interactive meetings and workshops.
Future Work: All surveys/studies will be completed by November 2023, after which validation workshops will be organized to share the major findings to stakeholders. Youth farmers will then be identified for a research trial set up and materials will be prepared to initiate field research activities. PhD and masters students will also be onboarded for research activities in line with project themes and objectives. Research trials will then be established in both open field conditions and under protected structures. The policy gap on youth involvement in agriculture will be analyzed with a special emphasis on horticulture at the local, provincial, and federal context. Production and business training will be organized in FY2024 to selected youth farmers and agriculture extension staff of the working municipality.
Presentations and Publications: N/A

MITIGATING SOILBORNE DISEASES TO IMPROVE SMALLHOLDER FARMER LIVELIHOODS AND FOOD SECURITY IN NEPAL

Location: Nepal

Description: This project will implement anaerobic soil disinfestation (ASD) combined in on-farm trials with native Nepal biocontrol isolates *Trichoderma asperellum* NT25 and *Bacillus* D22 and grafting technology to test their capacity to suppress soilborne pathogens and weeds in tomato and pepper production systems. Experiments will be conducted using a gender-balanced participatory action research (PAR) approach with 15 mother-baby trials. Disease and weed suppression, yield, quality and soil health improvement, economic feasibility, and farmers' perceptions of and willingness to adopt the new technologies will be assessed. Shifts in microbial community structure will be evaluated using high throughput sequencing technology.

Theory of Change: By promoting the adoption of profitable, and resilient plant health system, this will ensure enhanced crop production and assist in long-term food security

Collaborators: Nepal Agricultural Research Council (NARC)

Achievements: Of the major accomplishments for this year, the project has established a project management unit. This unit is under the direction of the PI. The project also established a Project Advisory Committee (PAC) to get guidelines, suggestions, feedback, and potential solutions for the challenges faced during the project implementation. There will be at least one meeting of PAC per year, but the number of meetings could be more than one as required. Additionally, the project recruited 12 research interns to implement the project activities. The project also held a project inception meeting in FY2023 with almost 80 participants from research, academia, government, developing partners, and media. Root-knot nematode samples were collected from several locations, and DNA extraction is ongoing for PCR test and species identification. Nematodes were collected from at least 20 locations and have been preserved at -40 °C. *Training to Farmers through Participatory Action Research (PAR):* Seven participatory action research trials were established in seven locations. The PAR included seven mother trials of 8 treatments of three replications and 6 baby trials associated with each mother trial. The baby trials have two treatments of three replications. *Green bioassay:* Soils samples were collected from each plot after ASD treatment in mother trials and transported to National Plant Pathology Research Center at Khumaltar. Soils were put in pot for bioassay in case there is no disease development in the field due to environmental impact.

Capacity Building: Two PhD students have been selected from NARC. These students will join Agriculture and Forestry University in October. Also, project staff and research interns were trained in different stages of ASD by the PI.

Future Work: The project is planning to organize three training programs in FY2024: Advanced Plant Breeding Workshop for Horticultural Crops; training workshops in disease and pest management in protected cultivation for horticultural crops; and advanced tools and techniques for vegetable grafting

Presentations and Publications: N/A

ADVANCING TECHNOLOGY BASED ON URBAN AND PERI-URBAN HORTICULTURE NEEDS IN BANGLADESH AND NEPAL

Location: Bagmati and Gandaki Province, Nepal and Dhaka, Mymensingh, and Khulna, Bangladesh.
Description: This project will identify high yielding varieties of fruit (banana, lime) and vegetables (asparagus, moringa, broccoli, cucurbits, Cole crops, chili) using field trials in multiple locations. The project will develop strategies to increase access to and adoption of quality planting materials, identify the barriers to participation in urban horticulture by women and youth, and develop a GIS-based spatial multi-criteria decision technique to assess urban horticulture potential.
Theory of Change: The rapid urbanization in Bangladesh and Nepal is making the city dwellers vulnerable for their food and nutrition and primarily dependent on the supply chain from the rural areas. Also, it has been a challenge to enhance the production of fruits and vegetables in urban and peri-urban areas due to the limited supply of quality planting materials. By addressing these issues can contribute to increasing urban communities' access to demand-based nutrient-rich fruits and vegetables, which can contribute to achieving food and nutritional security.
Collaborators: Agriculture and Forestry University, Nepal (AFU); Bangladesh Agriculture University (BAU); Ritsumeikan University, JAPAN; New Jersey City College

Achievements: The project has identified the possible study sites in three different cities of Bangladesh to conduct the project activities. Additionally, the provisional selection of the PhD students who will work on different project activities has been completed. Finally, two horticulture resource centers in Makwanpur and Kapilbastu districts in Nepal have been finalized. In Makwanpur, Anjali Nursery and in Kapilbastu, Parijat Fruits and Vegetable Nursery was selected as a partner. Two different youth community groups will be targeted to work in close collaboration for sustainable entrepreneurship.

Future Work: In FY2024, BAU will start the background survey or data collection from the identified study areas of Bangladesh. After completing the data collection, the location of the demonstration sites will be identified upon prior approval of the house owners. The design of the demonstration units will be established based on the responses of the community people. Youth and women community groups will be formed as defined in the project proposal.

Capacity Building: N/A

Lessons Learned: N/A

Presentations and Publications: N/A

IV. DETERMINING APPROPRIATE TECHNOLOGIES FOR CLIMATE SMART AGRICULTURE

PROMOTING TECHNOLOGY FOR HORTICULTURE PRODUCTION AS ADAPTATION TO CLIMATE CHANGE IN GUATEMALA

Location: Guatemala Highlands
Description: This project will develop and validate appropriate agricultural technologies adapted to climate change for small holders in the highlands of Guatemala where poverty, malnutrition, lack of opportunities and out-migration is present. Research will focus on tomato, potato, green beans, peas, strawberry, broccoli, and edible herbs. A multidisciplinary and interdisciplinary approach will be used that includes participation of women and youth. Research entails development of a baseline, co-creation/co-design, field implementation and training as well as dissemination of the results.
Theory of Change: The long-term goal of the project is to improve the quality of life and reduce malnutrition for all people through training, adaptation and appropriation of climate-smart practices to improve their production systems. Interventions will be co-created with communities and will seek to provide practical and effective solutions through a process of knowledge transfer in three thematic areas: protected structures and irrigation technologies, technologies and practices to improve soil health, integrated pest management and efficient water use, post-harvest technologies for quality, safe and nutritious produce, and promotion of indigenous food consumption to increase dietary diversity.
Collaborators: Universidad De Valle Guatemala
Achievements: During this year, all monitoring, evaluation, and learning systems have been designed. The systems have been developed at two levels. One is an internal system, intended to record all operational data, integrating strategic planning and monitoring indicators, as well as some Feed the Future indicators. The other system is intended to record results and evaluation indicators that will enable evidence-based decision-making and collect data for research and future endeavors.
Capacity Building: During the first phase of the project, the group that will be in charge of carrying out both the implementation and the general monitoring and evaluation of the project was put together. Specialists in all areas to be included in the project were integrated into a team that has met over subjects such as activity coordination, strategic monitoring and evaluation activities.
Lessons Learned: Constructing the monitoring, evaluation, and learning system has taught the team the critical importance of stakeholder engagement and clear communication from the outset. The project has learned that involving all relevant parties early in the process ensures that the system aligns with their needs and expectations. Additionally, maintaining transparent communication about the system's objectives, data collection processes, and expected outcomes has fostered a sense of ownership and commitment among our team and stakeholders. This collaborative approach has not only enhanced the system's design and effectiveness but also contributed to a culture of data-driven decision-making and continuous learning within our organization.
Future Work: The project is currently in the process of developing data collection instruments through a survey to be conducted in nine selected municipalities. This has involved a reconnaissance phase of the territories that is being carried out in September. In parallel, the teams in charge of the study of the 3 sub-themes and cross-cutting themes have made a first draft of the survey. Once these instruments are finalized, in FY2024, the team will conduct training with the field technicians and a pilot test with a small sample to make necessary adjustments. After this refinement phase, the project will commence fieldwork and subsequently process the collected data and the process of validation of the data collected with the farmers will begin, which will serve as the basis for a process of co-creation and co-design of strategies with them.
Presentations and Publications: N/A

PROMOTING SMALL FARM TECHNOLOGIES FOR CLIMATE SMART AGRICULTURE AND MARKET ACCESS IN GUATEMALA

Location: Guatemala

Description: This project will catalyze sustainable linkages to niche markets and increase incomes for farmers. Research three different types of protective structures for horticulture at farmer households. The research will create iterative improvement through farmers' use of a suite of harvest and post-harvest management practices, leading to increased buyer acceptability and sales of horticultural products and therefore solidifying farmer interest and buy-in. The project will establish a local research center to provide important quality benchmarks. The project will conduct comparative and cost-effectiveness analysis to identify a series of evidence-based recommendations about the most cost-effective mix of production infrastructure and harvest management practices.

Theory of Change: IF Acceso tests the infrastructure, technologies and practices for horticulture production to identify the best combinations for small scale production AND determines the best postharvest
technologies that increase the quality and shelf life of products; THEN small farmers can adopt the recommendations to improve their production in a profitable and efficient way to sustainably improve their food security and incomes.

Collaborators: Acceso, Universidad Rafael Landivar

Achievements: The project started the design of the project and the strategy to address the activities to establish a research center. Also, the project has been working on the design of the recruitment campaigns and the material that will be used during the training sessions with the beneficiaries. According to the organizational chart proposed, the project will start the recruitment of the local staff that will be hired in Guatemala by developing the terms of references and the recruitment process. The project will work on the initial barrier analysis, the development of gender training for staff (including the development of the specific material) and, development of key messages that will be included in the technical assistance and training that the project will provide to the beneficiaries.

Capacity Building: No capacity strengthening occurred in FY2023.

Lessons Learned: During the start-up phase of the project, some of the lessons learned are the barrier of the language in the intervention area. To address this challenge, the project will hire local personnel to ensure that the culture barrier is addressed in a better way. The evaluation of the crops that can be cultivated under protected infrastructure is limited in function and not all of the crops can be produced inside a greenhouse, shade house or macro tunnel. The project will evaluate the diverse type of crops that can be cultivated but also that meet with nutritional values that are relevant in the daily diet of the population.

Future Work: In FY2024, the project will establish a research center. The team in FY2024 will finalize the design of the protected structures that will be installed (greenhouses, shade houses and macro tunnel) with the drip irrigation system, making the final decision of the horticulture crops, design of the gender-focused sensitization and outreach campaigns, the recruitment campaigns for the farmers that will participate in the study (beneficiaries) including the respective surveys to collect data from beneficiaries, and the development of the training material for the production cycle. Also, the project will work on the design of training material for harvest and postharvest practices and develop the training sessions with the beneficiaries.

Presentations and Publications: N/A

EMPOWERING YOUNG HORTICULTURE RESEARCHERS IN HONDURAS

Location: Honduras
Description: A fellowship-oriented program that provides seed funding to higher-education students in Honduras to conduct small-scale research projects across the horticulture value chain. Students will be guided through a grant drafting and submission training program to increase capacity in applying for funding. Awarded applications will receive funding and expertise to implement research projects.
Theory of Change: IF Zamorano provides funding opportunities to young horticulture researchers AND the young researchers use the support to conduct small research projects for theses, along with receiving training on grant writing THEN young horticulture researchers will be prepared to be successful in their fields and will also conduct effective research for the promotion of horticulture.
Collaborators: Zamorano University, in collaboration with Honduran Universities.

Achievements: The project just started and is in progress. The Terms of Reference (TOR) for field research have been developed. The project will have 4 students during FY2024: 2 men and 2 women in the age range of 17 - 24 years old. These students will receive two leadership courses and will have the opportunity to interact with producers and science professionals to enhance their professional profile.

Capacity Building: Zamorano University has specialized staff in the area of vegetable and fruit science and technology research and a team of collaborating technical specialists who will dedicate time and space to establish research dynamics with young people in the field.

Lessons Learned: There needs to be a careful selection of students that considers gender and youth empowerment. In addition, topics need to be congruent with the objectives of the Feed the Future Innovation Lab for Horticulture.

Future Work: First, in FY2024 the project will hold an informative meeting with all those involved in the process, with the aim of making all the guidelines of the process known. Then the team will then TOR for student applications, and carry out the selection of the students so that they can then present a preliminary research project. The student will then establish field research, collect and analyze data from the research process, and present on the results of the research.

Presentations and Publications: N/A

V. CRITICAL ENGAGEMENT PROJECTS

INFORMAL MIDSTREAM ACTORS IN NIGERIA AND RWANDA [THIS PROJECT ENDED IN JUNE, FY2023]

Location: Nigeria and Rwanda

Description: This research proejct will test a methodology to diagnose the (potential) involvement of informal midstream actors in contributing to food system outcomes. This study will enhance understanding among policy makers and impact investors of the role of informal midstream actors using case studies in Nigeria and Rwanda (a previous Horticulture Innovation Lab project).

Theory of Change: By deepening our understanding of the informal economy and what drives its actors, we can engage them in enhancing food system outcomes, such as food safety and consumer demands to access nutritious and safe foods. We have to deepen our understanding of the informal economy and what drives its actors in order to achieve gains as efforts to reduce these value chain constraints often fail as the mid-stream actors are not registered and are operating in informality. Beyond conventional economic measures, there are likely other incentives could be more successful to drive change in the informal sector.

Collaborators: Wageningen University and Research (WUR)

Achievements: A literature review was conducted identifying possible drivers of innovation, adoption, and scalability of interventions driven by informal private sector actors. The project identified two case studies from Nigeria and Rwanda, where plastic crates were introduced in the tomato value chain. A survey was developed for the diagnosis, based on the desk review and the case analysis. The interview approach and draft questionnaires were tested during a joint field visit to Rwanda in August 2022 and adaptations were made. During the field visit the project team interviewed a number of midstream value chain actors involved in the tomato sector, including retailers and dealers supplying and active on the main urban markets in Kigali. After this, actual data collection took place. In Nigeria, it was done from 10 to 18 November in Ife (Osun State) Ibadan (Oyo State) and Lagos states covering all the major markets in the Southwest where tomato supply from the North is sold. In Rwanda, data collection took place from 20 to 26 December. Selected stakeholders occupying each segment along the value chain were interviewed. Interviews lasted between 40-60 minutes. In Nigeria 58 interviews were done and in Rwanda 38. The interviews are analyzed with Atlas.ti qualitative analysis software. Relevant data and statements were coded and compared across actors in different value chain segments and between Nigeria and Rwanda. A report containing findings has been drafted and is under editorial review.

Capacity Building: None to report

Lessons Learned: None to report

Future Work: This project has been completed, but findings will be presented to the Horticulture Innovation Lab Network.

Presentations and Publications:

Dijkxhoorn, Y., McGuire, E., Talabi, O, Termeer, E., Jarman, A., Ndayitabi, S., de Steenhuijsen Piters, B. (2023) Towards Food System Innovation: Engaging Midstream Actors in Informal Vegetable Value Chains. *The European Journal of Development Research.* [UNDER REVIEW]

DETERMINING THE TRADE-OFFS BETWEEN SHORT AND LONG HORTICULTURE VALUE CHAINS IN KENYA

Location: Across six counties in Kenya

Description: This project will determine the nutritional, economical, and social (gender equity and youth engagement) impacts on producers along both short and long value chains of banana, mango, tomato, kales, cowpeas and African nightshade, and determine to what extent information communication technologies (ICT) are incorporated and what are their benefits and/or impacts. Study outputs will increase understanding of the level of penetration and utilization of ICT in selected horticulture value chains; inform evidence on suitable horticulture access pathways that increase stability in markets and increase value chain efficiencies; document the enabling environments and key characteristics that facilitate positive aspects of access pathways.

Theory of Change: By increasing understanding of the trade-offs between short versus long horticulture value chains, and the impact of ICTs on those value chains, researchers will have critical information to guide where future interventions and innovations should be focused. This will achieve specific types of outcomes and avoid unintended harmful impacts from scaling/interventions. Furthermore, by collecting this data, researchers outside of Kenya can use the findings and approach as a framework for replication.

Collaborators: Jomo Kenyatta University of Agriculture and Technology (JKUAT); GROOTS Kenya

Achievements: The project team held 12 meetings in July and August to plan for an inception workshop and project activities. The four-day inception workshop was held at the end of August, with stakeholders that included policymakers at both national and county levels, small-scale farmers from the six counties included in the project scope, and traders of the selected horticultural products. The main activities that took place during the inception workshop were working with participants to validate the value chain map, prioritize outcome indicators and potential impact pathways, and discuss nutritional aspects along the value chain. As a result of the discussions from the workshop, study areas and production statistics were solidified and contacts from the selected counties and sub-counties for various value chains were established. An additional accomplishment the project has achieved thus far was the recruitment of a PhD student, who wrote a proposal that is currently under review for approval by the JKUAT Graduate School. The study mapped out a number of ICT models and organizations. These are Farmforce, eProd, National Horticulture Traceability system (NHTS), Kijani Kibichi, Twiga foods, Esoko Kenya and M-shamba

Capacity Building: One PhD student was recruited and attached to the project, which builds capacity and sustainability of research.

Lessons Learned: The results of the inception workshop showed that despite the fact more women are horticultural producers, they often have less access to land, credit, and other resources, which can limit their productivity. Women are also concentrated in low-paid and low-skilled jobs while men are more likely to be involved upstream in the value chain. The project also discovered that while women face more constraints in vegetable production, men who grow vegetables face a certain stigma, since vegetables are regarded as a woman`s crop. The team also observed that youth are rarely involved in the value chains, so including youth in sampling is necessary to ensure they are represented in the research. In addition, the project learned that while ICT platforms are available, their use is limited, which could be a result of the fact many farmers are not aware of the potential benefits of ICTs and how to use them.

Future Work: In FY2024, the project will perform a comprehensive literature review on six crops, as well as rapid market appraisals. In addition, the project will develop study tools, a sampling plan, and piloting, as well as key informant interviews (KII) and focus group discussions (FDGs). The project will also perform field surveys to investigate two objectives: 1) the different possible nutrition, economic, and social outcomes of short and long food value chains, and 2) the impact of ICTs on these value chains. There will be one large survey that covers all aspects of nutrition, economic, and social outcomes, as well as FGDs and KIIs. Data collected from this survey will then be analyzed to compare impacts between short and long value chains, and findings will be validated and disseminated. Additionally, in FY2024, a desk review to determine ICT platforms usage and uptake along the value chain, and their access by actors will be completed.

VI. TRELLIS FELLOWSHIP

TRELLIS FUND FELLOWSHIP FOR I890 GRADUATE STUDENTS

Location: Kenya, Honduras, Ghana, Nepal, Guatemala, Bangladesh, Uganda, Mali, Nigeria– Districts to be determined

Description: The Trellis Fund was started during the first phase of the Horticulture Innovation Lab. During this phase, 2021 to 2026, the Trellis Fund Fellowship program will be led by Consortium Partner, Florida Agricultural and Mechanical University (FAMU). The Trellis Fund will be a capacity building program that connects local, in-country organizations in developing countries and in-country graduate students, with U.S. graduate students from 1890 universities who have agricultural expertise to conduct research projects, thus generating benefits for both the students and the institutions.

Theory of Change: By providing international research opportunities to 1890 graduate students, and connecting those students with in-country graduate students and organizations, all parties benefit from field research experience, sharing of knowledge and experience, and develop data and technology beneficial for smallholder horticulture growers.

Collaborators: Florida Agricultural and Mechanical University (FAMU)

Achievements: During this reporting period, FAMU's Project Director, Harriett Paul, established the project within FAMU's Contract and Grant administrative framework, following the signing of the award on April 20, 2023. The contracting for the project's program associate was completed during the final quarter of this reporting period. During the final two weeks of September 2023, the FAMU team contacted all of the regional research groups to request their scopes of work (SOW) for Trellis fellows for FY2024. Harriett Paul presented at two Innovation Lab affiliated events the structure and design of the Trellis Fellowship program being led by FAMU.

Capacity Building: None to report

Lessons Learned: None to report

Future Work: During the first quarter of FY2024, research projects for fellows will be finalized and student recruitment begun. The contracting for a communications consultant will be carried out to bring this person on board by the start of the second quarter FY2024. The project anticipates announcing the successful fellowship applicants by January 2024 and successful fellows will participate in orientation and eight week capacity building study program in February- March. In April-May 2024, fellows will engage in research collaboration with host country research projects using electronic platforms prior to going to the field sites in the summer of FY2024.

