Horticulture Innovation Lab

Annual Report 2013-2014

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2013-14 Annual Report

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Management Entity Information

The Horticulture Innovation Lab builds international partnerships for fruit and vegetable research that improves livelihoods in developing countries. The Horticulture Innovation Lab is managed by a team at the University of California, Davis, in the College of Agricultural and Environmental Sciences, under the Department of Plant Sciences with support from the International Programs Office. The Horticulture Innovation Lab has been funded by the U.S. Agency for International Development (USAID) since October 2009.

The partnerships we support cross borders to strengthen horticultural value chains. Horticulture Innovation Lab projects provide critical information for development professionals on how to better enrich diets and increase incomes. Horticulture —growing fruits and vegetables—provides critical nutrients for a balanced diet. Not eating enough fruits and vegetables is a major factor in some of the world's most widespread and debilitating nutrient-related disorders. Farmers growing high value crops, such as fruits, vegetables, flowers or herbs, consistently earn more than those growing other commodities. Horticulture can be an engine for agricultural and economic diversification. All Horticulture Innovation Lab projects include aspects of gender equity, improved information access, and technological innovation. In the past four years, we have supported 40 research projects with 15 U.S. universities and over 100 organizations. The Horticulture Innovation Lab management entity is located at University of California, Davis. Our team is comprised of the following personnel:

<u>Leadership</u>

- Elizabeth Mitcham, Director
  Dr. Elizabeth (Beth) Mitcham is a postharvest biologist and extension specialist with the Department of Plant Sciences at UC Davis. Her research program is focused on maintaining the quality of fruit after harvest, mechanisms of calcium deficiency in fruit, and postharvest insect control.
- Amanda Crump, Associate Director
  Amanda Crump leads the gender equity and monitoring and evaluation programs. Her research interests include the development of novel agricultural extension education practices that impact farmers, particularly women.
- Michael Reid, Leader of Implementation of Innovative Technology and Special Projects
  Dr. Michael Reid is a professor and postharvest extension specialist emeritus in the Department of Plant Sciences. Specializing in postharvest handling of ornamentals, he has worked with flower growers in Africa, Latin America and Asia. He was recently inducted into the California Floriculture Hall of Fame.
- Mark Bell, Leader of Communications and Information Transfer
  Dr. Mark Bell is also the director of the UC Davis International Learning Center. Before joining UC Davis, he was head of both International Programs and the Training Center at the International Rice Research Institute (IRRI) in the Philippines.

<u>Accounting and fiscal management</u>

- Heather Kawakami, Budget Analyst
  Heather Kawakami is also the business unit manager for the Department of Plant Sciences.

- Sara Saberi, Budget Analyst
  Sara Saberi is also an account manager in the Department of Plant Sciences.

Programmatic and administrative support

- Britta Hansen, Regional Centers of Innovation Specialist
  Britta Lilley Hansen holds a master's degree in Development Practice. She previously worked in nutrition research at the University of Minnesota and has served with the Peace Corps in Liberia and Bolivia.
- Diana Puccetti, Office and Event Planning Assistant
  Diana Puccetti is a Certified Government Meeting Planner (CGMP). She is currently pursuing a B.S. in Technical Management and has previously worked in municipal government.
- Brenda Dawson, Communications Coordinator
  Brenda Dawson has communicated on behalf of the UC Small Farm Program, UC Division of Agriculture and Natural Resources, and UC Davis University Communications. She previously worked as a newspaper editor.

International Programs Office

- Jim Hill, Associate Dean
  Dr. Jim Hill is the associate dean of the UC Davis College of Agricultural and Environmental Sciences.
- Chelo Abrenilla, Analyst / Supervisor
  Rachel (Chelo) Abrenilla provides support to Horticulture Innovation Lab as an analyst and supervisor in the International Program Office.

Students

- Namho Kim, Graduate Assistant
  Namho Kim is pursuing a master's degree in International Agricultural Development and Agricultural and Resource Economics.
- Owen Cortner, Graduate Assistant
  Owen Cortner is pursuing a master's degree in International Agricultural Development.
- Azia Hasan, Undergraduate Assistant
  Azia Hasan is pursuing a bachelor's degree in American Studies, with a minor in Social and Ethnic Relations.

Special projects staff

- Amrita Mukherjee, Junior Specialist
  Amrita Mukherjee is the junior specialist on the Horticulture Innovation Lab project for sustainable potato storage in Bangladesh, in partnership with the International Potato Center (CIP). She holds a master's degree in biotechnology and most recently worked for the International Rice Research Institute (IRRI).

Contact Information

The Horticulture Innovation Lab office is located in room 190 of the Environmental Horticulture buildings on the University of California, Davis campus.
Our mailing address is:

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We can be contacted via the following means:

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- YouTube: http://www.youtube.com/user/hortcrsp
- Flickr: http://www.flickr.com/hortcrsp/

Technical and/or Advisory Committee Information

The Horticulture Innovation Lab's International Advisory Board (IAB) is the program's senior advisory council. The IAB appoints the technical review panels for Horticulture Innovation Lab projects and reviews the panelists' recommendations to ensure that Horticulture Innovation Lab priorities are met and integrated for maximum effectiveness. The IAB helps set priorities, allocate the budget, and ensure that USAID, Global Horticulture Assessment and Horticulture Innovation Lab objectives are met.

Members of the International Advisory Board

J.D.H. Keatinge, Ph.D.

- Dyno Keatinge is an agronomist and holds a Doctorate in Agriculture from Queen's University, Belfast, Northern Ireland and is Visiting Professor of Tropical Agriculture at The University of Reading, UK. He has global expertise in crop agronomy and he has worked at many of the CGIAR Centers including ICARDA in Syria, Pakistan and Turkey, IITA in Nigeria and Cameroon and ICRISAT in India and several countries in sub-Saharan Africa. He also was Professor of Agricultural Systems and Management at Reading University in UK for much of the 1990s and claims to have worked professionally in every continent on earth except Antarctica! Presently, he is Director General of AVRDC – The World Vegetable Center based in Taiwan, Chairman of the Global Horticultural Initiative, and a member of the Horticulture Innovation Lab's International Advisory Board.

Josette Lewis, Ph.D.

- Josette Lewis is associate director of the UC Davis World Food Center. She previously worked with Arcadia Biosciences to expand the company's licensing and partnerships, particularly in developing countries. Prior to joining Arcadia, Dr. Lewis spent sixteen years with the U.S. Agency for International Development. Most recently, she served as Director of the Office of Agriculture, where she played a leadership role in the development of the Administration's global initiative on food security; development of a new strategy for agricultural research, and initiated numerous new partnerships with universities, agricultural companies, and non-governmental organizations in the U.S. and developing countries.

Julio López Montes

- Julio López is a plant protection specialist and leads classes in integrated pest management and entomology as a professor at the University of Zamorano in Honduras. He is also the director of the Horticulture Innovation Lab Regional Center at Zamorano. Professor López has mentored students and participated in several courses on IPM in vegetables, fruits and grains crops at Zamorano, and at other Nicaraguan and Honduras agricultural universities. He also works with the extension of information in IPM, Farmer Field School methodology and alternative technologies for pest control for producers, handlers and consumers. He has been involved in several scientific publications in IPM, vegetable crop production, and pest management for farmers. He is also a member of the IPM Network for Central America, the Pest Plant Protection Network of Nicaragua and the National IPM Committee of Nicaragua.

Bob Nanes

- Bob Nanes is the Vice President of Technology and Innovation for International Development Enterprises (iDE), based at the organization's international headquarters in Denver, Colorado. As such, he is in charge of the Technology and Innovation Group, responsible for product development, international procurement, program development, and fostering innovation. He has worked with iDE in various capacities beginning in 1986, including leadership positions with the organization in Ghana, Nepal and Bangladesh. He holds a bachelor's degree in agricultural engineering from Cornell University.

Robert Paull, Ph.D.

- Robert Paull has been a Professor and Researcher in Plant Biology at the University of Hawai'i at Mānoa since 1985. Prior to receiving a PhD in plant physiology at UC Berkeley, Paull was a field agronomist in Australia doing cotton production research. He has served as a consultant to commercial companies, as well as national and international horticulture programs. His international experience includes Bulgaria, Cambodia, China, Colombia, Costa Rica, East Timor, Jamaica, Laos, Malaysia, Philippines, Taiwan, Thailand, Trinidad, Vietnam and the West Bank. Paull's area of research is in postharvest handling and storage of tropical fruits, vegetables and ornamentals, especially the impact of preharvest and postharvest factors on commodity quality. Current research involves changes in the gene expression of plant growth regulators and cell wall enzymes during abscission and fruit ripening. He has co-authored four books and co-edited an additional five, including the Encyclopedia of Fruits and Nuts and numerous peer-reviewed journal articles, conference papers and extension publications. Paull serves as an associated editor on two journals.

Idah Sithole-Niang, Ph.D.

- Idah Sithole-Niang is a professor in the University of Zimbabwe's Department of Biochemistry and a board member with the African Agricultural Technology Foundation (AATF). She holds a doctoral degree in biochemistry from Michigan State University. Her primary research specialty is in genetic improvement of cowpea, and she is particularly interested in working to improve livelihoods of smallholder farmers in developing countries.

Sally Smith, Ph.D.

- Professor Sally Smith is an Emeritus and Adjunct professor in the School of Agriculture, Food and Wine at the University of Adelaide, South Australia where she continues to carry out research on the roles of mycorrhizal symbioses in plant nutrition and growth, particularly in relation to phosphorus uptake in crop plants. She was educated in the UK and holds a PhD from Cambridge University and a DSC from the University of Adelaide. She is a fellow of the Australian Academy of Science and the recipient of both the Prescott and Taylor medals of the Australian Soil

Science Society. She is a former Board Member and Vice Chair of the Board of the AVRDC-The World Vegetable Center and a keen home vegetable grower.

Detlef Virchow, Ph. D.

- Detlef Virchow is the executive secretary of the Global Horticulture Initiative (GlobalHort) and also serves as project coordinator for the research program "Improving food security in Africa through increased system productivity of biomass-based value webs (BiomassWeb)" at the Center for Development Research ZEF-Bonn at the University of Bonn in Germany. He holds a doctoral degree in agricultural economics from the Christian-Albrechts University of Kiel in Germany. Virchow formerly worked as the executive manager of the Food Security Center at the University of Hohenheim in Germany and as director for the AVRDC Regional Center for Africa in Tanzania. His interdisciplinary research has included a variety of food security-related topics, including nutrition-sensitive agriculture, African indigenous vegetables and crop diversity.