Presentations and Publications: N/A

VII. SCALING PROJECTS

GENDER UP SCALING TOOL

Location: Global
Description: GenderUp supports project and research teams in scaling agricultural innovations in a gender responsible way. GenderUp will guide teams in a series of workshops to: identify gender and other relevant diversity among innovation users for more successful and inclusive scaling of agricultural innovations; and, improve their scaling strategy by anticipating unintended negative consequences for different groups in society.
Theory of Change: Through evidenced-based, structured training, researchers and innovators can learn how to scale their technologies and practices in a responsible manner, that in turn will increase gender equity through the scaling process.
Collaborators: Horticulture Innovation Lab, Bioversity International - International Center for Tropical Agriculture (CIAT), Wageningen University and Research, International Institute of Tropical Agriculture (IITA)
Achievements: GenderUp has a strong focus on scaling innovations in an equitable way. In FY 2023, this was exemplified across facilitator trainings, workshops, and in the impact of innovations that went through the GenderUp process. 63% of participants in trainings and workshops were women. These women are viewed as vital leaders on their diverse scaling teams, and they led discussions centered around improving the inclusivity of their innovations. Specific examples included driving higher market access for women producers in Malawi and adjusting the design of certain conservation agriculture tools to be more suitable and usable for women in Zimbabwe. In FY 2023, the GenderUp team hit the ground running by promoting the tool, hosting facilitator trainings, and supporting facilitators in conducting their own GenderUp workshops with external innovation teams. Two facilitator trainings were hosted, while three GenderUp workshops took place across the globe, indicating the beginning of GenderUp's own scaling process. Throughout these experiences, the GenderUp team came away with valuable insights on how to improve the tool to be more accessible, effective, and attractive to facilitators and innovation teams alike. These insights resulted in the redesign of the GenderUp website, which now includes more resources, a streamlined slide deck for workshops, and adjusted content that fits GenderUp's diversity and inclusivity goals. The team is confident that these improvements will increase engagement with GenderUp moving into FY 2024.
Capacity development: Participants in both the GenderUp facilitator trainings and GenderUp workshops for innovation teams were exposed to new ways of thinking about the positive and negative impacts of scaling. In the facilitator trainings, participants gained valuable facilitation skills and became masters of the inclusive scaling learning activities. In GenderUp workshops for innovation teams, participants discussed novel approaches to creating more inclusive scaling. They also had hard discussions on shifts they can make to their own scaling strategies and who will be responsible for those changes moving forward. In follow-up surveys, the GenderUp team received positive feedback on participants' ability to apply these concepts to other aspects of their roles. Also, throughout this year, the GenderUp team maintained strong partnerships with Wageningen University and Research (WUR) and The Alliance of Bioversity International and CIAT. Multiple team members worked together to write blog posts, develop training materials, redesign the website, and facilitate trainings. The GenderUp team leveraged funding through CGIAR's Diversification in East and South Africa (Ukama Ustawi) Initiative to write an outcome study. The GenderUp team also engaged in conversations with CGIAR's Fruits and Vegetables for Sustainable Healthy Diets (FRESH) program to explore potential areas of collaboration.
Lessons Learned: As facilitators and participants experienced the GenderUp 'journey', they shared valuable feedback and suggestions for improvements to the tool. One such suggestion was to make

GenderUp accessible to teams with poor internet connectivity. In response to this, the team developed printable handouts for all surveys, discussions, and learning activities. This will make the tool more inclusive to all innovation teams, especially in contexts where Feed the Future works. Others pointed out that the language within GenderUp is jargon-heavy and perhaps only meaningful to social scientists. In the process of redesigning the website and other materials, the team adjusted language to be more clear, concise, and explanatory.
Future Work: In the coming year, the GenderUp team plans to continue training GenderUp facilitators and supporting those facilitators in the workshops they conduct with innovation teams. With the redesign of the GenderUp website being finalized, the team hopes that these trainings will run more smoothly and facilitators will have more ready access to the resources they need. The team also plans to host a website "re-launch" event where facilitators share their experiences with GenderUp, the new website is unveiled, and attendees can get questions answered. Additionally, the GenderUp team will help to host the second iteration of the Scaling and Innovating for Social Transformation Class/Working Group. This class will take place in Spring 2024 and will focus on bringing together a diverse group of researchers, practitioners, and graduate students to discuss new avenues for responsible and inclusive scaling.
Presentations and Publications: N/A

DRYCARD FRANCHISE PROJECT

Location: USA, Tanzania, Rwanda, Nigeria, Thailand, Mexico, Guatemala, Myanmar, Kenya, Ghana, India, Uganda, Nepal
Description: The goal of this project is to increase awareness and adoption of the DryCard technology to improve storage systems and reduce postharvest losses. The Horticulture Innovation Lab is forming partnerships with organizations, businesses, and entrepreneurs to supply the DryCard to local communities of developing countries. This technology was highlighted in FY2022 workplan as a one that the Horticulture Innovation Lab continues to promote.

Theory of Change: By increasing awareness of the importance of properly drying and storing dried products, and empowering local entrepreneurs to be the distributor of an effective tool to measure dryness, smallholder farmers and traders will have greater access to nutritious dried fruits and vegetables, lower exposure to aflatoxins in maize and groundnuts in particular, and increased income from selling quality dried products.
Collaborators: Postharvest Consulting and Capacity Building Company, Tanzania; Agrifood Business Consulting, Rwanda; Willow Foundation, Nigeria; Go Organics, Thailand; EarthEmpower, Mexico and Guatemala; Ofori Agrochemical Services, Ghana; Mwino Group, Uganda; R&D Innovative Solution, Nepal; Vivia Foundation, India; Myanmar Innovative Life Sciences, Myanmar; BetterCrops Ltd., Kenya
Achievements: In FY2023, no new entrepreneurs were established, but several reported continued sales. Over 1000 DryCards were sold by only a group of five entrepreneurs. The DryCard continues to be promoted through different avenues (trainings from entrepreneurs, conferences, social media, websites) and interest is actually growing fairly rapidly in the United States due to networking within seed-saver groups. For FY2023 to be the first full year out of Covid impacts, we are thankful to have most of the entrepreneurs still operating.

Capacity development: The Management Entity did not engage directly in capacity development with the exception of training the new entrepreneurs on how to construct and use the DryCard. However, there are trainings being provided to entrepreneurs in different settings while selling the DryCards.

Lessons Learned: There is a lingering effect from Covid, with one entrepreneur going out of business (in Mexico) due to not being able to recover, and another individual entrepreneur dealing with severe effects of Covid in 2022 and 2023 thus reducing sales.

VI. ASSOCIATE AWARD RESEARCH PROJECT REPORTS

No associate awards to report in FY2023

VII. HUMAN AND INSTITUTIONAL CAPACITY DEVELOPMENT

FY2023 SHORT TERM TRAINING

Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Remote-United States	GenderUp Facilitator Training	Civil Society	0	9	9
Remote - United States	GenderUp Facilitator Training	Civil Society	1	9	10
United States	UC Davis Scaling for Social Transformation Class and Working Group	Civil Society	8	9	17
Remote - Malawi	GenderUp Workshop - Malawi Horticultural Marketplace App	Civil Society	5	2	7
Remote-Guatemala	GenderUp Workshop - Guatemala Community Survey	Civil Society	2	3	5
Nigeria	Enumerator training Nigeria	Civil Society	2	0	2
Rwanda	Enumerator training Rwanda	Civil Society	2	1	3
Uganda	Data collection and quality management for enumerators	Private Sector	8	2	10
Nepal	Participatory action research trials in anaerobic soil disinfestation at Nuwakot	Producers, Government	15	6	21

Nepal	Participatory action research trials to manage soilborne diseases in vegetable crops at Bara	Producers	21	24	45
Nepal	Participatory action research trials in anaerobic soil disinfestation to control soilborne diseases in vegetable crops at Madi, Chitwan	Producers, Government, Private Sector	14	4	18
Nepal	Participatory action research trails to manage soilborne diseases in vegetable crops at Pokhara, Kaski	Producers, Government	13	7	20
Nepal	Participatory action research trials in anaerobic soil disinfestation to control soilborne diseases in vegetable crops at Surkhet	Producers	9	27	36
Nepal	Participatory action research trials in anaerobic soil disinfestation to control soilborne diseases in vegetable crops at Kapilvastu	Producers	16	4	20
Honduras	Postharvest Training	Producers, Civil Society	12	3	15
Total			128	110	238

FY2023 LONG TERM TRAINING

Home Country	Name	Sex	University	Degree	Major	Graduation Date (Mo/Yr)
United States	2	Female	University of California, Davis	Master's	International Agricultural Development	June 2023
United States	3	Female	University of California, Davis	Master's	International Agricultural Development	December 2023
United States	4	Male	University of California, Davis	Bachelors	Horticulture and Agronomy	June 2023
United States	5	Female	University of California, Davis	Master's	International Agricultural Development	June 2023
Kenya	6	Male	Jomo Kenyatta University of Agriculture and Technology	Ph.D.	Agricultural and applied Economics	April 2026

Ghana	7	Male	University of Ghana	Ph.D.	Postharvest Technology	September 2024
Ghana	8	Male	University of Ghana	Master's	Food Science	September 2024
Nepal	9	Male	Nepal Agricultural Research Council	Ph.D.	Plant Pathology	August 2026
Nepal	10	Male	Nepal Agricultural Research Council	Ph.D.	Agricultural Economics	September 2026

FY2023 INSTITUTIONAL CAPACITY BUILDING

The Horticulture Innovation Lab collaborated with the Postharvest Training Center at UC Davis on a virtual course. The course, Postharvest Solutions for Small and Evolving Operations, was attended by representatives from many of the international institutions leading the Innovation Lab's projects along with organizations and companies in the United States. Furthermore, the Horticulture Innovation Lab invited representatives from the University of Nairobi and R&D Innovative Solutions from Nepal to present at the course.

Regional Hub Managers have been closely involved in the development of RFAs, contracting of subawards, onboarding of PIs, and assisting new projects meet USAID guidelines. This collaboration benefits the Management Entity at UC Davis, and strengthens the Regional Hub Managers' capacity to lead USAID funded research portfolios.

Approximately 95% of the Horticulture Innovation Lab projects are being led by PI's based in in-country organizations or universities. Some of these PIs have engaged in USAID funded projects, but many have not. Although they have extensive experience leading research projects, this exposure to implementing a USAID funded project will strengthen their capacity, and their host institutions.

VIII. INNOVATION TRANSFER AND SCALING PARTNERSHIPS

The Horticulture Innovation Lab supports the development of disruptive innovations and technologies to stimulate and facilitate horticultural development worldwide. Technologies and innovations have the ability to solve problems and to reduce barriers within the horticulture sector. With proper needs assessment, research, input and support, these technologies have the potential to change the lives of the world's smallholder farmers for the better. The Horticulture Innovation Lab will focus on technologies that reduce on-farm costs, reduce postharvest losses, use labor more efficiently, empower women and youth, take advantage of information communications technologies opportunities, and use limited natural resources more sustainably. Technologies and innovations come in a variety of forms. "Hard" technologies are devices, prototypes and designs that improve our lives and, in some way, change the current system. "Soft" technologies encompass innovation in systems, behaviors, and methods within the horticulture sector. Assemblies of ideas and thought processes make up a soft technology.

The Horticulture Innovation Lab recognizes the need to understand innovation network systems and how innovation creation and adoption can best be supported in the project regions. A research project was initiated that employs social network analysis to delve into stakeholder involvement within agricultural-based innovation systems. Within the four different regions, 202 experts within the horticultural sector responded to an extensive survey conducted at the FY2022 regional meetings. Data relating to organization type (academic, private sector, government, etc.), scale (local, national, international, etc.), value chain involvement, collaborators, and innovation capabilities are being analyzed from the survey. Initial findings show that the innovation network in East Africa stands out as a prime example of effective and advanced collaboration. It is characterized by a well-balanced participation of various actors, showcasing a model of excellence in innovation synergy. Analysis and follow up will continue with planned publications to disseminate this information once results are finalized. This research helps strengthen resilience among people and systems by identifying collaboration opportunities and knowledge exchange within agricultural innovation networks, making responses to global challenges more effective. It also supports inclusive and sustainable agricultural-led economic growth by highlighting diverse models of innovation collaboration across different regions.

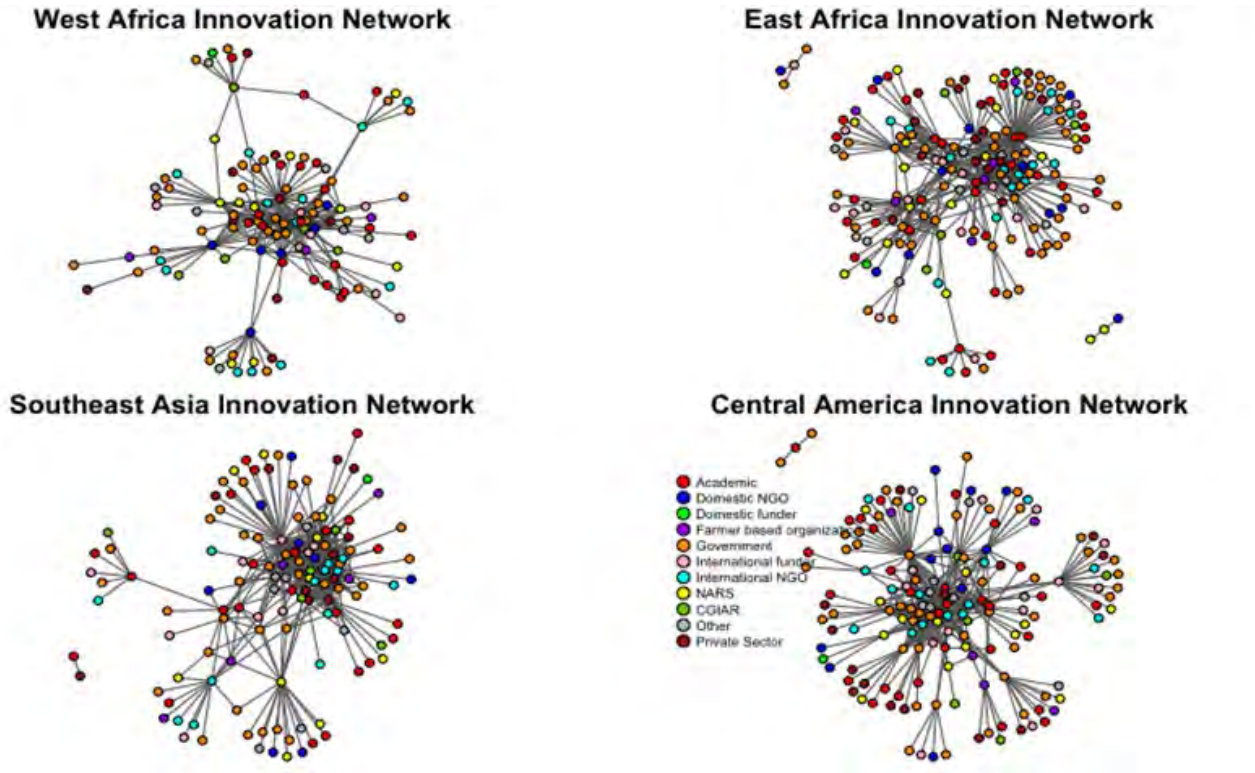


Figure 5 Visual representation of the institutions participating in the horticultural sector across our four regions

In addition to improving an understanding of innovation networks, the Horticulture Innovation Lab published a review paper in a special issue (The Kader Review) of the Postharvest Biology and Technology journal. The publication was a call-to-action for integrated, coordinated action to address food loss and waste, while sharing case studies in scaling and implementing postharvest practices and technologies in low- and middle-income countries (LMICs). The title of the publication is *Postharvest technologies for small-scale farmers in low- and middle-income countries: A call to action.*

The Horticulture Innovation Lab continues to promote the scaling of the DryCard through training from entrepreneurs, conferences, social media, and websites. Interest is actually growing fairly rapidly in the United States due to networking within seed-saver groups. For FY2023 to be the first full year out of Covid impacts, we are thankful to have most of the entrepreneurs still operating.

Additionally, the Horticulture Innovation Lab worked to scale the GenderUp tool globally. The GenderUp team maintained strong partnerships with Wageningen University and Research (WUR) and The Alliance of Bioversity International and CIAT, who developed the tool. Multiple team members worked together to write blog posts, develop training materials, redesign the website, and facilitate trainings. The GenderUp team leveraged funding through CGIAR's Diversification in East and South Africa (Ukama Ustawi) Initiative to write an outcome study. The GenderUp team also engaged in conversations with CGIAR's Fruits and Vegetables for Sustainable Healthy Diets (FRESH) program to explore potential areas of collaboration. GenderUp is being scaled using a Training of Trainers model, in which experts in the agricultural development field are being trained as facilitators who are then equipped to use the tool with innovation teams with only backend support from the GenderUp team. Two facilitator trainings were hosted in FY2023, while three GenderUp workshops took place across the globe. Throughout these experiences, the GenderUp team came away with valuable insights on how to improve the tool to be more accessible, effective, and attractive to facilitators and innovation teams alike. These insights resulted in the redesign of the GenderUp website, which now includes more resources, a streamlined slide deck for workshops, and adjusted content that fits GenderUp's diversity and inclusivity goals. The team is confident that these improvements will increase engagement with GenderUp moving into FY2024.

The Horticulture Innovation Lab has two Scaling Partners within the Consortium – Cultivating New Frontiers in Agriculture and the International Fertilizer Development Center. Their representation on the International Advisory Board has been invaluable to provide insights on how projects early on can be positioned for broad impact.

IX. ENVIRONMENTAL MANAGEMENT AND MITIGATION PLAN

The Horticulture Innovation Lab submitted an Environmental Management and Mitigation Plan (EMMP) template to our Agreement Officer's Representative (AOR) for review. During FY2023, the Horticulture Innovation Lab initiated four Initial Environmental Examinations (IEEs), one per region. Contained in these IEEs are activities that will be used to update the EMMP reporting expectations for the projects. Once the IEEs are approved, the existing EMMP will be updated to include these added activities and submitted to USAID for approval. The new activities include:

Projects/Activities	Categorical Exclusion Citation	Negative Determination
Project/Activity 1: Confined trials or monitored field trials	Applied research and capacity building that does NOT exceed 4 ha in a single location and DOES involve support or procurement of chemical pesticide, insecticide, or fertilizer input	Negative Determination, subject to the following conditions: · Appropriate pesticide and/or fertilizer use protocols to safeguard the health of research personnel and to protect local ecosystems are developed and implemented, based on toxicological and environmental data for the proposed pesticides or fertilizers. Such safeguards will address pesticide storage, handling and application, including the use of Personal Protective Equipment (PPE), cleanup and disposal. · Follow recommendations of PERSUAPS referenced in the IEE amendment.
Project/Activity 2: Confined trials or monitored field trials without pesticides	Conducting applied research not exceeding 4 ha in a single location and NOT involving support for procurement or use of chemical pesticides or fertilizers.	Categorical Exclusion,per 22 CFR 216.2 (c) (2) (ii) Controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored.
Project/Activity 3: Desktop studies, data analysis, program administration, workshops and meetings.	Desktop studies, data analysis, program administration, workshops and meetings.	Categorical Exclusion, per 22 CFR 216.2 (c)(2)(iii) Analyses, studies, academic or research workshops and meetings
Project/Activity 4: Capacity strengthening centers	Establishment of training centers that include the demonstration of production practices and postharvest practices	Categorical Exclusion, per 22CFR 216.2(c)(i) Education, technical assistance, or training programs Note: no technologies established will be considered permanent structures and are capable of removal.

Projects will immediately submit EMMPs including these new Project/Activity categorizations in early FY2024. Thus far, no projects have been out of compliance with existing, approved EMMP. The Management Entity will gladly provide completed EMMPs as they are submitted and project compliance with EMMPs will be tracked through the Piestar Database.

X. OPEN DATA MANAGEMENT PLAN

The Open Data Management Plan (plan) is tracked in our Piestar database in a format that aligns with approved Data Management Plan template. Data ready for submission will be either uploaded directly into the Development Data Library (DDL) or submitted to the DDL through a link to a publicly available data repository such as Harvard Dataverse. Updated Data Management Plans can be exported from Piestar and provided upon request.

In FY2023, a dataset for the project *Informal mid-stream actors in Nigeria and Rwanda* was uploaded to Harvard Dataverse then submitted to the DDL for review as this project has reached completion.

XI. GOVERNANCE AND MANAGEMENT ENTITY ACTIVITY

Staffing: The program went through a significant change in FY2023. Dr. Elizabeth Mitcham retired after over ten years as Director of the Horticulture Innovation Lab. Dr. Erin McGuire has stepped in to be the new Director of the Innovation Lab and Archie Jarman is now the Associate Director. In FY2023 a program officer was hired to fill Archie's position, Lydiah Maranga. Additionally, early in FY2023, the Innovation Lab hired a Communications Manager, Heather Hayashi and a postdoc, Dr. Michel Kabirigi. Michel will be leading analysis of the Horticulture Innovation Lab's innovation networks, an objective outlined in the proposal to USAID.

Innovation Lab Council Chair and Regional Meeting: As discussed above, the Horticulture Innovation Lab successfully completed its role as Chair of the Innovation Lab Council in FY2023. The Innovation Lab organized the Regional Partners Meeting in Nairobi, highlighting the Innovation Labs' work toward mitigating and adapting to climate change. As part of this meeting, the Horticulture Innovation Lab also organized a side event focused on local-led research, which highlighted the importance of involving local communities in the design and implementation of research projects. For the Innovation Lab Directors' Meeting in Washington D.C., the Innovation Lab organized a conference dedicated to building the Innovation Labs' capacity to conduct research that builds equity.

International Advisory Board: In FY2023, members of the Horticulture Innovation Lab's International Advisory Board (IAB) were settled and two meetings were held. One was remote, while the other was in person during the Horticulture Innovation Lab's Annual Meeting in Nairobi. A chair and co-chair of the IAB were elected and the IAB has provided valuable insights into the projects.

XII. OTHER TOPICS

The Horticulture Innovation Lab completed its role as Chair of the Innovation Lab Council in FY2023. It was an honor to be Chair and Dr. Erin Mcguire was able to guide the development of agendas for the in person meetings which received significant, positive feedback. The Horticulture Innovation Lab put together two forward-thinking agendas that align with the priorities of USAID and Feed the Future. The agendas were designed to promote local leadership, inspire global engagement, and mobilize action to tackle the most urgent challenges of our time, such as combating climate change, alleviating poverty, eradicating global hunger, and advocating for gender equity and climate justice.

The Regional Partners meeting for the Innovation Labs was held in Nairobi. The purpose of this meeting was for attendees to understand geographic differences, priorities, and trade-offs of climate change mitigation and adaptation strategies; highlight systems and scaling challenges and transformative solutions; and advance opportunities for local-led leadership and international collaboration. Close to 200 people from a range of backgrounds registered for this event.