On the 21st of March 2014 the International Advisory Board for the Horticulture Innovation Lab met in Tegucigalpa, Honduras. Three new members of IAB were introduced to the team; Bob Nanes from iDE, Idah Sithole Niang from the University of Zimbabwe and Detlef Virchow from Global Horticulture Initiative.

Several recommendations were made by the IAB about how to best further the efforts of the Horticulture Innovation Lab to position itself as a thought leader in global horticultural development; the IAB agreed that there needs to be more rigorous standards on how each research project furthers the goals of the Horticulture Innovation Lab. They agreed that the management entity should break down the goal objectives into a more accessible format for the investigators.

In addition, the IAB identified the following three objectives: innovative research, capacity building, and scaling-up as key foci. With respect to successful scaling-up, the IAB recommended outlining a clear pathway to achieve scale, influence policy, utilize the regional centers as a toolbox, and use training. Evaluation of the impact of a project after completion was also recommended to define the right pathway to scaling-up. Actions discussed to achieve the recommendations included clearly defining research hypotheses with rigorous research designs, making strategies to influence policies by funding policy research, and building capacity for partners through conversation with policy makers.

The Regional Centers' role as a place for cross-continental learning and building training models was emphasized as well. The IAB identified nutrition as a significant area where the Horticulture Innovation Lab can provide leadership. The weak linkage between improved horticultural production and improved horticulture consumption and nutrition should be addressed by studying markets.

The second part of the agenda was recommendations for phase two. The IAB agreed that the Horticulture Innovation Lab should support a balance of focused technology development projects as well as integrating larger scale projects. To identify research topics, the IAB recommended considering priorities in the regions using needs assessments and regional

partners, building on successes from phase one and building connections with nutrition partners. It was recommended that new projects be 5 years in length, with strong justification for why the pieces along the chain should be integrated.

Program Activities and Highlights

Now in its fifth year, the Horticulture Innovation Lab continues to advance horticultural science in developing countries by increasing capacity and information access while solving problems along horticultural value chains, with emphasis on gender empowerment, technological innovation, income generation and nutrient-rich crops.

Description of Actual FY14 Activities and Results

- The Horticulture Innovation Lab funded 16 projects in 16 countries during FY14, across a variety of fruit and vegetable crops and at various stages in the value chain.
- Our projects trained 6,750 farmers. Nearly 4,400 farmers adopted new technologies. Nearly 70% of trainees were women.
- The Horticulture Innovation Lab completed a third round of its Trellis Fund projects, training 2,473 farmers while building capacity for graduate students and supporting the needs of organizations in developing countries.
- The program's research has received buy-ins and recognition in several ways. Other organizations have chosen to invest in technologies we've promoted, such as the CoolBot and chimney solar dryer for projects in Kenya, Bangladesh, Tanzania, and Uzbekistan. A second student in our program won the BIFAD Award for Scientific Excellence.

Successes during FY14

- A project success: A project to improve postharvest in Zambia was so successful that DFID has invested $1 million to design and build a packinghouse and cooling facility for Zambian farmers.
- A project success: The chimney solar dryer, designed by UC Davis partners, has now been widely tested in Uzbekistan, and is in use with leafy greens in Kenya, apricots in Pakistan, and an array of products with women home gardeners in Bangladesh, including coconut, mango, banana, and cabbage.
- A project success: Partners in Cambodia formed 12 savings groups of farmers (83% women) with an average of $1,317 savings per group in one year. Selected investments included agricultural nets, with aspirations of making the nets locally.
- A project highlight: Researchers found that when Kenyan farmers are able to invest in postharvest handling and bring African indigenous vegetables to market quickly, they are indeed able to charge higher prices, especially for spider plant.

Challenges during FY14

- Cultivating relationships with some USAID Missions has been an ongoing challenge. To address this problem before projects begin implementation in FY15, we are dedicating funds for the program's leadership to travel with new project teams to meet with each Mission to form a solid foundation for collaborative research work over the next five years.

Description of expected FY15 activities

- The Horticulture Innovation Lab will launch its second phase in FY15, beginning five-year projects on gender equity, postharvest, and nutrition that will provide vital research useful to development practitioners. The program will fund expansions of

three previous projects and scaling of two technologies. Indicator targets will be set with the new projects.

Research Program Overview and Structure

Horticulture is the production, postharvest handling and marketing of fruits, vegetables, herbs, spices and ornamental plants. Investment in horticulture is important because of the close link between poverty and hunger and malnutrition. Horticultural development offers the opportunity to meet food needs and improve nutrition and human health in the developing world, while providing prospects for income diversification and consequent economic and social advancement of the rural poor. In addition, women are in many cases the main producers and marketers of horticulture crops, so increased horticultural production often leads to an improved income stream for women and their children. Horticultural crops such as green leafy vegetables, tree nuts, and orange fleshed sweet potatoes contain key vitamins and micronutrients. Increased horticultural production can help reduce the nutrient deficiencies that lead to decreased cognitive development in young children and as a result reduce adult economic and social potential. Typically, horticultural crops are both highly nutritious and economically valuable. Horticultural research is crucial to enable small-scale producers to overcome agronomic and market barriers and realize the benefits offered by horticultural development.