In Washington D.C. for the Innovation Lab's Directors' meeting, the meeting's theme was building systems to innovate and scale for social transformation. Additionally, the meeting included a reception on Capitol Hill along with a presentation from the Board for International Food and Agricultural Development (BIFAD) on their working paper on systemic approaches for addressing climate change.

XIII. ISSUES

The Horticulture Innovation Lab had continuing challenges with UEIs. Advice from AOR greatly helped speed up approvals, but the Innovation Lab had two organizations that ran into lengthy delays while trying to reinstate expired UEI numbers. One of two organizations received their UEI, the other is still waiting.

The Innovation Lab ran into a fairly unique challenge with receiving seed purchase approval. Several of the Horticulture Innovation Lab's projects are researching indigenous vegetables. It is common practice for growers to save seed from prior season to use for production in the following growing cycle. Projects that wanted to utilize this farmer-produced seed for trials in the same region were presented with challenges in terms of gathering sufficient seed certification information. The Innovation Lab has resolved this challenge by accessing small quantities that are sold by country-level research systems and then conducting a seed increase, but this did add an unanticipated step.

Finally, in terms of contracting, the Horticulture Innovation Lab learned late that an organization based outside of the U.S. would have a significant challenge wiring funds to a university operating as their subaward which is based in the U.S. The Innovation Lab will now directly subaward with the U.S. university so they can perform their component of the project.

XIV. FUTURE WORK

Programmatic: In the coming year the Horticulture Innovation Lab will be focused on getting each project awarded and contracted during this period into full operational capacity. This includes appropriate expertise, staff and students, data collection tools, in-field operations being conducted and initial results

being analyzed. As the management entity we will support all of our PIs/CO-PI, regional managers, and other stakeholders in disseminating the lessons learned along the way. Additionally, we will actively promote regional leadership within our network and contribute our expertise to global academic horticulture discussions.

Collaborations: The Horticulture Innovation Lab has begun to discuss ways in which the CGIAR FRESH initiative can work together more thoughtfully, as one of the only two initiatives focused on fruit and vegetable research. Some possible partnerships are working together on scaling innovation, using GenderUp; co-writing an academic article looking at the investment in horticulture research, and a joint science and policy day with WorldVeg at an upcoming food systems conference. The Lab also has engaged in discussions with CGIAR entities, including the International Livestock Research Institute, the Alliance of Biodiversity and CIAT, and Wageningen University to dive deeper into collaborations around scaling tools and research. The lab also hopes to leverage over a decade of research within the State VACs initiative. Further, the Lab will be finalizing and operationalizing contracts within Guinea Bissau to work on horticulture seed systems and extension programs.

Thought Leadership: The Horticulture Innovation Lab has a unique inclusion, systems-based approach to managing a traditional research portfolio. We will continue to highlight and share lessons learned on our gender and socially inclusive management strategies and our local-led structure. We will do this through our own in-house studies, presentations, blogs, and articles. The Horticulture Innovation Lab also will contribute to larger food systems and policy conversations on food systems change, including increasing biodiversity through AIFVs, supporting innovation in reducing FLW, and highlighting the benefits and tradeoffs of large-scale horticulture production.

XV. APPENDICES

APPENDIX A. LIST OF AWARDS GIVEN TO U.S. PARTNERS

Florida Agriculture and Mechanical University

- *Project: Trellis Fund Fellowship for 1890 Graduate Students*
- *Duration: FY2023 to FY2026*
- *Award total: $400,000*

North Carolina State University

- *Project: Enhancing Productivity, Post-harvest Management, and Market Access of AIVs in Kenya*
- *Duration: FY2023 to FY2026*
- *Award for NCSU: ~$98,000*

APPENDIX B. SUCCESS STORIES

See documents attached

APPENDIX C. PUBLICATIONS (ATTACHED TO ANNUAL REPORT)

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Success Story: Our Locally Led Research Process

This past year, the Feed the Future Innovation Lab for Horticulture began its 5-year project lifecycle with an inclusive new approach: funding horticultural research projects designed and led by local organizations and Principal Investigators, rather than U.S.-based funding entities. This is a major pivot from traditional Agriculture Research for Development models, which typically involve organizations based in the Global North taking lead roles in project design while leaving implementation to local partners. Currently, 12 projects are underway in four Feed the Future focus regions: East and West Africa, South Asia and Central America.

(above) Horticulture Innovation Lab South Asia Regional Hub participants (below) Central America Regional Hub (furthest below) East and West Africa.

The first step in this locally led research process was selecting horticultural research priorities, which was accomplished through four regional workshops in summer 2022. These were multi-day events in Ghana, Kenya, Honduras and Nepal that brought together farmers, politicians, industry actors, and researchers. Each workshop produced a list of priorities that were then narrowed down in October 2022 at an all-partners meeting at Florida Agricultural and Mechanical University, which was attended by members of the Horticulture Innovation Lab's: UC Davis management entity, Consortium, and Regional Hub Managers. Priorities were selected based on their relevance to a chosen regional archetype, which, for example in West Africa, was a 30-year-old mother of three. The West Africa working group then decided health and nutrition was the theme that would most improve her life, and Requests for Applications (RFAs) were sent out based on this theme. The same process was followed for the other three regions as well.

The incredible amount of applications received–125 in total–were a testament to the extent to which locally-selected research priorities resonated within local academic networks. To decide the top applications, horticultural experts from around the globe were consulted to assess each proposal for scientific rigor and feasibility, utilizing the LASER PULSE (Long-term Assistance and Services for Research Partners for University-Led Solutions Engine) platform. Ultimately, 11 applications were chosen for funding, with collaboration between the management entity and project organizations already demonstrating the value and knowledge from the deep pool of local expertise - something that is often overlooked or underestimated by global development organizations.

Local researchers and regional partners are skilled at finding solutions for daily challenges not often faced by institutions in the Global North, such as inconsistent electricity and inadequate access to research equipment and facilities. Similarly, local partners are more adept at innovating locality-specific solutions to issues such as climate change and food insecurity. This is apparent with our project partners, who have chosen to directly address these challenges through research on indigenous vegetables, horticultural production technologies, and integrating youth and women in the horticultural value chain. We look forward to the wealth of knowledge these projects will bring to light, as well as the impact that these research initiatives will have not only for their regions, but for the global community as a whole.

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Success Story: Engaging Midstream Actors in Informal Vegetable Value Chains

Feed The Future Innovation Lab for Horticulture collaborated with Wageningen University and Research to identify technological adoption gaps with midstream actors, focusing on tomato traders in Nigeria's Southwest and northern regions. One of the key priorities for the Horticulture Innovation Lab is working with stakeholders to find innovative ways to reduce food waste along value chains. Post-harvest management requires integrated innovation strategies incorporating technological innovations and capacity building.

Midstream actors play an essential role in delivering fresh fruits and vegetables in various markets. If not handled well, this may lead to huge losses. Policymakers and researchers have done little to involve informal midstream actors in identifying and testing the effectiveness of interventions in the informal economy. Therefore, the Horticulture Innovation Lab worked closely with Wageningen University to identify incentives that inform these informal groups to adopt innovations, build resilience, and apply entrepreneurship skills to deliver safe and healthy produce to the market.

The study reviewed a 2016 case study from Nigeria, a project funded by the Multi-Donor Trust Fund, and was administered by the World Bank. Plastic crates were introduced in the Southwest and North regions to midstream actors to transport tomatoes to the market. The results showed a great preference for plastic crates over raffia baskets, which provided notable benefits such as increased volume of quality products, standardization of measuring units, and ease of handling of the commodity.

The project's outcome provided insights for our research question: "*What motivates informational midstream actors to be involved in addressing the value chain challenges that impact the affordability and availability of healthy and safe foods for consumers?*" The premise was that there is no significant regulation in the informal sector, which could inform how the sector performs regarding technology adoption.

While government agencies have focused on interventions such as making registration more accessible and lowering the cost of entry, these approaches have had little to no effect.

Tomatoes in regional domestic markets being carried in raffia baskets.

Three things that emerged from the study include:

Plastic crates reduced food loss, increased food safety, and made more affordable vegetable prices for low-income consumers. These gains benefit food system transformation if there is a collaboration between informal actors and formal service providers. Most respondents pointed out that a lack of cash flow mainly hinders their financial growth. Therefore, business growth is realized by reducing post-harvest losses, and higher-quality tomatoes lead to a direct profit increase for traders, allowing them to stay resilient.

Secondly, there is a relatively high innovation capacity within the informal groups (dealers and retailers) when engaged with a group. The study showed that traders of the same groups are more willing to cooperate as they demonstrate a high level of organization. Members of a group have facilitated streams to do business together.

Finally, there is a potential opportunity for the plastic crate business if the social capacity and desire to co-invest are elsewhere in the value chain. Subsidies from donor programs can make adoption possible initially, and as the business expands, it will encourage other formal actors (non-native to the vegetable trade) to invest in this sector such as production of plastic crates.

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Success Story: Leading the Recovery & Advancement of Global Partnerships and Collaboration Research

Shocks to the global food system caused by the COVID-19 pandemic increased global poverty, and doubled the number of severely food-insecure people from before the pandemic to 276 million (U.S. Global Leadership Coalition, 2022). As the world began its recovery, Feed the Future Innovation Lab for Horticulture Director and Chair of Feed the Future Innovation Labs Council of Directors, Erin J. McGuire, set in motion a plan to rebuild a more resilient, sustainable and collaborative global research network and community.

In May, 2023 in Nairobi, Kenya, the Horticulture Innovation Lab hosted the first in-person conference since before the pandemic. The agenda, envisioned by McGuire and USAID, engaged the global community and placed local voices center stage. Nearly 200 registrants responded, with guests gathering from across the globe, to learn from East Africa's global leadership and expertise in climate adaptation and mitigation, agricultural international development, and to hear first-hand from those actively combatting the Horn of Africa's most devastating drought. Attendees included representatives from 18 of the 20 Innovation Labs, as well as government officials and dignitary guest speakers Mike Michener, Rob Bertram, Sheila Roquitte from USAID and Harry Kimtai from Kenya Ministry of Agriculture.

From speaker presentations, workshops, to site visits, the weeklong conference, themed *Systemic and Innovative Solutions for Climate Adaptation and Mitigation in Agriculture, Food, and Nutrition Systems*, provided participants with a greater understanding of the geographic differences, priorities, and trade-offs of climate change mitigation and adaptation strategies. It also highlighted systems and scaling challenges and transformative solutions; and international collaboration.

Deep discussions over the advancement of equity and inclusion emphasized the strong correlation between women empowerment and higher nutrition rates.

Guest dignitary speakers from USAID and Kenya Ministry of Agriculture visit the Feed the Future Innovation Labs exhibition hall, Horticulture Innovation Lab booth with former Director Beth Mitcham.

While emphasis on the interconnected complexities of interpersonal dynamics was made, noting that "if you want to empower the women, you need to invite the men." Field site visits brought attendees to witness East Africa's most vital agricultural research in action, providing crucial insight into current and emerging threats to food security within the region, and the innovative research solutions being developed to resolve them.

The conference exemplified the power of collaborative research and international cooperation in tackling climate change and agricultural development challenges. Throughout the conference, speakers from all sectors expressed their agreement on the key to success being "if you want to go fast, go alone, but if you want to go far, go together." The conference was a success in that it facilitated reconnection and reaffirmed the importance of global collaborative research in agricultural development in order to achieve collective climate action. Attendees came to share diverse new ways of thinking, and left with ideas and renewed - if not new - partnerships as well as strategies for reducing poverty and hunger, improving access to nutrition, and ultimately, building a more resilient and sustainable global community to withstand future disruptions.

Feed the Future Innovation Lab for Horticulture

South Asia Horticulture Workshop focuses on strengthening gender equity and the fruit sector as the region become increasingly threatened by climate change

South Asia Horticulture Workshop focuses on strengthening gender equity and the fruit sector as the region become increasingly threatened by climate change

Posted by Siobhan Catherine Rubsam on October 20, 2022

Feed the Future Innovation Lab for Horticulture

The South Asia regional horticulture workshop, hosted by FORWARD Nepal in September, wrapped up a series of four very successful workshops that took place in each of the regions Feed the Future Innovation Lab for Horticulture will conduct research in: East Africa (Kenya), West Africa (Ghana), Central America (Honduras) and South Asia (Nepal). The 3-day workshop featured experts in the horticulture sector from both Nepal and Bangladesh, with representatives from universities, NGO's, research institutes, private industry, and government agencies creating a rich dialogue of diverse perspectives that highlighted a few major themes.

Advancing the fruit sector depends on improving varieties

There is significant potential for fruit production in South Asia, but in order for this to be harnessed, farmers need access to improved varieties. The Catch-22 is that Nepal and Bangladesh do actually have high levels of fruit production–but due to a lack of high quality cultivars, the region experiences low productivity compared to other parts of the world. A main

of buying from a nursery. This can lead to trees that are susceptible to viruses and other diseases, and cannot produce the product quality necessary for market, especially for export. Biotechnology was proposed as one solution to this problem. Dr. Bahneshwor Pokrel spoke about the potential for micropropagation of fruit tree varietals, specifically, in order to create lab-grown cultivars that will stay true to their original characteristics. Innovations like these may be necessary to meet the growing demand for fruit both regionally and internationally, and as South Asia becomes increasingly threatened by climate change, fruit orchards may be a sustainable and profitable solution to increasing forested land area in places like Bangladesh which currently fall below recommended levels.

Fruit consumption in Nepal is increasing, as evidenced by fruit carts popping up on street corners in cities.

Gender equity quintessential to a prosperous horticulture industry

There is currently a massive outmigration of men in South Asia–both to cities and to other countries–which has left women to manage farms. The 10% increase of women in agriculture has exposed severe gender disparities that inhibit their participation in the sector. For instance, they don't own their own land (only 21% of land is women-owned), can't obtain loans, have limited knowledge of and comfort with farm equipment, and don't have access to infrastructure that supports mothers (e.g. women at the market don't have a place to breastfeed). Yet the shift to women-run farms also presents a great opportunity to increase gender equity in the region, since the very fate of agriculture in some areas depends on it. Presenters stressed that in order for this

becoming leaders in the fight to protect their countries against the onslaught of climate change. A striking example of this comes from Ms. Swastika Shrestha, a student at the Agriculture and Forestry University (AFU) in Nepal who was selected to give a presentation on an innovation she was testing that uses plant-based alternatives to plastic packaging for fruits and vegetables.

Prof. Dr. Durga Devkota, from the Agriculture and Forestry University (AFU) in Nepal, presented on the potential of Gender Empowerment and Social Inclusion (GESI) and youth entrepreneurship in the fruit and vegetable sector in South Asia.

Adapting the horticulture sector to a present and future of climate change

Nepal and Bangladesh are two of the most vulnerable countries in the world to climate change, according to various ranking criteria. Nepal--with its steep terrain and heavy monsoons--is highly prone to natural disaster, especially as temperatures continue to climb. This will cause flooding and erosion events to become more frequent and more severe, with particularly devastating impacts on remote villages with little access to the rest of the country. Bangladesh, on the other hand, consists of very low-lying land that is highly affected by ocean flooding, causing salt intrusion that negatively impacts crop production.

The extreme climatic conditions of both countries will only increase in intensity with climate change, but there are also a lot of people, like those that attended the conference last month, who continue to research and innovate new climate adaptive ways for agriculture to meet a

Accreditation Body. This is a government-run program that certifies entire states as organic. However, presenters at the conference pointed out that in order for this system to work, government agencies on the national, regional, and local level need to improve their communication channels. They also stressed the importance of increasing research and extension on organic production, as current knowledge of organic practices and inputs is limited. For example, farmers may brand their products as organic as long as they are not using chemical fertilizers or pesticides, even if they are not abiding by organic standards. There are also farmers who only have access to older, unsafe pesticides that are highly toxic. This is one of the many reasons researchers at the workshop emphasized the importance of a robust extension system where agents receive skill-specific training rather than a more generalized focus.

Feed the Future Innovation Lab for Horticulture

Breakout groups have been a key feature of all the regional workshops, facilitating discussion between people of diverse backgrounds and expertises.

Thank you to everyone who attended in-person and remotely, especially all those who gave such compelling presentations. So many important insights surfaced during this conference that will inform the future of horticulture research in the region. Special thanks to FORWARD Nepal for hosting and making it such a success! We are excited to continue working with our Nepali and Bangladeshi partners over the coming years.

Feed the Future Innovation Lab for Horticulture

Research priorities determined at Consortium meeting

Consortium meeting participants included regional leaders, members of the Horticulture Innovation Lab, Consortium specialists, and FAMU staff.

Posted by Siobhan Catherine Rubsam on November 15, 2022

Last week marked an important step for Feed the Future Innovation Lab for Horticulture's five-year program lifecycle.

Members of the management entity (ME), Consortium, and regional leaders (coming from Kenya, Ghana, Honduras, and Nepal), met at Florida A&M University (FAMU) in Tallahassee to analyze the results of the four regional horticulture workshops held this past summer (see previous blogs

coming years.

The prioritization process: Multi-step and local-led

So many important horticultural challenges and opportunities were showcased at each regional workshop–how could they be narrowed down to just one priority? To start, regional leaders–teams of two per region presented to the Consortium the top three priorities that materialized out of their respective workshops. They also identified a regional archetype, which is the embodiment of the person they most want to benefit with their research. Then, regional leaders led breakout sessions with members of the ME and Consortium to discuss *which* priority will most pointedly meet the needs of the chosen archetype. Based on those discussions, one priority per region was chosen.

The second and final day was about choosing sub-themes to accompany each regional priority. Attendees again split up into groups to discuss which sub-themes will most a appropriately address the main research priority. Participants were also encouraged to consider cross-cutting themes including gender, nutrition, and youth when choosing priorities. By the end of the day, sub-themes were selected for each research priority and region.

Dr. Julio Lopez of Zamorano University in Honduras presents on research priorities for Central America.

Regional example: West Africa

But how does the prioritization process translate to real-world contexts? To demystify this exercise, one can look at how it played out for West Africa. Regional leaders first identified three major priorities: 1) Health and nutrition, 2) Youth and gender, and 3) Postharvest Technology and Food Safety. They also identified their archetype–a 30-year old mother of three with limited access to financial resources but with dreams of expanding her agricultural ventures. Then, through breakout discussion, group members determined health and nutrition to be the top priority for West Africa. The sub-themes selected to accompany this priority were: 1) school gardening to introduce youth to concepts of nutrition, indigenous vegetables, and agribusiness, 2) research on indigenous vegetables to understand their potential market value (as both fresh and processed products), and 3) understanding access to healthy diets to identify the barriers impeding people from eating nutritious foods.

What now? Local leadership driving next steps

proposals will then be evaluated by regional experts and members of the ME and Consortium to determine which ones to fund. It is important to note that last week was really just the culmination of months and even years of research by in-country leads to understand the horticulture sector in their regions. This approach also turns the traditional globally-led, locally-supported approach on its head–local organizations are the ones leading prioritization, research, implementation, and monitoring and evaluation, with ME and Consortium members providing financial and technical support. This local leadership would not be possible without the dedication and hard work of regional hub managers Dr. Peninah Yumbya of International Centre for Economic Development (ICED) in Kenya, Dr. Naalamle Amissah of University of Ghana, Dr. Julio Lopez of Zamorano University, and Krishna Sapkota of Forum for Rural Welfare and Agricultural Reform for Development (FORWARD) Nepal.

Special thanks to our Consortium partners at FAMU, especially Professor Harriet Paul and her team, for hosting and facilitating this meeting. We are grateful to have such a talented, dedicated group of people from around the world be able to come together and work towards common goals of food security, health, and environmental and human well-being.

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MENU

Locally Led, Globally Supported: A Not-So-New Approach to Horticulture Development

Siobhan Rubsam | May 3, 2023

South Asia Horticulture Conference participants

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As we celebrated localization month in April, it seems fitting to look back on the whirlwind of activities that have taken place to establish the Feed the Future Innovation Lab for Horticulture <https://horticulture.ucdavis.edu/> (ILH) at the University of California, Davis. Last year, we began a 5-year project lifecycle <https://horticulture.ucdavis.edu/blog/usaid-awards-uc-davis-15-million-global-horticulture-research-program> to fund horticultural research projects in four Feed the Future focus regions: West and East Africa, South Asia, and Central America. However, we chose to do it very differently than we have in the past. We pivoted away from the often-employed Agriculture Research for Development (AR4D) models, which typically take a globally led, locally supported approach, and stepped into the background to make room for local organizations and experts to take the lead on the research process. This process has thus far positioned local researchers to identify research priorities, design and review proposals, and now, implement research in its beginning stages.

Local Voices Choose Local Priorities

Research priorities were selected at four regional workshops last summer — multi-day events in Ghana, Kenya <https://horticulture.ucdavis.edu/blog/workshops-kenya-and-ghana-shaping-future-horticulture-research-east-and-west-africa>, Honduras <https://horticulture.ucdavis.edu/blog/workshop-honduras-highlights-importance-knowledge-sharing-strengthen-horticulture-sector> and Nepal, <https://horticulture.ucdavis.edu/blog/south-asia-horticulture-workshop-focuses-strengthening-gender-equity-and-fruit-sector-region> which brought in local horticultural experts from both the public and private sector to discuss what they believed were the greatest challenges and opportunities involving horticulture in each region. Through presentations by experts, breakout sessions, and larger group discussion, each workshop produced a list of research priorities that were then narrowed down in October at an all-partners meeting at Florida Agricultural and Mechanical University <https://horticulture.ucdavis.edu/blog/research-priorities-determined-consortium-meeting>. This meeting, attended by UC Davis Management Entity, ILH Consortium, and Regional Hub Managers, used a rigorous prioritization process in which researchers from each region assessed their list of research priorities (that came from the summer workshop) based on the potential for that research to meet the needs of a chosen regional archetype.