The Horticulture Innovation Lab is committed to transparency, and particularly to open competition for awards. The purpose of each call for proposals is different, but each call has been open to all persons with PI status at public universities with the exception of continuation and focus projects which were targeted to investigators who had already received Horticulture Innovation Lab funding on previous proposals. A concerted effort is made to target Historically Black Colleges and Universities (HBCU) and Minority Serving Institutions (MSI) when RFAs are released.

The Horticulture Innovation Lab has funded seven types of subawards to date, each with a different size and scope of activities. The seven subaward types are: Immediate Impact Projects (IIPs), Exploratory Projects (EPs), Pilot Projects (PPs), Comprehensive Projects (CPs), Continuation and Focus Projects (FPs), and Trellis Fund Projects. There is a specific rationale for each type of project.

Immediate Impact Proposals (IIPs): Leveraging shovel ready horticultural proposals to the USDA and their respective PIs, the Horticulture Innovation Lab seized the opportunity to hit the ground running with their first set of 15 projects. These projects were funded up to $150,000 for one year. This relatively modest sum was committed to the projects in order to use existing connections or research to make an immediate impact in a short period of time. The wide net of 15 projects also allowed the Horticulture Innovation Lab to gain valuable experience about working with the projects and gain more perspective about our relative strengths.

Exploratory Projects (EPs) were the next set of projects and were funded at $75,000 for one year. Through our first set of projects the Horticulture Innovation Lab recognized that many researchers in the U.S. and in developing countries have the interest and capability to conduct appropriate research and training programs, but have not developed the teams or the background information/proof of concept that would ensure success in an application for a more long-term, involved project. The intent of the Horticulture Innovation Lab Exploratory Projects was to provide funding that would encourage formation of such teams

and the acquisition of background or preliminary information that could provide the basis for a more comprehensive long-term project.

Pilot Projects (PPs) were a longer-term source of funding for awards of up to 3 years duration at up to $500,000. These projects were more comprehensive in nature and were asked to conduct research that addressed one or more of the three themes of the Horticulture Innovation Lab: building local scientific and technical capacity, applying research findings and technical knowledge to increase small producers' participation in markets, and facilitating the development of policies that improved local horticultural trade and export capacity. Our prior experience with IIPs and EPs allowed us to successfully evaluate valuable projects for committing this larger investment. PPs needed to demonstrate prior or initial problem analysis and include benchmarks for evaluation of performance. Some were developed out of the original IIPs. As these proposals were larger in scale and scope, funded projects were crosscutting and interdisciplinary. Moreover, all proposals were required to include a training and education component, and to demonstrate how successful completion would not only facilitate the participation of the rural community in the horticulture value chain, but would also build research and/or training capacity in the target country or region.

The Comprehensive Projects (CPs) were a response to direct feedback from the International Advisory Board and from USAID that encouraged us to commit our remaining funding to more long-term comprehensive projects. These projects were expected to consider the entire system within the chosen topic area, but focus the greatest attention on bottlenecks within that system. The four topic areas were Seed Systems, Postharvest, Orange fleshed Sweet Potato and African Indigenous Vegetables. From our past experiences, we knew the value of collaboration and encouraged PIs that had previously worked with Horticulture Innovation Lab to consider collaborations with other Horticulture Innovation Lab PIs and collaborators with needed expertise for their proposal, as well as PIs and collaborators not currently associated with the Horticulture Innovation Lab.

Focus and Continuation Projects (FPs) were targeted proposals that were born from successes in past projects or identified bottlenecks in current projects. As these projects targeted particular issues or audiences they were not open to competition. However, it should be noted that not every continuation or focus project solicited was funded. These projects were funded at different levels and for different periods of time depending on the identified needs.

The Trellis Fund sub-awards program allows the Horticulture Innovation Lab to directly develop the capacity of US graduate students and in-country organizations by connecting them with one another to work collaboratively on a small project identified by the in-country organization. These very small competitive grants ($2,000 to the organization for a period of 6 months plus US graduate student travel costs) enable developing-world organizations (DWOs) to empower smallholder farmers with new information as well as build longstanding relationships between DWOs and U.S. researchers. The Trellis Fund was created with the belief that small organizations can do significant work, especially where they have strong ties to the community, but they are often excluded from grant opportunities because of economies of scale. We also believe that U.S. graduate students are

motivated and can leverage their resources to assist organizations in their activities and will be encouraged to carry international work into their research and professional futures through this project.

Research Project Reports

Theme A - Seed systems and Germplasm

Project 1

Seed Systems – Improving Seed Quality for Smallholders

Description:
This project builds on a completed immediate impact project "New Technology for Postharvest Drying and Storage of Horticultural Seeds" by Kent J. Bradford from University of California, Davis.

Improving the ability of smallholders to access high-quality seeds of improved varieties of horticultural crops is fundamental to increasing productivity and incomes. Traditional seed production and storage methods in humid tropical regions without temperature and moisture control result in rapid deterioration of seed quality.

With collaborating institutions and partners, this project demonstrated and implemented a novel seed drying and storage technology (desiccant drying beads) that can dramatically improve seed quality and longevity for smallholders in tropical climates. The project objectives are to:

- Organize international workshops, in collaboration with Horticulture Innovation Lab's Regional Centers of Innovation, to publicize the availability of drying beads, to solicit additional local cooperators and to explore additional applications in germplasm conservation and dried horticultural products;
- Conduct socio-economic and technical analyses of the horticultural seed production, distribution and marketing value chains in focus countries to identify critical points where seed quality is at risk;
- Provide technology support and on-site advice to assist cooperators in establishing improved seed production, storage and utilization procedures in their own operations or among their stakeholders;
- Establish sustainable, market-based systems for enabling local adoption of improved seed production, handling, storage and distribution procedures;
- Build local technical capacity through extension educational programs focusing on producing and maintaining high seed quality; and
- Enhance economic opportunities for women, who represent the majority of workers engaged in horticultural seed production, preservation and utilization.

This comprehensive project will disseminate a novel, economical and appropriate technology to improve seed quality and enhance the horticultural value chain, particularly in humid climates.

Collaborators:

- Luke Colavito, International Development Enterprises (iDE), Nepal
- Jwala Bajracharya, Nepal Agricultural Research Council (NARC), Nepal
- Indra Raj Pandey, Center for Agricultural Policy Research, Extension and Development (CEAPRED), Nepal

- Roger Day, CABI Africa (Centre for Agricultural Bioscience International), Kenya
- Keshavulu Kunusoth, Acharya N G Ranga Agricultural University, India
- Johan Van Asbrouck, Rhino Research, Thailand
- Ganesh Shivakoti, Asian Institute of Technology (AIT), Thailand

Achievements:
Collaboration with other Horticulture Innovation Lab Projects: PI Kent Bradford organized a training program for another Horticulture Innovation Lab project led by James Nienhuis on vegetable seeds at Madison, Wisconsin from Aug 14-17, 2013. This seed project centered in Central America is titled "*Semillas de Esperanza*". PI Bradford recently met with Jim Nienhuis, who reported that participants in the Drying Beads workshop in Madison were using the technology to store vegetable seeds produced through their project. We also collaborated with another Horticulture Innovation Lab project on African Indigenous Vegetables (AIVs) led by Dr. Steve Weller at Purdue University. Our collaborators in Kenya have provided two trainings to researchers at Karamega KARI, Academic Model Providing Access to Healthcare (AMPATH) and leader farmers to help them preserve seeds of AIVs using Drying Beads.

Research in Nepal: The desiccant seed drying experiment on foundation maize seed was implemented by the end of 2013 at HMRP/CIMMYT Nepal with involvement of NARC. Continuous monitoring of seed eRH showed that beads reduced MC of maize seeds from 13% (60% eRH) to 8.2% (32% eRH) in 9 days and became stable by 11 days. HMRP/CIMMYT noted, "Corn seed moisture was significantly reduced by using the beads due to 'additive' drying after classical drying." Encouraged by these results, CIMMYT set up another larger scale drying experiment at National Maize Research Program (NMRP), Rampur, Chitwan in Feb 2014. A larger scale bead drying experiment was set up at SEAN (Seed Entrepreneurs Association of Nepal) at Kathmandu. Beads lowered seed equilibrium relative humidity (eRH) from 58% to 22% after 5 days in Superbags. Seed companies and our collaborators were convinced that the beads can dry larger seed quantities using Superbags in a static system and that low seed moisture can be maintained following drying as long as the containers are waterproof. We are now pursuing the commercial-scale demonstration of drying and proper packaging at seed production co-operatives in Rukum. More studies on efficacy of drying beads were implemented with various partner institutes including CEAPRED, NARC, Nepal National Genebank, Community Seed Bank (CSB). In general the results of the experiments show positive impacts on reducing the eRH of drying beads despite the variation of results by region and species of seed.

Research in Bangladesh: The activities designed and budgeted for Bangladesh were for two years. During this time iDE has worked with seed producers, local seed companies and seed retailers. According to the activity plan agreed with Horticulture Innovation Lab, iDE tested and extended this technology to stakeholders on a small scale. iDE has recently introduced the bead technology to national level seed companies and Bangladesh Agricultural Research Institute (BARI) to increase awareness of the technology and gain endorsement at the government level. iDE has been involved with BARI through the AgLearn project administered by AIT, Bangkok. During this period, iDE has been reporting on the activities

with medium and large seed companies. It is anticipated that the results from BARI will be reported in next semester.

Research in India: The Drying Bead technology was showcased at the National Industrial and Agriculture Exhibition at Butwal, held during December 24, 2013 to January 5, 2014. An estimated 100,000 people observed the bead technology from outside the booth.

Research in Kenya: CABI was invited to participate at the Annual Congress of Seed Trade Association of Kenya (STAK) and AFSTA Congress 2014. CABI exhibited the bead technology at the 2nd STAK Congress and Expo at Safari Park Hotel Nairobi from November 6- 8, 2013. The theme of the Congress was "Embracing Novel Technologies for Agricultural Solutions" which was attended by STAK members, delegates from the national seed associations (AFSTA members) from Uganda, Tanzania, Malawi, Zambia and Ethiopia, the United Nations Food and Agricultural Organization (FAO), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Universities (both local and international), CIMMYT, KARI, Syngenta International, BAYER, students and farmers and other stakeholders.