For example, the West Africa working group chose a 30-year-old mother of three as their archetype, so after group discussion it was decided that research focusing on health and nutrition would most improve her life. Sub-themes to the research priority were then determined by each group, so in the example of West Africa, they were to better understand: 1) Behavior change through nutrition education that benefits youth, 2) Culturally relevant production and marketing of indigenous vegetables, and 3) Economic leverage points in accessing healthier diets. Requests for Applications (RFAs) were then designed based on the priorities and sub-themes that resulted from the summer workshops and October all-partners meeting.

Locally Selected Research Priorities Hit Home

In releasing the ILH RFA for sub-awards, we chose to allow only local Principal Investigators (PI) to be eligible as lead PIs on the sub-awards. As usual, we prioritized sub-awards that advance regional and global partnership. The incredible number of full applications we received following the RFA — 125 in total — are a testament to how much the research priorities resonated within local academic networks. In addition, local experts didn't just submit applications — they also reviewed them. Using the LASER PULSE <https://laserpulse.org/> (Long-term Assistance and Services for Research Partners for University-Led Solutions Engine) platform, a diverse team of horticultural experts from around the globe assessed each application for scientific rigor and feasibility, culminating in consensus panels that chose the top applications to move on to the final selection process. Ultimately, 11 applications were chosen for funding out of a fiercely competitive pool of applicants — demonstrating the deep pool of local expertise available to lead and conduct this research.

The successful projects represent a diverse portfolio of horticultural research topics, including but not limited to: testing technology for adaptation to climate change, facilitating women and youth participation in horticultural enterprises, improving horticulture production and marketing in urban and peri-urban areas, refining production and marketing of indigenous fruits and vegetables, and developing evidence that will demonstrate to smallholder farmers the advantages of planting indigenous fruits and vegetables alongside staple crops. All project activities will be headed by top researchers from each of the four focus regions, who

will not need the extensive onboarding that would be necessary for outside scientists less familiar with local languages, customs, and challenges because they are already accustomed to local contexts. This will not only allow researchers to hit the ground running, but local familiarity will also facilitate an effective problem-solving model in which researchers are able to more easily identify challenges that arise and local solutions that can be innovated.

Local Expertise Has Been Missing from the World Table

As climate change increasingly threatens global food security and community resilience, especially in lower and middle-income countries (LMICs), the expertise of local researchers will be essential to finding solutions for their localities. Their perspective is not just needed locally — they offer diverse and specialized knowledge that is an asset to the global effort to mitigate climate impacts and food insecurity. If AR4D models are to be more effective in the long-term promotion of healthy, resilient populations, they need to be led by local actors who are deeply rooted in the places they work and thus are more adept at innovating long-term solutions for those places.

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Feed the Future Innovation Lab for Horticulture

Feed the Future Innovation Lab for Horticulture convenes meeting on behalf of USAID

Posted by Heather N Hayashi on August 08, 2023

Collective climate action for the global community

Feed the Future Innovation Lab for Horticulture convenes meeting on behalf of USAID

In Nairobi, Kenya this past May 15 — 19, the Feed the Future Innovation Lab for Horticulture hosted the 2023 Feed the Future Innovation Labs Regional Partners Meeting, bringing to the fore, the global conversation on climate change and agricultural international development as well as lessons learned from the Horn of Africa's most devastating drought. The meeting provided a platform for regional experts actively combatting the devastating effects of climate change in their regions to share their experiences, and for all involved in the international community to directly engage with key stakeholders in support of innovative research and development solutions being implemented by partners in East Africa.

and scaling challenges and transformative solutions; and advance opportunities for local-led leadership and international collaboration. As Chair of the Feed the Future Innovation Lab Council of Directors, Erin McGuire, and USAID curated the agenda. Presentations ranged from a diverse panel of speakers with incredible breadth — emphasizing the importance and urgency of bringing together regional experts to field and lab site-visits that provided crucial insight into current and emerging threats to food security within the region, and the innovative research solutions being developed to resolve them.

Guest dignitary speakers from USAID and Kenya Ministry of Agriculture, arrive to speak on opening day.

Day one began, with leaders from all over the world ready to engage, including representatives from 18 of the 20 U.S.-based Innovation Labs, government officials from Washington, D.C. and Kenya, and guest dignitary speakers such as Mike Michener, Harry Kimtai and Sheila Roquitte, with moderators such as Rob Bertram and Jerry Glover. USAID and Kenyan dignitaries visited every Innovation Labs' exposition booth, giving each Innovation Lab the opportunity to share and discuss critical issues and specialized areas of research focus. The visitors then took to the stage to address climate change challenges and solutions, and speak on the benefits of collaborative partnerships.

Feed the Future Innovation Lab for Horticulture

Feed the Future Innovation Lab exhibition hall, shown here visiting booth for Horticulture Innovation Lab with Director (recently retired), Beth Mitcham.

Feed the Future Innovation Lab for Horticulture

Chair of the Feed the Future Innovation Lab Council of Directors, Erin McGuire served as master of ceremonies.

Feed the Future Innovation Lab for Horticulture

Lusike Wasilwa serving as moderator for panel discussion, on engaging and scaling research results with national governments and the private sector, with Josphat Muema and Getaw Tadesse.

Day three was a working day focused on local-led research, with group discussion and brainstorming to determine a collective vision for local leadership going forward, and plans for how to make it a reality. While the group acknowledged significant barriers — including administrative, logistical, and institutional — the desire from both the Innovation Labs' management entities and local partner side to turn development over to local experts was evident.

Feed the Future Innovation Lab for Horticulture

Group photo at International Livestock Research Institute (ILRI), Nairobi campus.

During the fourth day, Innovation Labs and their partners took to the field to witness some of East Africa's most vital agricultural research. International Livestock Research Institute's (ILRI) Kapiti Research Station and Wildlife Conservation provided examples of climate adaptation in action; drought and heat-tolerant cattle breeds developed by researchers and the study of desert-adapted livestock such as camels. At the Kenya Agricultural and Livestock Research Organization's (KALRO) dryland crops research site, the group learned about how researchers are improving seed varieties in order to mitigate low agricultural productivity that plagues many farmers in the region. At ILRI Nairobi, Kenya campus, visitors learned about the applied research taking place to address a range of critical agricultural challenges and in particular, how to improve livestock systems.

Feed the Future Innovation Lab for Horticulture

Herd of Kenyan red Masaai and exotic Dorper sheep at International Livestock Research Institute's (ILRI) Kapiti Research Station, ILRI Kapiti Conservancy

Feed the Future Innovation Lab for Horticulture

Group photo at KALRO Station, Katumani.

> Day four included stops at International Livestock Research Institute's (ILRI) Kapiti Research Station and Wildlife Conservation, Kenya Agricultural and Livestock Research Organization's (KALRO) dryland crops research site, and ILRI Nairobi, Kenya campus.

On the fifth and last day, the group traveled to Muranga County, to visit Michigan State University's Scientific Animations Without Borders' (SAWBO) community demonstration plot. They learned about the impact of digital videos being used to promote good agricultural practices (GAP) have on farmers, where several lead farmers have taken this information and implemented it in their own fields. The final stop was a tour of the horticulture nursery and banana tissue culture lab at Jomo Kenyatta University of Agriculture and Technology (JKUAT), where student and faculty researchers shared sustainable farm-to-kitchen and -market production methods, from utilizing the pellets of meat-farm rabbits for fertilizer, greenhouse irrigation systems, color-lighting lab studies of sprouts, to raising nursery mushrooms at a capacity to scale and create a new market. The holistic approach to student-led campus farming led by JKUAT reflected a recurring theme voiced by many throughout the week, that "if you want to go fast, go alone, but if you want to go far, go together."

change and agricultural development challenges. Together, through shared knowledge and inclusive partnerships, we can build a sustainable future for the global community

Group photo at Jomo Kenyatta University Of Agriculture And Technology (JKUAT) campus.

Feed the Future Innovation Lab for Horticulture

Feed the Future Innovation Lab for Legume Systems Research, Muranga SAWBO Animations Site.

Mushroom, worm composting; sustainable farming initiative leaders at Jomo Kenyatta University Of Agriculture And Technology

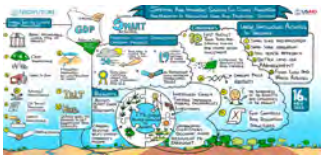
Feed the Future Innovation Lab for Horticulture

Visits on day five, to Muranga County to visit Scientific Animations Without Borders' (SAWBO), and then Jomo Kenyatta University of Agriculture and Technology (JKUAT).

Additional resources and documentation

For those unable to attend, we have made available the following:

- Flickr photo album
- Short-video **of conference highlights**
- **recorded zoom sessions** and **PowerPoints shared by the presenters** may be found **on the** conference webpage.



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Feed the Future Innovation Lab for Horticulture

Director of Feed the Future Innovation Lab for Horticulture Announces Retirement and Introduces New Director and Associate Director

Dr. Elizabeth J. Mitcham speaking on systems adaptation at Feed the Future Innovation Labs Regional Partners Meeting in Nairobi KE, May 2023.

Posted by Heather N Hayashi on July 10, 2023

Director of Feed the Future Innovation Lab for Horticulture Announces Retirement and Introduces New Director and

Feed the Future Innovation Lab for Horticulture

July 10, 2023

DAVIS – After a successful tenure of 31 years serving at the University of California, Davis, within the Department of Plant Sciences, Dr. Elizabeth J. Mitcham, esteemed Cooperative extension specialist, pomologist, Director of Postharvest Technology Center and Director of the Feed the Future Innovation Lab for Horticulture has retired, effective June 30, 2023. Under her visionary leadership, the Innovation Lab for Horticulture has achieved significant milestones, and her contributions - including but not limited to work in emerging economies to make horticulture a profitable business for smallholder farmers, will be remembered with deep appreciation.

Dr. Mitcham announced her plans for retirement earlier in May, at the start of the 2023 Feed the Future Innovation Labs Regional Partners Meeting in Nairobi, Kenya, while also sharing the news of her successors, Dr. Erin J. McGuire as the new Director, and Archie Jarman as the new Associate Director. Mitcham expressed her confidence in the transition, stating, “Erin and Archie have been a part of the leadership team at the Innovation Lab for Horticulture for many years, and I am happy the program will be in such good hands moving forward!" In a warm farewell message to Beth, Rob Bertram, Chief Scientist in USAID’s Bureau for Resilience and Food Security said, “In the earlier days, you had set the standard of doing, and you passed this on now to Erin so beautifully. We're so grateful to all of you for the leadership of your lab, it has just been a real pleasure.”

Feed the Future Innovation Lab for Horticulture

USAID Chief Scientist, Rob Bertram and Feed the Future Innovation Lab Associate Director, Erin McGuire bid Director of the Innovation Lab for Horticulture, Beth Mitcham, farewell and congratulate her on retirement, Nairobi KE.

In a heartfelt farewell, Archie said, “Beth has those unique qualities that have made her an amazing leader – she was completely committed to achieving the goals of the Innovation Lab; passionate about horticulture, has expertise in a broad set of critical areas, and was engaged in making sure that her staff and the Horticulture Innovation Lab network operates as a supportive team that achieves both professional and programmatic goals."

Feed the Future Innovation Lab for Horticulture is pleased to formally introduce the new Director, Dr. Erin J. McGuire. With a distinguished academic research career, including extensive experience specializing in diversifying agricultural innovation pipelines and equity in scaling, McGuire’s work focuses on empowering disadvantaged women and children with better health, and small-scale farming communities with financial prosperity. She has been with the Lab for over a decade; starting as a graduate student researcher, then later serving as Associate Director since 2016; and has held leadership roles at several renowned organizations prior, including US Congress and the National Farm to School Network. McGuire brings a wealth of experience and expertise to guide the organization's future endeavors. Her background encompasses the spectrum, from research, policy, and connecting social and science research to benefit smallholder farmers as well as consumer markets, while demonstrating exceptional skills in strategic planning, team management, and achieving organizational growth.

Feed the Future Innovation Lab for Horticulture

Erin and Beth after a full day of meeting with members of Congress, discussing the impactful work of Feed the Future Innovation Labs, Washington DC, March 2023.

(left to right) Feed the Future Innovation Lab for Horticulture new Associate Director, Archie Jarman; Jefferson Science Fellow, Dr. John Leslie; former Director of Innovation Lab for Horticulture, now retired, Dr. Beth Mitcham; and U.S. Department of State Special Envoy for Global Food Security, Dr. Carey Fowler at welcome reception hosted by Horticulture Innovation Lab at UC Davis, April 2023.

Accompanying the appointment of the new Director, the Innovation Lab for Horticulture is excited to announce the promotion of Archie Jarman as the Associate Director. Jarman has been an integral part of the organization for over four years, serving as the Operations Manager, and has proven to be an invaluable asset. Known for his outstanding contributions and dedication to strengthening research communities, building cross-sector and industry partnerships to enhance the livelihoods of smallholder farmers, and innovative approaches to preventing food loss and waste in postharvest technologies, Archie will play a pivotal role in supporting the new Director, and ensuring the continued success of the Horticulture Innovation Lab.

Both Erin McGuire and Archie Jarman possess a shared commitment to upholding the Horticulture Innovation Lab's core values, maintaining excellence, and driving innovation. Their combined leadership and expertise will propel the organization forward, building upon the foundation laid by former Director and now retired, Beth Mitcham.

Staff members extend their heartfelt gratitude to Beth for her exceptional leadership, unwavering commitment, and countless contributions during her tenure. The Horticulture Innovation Lab owes its current success to her guidance and vision.

Lab for Horticulture looks forward to continued growth and success in the years ahead.

Dr. Beth Mitcham celebrating 31 years of service at UC Davis farewell reception, with past and present Feed the Future Innovation Lab for Horticulture team members.

Feed the Future Innovation Lab for Horticulture

New Associate Director, Archie Jarman, and new Director, Dr. Erin J. McGuire, on their way to ensure all is ready, the day before the 2023 Feed the Future Innovation Labs Regional Partners Meeting in Nairobi, Kenya.

Feed the Future Innovation Lab for Horticulture

Feed the Future Innovation Lab for Horticulture Announces New Portfolio of Regionally-led Research Initiatives

Posted by Heather N Hayashi on August 25, 2023

FOR IMMEDIATE RELEASE

Innovation and Advancement in Global Food Security and Gender Equity: Feed the Future Innovation Lab for Horticulture Announces New Portfolio of Regionally-led Research Initiatives

Government's global hunger and food security initiative. The Horticulture Innovation Lab's global research network partners with and promotes local leadership to advance horticulture and social innovations, empowering smallholder farmers to earn more income while better nourishing their communities. This new 3.5-year portfolio comprises regionally-led research initiatives across East and West Africa, Central America, and South Asia. Research initiatives will be managed by four Horticulture Innovation Lab Regional Hubs based at the International Center for Evaluation and Development (ICED), University of Ghana, Zamorano University, and FORWARD Nepal.

The new portfolio represents the Horticulture Innovation Lab's commitment to finding creative solutions to the most pressing challenges facing the horticulture sector and global agricultural community, from climate change and social transformation, to malnutrition, food safety and security. By investing in applied research, technologies and development initiatives, the Horticulture Innovation Lab will foster a culture of innovation and collaboration through global partnerships and continuous learning.

Each project is carefully designed to respond to local priorities by exploring untapped opportunities, establishing new partnerships, and contributing to the advancement of sustainable horticulture worldwide.

"We are committed to driving and applying innovation that promotes the empowerment of smallholder farmers and their communities, and look forward to long-term partnerships with our Regional Hub management teams who will be leading the charge of these research initiatives," said Dr. Erin J. McGuire, Director at Feed the Future Innovation Lab for Horticulture. "Through these projects, we are advancing horticultural innovation and supporting robust academic eco-systems."

All research initiatives are led by teams of distinguished researchers and specialists in their respective fields. The portfolio will also provide opportunities for the Horticulture Innovation Lab network and beyond, including government, academic, extension entities, and private sector collaborators. Together, the Horticulture Innovation Lab network will extend its impact and accelerate the pace of innovation.

To learn more about each region's portfolio of projects:

- East Africa: *Empowering Rural Women Farmers: Boosting Vegetable Access for Better Nutrition*
- West Africa: *Improving Affordability and Availability of Healthy Diets Through Female Smallholder Farmer Engagement*

- South Asia: *Increasing Smallholder Farmer Horticulture Production and Empowering Youth*

For more information about our research portfolio and collaboration opportunities, please visit ***horticulture.ucdavis.edu*** or contact Associate Director, Archie Jarman at rajarman@ucdavis.edu.

About Us

Feed the Future Innovation Lab for Horticulture, also known as the Horticulture Innovation Lab, is funded by the United States Agency for International Development as part of the Feed the Future global hunger and food security initiative, and based at the University of California, Davis. The research program is funded at $15.8 million over 5-years.

For media inquiries contact Communications Manager, Heather Hayashi at hnhayashi@ucdavis.edu.

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Feed the Future Innovation Lab for Horticulture

Empowering Rural Women Farmers: Boosting Vegetable Access for Better Nutrition

Enhancing Productivity, Post-harvest Management, and Market Access of African Indigenous Vegetables in Kenya. Image credit: Kenya Agricultural and Livestock Research Organization (KALRO).

Posted by Heather N Hayashi on August 25, 2023

FOR IMMEDIATE RELEASE

Empowering Rural Women Farmers: Boosting Vegetable Access for Better Nutrition

Feed the Future Innovation Lab for Horticulture

Regional Hub Managers, David S. Ameyaw, Peninah Yumbya, and Annesofie Misiani from the International Center for Evaluation and Development (ICED). “These projects will transform East Africa's horticulture sector,” says Yumbya. “They will elevate the horticulture industry towards empowering small-scale farmers, especially women in the region. The focus on enhancing productivity, reducing postharvest losses, enhancing market access, and fostering innovations will undoubtedly contribute to sustainable horticultural production.”

These 3.5-year projects focus on priorities that were identified during a 2022 regional stakeholder meeting. The first priority is to address pre- and post-harvest management to reduce food waste and losses in vegetables. The second priority is to improve the marketing of and access to vegetables in the East Africa region through the empowerment of rural smallholder women farmers growing vegetables on a small-scale level. Each project was specifically “designed to unlock access to vegetables for women smallholder farmers,” said Misiani. “This will be critical in enhancing the important role women play - the majority of whom are underserved - in addressing food insecurity and nutrition across Africa.” The four projects and their foci are as follows:

- *Enhancing Productivity, Post-harvest Management and Market Access of African Indigenous Vegetables in Kenya* led by Mumina Shibia from the Kenya Agriculture Livestock and Research Organization with support from the University of Nairobi and North Carolina State University. The research will identify optimal pre-harvest and postharvest interventions that can have significant impacts on increasing the availability of African Indigenous Vegetables (AIVs) in the marketplace. AIVs in Kenya have unique characteristics to help improve food and nutrition security, promote gender equity, and enhance the resilience of agricultural systems.

- *Developing innovative horticulture technologies for small-scale women farmers in Uganda* led by Robert Kajobe from Muni University - will be utilizing a participatory research approach to improve pre-and post-harvest practices and innovations in the horticulture sector in Uganda. By engaging farmers in the research design and implementation, selected practices and innovations will more likely sustainably meet the need to improve family household nutrition, increase sales of vegetables, and ultimately empower smallholder women farmers through greater financial independence and enhanced livelihoods.

will determine the cost-benefit of integrating horticulture with staple production for women small-holder farmers in Kenya, as well as examine structures of decision-making regarding nutritious diet, income, land use, and time availability. This will inform policymakers and small-scale women farmers on the best approaches to and benefits of integrating horticulture with staple crops at a small scale.

- *Determining the trade-offs between short and long horticulture value chains in Kenya* led by Willis Owino from Jomo Kenyatta University of Agriculture and Technology and Fridah Githuku with GROOTS Kenya - will investigate the nutritional, economical, and social (gender equity and youth engagement) impacts on producers along both short and long value chains, and determine to what extent Information Communication Technologies (ICTs) are incorporated. This will increase understanding of: the impact of ICTs in selected horticulture value chains, horticulture access pathways that increase stability and efficiency in value chains, and document the enabling environments and key characteristics that facilitate positive aspects of access pathways.

Ameyaw noted that “the partnership with the Feed the Future Innovation Lab for Horticulture, through the generous funding of USAID, has been invaluable in bringing these projects to life.” He also stated, “These globally supported, regionally-led projects reflect the shared commitment to promote the East Africa horticulture sector, contributing to the transformation of livelihoods for all small-scale farmers.”

"These projects in East Africa get right to the heart of our mission," said Erin McGuire, Director of the Feed the Future Innovation Lab for Horticulture. "We're targeting key areas like smallholder women farmers' empowerment and reducing food waste. It's practical, focused, and I believe it will make a real difference in the region."

As we embark on this transformative journey, our vision extends beyond just the immediate projects. We envision a future where the tireless efforts of women smallholder farmers are acknowledged, where fresh vegetables are within everyone's reach, and where every household in East Africa enjoys improved nutrition and health. Together, with the combined expertise of our regional partners and the steadfast support of our global allies, we are planting seeds for a brighter, more nourishing tomorrow.

For more information about our Research Project Portfolio and collaboration opportunities, please visit ***horticulture.ucdavis.edu*** or contact Associate Director Archie Jarman at rajarman@ucdavis.edu.

Feed the Future Innovation Lab for Horticulture

Developing innovative horticulture technologies for small-scale women farmers in Uganda. Image credit: Muni University.

Feed the Future Innovation Lab for Horticulture

Determining the cost-benefit of integrating horticulture into staple crop production in Kenya. Image credit: International Center for Evaluation and Development.