Lessons learned:
Seed production is undertaken under three systems: the contract seed system, quality declared seed production and the informal seed production system. Under the contract seed system, the seed producers receive inputs and produce the seed which is eventually purchased by the company for bulk packing and sale to the agro-input dealers for final sale to the seed users. At the company level, measures need to be in place to assure quality by use of a number of drying, bulking and storage methods that improve seed quality. In the case of the contract system, quality control can be assured given the supervision of the technical experts who encourage use of good agricultural practices. Thus, quality of seed is at risk at two levels: farm level and company level. At the farm level, requisite drying facilities may be inadequate due to delays in purchases by the companies. If the seeds are not dried well, seed quality deteriorates during transportation to the company and at storage before selling the seed to stockists or agro-dealers. In this case, opportunities exist for the use the drying and storage technology on a rotational basis with contracted farmers. Quality of seed is also at risk at stores of the seed company and seed stockist. At the company level, the seed may still be in the original package of the producer but it needs to be packaged using water-resistant containers that will be used to store and distribute at the seed stockist level. From the seed company end, there is need of good drying and storage facilities that will ensure that the seeds do not increase in seed moisture in transit to the seed stockists/ traders or while in the seed stockists' shops pending purchase by the seed users. This means that storage has to ensure that there will be no increase in seed moisture which causes deterioration in the quality of the seed. Given the production of high quantities of seed by seed companies, it is possible to sustainably use the repeatedly reusable desiccant beads for drying and storage.

For the quality declared seed production which is found in Tanzania, where quality control is undertaken by the Tanzania Official Seed Certification Institute, it would be necessary for the groups involved to be trained on good harvesting, drying, packaging and storage

methods. This may involve group sharing of the available drying facilities. The storage could be undertaken using hermetic containers and other facilities that assure no entry of moisture into the seeds. In this case, the quality of seed is at risk at the individual farmer level as the farmers are involved in seed production. In the informal seed production system, the quality of seed is at risk during the drying process and during storage. For all the seed production systems, seed quality is at risk at the stores due to lack of adequate drying and hermetic packaging.

Capacity building:
Throughout the project ten institutions, agencies and organizations were in direct cooperation. 118 professionals from the host countries attended workshops. 18 host country professionals have involved in providing training to other host country professionals. 15 professionals from host countries were involved in the research activities.

Presentation and publications:

- Peter J. Nassari of TOSCI, Tanzania, currently collaborating with CABI, Kenya had earned MS degree under supervision of co PI Keshavulu Kunusoth at ANGRAU, Hyderabad, India. His research work has been published in American Journal of Research Communication.
- Nassari PJ, Keshavulu K, Rao M, Chandra Shekar Reddy K, Raheem A. 2014. Postharvest drying of tomato (Lycopersicon esculentum Mill) seeds to ultralow moisture safe for storage using desiccant (zeolite) beads and their effects on seed quality. American Journal of Research Communication, 2(4): 74-83. www.usa-journals.com, ISSN: 2325-4076.
- STAK Congress 2013.
- An article targeting AFSTA audience was revised and submitted. The revised article has been accepted by AFSTA for publication in three outlets, that is, AFSTA E-Review (March edition), Daily Nation Newspaper in Kenya and MESHA website (www.wfsj.org/mesha). (not yet uploaded at AFSTA site)
- CABI in Africa Newsletter 2013/14 ((www.cabi.org/news-and-media/2013/newsletter-cabi-in-africa-201314/).

Theme A - Seed systems and Germplasm
Project 2
Semillas de Esperanza

Description:
Acute poverty and meager economic opportunities exist in many rural regions of Central America. Vegetable and seed production are technology-driven economic activities that can significantly contribute to economic growth in communities and families, and specifically provide new opportunities that contribute to the economic empowerment of women. The factors limiting this horticultural transformation are access to:

- vegetable cultivars with resistance to endemic diseases
- high quality seed of adapted cultivars
- business know-how and basic management and marketing skills
- connections to regional supply chains that provide stable, predictable markets

Cultivars developed by the World Vegetable Center (AVRDC) have demonstrated tolerance to diseases endemic to Central America. Quality seed can be produced in the tropics in screen houses. The UW Center for International Business Education and Research (CIBER) is a small business incubator. Hortifruti is the dominant regional purchaser, distributor and marketer of vegetables. The supply chain benefits include:

- families and women's groups develop technology-based seed and vegetable production businesses within each country
- access to high quality seed of adapted cultivars reduces risk, minimizes losses and increases profitability in sustainable production for growers, cooperatives, and women's groups
- increased consumption of vegetables contributes to a healthier, more diverse diet

Collaborators:

- Drs. Peter Hanson and Paul Gniffke, World Vegetable Center (AVRDC), Taiwan
- Dr. Victor Cabrera, University of Wisconsin, USA
- Doris Hernanadez and Edgar Ascensio, CARE, El Salvador
- Ana Gloria Marin, Leader of women's group in Usulutan, El Salvador
- Claudia Eugenia Flores de León, Guatemala
- Martha Moraga, Maria de los Angeles, Francisco Salmeron and Tomas Laguna, Universidad Nacional Agraria, Nicaragua
- Dr. Javier Diaz, Director of Research, Fundacion Hondureña de Investigación Agricola, Honduras

Achievements:

- The project developed networks among a diverse array of cooperators in the Central American regions.
- UW-based workshops were the highlights of the project since they were very successful as well as cost-effective.

- We were, as a group of collaborators, successful in getting AVRDC seeds distributed to the project countries. It was not a minor achievement based on the complex protocols, politics and regulations in each country for the importation of seed.
- We developed a protocol for evaluation of the genetic materials.
- The biggest success and impact of this project was to introduce, evaluate and identify new tomato and pepper cultivars that possessed resistance to the white-fly transmitted Gemini viruses.
- Commercial seeds that are resistant to the virus are so expensive that it precludes their use by women's cooperatives in rural areas. The project was successful in introducing high quality virus resistant tomato cultivars to women's cooperatives in each country.
- The original intent of the project was to have the women's groups not only produce seed but also sell the seed as a local distributor. However, due to the complexity of seed business and laws, the model has shifted to produce and selling seedlings instead of seeds.
- From cooperation with Kent Bradford from UC Davis, we introduced the drying beads to preserve seed quality. Several workshops were held at UW-Madison and in Guatemala and El Salvador regarding usage of the drying beads.
- Collaboration with another Horticulture Innovation Lab project has been made. The objective of the collaboration is to develop a value-added and unique business model in which the women's group would sell grafted seedlings. We started the training and technology transfer in tomato grafting technology, but to make this successful we need to partner with the regional center at Zamorano and focus on regional training.

Capacity building:
We organized training sessions held at the University of Wisconsin campus in August of 2011, 2012 and 2013 focusing on greenhouse production, business development and seed technology respectively. The 28 people participated in 2011, 30 in 2012 and 12 in 2013. Each fall or winter we organized regional training sessions attended by 4-5 persons from each participating country in Honduras, Nicaragua and Costa Rica focusing on germplasm evaluation, seed production and processing and greenhouse management respectively. Raul Guerra, a student from Nicaragua, successfully completed his M.S. degree in Plant Breeding and Genetics and returned to Nicaragua to work in vegetable cultivar development in cooperation with the Universidad Nacional Agraria in Managua.

Lesson learned:

- Working in four countries often created a logistical nightmare and undue complexity in coordination, planning and execution. It would have been much easier if we had focused on one or more countries and the personnel and cooperatives there. However, in spite of the complexity of this project, each of these disparate organizations played a unique role in this project and were often complementary.
- Listen and learn from cooperators. The business model shifted from seeds to seedlings, this was an initiative not just from our cooperators, but from the women's cooperative and groups themselves.

Presentations and publications:

- Guerra, Raul. 2013. Participatory varietal selection and post-harvest evaluations of tomato genotypes with resistance to yellow leaf curl virus. M.S. Thesis. Dept. of Horticulture, University of Wisconsin, Madison, WI
- Guerra, Raul. and J. Nienhuis. 2013. Tomato breeding for virus resistance in Central America. Annual meeting of the American Society for Horticultural Science, July 22-25, Palm Desert, CA pp. 82.
- Ramirez, Carlos Vinicio, and J. Nienhuis. 2012. Crecimiento y productividad del tomato bajo cultivo protegido en tres localidades de Costa Rica. Revista InfoTEC. Instituto Tecnologico de Costa Rica. Sta. Clara, San Carlos, Costa Rica
- Duran Huertas, Katherine. 2014. Evaluacion de patrones con Resistencia a Ralstoia para produccion de tomate injertado. Tesis de Ingienero Agronomo. Instituto Tecnologico de Costa Rica. Sta. Clara, San Carlos, Costa Rica (in progress)
- Seeds of Hope, Literally. Wisconsin Magazine for the Life Sciences, spring 2014 pp 9-10. This is a University of Wisconsin Publication which had a nice article about our Horticulture Innovation Lab project 'Seeds of Hope'.

Theme B: Sustainable production of horticultural crops

Project 1

Demonstrating nets and floating row covers: Benin, Kenya

Description:
Rapid urbanization in Sub-Saharan Africa (SSA) has resulted in an increase in demand for food. Almost 33% of the SSA population, close to 200 million people, is undernourished (FAO, 2006). Fruit and vegetable consumption in SSA remains 22-82% below the intake value threshold of 400 g/day recommended by the World Health Organization and Food and Agriculture Organization. This severe malnutrition leads to many chronic diseases among the population. Vegetable growers, mainly smallholders, are poor and have no access to inputs for improved germplasm, pest and disease control tools, or improved crop production techniques. Vegetable farms are routinely devastated by pests and extended drought conditions.

We harnessed alternative pest management techniques, micro-climate modifications, and growers' education and training to improve small-scale vegetable production in East and West Africa. A participatory approach was used 1) to demonstrate efficacy of Eco-Friendly Nets (EFN), insect barrier nettings (either treated or not treated with insecticides), at protecting vegetables against pests and associated viral diseases; 2) to demonstrate efficacy of floating row covers at improving crop micro-climate and enhancing yield and produce quality; and 3) to assess and address farmers' perception of EFN in order to increase the adoption and use of the technology.