Feed the Future Innovation Lab for Horticulture

Determining the trade-offs between short and long horticulture value chains in Kenya. Image credit: Jomo Kenyatta University of Agriculture and Technology.

New Portfolio of Regionally-led Research Initiatives Leading Innovation and Advancement in Global Food Security and Gender Equity

The Feed the Future Innovation Lab for Horticulture at the University of California, Davis, is proud to unveil its new research portfolio as a part of Feed the Future, the U.S. Government's global hunger and food security initiative. The Horticulture Innovation Lab's global research network partners with and promotes local leadership to advance horticulture and social innovations, empowering smallholder farmers to earn more income while better nourishing their communities. This new 3.5-year portfolio comprises of regionally-led research initiatives across East and West Africa, Central America, and South Asia. Research initiatives will be guided by four Horticulture Innovation Lab Regional Hubs based at the International Center for

Feed the Future Innovation Lab for Horticulture

About Us

Feed the Future Innovation Lab for Horticulture, also known as the Horticulture Innovation Lab, is funded by the United States Agency for International Development as part of the Feed the Future global hunger and food security initiative, based at the University of California, Davis, within the Department of Plant Sciences. With a focus on horticultural, social, and technological advancements, we develop groundbreaking solutions to improve nutrition and food security. As advocates for innovations and policies that promote gender equity, social and environmental responsibility, we are dedicated to improving the livelihoods of smallholder farmers while empowering communities through horticulture, including better access to nutrition and healthy diets.

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Feed the Future Innovation Lab for Horticulture

Increasing Smallholder Farmer Horticulture Production and Empowering Youth

Empowering youth entrepreneurs through appropriate horticulture interventions in Nepal. Image credit: FORWARD Nepal.

Posted by Heather N Hayashi on August 30, 2023

FOR IMMEDIATE RELEASE

Increasing Smallholder Farmer Horticulture Production and Empowering Youth

[DAVIS] – The Feed the Future Innovation Lab for Horticulture is pleased to announce the launch of three new regionally-led research initiatives to be coordinated by the Horticulture Innovation

Feed the Future Innovation Lab for Horticulture

Each research project effectively addresses regional priorities – increasing horticulture production efficiency and empowering youth – which were identified by stakeholders based in South Asia. The projects span a wide range of horticulture research initiatives designed to increase production in urban and peri-urban environments, reduce the impact of soil-borne pathogens on tomatoes and peppers, and engage youth in profit-oriented horticulture production systems. The three projects and their foci are as follows:

- *Mitigating soilborne diseases to improve smallholder farmer livelihoods and food security in Nepal* led by Ram Khadka from Nepal Agricultural Research Council (NARC) - will be investigating the viability of bundling technologies in Nepal to provide farmers with an accessible solution to soil-borne pathogens, a common problem arising from soils used to produce tomato, pepper, potato without rotation. Participatory inclusion of women farmers throughout the entire research project lifecycle will reveal critical insights into how the technology can be best scaled equitably.

- *Empowering youth entrepreneurs through appropriate horticulture interventions in Nepal* (YUVA) led by Bishnu Kumar Bishwakarma from FORWARD Nepal and Sushil Raj Ghimire from Welthungerhilfe - will be identifying viable, sustainable, and profitable horticulture business models for youth utilizing barren lands in the mid-hills and Terai of Nepal, and sharing these opportunities via networks and platforms geared towards youth as well as policy makers. This approach will empower and offer new possibilities to young Nepali's to generate income in-country, rather than leaving to seek livelihoods elsewhere.

- *Advancing technology based on urban and peri-urban horticultural needs in Bangladesh and Nepal* led by Kalyani Tripathi from Agriculture and Forestry University Nepal and Md Anwarul Abedin from Bangladesh Agricultural University (BAU) - will be identifying opportunities for women and youth in urban and peri-urban production, with improved practices and supply of quality planting materials to enhance fruits and vegetables in Nepal and Bangladesh. Geographic Information Systems (GIS) will be used to map out the most optimized production zones and calculate potential output, involving an urban agribusiness approach to determine suitable rooftops for vertical agriculture, to generate evidence that will inform city leaders and organizations on how to integrate horticulture into urban and peri-urban systems.

Sapkota looks forward to what the future holds. "I am very optimistic and excited to see these regionally-led and globally-supported Feed the Future Innovation Lab for Horticulture research

while also contributing impactful research and development to benefit the global community."

"I'm genuinely excited about these new initiatives," said Erin McGuire, Director of the Feed the Future Innovation Lab for Horticulture. "We have the right PIs and regional hubs in place, and I have full confidence in their ability to meet these challenges. This is about more than just increasing production; it's about sustainability, nutrition, and empowering our next generation of researchers in Nepal and Bangladesh."

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Mitigating soilborne diseases to improve smallholder farmer livelihoods and food security in Nepal. Image credit: Nepal Agricultural Research Council (NARC).

Feed the Future Innovation Lab for Horticulture

Advancing technology based on urban and peri-urban horticulture needs in Bangladesh and Nepal. Image credit: Bangladesh Agriculture University (BAU).

New Portfolio of Regionally-led Research Initiatives Leading Innovation and Advancement in Global Food Security and Gender Equity

The Feed the Future Innovation Lab for Horticulture at the University of California, Davis, is proud to unveil its new research portfolio as a part of Feed the Future, the U.S. Government's global hunger and food security initiative. The Horticulture Innovation Lab's global research network partners with and promotes local leadership to advance horticulture and social innovations, empowering smallholder farmers to earn more income while better nourishing their communities. This new 3.5-year portfolio comprises of regionally-led research initiatives across East and West Africa, Central America, and South Asia. Research initiatives will be guided by four Horticulture Innovation Lab Regional Hubs based at the International Center for Evaluation and Development (ICED), University of Ghana, Zamorano University, and FORWARD Nepal.

Feed the Future Innovation Lab for Horticulture

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Feed the Future Innovation Lab for Horticulture, also known as the Horticulture Innovation Lab, is funded by the United States Agency for International Development as part of the Feed the Future global hunger and food security initiative, based at the University of California, Davis, within the Department of Plant Sciences. With a focus on horticultural, social and technological advancements, we develop groundbreaking solutions to improve nutrition and food security. As advocates for innovations and policies that promote gender equity, social and environmental responsibility, we are dedicated to improving the livelihoods of smallholder farmers while empowering communities through horticulture, including better access to nutrition and healthy diets.

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Feed the Future Innovation Lab for Horticulture

Improving Affordability and Availability of Healthy Diets Through Female Smallholder Farmer Engagement

Enhancing the production and consumption of AIVs to improve diets in Ghana and Mali. Image credit: University of Ghana.

Posted by Heather N Hayashi on August 25, 2023

FOR IMMEDIATE RELEASE

Improving Affordability and Availability of Healthy Diets Through Female Smallholder Farmer Engagement

[DAVIS] – The Feed the Future Innovation Lab for Horticulture is delighted to announce the launch of three regionally-led research initiatives, to be coordinated by the Horticulture Innovation Lab's West Africa Regional Hub Managers, Naalamle Amissah and Freda E. Asem, based at the University of Ghana.

involved in African indigenous vegetable (AIV) production and sale, was identified as a priority by the horticulture sector in West Africa. Targeting this community has far-reaching nutrition and health benefits at the household level. Thus the three projects and their foci are as follows:

- *Enhancing the production and consumption of AIVs to improve diets in Ghana and Mali* led by Gloria Essilfie from the University of Ghana in collaboration with CSIR Food Research Institute, Young Professionals for Agricultural Development, Forum for Agricultural Research in Africa, and the University of Sciences, of Techniques and Technologies of Bamako - will improve nutrition for Ghanaians and Malians through diet diversification by promoting indigenous fruits and vegetables access and consumption. Research will assess the AIV value chain to profile and identify cultural properties of indigenous fruits and vegetables and to understand regional demand and supply by characterizing them in terms of agronomic practices, nutritional composition, postharvest practices and value addition potential.
- *Promoting food and nutrition security through indigenous fruits and vegetables in Ghana and Mali* led by Freda A. Asem and Naalamle Amissah from the University of Ghana in collaboration with the World Vegetable Center, CSIR- Plant Genetic Resources Research Institute, and CSIR Savanna Agricultural Research Institute - will provide a deeper understanding of indigenous vegetables and how to build a sustainable supply chain, including strengthening seed supply, to increase production of and access to these highly nutritious and resilient crops. A comprehensive database detailing selected AIV varietals' nutrition profile, optimal cultivation practices under different agro-ecological zones, and abiotic stress tolerance will be determined to provide stakeholders with solutions to more effectively build nutrition security for their communities through the integration of indigenous vegetables.
- *Engaging youths in the production of indigenous vegetables and fruits in Nigeria* will be led by Atanda Oladejo and Cornelius Atere from Obafemi Awolowo University in collaboration with Utah State University - will investigate optimal agronomic practices for AIVs while incorporating youth engagement through school gardens and participatory research trials focused on indigenous vegetables. Research will advance input supply chains to support indigenous vegetable production, while examining the nutritional impact consuming these crops to reduce malnutrition among youths and community members.

These projects will unlock great potential by providing deeper insight into Africa's rich biodiversity, which remains widely unknown to the global community. For Amissah and Asem,

Feed the Future Innovation Lab for Horticulture

"A focus on indigenous vegetables will generate critical insights into crops that have been relatively under-researched, but offer unique benefits in terms of high micronutrient content and resilience to climate change," said Erin McGuire, Director of the Feed the Future Innovation Lab for Horticulture. "By engaging women farmers, we aim to improve access to these nutritious and sustainable options. I'm confident in our team's ability to achieve these goals."

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Promoting food and nutrition security through indigenous fruits and vegetables in Ghana and Mali. Image credit: University of Ghana.

Feed the Future Innovation Lab for Horticulture

Engaging youths in the production of indigenous vegetables and fruits in Nigeria. Image credit: Obafemi Awolowo University.

New Portfolio of Regionally-led Research Initiatives Leading Innovation and Advancement in Global Food Security and Gender Equity

The Feed the Future Innovation Lab for Horticulture at the University of California, Davis, is proud to unveil its new research portfolio as a part of Feed the Future, the U.S. Government's global hunger and food security initiative. The Horticulture Innovation Lab's global research network partners with and promotes local leadership to advance horticulture and social innovations, empowering smallholder farmers to earn more income while better nourishing their communities. This new 3.5-year portfolio comprises of regionally-led research initiatives across East and West Africa, Central America, and South Asia. Research initiatives will be guided by four Horticulture Innovation Lab Regional Hubs based at the International Center for

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Adel Kader Review

Postharvest technologies for small-scale farmers in low- and middle-income countries: A call to action

Archie Jarman *, James Thompson, Erin McGuire, Michael Reid, Siobhan Rubsam, Kristen Becker, Elizabeth Mitcham

Feed the Future Innovation Lab for Horticulture, University of California, Davis, USA

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ABSTRACT

The benefits of agricultural innovations in increasing productivity and reducing postharvest losses have not been shared universally. Postharvest losses of horticultural crops are high in low- and middle-income countries (LMICs) where small-scale farms play a critical role in production. A number of innovations in application of the cold chain and the dry chain to address postharvest losses are appropriate for small-scale enterprises. Case studies offer additional insights about some of these technologies, including how they made an impact for small-scale farms. Increasing global food insecurity demands could be mitigated by rapid and sustainable changes in postharvest management in LMICs. Relatively recent attention on food loss and waste (FLW) among key global organizations offers an opportunity for greater levels of resources being dedicated to this urgent issue. Major production-side global initiatives have achieved systemic impacts across LMICs. A more coordinated effort among researchers and other stakeholders working to reduce postharvest losses is needed to achieve significant reductions in LMICs.

1. Introduction

In the past century, steady adoption of research-driven technological innovations by the produce industry in high income economies has reduced postharvest losses due to product deterioration causes and improved the quality of perishable products marketed from these regions (Kader, 2006). Pre-cooling, refrigerated storage and transportation, drying and dry storage, controlled atmosphere storage, improved packaging and unitization, regulated ripening, growth-regulating chemicals and other technologies provide high quality fruit and vegetables for consumers on a year-round basis, and reduce postharvest losses during marketing. In contrast, losses of harvested perishable products before consumption have been estimated at nearly 40% in low- and middle-income countries (LMICs) (Kader, 2005; Spang et al., 2019), while worldwide losses of fruits and vegetables between harvest and retail were estimated at 22% (FAO, 2019). However, it is clear that losses vary widely, depending on the specific crop, season and growing location. These losses are not just economic and nutritional - they also reduce sustainability of horticultural production and make a significant contribution to global climate change (Buzby et al., 2011; Foresight, 2011).

Advanced postharvest technologies are employed in LMICs, but chiefly by large-scale or high-value export enterprises seeking to minimize losses and provide high-quality products for consumers to the upper- and middle-income countries (bananas from Ecuador to the US, green beans and ornamentals from Kenya to Europe). Smallholder farmers, usually women, who provide horticultural products for the local market or even to those export-oriented industries, do not have access to technologies that would reduce the devastating losses they experience between harvest and market.

Recent reviews related to this topic have focused on specific types of technologies, such as cooling and cold storage (Behdani et al., 2019; Makule et al., 2022), solar dryers (Devan et al., 2020), and hermetic grain storage (Baributsa and Njoroge, 2020). We highlight the principal sources of loss, and consider opportunities for development of innovative technologies to reduce them, with an emphasis on cooling and drying technologies. In particular, we point to the dramatic reductions in costs and increased capability of information dissemination and renewable power sources as drivers for technological innovation that might change the postharvest dilemma for smallholder farmers without requiring them to replicate the large-scale and high-cost postharvest systems that have been so successful in high-income economies

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(mechanical refrigeration systems, vacuum coolers, convection dryers). We emphasize technologies that have been demonstrated as effective in LMICs and discuss potential improvements to these technologies. Case studies are included to emphasize these points. This review is also intended as a call to action for the postharvest biology and technology community to focus on the needs of smallholder horticulturists in LMICs (Behdani et al., 2019).

1.1. Postharvest losses – magnitude and impact

In LMICs postharvest losses of perishable horticultural crops average about 38% (Spang et al., 2019), but can be as high as 80% (Kitinoja and Kader, 2015). Postharvest losses have been estimated to contribute eight percent of global annual greenhouse gas emissions (FAO, 2019; Project Drawdown, 2023). On a weight basis, horticultural crop losses exceed all other types of food loss (Lipinski et al., 2013). Because of unpredictable weather and losses of arable land, anthropogenic climate change has decreased productivity of global agriculture by 21% since 1961. Reduction of postharvest losses could offset this decrease, increase food availability, and reduce greenhouse gas emissions (Ortiz-Bobea et al., 2021).

In LMICs, most postharvest losses occur early in the value chain (Gustavsson et al., 2011; Kader, 2005). Factors responsible for these losses include poor temperature management, physical damage, inadequate packaging, poor storage, poor transportation and marketing infrastructure, adverse policy decisions, and lack of access to postharvest information and technology.

1.2. Importance of losses at the smallholder farmer level

The United States Agency for International Development (USAID) defines a smallholder producer or farmer as one who has less than 5 ha of arable land (Feed the Future, 2019). Small-scale farms are critical for the production and supply of horticulture crops in many LMICs (FAO, 2021), and fruit and vegetables are often more profitable than staple crops (corn, rice, beans, etc.) (Rahiel et al., 2018). Horticulture production by smallholder farmers builds resiliency, mitigates climate-risk, and can be an important source of income and nutrients (Schreinemachers et al., 2018).

Excessive postharvest losses detrimentally impact the potential benefits of horticulture, often forcing smallholder producers to be 'price-takers' (Ambuko et al., 2018). Lacking on-farm postharvest storage, growers may need to accept whatever price is offered (Yeshiwas and Tadele, 2021), and are obliged to sell produce immediately after harvest, even when the market is oversupplied and profit margins are low (Rutta, 2022; Rahiel et al., 2018). For example, the cost of tomato production in Uganda is estimated at $625 per hectare (Omia Agribuisness Development Group, 2023). Production ranges from 10.1 to 20.2 tons per hectare. If losses after harvest are 50% (Aidoo et al., 2014), this represents a loss of $3.13 per kg of production or $312 per hectare. There is also the lost opportunity cost. If tomatoes sell for $0.50 per kg, for example, at the low end of production (10 tons per hectare) income potential is $5000. A 50% loss not only costs the $312 of production costs, but also the lost potential income of $2500.

Discouragingly, over a twenty-year period between 1994 and 2014, there was no significant decrease in the level of postharvest losses of horticultural crops in LMICs (Singh et al., 2014). Vegetable and fruit production can improve the health and economic vitality of smallholder farmers; and recognition of the significance of postharvest horticultural losses has led to a focus on this issue by FAO, the World Bank, the United Nations Environmental Program, the United States Department of Agriculture, the World Food Program, and USAID. The United Nations' Sustainable Development Goal (SDG) 12.3 targets reductions in losses throughout the supply chain, and the African Union Member states have pledged to cut postharvest losses in half by 2025 (Stathers et al., 2020).

However, investments in agriculture are still predominantly focused on staple crops (Haddad et al., 2016), and horticulture generally has not received the research investment it deserves, there is on average only one horticulture researcher per 1 million of population, while cereal crops have 4–5 (Schreinemachers et al., 2018). Moreover, postharvest research capacity is only a small fraction of horticultural research (Kitinoja et al., 2011). Furthermore, there has been a general lack of interdisciplinary cooperation to address postharvest losses in horticulture (Kitinoja et al., 2011).

Factors limiting the impact of investments to decrease postharvest losses in horticulture crops have included inappropriate scale of interventions, lack of focus on improving knowledge and practices, continued deficiencies in coordination, lack of market connections, and short time frames for research projects (Stathers et al., 2020). As production and efficiency has increased in fruits and vegetables, the growth in losses has also increased (Abbade, 2020).

1.3. Causes of postharvest loss

The causes of food losses after harvest differ between fresh and dried commodities. For fresh fruits and vegetables, poor management of temperature and relative humidity (generally temperatures above optimum and relative humidities below optimum), poor packaging, inadequate storage facilities, transportation and roads, and poor planning and policies are responsible for the high percentage losses of fruits and vegetables (Kader, 2005). High temperatures increase the speed of ripening and softening, decay development, and water loss (Kader, 2013). Low relative humidity in the environment around the commodity also increases water loss, and many packages that are commonly used in LMICs are not able to maintain high relative humidity. Poor packaging, transportation and roads lead to physical damage, which generally increases water loss, ethylene production (accelerating ripening and senescence), and decay (Kader, 2010). Inadequate sanitation of workers and water systems can lead to contamination by human pathogens that may interfere with market opportunities, especially for export markets. All of these issues are exacerbated by poor production planning and coordination, and lack of access to markets, which leads to gluts of harvested product with inadequate means of preservation.

For dried products, inadequate drying and poor storage conditions are the main drivers of postharvest insect and fungal contamination (Kumar and Kalita, 2017). Fungal contamination of dried foods reduces the value of the commodity for market and frequently renders the product inedible, and even toxic. Drying after harvest is an excellent way to stabilize products and allow storage without refrigeration. However, to be successful, it is critical that the product is dried to, and stored hermetically at, a water activity (A_W) of less than 0.65 (65% equilibrium relative humidity (ERH)) (Bradford et al., 2018). Equilibrium relative humidity is the relative humidity that develops in the air around a dried commodity after it is sealed in a container for a period of time. An A_W below 0.65 prevents the growth of microorganisms and, in combination with low oxygen atmospheres that develop in hermetic bags, reduces insect growth. Storage in a hermetic package (GrainPro, PICS Network, Vestergarrd's ZeroFly Bag) also prevents moisture absorption from the air, and is particularly important in humid climates. In LMICs, it is very common to observe dried products stored in jute sacks and other types of porous packaging that do not protect the product from re-absorbing moisture, resulting in product deterioration (Bradford et al. 2018).

2. Opportunities to reduce losses

2.1. Cold chain

Temperature management is critical for limiting postharvest losses in fresh fruits and vegetables. High temperatures during harvest, storage, and transport accelerate metabolic activity, increase water loss, can stimulate production of ethylene, and promote decay of fruits and vegetables, thereby shortening their shelf-life and reducing their quality and

nutritional content (Yahia and Elansari, 2011). Ideally, products should be pre-cooled immediately after harvest to remove field heat (Elansari et al., 2019), then maintained at the optimal cool temperatures in a 'cold chain' from harvest to consumption (Islam et al., 2022). Limited resource smallholder farmers can apply simple practices such as harvesting during cooler periods of the day and placing products in the shade, and couple these with low-cost technologies to reduce temperature-related losses (Amwoka et al., 2021). However, the lack of refrigeration during the "first mile" of rural horticulture value chains can result in major postharvest losses (Lipinski et al., 2013). Access to cooling and cold storage facilities, as well as cold transport, is a critical need for farmers in LMICs.

2.1.1. Evaporative cooling

In evaporative cooling, dry air absorbs water, cooling itself and the water in the process. Cooling capacity is highest when the ambient air is at low humidity, and temperatures are moderate (Kumar et al., 2018); therefore, it works best in the dry tropics and sub-tropics. For postharvest management, evaporative cooling systems in which external air passes through wetted material into a storage chamber are most common (Manuwa and Odey, 2012). In passive evaporative cooling systems, evaporation occurs at a wetted surface and heat is transferred by conduction and convection; while active systems use an external device to force air through the wetted material, thereby increasing cooling efficiency (Ndukwu and Manuwa, 2014).

Evaporative coolers are attractive to smallholder farmers in LMICs because they are affordable, can be made with locally available materials, generate high relative humidity (thereby reducing water loss), and, under ideal conditions, can provide the correct temperature (10 – 12 °C) for storing chilling-sensitive commodities (lal Basediya et al., 2013). In the right climates, evaporative cooling is suitable for short-term storage of fruits and vegetables and can also be used to precool products (Amwoka et al., 2021). The limitations of evaporative cooling include the use of water, which may not be readily available, and the physical limitations on cooling potential in high humidity conditions (Verploegen et al., 2019).

2.1.1.1. Passive evaporative coolers. The Zero Energy Cooling Chamber (ZECC) (Fig. 1), a common passive evaporative cooling chamber invented in the early 1980s in India, comprises a rectangular chamber enclosed by a double wall of bricks with sand filling the gap between the two brick walls (Roy and Khurdiya, 1982). Product is placed inside the chamber and a cover is placed over the top. Water is trickled into the sand, and the chamber is cooled by evaporation from the surface of the bricks. Pot-in-Pot coolers (also known as Zeer Pots) (Fig. 2) are low-cost passive evaporative cooling units constructed of two unglazed pots (one large, one slightly smaller) with sand filling the void between the two pots (Verploegen et al., 2019), much as in the ZECC. Water is applied to the sand and a damp cloth is placed on top of the pot opening to generate evaporative cooling effects (Kader, 2005). The volume of such pots is quite limited, but they can be useful for home storage. The Charcoal Cooler is a passive, evaporatively cooled room that can be as simple as a wood frame wrapped with interior and exterior mesh or chicken wire, with the void between the layers of mesh filled with charcoal that is wetted by dripline or by hand (Ndukwu and Manuwa, 2014). Ambuko et al. (2017) noted the ability to maintain high humidity levels, thereby reducing weight loss, and consistent temperatures as two of the key benefits of using ZECCs. In a trial evaluating the ZECC with amaranth, these ZECC attributes reduced water loss by nearly 50% in ZECC-stored product compared to ambient room control, and maintained significantly higher levels of vitamin C.

In the humid tropics, the value of the ZECC is solely in reducing water loss, since cooling potential is very limited in those environments. An important consideration for postharvest researchers exploring alternative cooling systems is choosing the comparisons that they make. In the examples cited above, the evaporative cooling system is typically compared with standard practice (no cooling, or simple shade). While

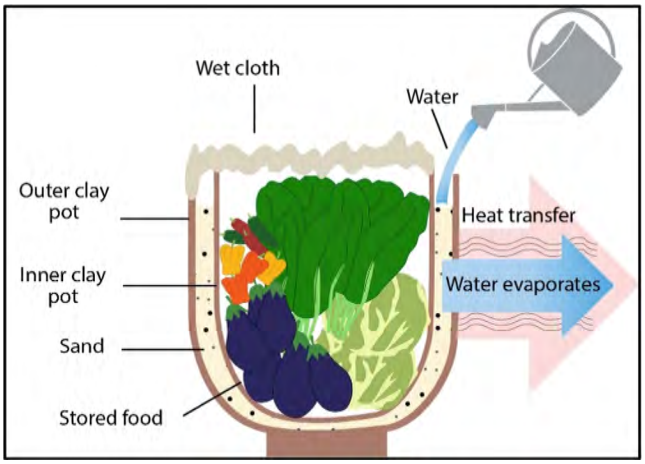

Fig. 2. Pot-in-Pot evaporative cooler. Courtesy of MIT D-Lab: A Guide to Assembling, Using, and Maintaining Clay Pot Coolers. Sourced from: https://d-lab.mit.edu/resources/publications/guide-assembling-using-and-maintaining-clay-pot-coolers.

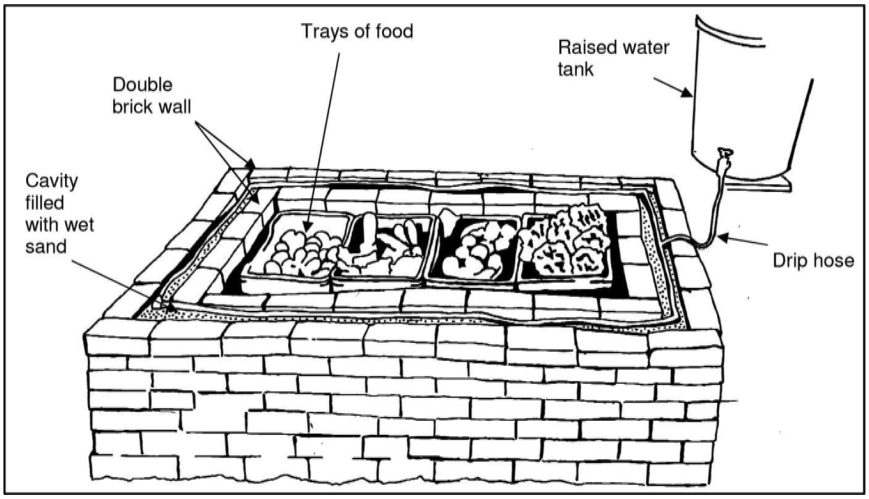

Fig. 1. Zero Energy Cooling Chamber (ZECC). Courtesy of Practical Action, Neil Noble. Sourced from: https://srrweb.cc.lehigh.edu/app/ZECC.

this may indicate some benefit, it does not provide a comparison with the effectiveness of proper refrigeration.

2.1.1.2. Case study - Not always low-cost. Wheeler and Kitinoja (2014) *found the price of a ZECC to be highly variable depending on local material costs, with prices for a 100 kg capacity unit ranging from $280 ($2.80 per kg) in Ghana for the ZECC unit alone – with no shade structure, no raised tank or irrigation lines – to $615 in Thailand.* Verploegen et al. (2019) *determined that a larger pot-in-pot capable of holding 70 kg of product, and sitting in a plastic bowl with wetted sand in the space between, was a highly cost-effective evaporative cooling option at $17 ($0.24 per kg) in Burkina Faso, where clay pot production is common. Working within the constraints of local materials is important for providing technology options that provide fairly rapid return on investment.*

2.1.1.3. Active evaporative coolers. Active evaporative coolers incorporate fans to move air through the wetted cooling medium, and can achieve lower temperatures than passive coolers (lal Basediya et al., 2013). Workneh (2010) designed an active, direct, 800 kg capacity unit that incorporated a fan, for a total cost of approximately $440 ($0.54 per kg), and determined that reduction in losses in a smallholder farming community in Ethiopia would cover this cost in as little as 1.2 years. Active evaporative cooling units can also incorporate pumps to recirculate water. For example, a small 0.4 m^3 solar-powered unit in Nigeria described by Olosunde et al. (2015), utilized a pump recirculating water through a wetted jute fiber pad. Storage in this unit extended the shelf life of tomatoes, mangos, bananas and carrots by 15, 9, 12, and 20 days, respectively, compared to ambient storage.

In the 'Pusa' evaporative cooler developed and tested in India (Chopra and Beaudry, 2018a), nylon felt fabric covers the cooler walls. The fabric retains and spreads water that is continuously applied using a pump, thereby improving system efficiency. Chopra and Beaudry (2018b) compared a ZECC to the Pusa evaporative cooler, and over a 5-day period the temperature of product stored in the fabric evaporative cooler was 3.5 °C lower than that in the ZECC. The Pusa unit, costing about $4000, can hold 2000 kg of fruit and vegetables, and provided significant air temperature reductions (up to 14 °C) during the day; but high humidity levels at night limited air temperature reductions to only 4.7 °C below ambient temperature.

2.1.2. Mechanical/Traditional cooling

Proper implementation of the cold chain for most horticulture products still depends on mechanical refrigeration. Despite the negative environmental impact of older refrigerants, the high efficiency of the Carnot cycle makes standard compressor/evaporator refrigeration the most sustainable means of achieving low temperatures (Oxtoby et al., 2011). The need for cooling and cold storage underscores the need for access to reliable and affordable energy through an electric grid or through standalone systems such as solar, solar with batteries, or generators. Solar powered cold storage is now being recommended as part of essential infrastructure to reduce postharvest losses for smallholder farmers (UNIDO and REEEP, 2020). Unfortunately, the high costs of standard refrigeration equipment, insulated rooms, and solar power supply make this key technology inaccessible for smallholder farmers in LMICs.

2.1.2.1. The CoolBot™. One approach to providing affordable cooling is to minimize the cost of the refrigeration equipment. StoreItCold's CoolBot™ is a controller that overrides the temperature control on a standard home air conditioning (AC) unit, allowing the unit to cool a room to as low as 2 °C while also preventing the AC unit's fins from freezing (StoreItCold, 2023). The CoolBot™ controller costs $374, and an off-the-shelf split unit 12,000 BTU/h AC costs $800, a combined cost much lower than commercial refrigeration systems. However, an approximately 8 m^3 turnkey unit (insulating panels, AC unit and CoolBot™) in the United States costs $5250, highlighting the fact that insulated panels and room construction are still a major cost. Despite the substantial capital cost of a CoolBot™ equipped cold room, the system is an effective solution to LMICs' critical need for cold storage. In comparison to even the best evaporative coolers, a CoolBot™-equipped cold room provides wider temperature control, higher cooling capacity, works in all climates, and allows for longer storage periods, when desirable.

Although CoolBot™ rooms are considerably less expensive than traditional refrigerated cold rooms, the upfront cost remains a barrier for smallholder farmers (Kitinoja and Barrett, 2015), although a positive return on investment could be achieved in as little as two to three years in certain markets (Reid and Kornbluth, 2011; Saran et al., 2012). Controlling capital costs, either by reducing the cost of materials (room construction, insulation) or providing subsidies; increasing utilization of the room with high value crops, implementing a space rental model, or coordinating the purchase of units by farming cooperatives, are critical steps to give smallholder farmers access to effective cold chain technologies.

2.1.3. Coldroom construction

As noted above, the cost of proper cooling is largely the cost of building a well-insulated structure. The effectiveness of a refrigerated room is absolutely dependent on the quality of its insulation and the use of a good vapor barrier. Small commercial coldrooms use insulated panels (typically polystyrene or polyurethane) and large rooms are often insulated with spray-on polyurethane foam, which provides both high quality insulation and a vapor barrier. Polyurethane foam also has structural properties; and very large insulated rooms have been constructed by spraying polyurethane foam on the inside of an inflated balloon, followed by a layer of concrete sprayed over reinforcing steel (Bomberg and Kumaran, 1999). The high cost of the insulated panels used to construct CoolBot™ coldrooms in Bangladesh by the Feed the Future Innovation Lab for Horticulture suggested an examination of locally-sourced insulation materials, such as feathers (produced in large volumes at poultry operations), rice hulls, or chopped straw. Any of these materials (or other finely divided dry organic waste material) could serve as insulation in a double-walled room, provided that the outer wall included an adequate vapor barrier. An alternative strategy that warrants testing is to spray polyurethane foam on an existing structure, providing insulation and vapor barrier at the same time. Additional research and development are needed in this area.

2.1.4. Case study - The role of government in advancing cold chains

*In Nepal, government subsidies allowed R&D Innovative Solutions, Inc. to provide 150 CoolBot™ cold rooms to horticulture producers that otherwise could not afford the unit. For smallholder kiwi fruit growers, access to cold storage reduced losses. Some of these rooms used minimal insulation, but the improvement in quality of stored product was still significant enough to create positive returns. In another example of government support, an Uzbek government preferential lending program for cold storage, implemented with the support of international financial institutions, led to more than a 1000-fold increase in the country's cold storage capacity in 2011 (*Tracy and Taylor, 2017*). Government support can be critical for the growth of a cold chain. But for sustainability, reliable market demand for produce from improved cold storage facilities is essential (*Amwoka et al., 2021*).*

2.1.5. Case study - Know your market

Lewis et al. (2017) *conducted an analysis of the CoolBot™'s economic feasibility in Bangladesh using field data sourced from a Feed the Future Innovation Lab Horticulture project in collaboration with the Feed the Future*

Innovation Lab for Nutrition. Primarily due to the high import tariffs levied on aluminum-sided insulated panels, the capital cost of the CoolBot™ powered cold room was extremely high in Bangladesh – $12808. Additionally, the farming cooperatives utilizing the cold rooms only used, on average, less than 1% of the available roughly 36 m³ storage capacity. The research showed that if a CoolBot™ powered coldroom's space is used efficiently, if high-value commodities are stored, if subsidies are provided for capital costs, and if low-cost but effective insulation is used, a CoolBot™ coldroom in this LMIC scenario could be very profitable for users.

2.1.6. Case study - Rental model

Several technologies and financing approaches have been demonstrated to overcome the accessibility issues for smallholder farmers in LMICs resulting from the high capital costs of cold storage units and required energy access. The ColdHubs organization provides solar-powered, battery-supported, cold storage units at markets and farms in Nigeria (Fagundes, 2019). *The high capital cost of the unit (*ca. *$45,000) is amortized by farmers and traders renting space in the cold room on a crate per day basis* (Makule et al., 2022). *This rental model is also used by FreshBox in Kenya (farmers pay $0.70 per crate per day to store horticulture products in solar-powered coldrooms)* (FreshBox, 2022), *and SokoFresh in Kenya (farmers pay SokoFresh $0.02 per kg and SokoFresh also provides training in postharvest management practices to customers)* (SokoFresh, 2023).

2.1.7. Cost benefit of cooling technologies

It is important to consider the costs benefits when comparing cooling and cold storage technologies. Direct, passive evaporative systems, such as the ZECC, alone are not adequate components of a fully-implemented, longer-term storage, cold chain for reducing food losses in LMICs. Mechanical refrigeration in all its manifestations, and evaporative cooling systems that incorporate fans to increase airflow through wetted material, are more effective solutions in suitable locations. Mechanical cooling units, such as the CoolBot™ or evaporative coolers with fans, despite their high up-front costs, are either cheaper or very competitive on a volumetric basis with the direct evaporative cooling units, and have the significant advantage of being able to reach optimal storage temperatures for fruits and vegetables in many locations (Table 1). A key constraining factor, of course, is access to energy; solar panels and batteries are emerging as affordable options in certain LMICs.

Table 1
Cost-benefit analysis of cooling technologies; costs adjusted for inflation to reflect current values.

Technology	Source	Cost	kg capacity[z]	Cost/kg
ZECC at lowest cost found	Verploegen et al., 2019	$61	100	$0.6
ZECC at low range	Wheeler & Kitinoja, 2014	$365	100	$3.65
ZECC at highest cost	Wheeler & Kitinoja, 2014	$802	100	$8.02
Large Capacity Pot in Pot	Verploegen et al., 2019	$21	70	$0.3
ZECC with shade structure, irrigation, average cost across six sites	Wheeler & Kitinoja, 2014	$946	100	$9.46
Evaporative cooler using felt nylon – the Pusa	Chopra and Beaudry, 2018b	$4340	2000	$2.17
Evaporative cooler with fan	Workneh, 2010	$620	819	$0.75
Turnkey CoolBot™ from StoreltCold (current)	StoreItCold LLC, 2023	$4925	1282	$3.84
CoolBot™ Bangladesh	Lewis et al., 2017	$16,902	5667	$2.98

[z] Capacity for CoolBot™ units was based on 340 crates being the approximate capacity of a 36 m³ cold room (Lewis et al., 2017). Capacity for evaporative cooler was 6 crates (Wheeler and Kitinoja, 2014).

2.1.8. 'Novel' cooling technologies

2.1.8.1. Liquid nitrogen. Liquid nitrogen has been suggested as a refrigeration system for use during storage and transport (Linde, 2023; Yun et al., 2018). However, since the boiling point of liquid nitrogen is − 196 °C, the evaporation rate must be carefully controlled to prevent the stored products from freezing (Valeriu et al., 2010). Liquid nitrogen cooling has a few advantages compared to mechanical cooling, including reduced need for mechanical parts, no need for refrigerants that may contribute to ozone depletion, and quiet operation. However, in the context of LMICs with variable infrastructure, it is questionable whether sufficient production of liquid nitrogen and transport of the liquid nitrogen, is viable or affordable. Liquid nitrogen may be more appropriate for expensive horticultural products for medium or large enterprises in LMICs until the technology has been adapted to become more affordable and reliable in variable conditions.

2.1.8.2. Peltier or thermoelectric cooling. Thermoelectric cooling uses the Peltier effect to create a temperature difference between two junctions of dissimilar materials, for example different metals like copper or zinc (OEERE, 2023). A Peltier cooler is a solid-state active heat pump comprising many parallel junctions between two ceramic plates, and transfers heat from one side of the device to the other when a DC voltage is applied. Peltier coolers are widely used in small-scale cooling applications, cooling high speed computers, microscope stages, portable beer coolers and the like. These devices have relatively low efficiency compared to heat-pumps, but they are inexpensive (current prices are around $50 per kW of cooling), and extremely simple. To provide the equivalent of a small air conditioner, a bank of Peltier devices would be fitted with heat exchangers and fans (interior and exterior) and an appropriately-sized power supply (grid, solar, or generator).

2.1.8.3. Ice. The use of ice for cooling has a long history. The success of California's fresh horticultural exports to the Eastern U.S. depended on rail cars cooled by ice 'bunkers' at each end of the car, and fans that circulated room air through the melting ice. The system provided high humidity air, close to the freezing point, but without any danger of freezing high freezing point commodities like lettuce. In LMICs, ice is commonly used for handling fish, and large block ice production and crushing equipment can be found at fishing ports and fish markets. Technologies that allow smallholder farmers to use ice for pre-cooling and transporting their products merit consideration. However, it will be critical to use potable water to make ice and prevent contact of melted ice with the commodity due to risks of cross-contamination.

2.1.9. Cool transport

Refrigerated transport is infrequently used in many LMICs, even for very perishable products. Even accessing non-refrigerated transportation can be a challenge for producers in LMICs. These countries typically have limited high quality road systems and few vehicles designed to transport fresh horticulture crops (Kader, 2005), and the transportation is generally not under the control of the producer. Whether on rickshaws, trucks, trailers, or on top of buses, products are exposed to ambient temperatures, inclement weather, sun, dust (Faqeerzada et al., 2018), and physical damage. Ineffective transport from farm to market can be the most consequential driver of postharvest losses in LMICs (Rubagumya et al., 2023). Precooling and packaging are important steps prior to transport (Behdani et al., 2019), but as highlighted earlier, these postharvest interventions can be lacking in LMICs. Lack of cool transport can isolate smallholder farmers from markets; especially markets that offer a premium such as in urban centers (Filmer et al., 2021). Aggregation centers, equipped with cold storage and supported by national policy, can help smallholder farmers' access markets and reduce transport costs (Cooper et al., 2021).

Cool transport in LMICs for fruits and vegetables receives relatively

little attention as a postharvest intervention (Tapsoba et al., 2022). There are efficient cold transport systems in LMICs that can deliver horticulture products thousands of miles away, like the export of floriculture crops from Kenya and Ethiopia to Europe (Button, 2020); but the technological advancements in these markets do not always spread to smaller-scale domestic farmers. For all aspects of transportation for the postharvest sector in LMICs, there needs to be better transfer of technology from high-value, export-oriented operations to smallholder operations. In the case of cool transport, adaptation of mobile reefer units to vehicles such as tuk tuks, rickshaws, and trailers is needed to curb losses during transport.

2.2. Dry chain

Implementation of the dry chain for staples (grains, pulses and nuts) and for dried high-value products (fruit, vegetables), extends storage life and reduces insect attack and development of fungal toxins (Mahuku et al., 2019; Bradford et al., 2018). Drying can be a solution to the losses associated with production peaks in horticultural crops, when high quality product is often discarded, or sold at a loss because supply of fresh product exceeds demand in the market and cold storage is not accessible. Drying is a ubiquitous step in staple crops; but also 20% of perishable, horticulture crops are dried for preservation (Grabowski et al., 2003). While drying reduces the nutritional content of horticultural crops, a significant portion of nutrients remains and is available in the now-preserved product (Smith et al., 2018).

2.2.1. Solar drying

Open air sun drying is the most widespread method of drying agricultural products in LMICs, and can be effective under warm, dry conditions; however, those conditions are infrequently available during the harvest season or in humid climates (Mendoza et al., 2017; Bradford et al., 2018). In addition, traditional open air drying, whether on the ground, on trays, in baskets, on paper or plastic sheets, or on roofs, leaves products exposed to pests, predation, theft, and contamination (Nagwekar et al., 2020). Solar dryers not only dry products faster than open air drying, but are more hygienic, can better preserve nutritional value of a dried commodity, and can be inexpensive (Chua and Chou, 2003). The flow of low-humidity heated air over the product in solar dryers increases the efficiency of evaporation of water from the product to the air (Fuller, 2010). The many solar dryers that have been developed are either direct dryers (drying product is heated by solar radiation), indirect dryers (solar heated air is passed over drying product), or mixed (combination of both solar radiation and externally heated air) (Devan et al., 2020). Additionally, active solar dryers use fans to improve airflow, while passive solar dryers rely on convective movement of air (Matavel et al., 2021). Upfront costs for solar dryers can be a significant barrier for smallholder farmers (Nagwekar et al., 2020); relatively low-cost options that could be purchased by an individual or cooperative are discussed below.

2.2.1.1. Indirect, active solar dryers. The Pallet Dryer (Figs. 3 and 4) is an indirect, active solar dryer that can be used to dry product in a bulk bin (Reid et al., 2022). The dryer is built with a bottom black sheet of plastic or fabric on the ground. A pallet or other such platform is placed at one end of the black substrate and a sheet of clear plastic over the pallet acts as a solar collector. Holes cut in the clear plastic over the slots in the pallet allow hot air to rise into a bin with a perforated base placed on the pallet. The air under the clear plastic is heated by the sun's radiant energy on the black substrate (the solar collector), and the heated air flows through the pallet opening and the bin. A lid placed on the bin is fitted with a 60-watt solar panel and a 60-watt, 12 V fan (rated at 300 cfm) that pulls warm air from the solar collector through the product being dried. The Pallet Dryer is low-cost (ca. $150) and can hold approximately 150 kg of bulk product. In a trial drying 50 kg of coffee beans, the moisture content of the beans reached the 12% target after 30 h in the Pallet Dryer, less than half the 72 h required for beans on a raised bed in a direct, passive greenhouse dryer. Etim et al. (2020) also had success with an indirect, active solar dryer in Nigeria that dried ca 5 kg of bananas to desired moisture content 40% faster than open air drying.

2.2.1.2. Chimney solar dryer. The Chimney Solar Dryer is a low-cost (ca. $150) mixed, passive drying unit that was designed to be a better drying alternative to cabinet dryers using stacked trays of product (Fig. 5). By laying trays of product on a long table, the Chimney Solar Dryer design allows for heated air to travel around and over the trays of product rather than through them. Constructed with materials that can be sourced locally in LMICs, the dryer includes a drying table covered in black or dark material that is connected to a chimney. Products to be dried are placed on trays on the table and covered with greenhouse polyethylene to create a solar collection tunnel and the heated air is drawn through the tunnel by convection up the chimney. Research has shown the value of the Chimney Solar Dryer for smallholder farmers, as it is capable of drying twice as much product in roughly half the time compared to an FAO-type cabinet dryer (Deltsidis et al., 2018); is significantly faster than open-air drying (Mithun et al., 2021; Kumi et al., 2020); and has a short return on investment period if the product being dried fetches a premium price in the market (Lewis et al., 2017).

2.2.1.3. Tunnel dryers. Tunnel dryers can use passive airflow with venting or incorporate fans to generate airflow, and are typically mixed solar dryers consisting of a rounded frame covered in polyethylene plastic (Devan et al., 2020). Getahun et al. (2021) developed an indirect tunnel dryer in Ethiopia with solar powered fans forcing heated air across the product in a two-stage solar dryer that transfers heated air from the first tunnel to a second tunnel. The unit dried 65 kg of chilies 30–54 h faster

Fig. 3. The Horticulture Innovation Lab's Pallet Dryer.

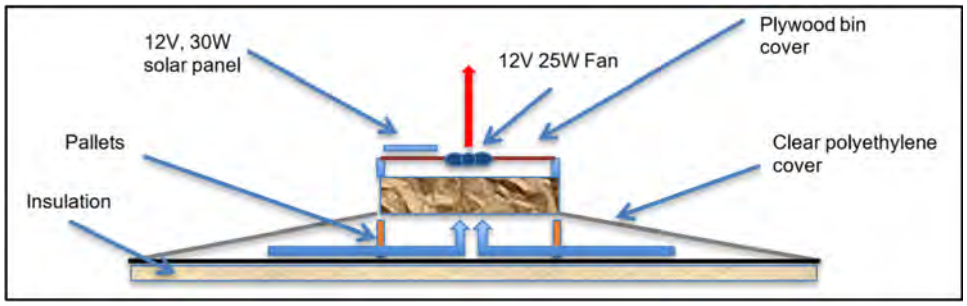

Fig. 4. Cut away view of the Pallet Dryer demonstrating airflow of heated air through bin with drying product inside.

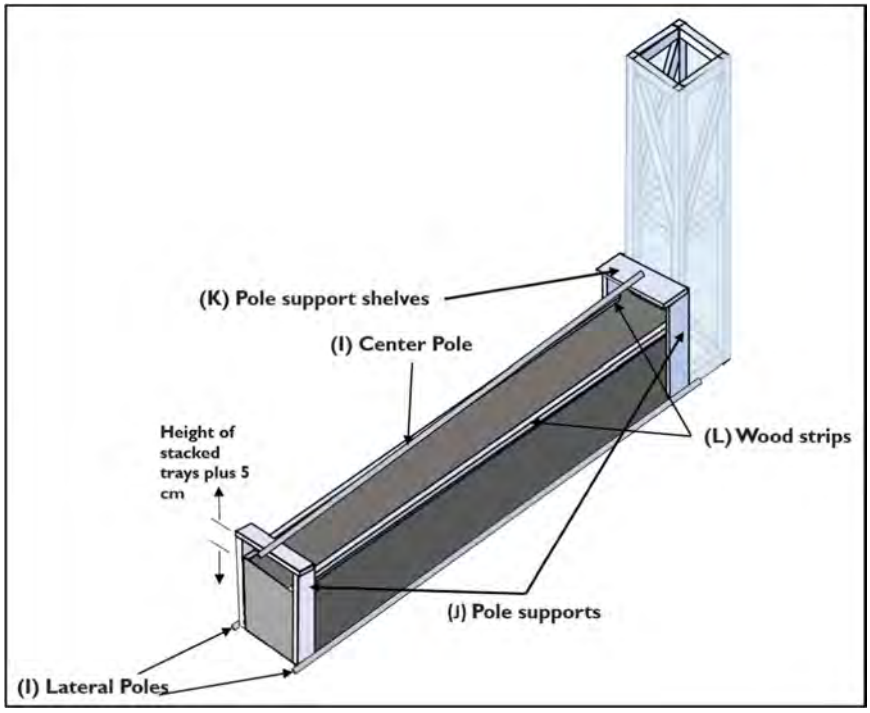

Fig. 5. Horticulture Innovation Lab's Chimney Solar Dryer - In this image the plastic covering the table is not pictured.

than open air drying. An 8.5 m long, mixed active solar tunnel dryer with two axial fans and a large solar collection area dried 8.5 kg of ginger 40% faster than open air drying (Tesfaye and Habtu, 2022).

2.2.1.4. Cabinet dryers. Cabinet dryers are small units meant primarily for household use (Ekechukwu and Norton, 1999). These smaller dryers can be direct, indirect, or mixed dryers using passive or active airflow. A mixed, passive cabinet dryer promoted by FAO (Fig. 6) has a solar collector at the entrance to the dryer box (Dauthy, 1995). Purdue University's Dehytray (ca. $120) is a compact cabinet, direct solar dryer that is a vented black tray with a clear, tight fitting lid to generate higher temperatures compared to ambient, and has been utilized by smallholder farmers (Mobolaji et al., 2021). Limitations of cabinet dryers include their small capacity and the stacked arrangement of the product in some of the units' drying boxes which impedes airflow (Precoppe et al., 2015).

2.2.1.5. Greenhouse solar dryers. Greenhouse solar dryers have been used in LMICs to dry relatively large quantities of commodities. A direct, passive greenhouse dryer is simply a frame with a transparent covering – glass, greenhouse plastic or polycarbonate sheets. The product is placed on the ground or on raised trays within the structure to dry in the heated air (Matavel et al., 2021). Direct, active greenhouse dryers incorporating exhaust fans to improve air flow can dry horticulture products up to 50% faster than open air drying (Shahi et al., 2011). Mixed active greenhouse solar dryers can also add an external heat source and fans to increase drying efficiency (Matavel et al., 2021). In an effort to develop a highly efficient greenhouse dryer for large quantities of chili, Kumar et al. (2020) incorporated both fans and a chimney to remove moist air.

2.2.2. Hermetic storage for dried horticulture products

Hermetic storage is critical in the postharvest preservation of dried commodities, as it prevents moisture intrusion, preventing fungal growth and reducing insect activity, and can also create a low-oxygen environment (Murdock et al., 2012; Alemayehu et al., 2023). Hermetic storage can also preserve the visual and organoleptic quality of dried horticulture crops (Villers et al., 2008). The Purdue Improved Crop Storage (PICS) hermetic storage bags have been used by thousands of farmers and traders in LMICs and cost between $2 to $4 each (Baributsa & Njoroge, 2020; Purdue Education Store, 2022). GrainPro Inc. offers a low-cost hermetic storage bag specifically for smallholder farmers and ZeroFly's hermetic bag includes an outer woven storage bag treated with an insecticide (GrainPro Company, 2022;Vestergaard, 2022). It is worth noting that, even with a documented high return on investment, the price point of the bags can be too high for some smallholder farmers (Masters and Guevara Alvarez, 2018; Villers et al., 2008).

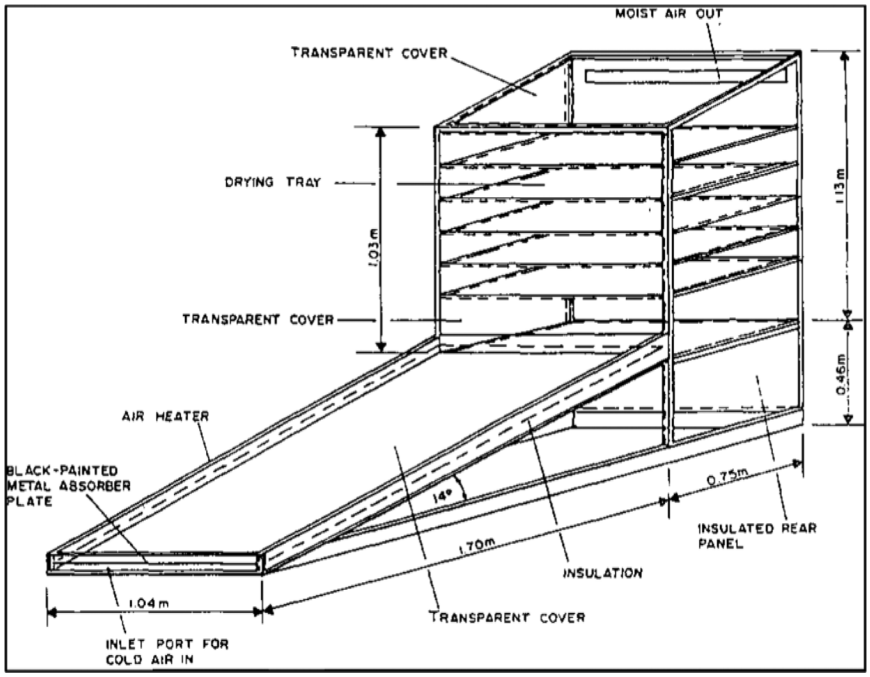

Fig. 6. Solar cabinet dryer with separate air heater featured by FAO. Courtesy of FAO. Source: https://www.fao.org/3/v5030e/V5030E0c.html.

2.2.2.1. DryCard and other moisture meters. For hermetic storage to be effective, it is important that the product be properly dried (Tubbs et al., 2016); but accurate, affordable, and accessible methods to test moisture content are lacking in LMICs. Electronic moisture meters can be too expensive for small-scale producers and traders, who rely on inaccurate subjective tests, such as chewing or handling the product, to determine dryness (Vera Zambrano et al., 2019). Measuring moisture content requires meters with specific calibration curves for each product (Vera Zambrano et al., 2019). A better approach is the use of hygrometers, which measure equilibrium relative humidity (ERH) which is directly related to the product's A_w. An A_w of 0.65 (ERH of 65%) is the threshold for fungal growth in all dried products, and therefore provides a universal standard for determining the safe dryness threshold of dried products.

New sensors have permitted the development of inexpensive electronic hygrometers. Feed the Future's Food Processing Innovation Lab calibrated an off-the-shelf hygrometer costing $2 to $4 (Feed the Future Food Processing Innovation Lab, 2019). The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss is promoting the GrainMate moisture meter for traders and aggregators. This device costs approximately $75 and can provide an accurate moisture content reading within six minutes (Lloyd, 2017).

The Horticulture Innovation Lab's DryCard™ is a low-cost, accurate dryness indicator (Fig. 7). The DryCard is a business card-sized tool incorporating a strip of $CoCl_2$ humidity indicator paper (Hydrion Humidicator Paper, Micro Essentials Laboratory, New York, NY) and a relative humidity color scale. The color of the humidity paper reflects the relative humidity in the headspace (ERH), which is directly correlated to the moisture content of the commodity. The DryCard includes a demarcation at the mauve color that corresponds to a relative humidity of 65%, the critical threshold for preventing fungal growth during storage. The $CoCl_2$ strip's color changes perceptibly from blue at 33% relative humidity to pink at 75%. Relative humidity can be determined, with the scale printed on the card, to an accuracy of 2% relative humidity (Thompson et al., 2017). If stored dry between uses, the DryCard can be reused many times. With the exception of the $CoCl_2$ humidity paper, DryCards can be made with materials available in LMICs, and sold for sufficient profit ($1 to $1.50) to sustain a small business.

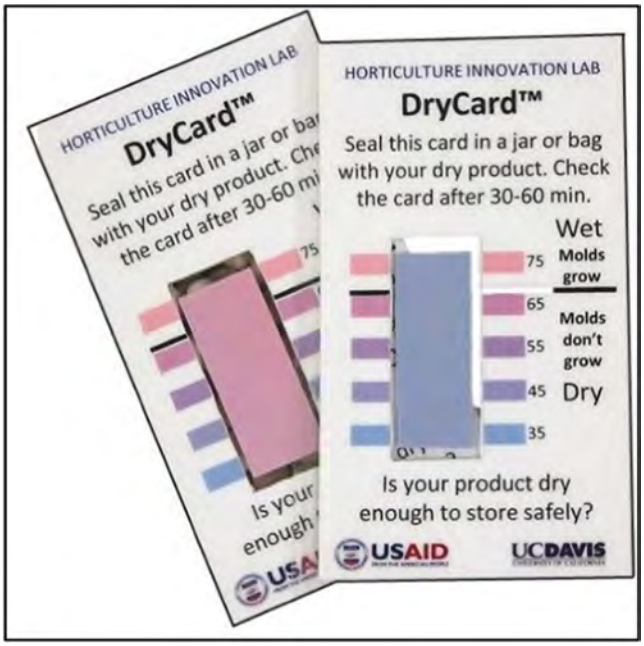

Fig. 7. The Horticulture Innovation Lab's DryCard. Pink means wet, not pink means dry.

2.2.2.2. Case study - The dry chain in action. A young female entrepreneur in Guinea began a successful pineapple drying business using the Chimney Dryer, the DryCard, and hermetic containers for storage, that employs 15 people who process and package dried pineapple. The dried pineapples are sold at local gas stations for 20 mil Guinean francs (GNF) (~$2) (CORAF, 2021). *This is a significant value addition considering one package consists of just a few pineapple slices and an entire pineapple can sell for 5–10 mil GNF ($0.50 – 1.00) during the peak of the pineapple season.*

2.3. Packaging for water loss and physical protection

2.3.1. Packaging to prevent water loss

Among the most perishable of horticultural crops are the leafy vegetables. Their high surface to volume ratio and the low resistance of their epidermis to water movement means that they quickly lose enough water to wilt, resulting not only in significant loss of saleable weight, but also loss of visual, textural, and nutritional quality. While high humidity refrigeration is the ideal technology for reducing water loss in these and other less perishable horticultural commodities, a practical method to maintain high relative humidity for many smallholder farmers and traders has been the use of perforated or non-perforated polyethylene bags. The negative environmental consequences of using these bags has led to prohibition of their use in the marketing of foodstuffs in several places. In Rwanda, as an example, single use polyethylene bags are outlawed (Nielsen et al., 2019).

Compostable and biodegradable polymers have been used to manufacture alternatives to high density polyethylene (HDPE) bags, but the present polymers have higher water vapor transmission rates than HDPE, and are thus less effective in preventing water loss, in addition to being significantly more expensive.

Shogren (1997) evaluated the water vapor transmission rates (WVTR) of several biodegradable polymers to determine their suitability as water-resistant membranes. Values of WVTR at 25 °C ranged from 13 to 2900 g/m^2/day. Polyester and polylactic acid films (which are among those commonly used for compostable bags) had WVTRs of 172 and 680, respectively. The WVTR of HDPE is ca. 1 g/m^2/day (Combellick, 1987), so water loss from produce stored in bags made from alternative polymers would be much higher than would be expected in HDPE bags.

There is a clear opportunity for polymer chemists to develop an affordable biodegradable membrane that is tailored to the needs of perishable horticultural products, with good physical properties, a low water vapor transmission rate, and preferably oxygen and CO_2 transmission rates that would facilitate the establishment of modified atmospheres at ambient temperatures. Promising results from compostable, microperforated polyester films have recently been reported by Rodov et al. (2022) with ripening bananas and Owoyemi et al. (2021) with red bell peppers; both demonstrated improved shelf life and quality maintenance in bags made from these compostable polymers.

2.3.2. Improved packaging for reducing damage of fresh produce

Sacks, baskets, or rough wood crates are most commonly used for packing fresh commodities in LMICs, and can cause significant mechanical damage during storage and transport due to their rough surfaces, oversized dimensions, and inability to protect the product from weight stacked on top (Kitinoja and AlHassan, 2012; Faqeerzada et al., 2018). Plastic crates or improved baskets can significantly reduce losses (Stathers et al., 2020), but have difficulty competing with low cost baskets or sacks (Yeshiwas and Tadele, 2021) or are not accessible for smallholder farmers.

Integrating plastic crates into value chains can be complicated in LMICs. Determining which entity or individual should own the crates, establishing a return system for crates, ensuring that the market provides a premium for the higher-quality product in the crates, and negotiating with transporters to load product in crates all factor into the feasibility of crates being integrated into a value chain, along with the smallholder farmer's level of risk aversion and social norms (van Wagenberg et al., 2019).

2.3.3. Case study - Adoption of plastic crates

Traditional handling of tomatoes in Rwanda results in an average loss of 35% of the product after harvest, largely as a result of physical damage (Gill, 2019). *A plastic crate capable of holding 25 kg of tomatoes costs ca $7.00 in Rwanda, and good quality tomatoes sell at wholesale for* ca. *$1 per kg. One trip with a returnable plastic crate would result in an increased income of $8.75 per crate, (assuming that it eliminates the postharvest losses) more than covering the cost of the crate, which can be used multiple times. A farmer with a small-scale vegetable farm recorded postharvest losses of 50 kg a week until he adopted improved grading and sorting practices, purchased 10 crates and stored product in cooler temperatures. These postharvest improvements resulted in his produce being first quality rather than "second-grade"; profit from just his eggplant production increased by $150 in one growing season. The Rwandan Standards Board certifies organizations that meet certain food handling standards including the use of plastic crates, and there are several examples of higher end retailers integrating plastic crates into value chains* (Dijkxhoorn et al., 2016). E*ven within an enabling environment, capital costs for the crates are universally considered a barrier in LMICs that could be lowered through government interventions to encourage low-interest rate loans, reduce tariffs on imported crates, or subsidize local manufacture of crates* (Hosking et al., 2021).

2.4. Edible coatings

Edible coatings for fresh horticulture products have been used for many years to enhance product shelf life (James and Zikankuba, 2017). Edible coatings provide a barrier against gas and moisture exchange on the surface of produce, slowing respiration, senescence, and enzymatic oxidation (Cofelice et al., 2019). Enhanced interest in reducing food loss and waste, as well as in reducing the use of single-use plastic packaging, have fueled a resurgence of interest in edible coatings. Edible organic coatings typically consist of lipids, proteins, and/or polysaccharides (Flores-López et al., 2016). Edible coatings based on *Aloe vera*, mineral oils, polyvinyl acetate, chitosan, cellulose, and protein have shown desirable effects on fresh produce, including reduced decay, without negative impacts on taste (Dhall, 2013); but much of this work remains at the research stage and has not translated into commercial products. For example, bananas coated in 1% chitosan (sourced from shrimp shells) in Bangladesh had a 4-day extension in shelf-life (Hossain and Iqbal, 2016). Papaya coated with 1.5% *Aloe vera* gel, a coating derived from Aloe plants grown in arid locations in many parts of the world, lost 10% less water compared to uncoated papayas, and more effectively preserved quality and key nutrients (Sharmin et al., 2015).

The use of nanotechnology to develop coatings with improved barrier, mechanical, optical, and thermal properties, and improved active properties (antimicrobial), is a new emphasis in coating research (De Oliveira Filho et al., 2022). In recent years, a number of companies have introduced new edible coating products for fresh fruits and vegetables including Apeel™, Mori™ and Sufresca®, among others. The impact of these new products won't be known for a few years as there is little independent research, but it is clear that there is a lot of interest in the produce sector in use of coatings.

There is some question as to the accessibility and feasibility of coating technologies for smallholder farmers in LMICs. Will they have access to purchase coatings locally, and can they afford them? Do they have the means to effectively apply coatings? Will the coatings be as effective or perhaps more effective with poor temperature management?

Most edible coatings can be applied directly onto the surfaces of fresh produce by dipping or spraying, followed by air drying (Tahir et al., 2019); therefore, simple washing and packaging equipment is sufficient for effective use. However, in LMICs, most smallholder farmers do not utilize washing and packing equipment for produce. Investment in washing and coating application equipment, availability and affordability of coating materials, and the regulatory status for different coating materials are currently limitations to commercialization of this technology. In addition, to maximize the potential of these coatings, other foundational postharvest practices and technologies to manage temperature and prevent physical damage, among others, need to also be in place at the smallholder level.

2.5. Genetic modification

Molecular and cell biology approaches have provided important information on factors affecting the postharvest life of perishable crops, and early research demonstrated the power of these technologies in extending postharvest life of perishable products. Oeller et al. (1991) demonstrated that ripening in tomatoes could be inhibited by antisense silencing of genes encoding ACC synthase, and Ayub et al. (1996) demonstrated the same effect in melons by silencing ACC oxidase. Concern about the safety of genetically modified organisms meant that these exciting results remained just research curiosities, but new techniques that eliminate the need for foreign genetic material have led to regulatory approval and release of engineered crops with improved postharvest performance or quality in high income economies. Examples include the Arctic® (non-browning) apple, produced using a sense post-transcriptional silencing approach (Stowe and Dhingra, 2021), potatoes with reduced browning and acrylamide production using 'all native DNA' transformation (Rommens et al., 2008), and mushrooms engineered to reduce browning using the CRISPR-Cas9 gene editing technology (Waltz, 2016).

So far, these powerful tools for improving postharvest life using molecular or genetic approaches have not been applied to the benefit of smallholder farmers in LMICs. Genetic modification of important ethylene-responsive crops such as mango could provide cultivars with extended postharvest life. Many of the important crops for smallholder farmers in LMICs are chilling sensitive, responding negatively to low but non-freezing temperatures. Their potential postharvest life is relatively short because they cannot be stored at temperatures below 10–12 °C. Molecular-genetic approaches to cold response in plants have identified many avenues for investigating and possibly preventing chilling injury. Some researchers have explored transcription factors that appear to be involved in plant responses to low temperature. For example, Yang et al. (2020) found that over-expression of the cold-response C-repeat binding transcription factors from longan fruit improved cold-tolerance of Arabidopsis. Future studies in LMICs could apply such basic research findings to improving the postharvest performance of many important and indigenous crops.

3. Adoption and scale up experiences with solar dryers

The scaling of technologies can be thought of as a series of processes to disseminate technologies and practices through a structured approach, with the goal of equitably increasing the impact of the technologies (Willis et al., 2016). Scaling of solar dryers can be challenging (Boroze et al., 2014), and research examining the efficiency of postharvest technologies has at times failed to capture the potential return on investment for the smallholder farmer (Kitinoja, 2013); a key metric for successful uptake.

Solar drying is competing with open air drying, a traditional method that is cost free. Therefore, researchers need to address the end-users' unique needs, available resources, and potential motivations for adopting a new drying approach. Preservation of fruits and vegetables is not always the overriding factor. For example, Howe (2019) determined that the improved product hygiene that solar dryers offer was a major consideration for smallholder farmers in Nepal. In Guinea, female farmers appreciated the reduction in labor the Chimney Solar Dryer provided, since they found it was much easier to rotate trays than to carry heavy drying tables in and out of a storage area on a daily basis.

An advantage of greenhouse solar dryers is that the units can be used for other purposes when not drying. The disadvantage is that the hot air rises, so these dryers can be inefficient. Active solar drying units that incorporate solar panels and fans provide access to a source of energy for alternative uses (charging cell phones, powering lights) or can be incorporated into evaporative cooling systems. With the cost of these components decreasing and accessibility increasing, active solar drying units could provide unique advantages. Research approaches should consider models for how solar drying units that are not multi-purpose can be more fully utilized throughout the year, rather than based on the seasonality of one commodity. This could be through cooperative ownership models, which lowers capital costs; but the success of a cooperatively owned unit can depend as much on social, organizational, and institutional issues as on the effectiveness of the technology itself (Glover et al., 2019). Additionally, reflecting the complexity of agricultural and food systems, research teams should collaborate across fields, including physical sciences with social sciences, to improve scaling outcomes and sustainability.

Understanding local markets and local consumption patterns for dried horticulture products is essential. Depending on the cost of the solar drying unit being distributed, markets that offer a premium for high-quality, food-safe, dried fruits and vegetables could be crucial for positive return on investment. An analysis of the chimney solar dryer in Bangladesh found that the profitability of the dryer was dependent on the products being dried (Lewis et al., 2017). Even if a minimal local market exists, it is possible for farmers to export their dried goods to larger cities or other countries where the demand is higher; but this depends on the components of market access (market information, trading contacts, transportation systems) being available to the farmer. If dried fruits and vegetables are not part of the typical diets, researchers need to pair technologies with guidance on how the products can be incorporated into meals and are a source of nutrition.

In order to deliver an end-product to market, the scaling of solar dryers demands that technologies are bundled with effective storage methods, tools to determine dryness, and knowledge-strengthening on implementing the dry chain. All components of the dry chain are necessary to produce high quality products and meet users' outcome expectations. Farmers in LMICs often rely on open-air drying, but, particularly in humid climates, this practice is often ineffective (Bradford et al., 2018). Improperly dried products are often also stored in non-hermetic storage, allowing them to reabsorb moisture from the air. The lack of dry chain technology bundles leads to excess moisture content, which drives quality degradation and also increased levels of mycotoxin contamination (De Beuchat, 1983). Aflatoxin, a type of mycotoxin, is considered one of the most toxic natural substances in the world (Ortega-Beltran and Bandyopadhyay, 2021).

As with any technology, the broader enabling environment for uptake of a technology needs to be comprehensively understood. Agricultural systems are complex (Ostrom, 2009), and when components of those systems, such as policies, institutions, and financing, are aligned toward reducing postharvest losses, this would enhance an enabling environment to support technology adoption (Díaz-Bonilla et al., 2014).

4. Postharvest extension and new forms of information dissemination

In many LMICs, the agricultural extension services are underfunded and poorly coordinated (Davis et al., 2020). Specifically, postharvest extension programs and knowledge sharing systems are often lacking in LMICs (Kitinoja et al., 2011; Hewett, 2012). Postharvest training and service centers (PTSCs) are a proven effective extension approach in LMICs, with one program at the World Vegetable Center facility in Tanzania reaching over 22,000 growers in sub-Saharan Africa through a master trainer, train-the-trainer type program (Kitinoja and Barrett, 2015). These centers are strategically located hubs where producers and traders can receive training on proper postharvest practices, access cold storage and drying units, and purchase supplies.

Digital platforms for agricultural extension can be further leveraged to close knowledge gaps in postharvest management. Mobile phones, specifically, can be used as conduits for agricultural extension (FAO, 2017). Mobile phones are becoming more common in smallholder farming communities as noted in a recent survey of smallholder farmers in Kenya which found that 98% of the respondents owned a mobile phone (Krell et al., 2020). Videos, information, and market data

provided through mobile phones can close knowledge gaps in postharvest management of horticultural crops and help farmers make informed decisions (Ali and Kumar, 2011). The effectiveness of the extension information provided in digital media is dependent on its quality and applicability to the end-user (Asasira et al., 2019); but initiatives such as Scientific Animation Without Borders (SAWBO) have noted improved practices when participants are shown animations in local languages of scientifically-based postharvest technologies or practices (Bello-Bravo et al., 2018). There are also locally-driven initiatives such as a smart-phone app being developed by R&D Innovative Solutions in Nepal that will provide commodity- specific maturity indices, ideal storage temperatures, and typical storage times.

Although mobile phones are becoming more and more ubiquitous, scaling or sharing postharvest practices or technologies through the platform needs to be done responsibly, as is the case with all innovations (Wigboldus and Leeuwis, 2013, McGuire et al., 2022). A household in a smallholder farming community may own a mobile phone, but access to the phone may be inequitable between men and women. Inequitable access to information could reinforce inequitable gender roles. An approach used by an organization in Northern Africa to avoid reinforcing inequities was to build a network consisting of women controlling the postharvest information digital platform while exchanging information with interconnected women farmers (El-Neshawy, 2018).

5. Conclusion

The world is facing a confluence of challenges impacting global food security, including climate change, increased input costs, and disruptions to supply chains due both to the pandemic and to the war in Ukraine (Rice et al., 2022). It is critical that postharvest losses and waste in agriculture are rapidly minimized at all levels (small-scale to industrial) and in all geographies to increase access to food. Major achievements have been made in postharvest management, but these advances have not been universally translated across global agricultural systems. To achieve a significant reduction, interdisciplinary expertise is critical in translating postharvest research into agricultural impact. Furthermore, experts in LMICs should play a central role in the development of technological solutions as in-country expertise can be critical in adapting and developing innovations to meet local constraints and opportunities.

This paper presents several innovations in postharvest management introduced in LMICs that have made impacts; however, more comprehensive and systemic impacts are required. For example, we focused on smallholder farmers, but medium-sized operations in LMICs, along with the formation of cooperatives or associations among smallholder farmers, can be conduits for adopting technologies with higher capital costs. Ultimately, greater cohesion and urgency is needed among policymakers, researchers, private industry, sociologists, agro-economists, public sector, local-leaders, among others, to meet this call to action to finally make significant reductions in postharvest losses in LMICs.

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Declaration of Competing Interest

All authors are in some capacity affiliated with the Feed the Future Innovation Lab for Horticulture at UC Davis, either as staff or as voluntary contributors. Furthermore, the authors have all had involvement in the development of several technologies highlighted in this review paper, including the DryCard, the Chimney Solar Dryer, and the Pallet Dryer.

Data Availability

No data was used for the research described in the article.

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Feed the Future Innovation Lab for Horticulture

U.S. State Department Visit to UC Davis Hosted by UC Davis Feed the Future Innovation Labs

(left to right) Attendees of morning presentations on Day one: John E. Kinsella Endowed Chair in Food, Nutrition and Health Professor Li Tian; Distinguished Professor Patrick Brown; Travis Parker; Visiting Professor Fetien Abay ABERA; Professor of Cooperative Extension and Center Director, UC Postharvest Technology Center and Director of Feed the Future Innovation Lab for Horticulture Beth Mitcham; Feed the Future Innovation Labs Chair and Associate Director of the Innovation Lab for Horticulture, Erin McGuire; Associate Director of Feed the Future Innovation Lab for Markets, Risk & Resilience Tara Chiu; Director of Feed the Future Innovation Lab for Markets, Risk & Resilience Michael Carter; Professor and Chancellor's Fellow, Director of Feed the Future Innovation Lab for Genomics to Improve Poultry Huaijun Zhou; and Distinguished Professor

Feed the Future Innovation Lab for Horticulture

Posted by Heather N Hayashi on June 13, 2023

U.S. State Department Visit to UC Davis Hosted by UC Davis Feed the Future Innovation Labs

by Archie Jarman
Editors Heather Hayashi, Alex Russell

This spring, Feed the Future Innovation Labs for Horticulture and Markets, Risk and Resilience had the pleasure of co-hosting U.S. State Department Special Envoy for Global Food Security, Cary Fowler, for a two-day visit at the University of California, Davis. Joining Fowler for his visit were State Department Jefferson Science Fellow, John Leslie, and United States Agency for International Development (USAID) Agreement Officer Representative, Daniel Bailey.

Day one began with learning more about UC Davis plant breeding efforts by the Orphan Crops Program and international Plant Breeding Academy, through engagements with Senior Fellow Howard Shapiro, Associate Director of Plant Breeding Center Allen Van Deynze, and staff of Distinguished Professor Paul Gepts.

Presentations were then given, on the research and development being done to address global hunger and food security through the Feed the Future Innovation Labs (FTFILs) and UC Davis Department of Plant Sciences, by the FTFILs Council Chair and Associate Director of the Innovation Lab for Horticulture, Erin J. McGuire, and Distinguished Professor and John B Orr Endowed Professor in Environmental Plant Sciences and Chair of the Department of Plant Sciences, Gail Taylor.

In attendance, were staff from all three UC Davis-based Innovation Labs, including the Innovation Lab for Genomics to Improve Poultry, along with key faculty and staff from the Department of Plant Sciences, who were all gathered to learn more about, discuss and exchange ideas on how to provide support for the U.S. State Department Vision for Adapted Crops and Soils (VACS) program, an initiative guided by Fowler. Still in its early stages, VACS is anticipated to be a multi-phase initiative focused on building soil health and advancing indigenous crops in Africa. The discussion that ensued was insightful, inspiring, and fruitful.

The remainder of the day was spent in talks with the Innovation Lab for Markets, Risk and Resilience, led by Michael Carter, to learn more about the role crop insurance and financing plays

the keystone findings and results from the lab's research in Kenya, Mozambique, Tanzania, Uganda and elsewhere that can be leveraged to improve food security globally.

Discussing U.S. State Department Vision for Adapted Crops and Soils (VACS) program with UC Davis faculty and staff from Department of Plant Sciences.

"Our guests had important questions about potential solutions to some very hard problems related to food security policy," said Michael Carter, MRR Innovation Lab director and distinguished professor of agricultural and resource economics at UC Davis. "We were able to discuss a number of approaches, many of which seek to address some of the risks for smallholder farmers."

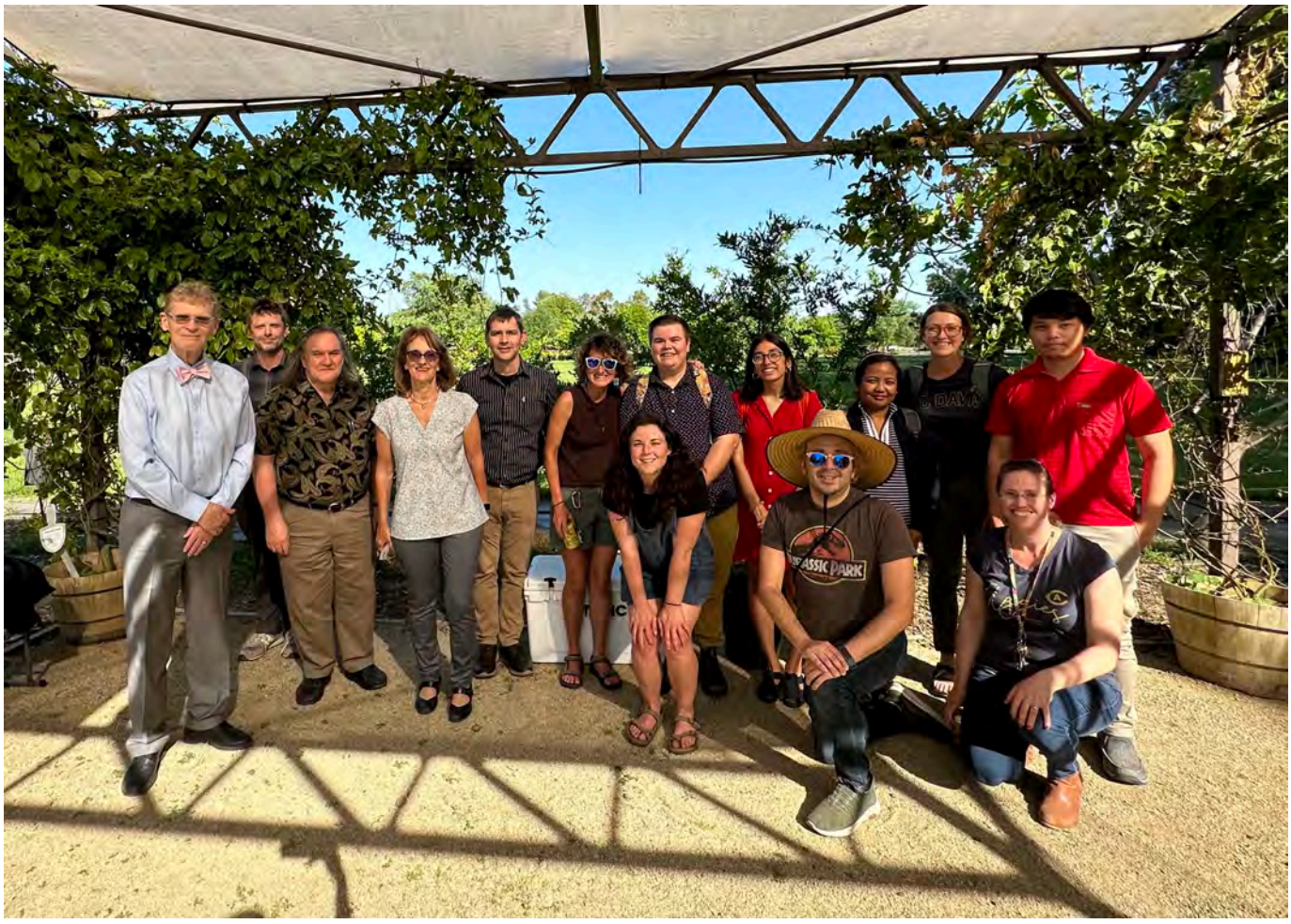
On the second day, the visitors spent their morning with the Innovation Lab for Horticulture, led by Elizabeth Mitcham, and learned more about the lab's new locally-led research project portfolio involving African indigenous fruits and vegetables - directly from project Principal Investigators in Africa via Zoom, in addition to ongoing efforts to improve seed preservation through proper drying.

Morning meeting with principle investigators presenting their research on AIVs in East and West Africa via zoom.

In the afternoon, Fowler was joined by distinguished guests from UC Davis, including Dean of Global Engagement Ermias Kebreab, Professor Douglas Cook, and Director of the Institute for Global Nutrition Christine Stewart, who all provided Fowler information on various international research projects at UC Davis, including those focused on nutrition and chickpea varietal development.

Ending the day, an evening reception was held at the Innovation Lab for Horticulture's Demonstration Center, which included a tour of various technologies at the Center, and was attended by Hubert H. Humphrey Fellows and International Agriculture Development students from UC Davis. Student attendees were able to network and learn from the representatives what a career path within the field of agriculture and international development might be like with U.S. Department of State and USAID.

Daniel Bailey, and look forward to seeing the VACS program develop.



Attendees at the Innovation Lab for Horticulture Demonstration Center tour and evening reception included UC Davis Feed the Future Innovation Lab for Horticulture staff as well as Humphrey Fellows and International Agricultural Development students. (left to right) Carey Fowler, Archie Jarman, John Leslie, Beth Mitcham, Daniel Bailey, Siobhan Rubsam, Kristen Becker, Peter Bowman, Marina Vergara, Matthew Serna, Sushila Thing, Katheryn Gregerson, Arlan Rodeo, Katie Schroeder.

Photo album available at Flickr.

Story shared by UC Davis Department of Plant Sciences.

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- Announcement

Feed the Future Innovation Lab for Horticulture

Small to Medium Farmholders Improving Horticulture Production Through Climate Smart Agriculture

Promoting Small Farm Technologies for Climate Smart Agriculture and Market Access in Guatemala. Image credit: Acceso.

Posted by Heather N Hayashi on August 25, 2023

FOR IMMEDIATE RELEASE

Small to Medium Farmholders Improving Horticulture Production Through Climate Smart Agriculture

[DAVIS] – The Feed the Future Innovation Lab for Horticulture is delighted to announce the launch of three regionally-led initiatives – two research initiatives and one fellowship program – to be coordinated by the Horticulture Innovation Lab's Central America Regional Hub Managers, Julio Lopez, Celia Trejo and Patricia Arce from Zamorano University.

to increase the nutrition and income of small-holder women farmers. Climate change mitigation and adaptation, through protected cultivation and improved soil health, were identified as a priority by the horticulture sector in Central America during a stakeholder meeting in 2022. The three projects and their foci are as follows:

- *Promoting technology for horticulture production for adaptation to climate change in Guatemala* led by Rolando Cifuentes and Catalina Galdamez from the Universidad del Valle de Guatemala (UVG) - will strengthen smallholder farmer sustainability in the Western Highlands of Guatemala by identifying the most effective climate-smart production methods, irrigation schemes, practices to improve soil health, and postharvest technologies. The multidisciplinary approach will be developed by and with women and youth small farmers who produce tomato, potato, green beans, peas, strawberry, broccoli, and edible herbs, among others, for the local market - through a process of "Learning by Doing."

- *Promoting Small Farm Technologies for Climate Smart Agriculture and Market Access in Guatemala* led by José Salvador Vega Prado Leiva with Acceso in collaboration with Edgar Garcia from Rafael Landivar University, Guatemala - will research climate smart agricultural technologies that, when used in combination, will generate rapid returns on investment for producers in the Guatemalan highlands. This research will increase access to viable technologies to build resilience to climate change, while also promoting gender-equity for communities of smallholder farmers.

- *Empowering Young Horticulture Researchers in Honduras* will be led by Julio Lopez as part of the Zamorano Fellowship, a program that provides seed funding to higher-education students in Honduras to conduct small-scale research projects across the horticulture value chain. Students will be guided through a grant drafting and submission training program, while awardees will receive funding and mentorship in the implementation of their research projects.

With many smallholder farmers experiencing the effects of climate change around the world, equitable, climate-smart agricultural practices are critical to build resilience. The projects being initiated in Central America address not only regional but global priorities. "Thanks to the collaboration and cooperation provided by the Horticulture Innovation Lab, these projects," Julio Lopez notes, "will strengthen the horticultural value chains that small producers are developing, in order to place quality and safe products in the market, for food and nutrition security."

Innovation Lab for Horticulture. "Through a focus on climate-smart agriculture and the empowerment of smallholder farmers, particularly women, we're not just addressing immediate needs but building a foundation for sustainable growth and resilience."

For more information about our Research Project Portfolio and collaboration opportunities, please visit ***horticulture.ucdavis.edu*** or contact Associate Director, Archie Jarman at rajarman@ucdavis.edu.

Promoting technology for horticulture production for adaptation to climate change in Guatemala. Image credit: Universidad del Valle de Guatemala (UVG).

Empowering Young Horticulture Researchers in Honduras. Image credit: Zamorano University.


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Initiatives Leading Innovation and Advancement in Global Food Security and Gender Equity

The Feed the Future Innovation Lab for Horticulture at the University of California, Davis, is proud to unveil its new research portfolio as a part of Feed the Future, the U.S. Government's global hunger and food security initiative. The Horticulture Innovation Lab's global research network partners with and promotes local leadership to advance horticulture and social innovations, empowering smallholder farmers to earn more income while better nourishing their communities. This new 3.5-year portfolio comprises of regionally-led research initiatives across East and West Africa, Central America, and South Asia. Research initiatives will be guided by four Horticulture Innovation Lab Regional Hubs based at the International Center for Evaluation and Development (ICED), University of Ghana, Zamorano University, and FORWARD Nepal.

About Us

Feed the Future Innovation Lab for Horticulture, also known as the Horticulture Innovation Lab, is funded by the United States Agency for International Development as part of the Feed the Future global hunger and food security initiative, based at the University of California, Davis, within the Department of Plant Sciences. With a focus on horticultural, social and technological advancements, we develop groundbreaking solutions to improve nutrition and food security. As advocates for innovations and policies that promote gender equity, social and environmental responsibility, we are dedicated to improving the livelihoods of smallholder farmers while empowering communities through horticulture, including better access to nutrition and healthy diets.

For media inquiries contact Communications Manager, Heather Hayashi at hnhayashi@ucdavis.edu.

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