Collaborators:

- Mathieu Ngouajio and Vance Baird of Michigan State University
- Thibaud Martin, CIRAD, France
- Françoise Komlan, INRAB, Benin
- Lusike A. Wasilwa, KARI, Kenya
- Anselme Adégbidi, Abomey Calavi University, Benin
- Damien Ahouangassi, Association des Personnes Rénovatrices des Technologies Traditionnelles' (APRETECTRA), Benin
- Serge Simon, INRAB/CIRAD, Benin
- Mwanarusi Saidi, Egerton University, Kenya
- Pierre Guillet, AtoZ Textile Mills International, Tanzania
- Laurent Parrot, CIRAD, France

Achievements:
The project allowed our team to: (1) build local scientific and technical capacity, and (2) use research findings and technical knowledge to increase small producers' participation in markets. Outreach and extension activities were core components of this project. We created a video at the end of the project to showcase major outputs and the appropriation of EFN and row covers by small-scale farmers in vegetable systems. Major outputs from this project include:

- Improved vegetable quality and productivity by developing low-cost, innovative technologies adaptable to the production system of small-scale farmers.
- Improved pest control and management by strengthening of IPM strategies.
- Reduced dependence on pesticides and therefore reduced their negative environmental impacts
- Development and dissemination of educational materials.
- Training of farmers and researchers.
- Creation of new jobs around the production and the recycling of Eco Friendly Nets and row covers.

Capacity building:
Thirty-three students in Benin, Kenya, and France were at least partially supported in their training by this project. More than a dozen host country institutions, agencies, and/or organizations were in direct cooperation or collaboration. Many host country professionals, both male and female, attended workshops or other trainings, including some workshops organized by the project. There were also a number of host country professionals who themselves were involved in providing training to other host country professionals. 43 host country professionals were directly involved in research activities for the grant. 6 certificate training programs were held in 2013 alone. 4 graduate degrees were earned in 2012 as a result of the project.

Lessons learned

- At the conclusion of this project, it is very clear that a simple technology like the use of nets may have major implications in agriculture. However, it was essential to work closely with experts and scientists in each country and to give them significant oversight on the project. We also noticed that it was particularly important to include female colleagues on the team. That enhanced team dynamics and productivity. Finally, the key to adoption of our technology was direct collaboration with farmers and on-farm demonstration trials.
- We partnered with NGOs (APRETECTRA in Benin and KOAN in Kenya) to achieve project goals. We also established strategic partnerships with AtoZ International, a Tanzanian manufacturer of nets. We hope that a three legged system including NGOs, private companies and growers' organizations will increase the likelihood of sustaining the use of EFN and row covers beyond this funding.

Presentations and publications:

- Vance Baird presented project results at the Annual Meeting of Horticulture Innovation Lab in Tegucigalpa, Honduras in April, 2014. He was assisted by Lusike Wasilwa, Mwanarusi Saidi and Thibaud Martin.
- Thibaud Martin presented project results at the International Horticulture Conference in Brisbane, Australia in August 2014. He was assisted by Vance Baird.
- A YouTube video of the project was produced in 2014; it is available online in:
    - (English) http://youtu.be/Vb-Ewrq42lI
    - (French) http://youtu.be/FKyJjpC4p2g

- Another video was produced in Benin "Insect nets seedbeds" available at: http://www.accessagriculture.org/node/1262/fr
- Gogo E.O, M. Saidi, F.M. Itulya, T. Martin and M. Ngouajio. 2014. Eco-Friendly Nets and Floating Row Covers Reduce Pest Infestation and Improve Tomato (Solanum lycopersicum L.) Yields for Smallholder Farmers in Kenya. Agronomy, 4, 1-12; doi:10.3390/agronomy4010001.
- Muleke E.M., M. Saidi, F.M. Itulya, T. Martin & M. Ngouajio. 2014. Enhancing Cabbage (Brassica oleraceae Var capitata) Yields and Quality Through Microclimate Modification and Physiological Improvement Using Agronet Covers. Sustainable Agriculture Research; Vol. 3, No. 2; pp24-34.
- Martin T., E.O. Gogo , M. Saidi, A. Kamal, E. Delétré, R. Bonafos, S. Simon and M Ngouajio 2014. Repellent effect of an alphacypermethrin treated net against the whitefly Bemisia tabaci Gennadius. Journal of Economic entomology 107(2): 684-90.
- Azandémè-Hounmalon GY, Fellous S, Kreiter S, Fiaboe KKM, Subramanian S, Kungu M, and Martin T. 2014. Dispersal Behavior of Tetranychus evansi and T. urticae on Tomato at Several Spatial Scales and Densities: Implications for Integrated Pest Management. PLoS ONE 9(4): e95071. doi:10.1371/journal.pone.0095071. http://www.plosone.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pone.0095071&representation=PDF
- Gogo E.O, M. Saidi, J.M. Ochieng, T. Martin, V. Baird and M. Ngouajio. 2014. Microclimate Modification and Insect Pest Exclusion using Agronet Improves Pod Yield and Quality of French Bean. HortScience Journal (in press).
- Vidogbéna Faustin, Anselme Adégbidi, Rigobert Tossou, Françoise Assogba-Komlan, Mathieu Ngouajio, Thibaud Martin, Serge Simon, Laurent Parrot, Kerstin K. Zander. Control of Vegetable Pests in Benin 2014 Farmers' Preferences for Eco-Friendly Nets as an Alternative to Insecticides. Journal of Environmental Management (accepted)
- Simon, S., Assogba Komlan F., Adjaïto, L., Mensah, A., Coffi, H., Ngouajio M. and Martin, T. 2014. Efficacy of insect nets for cabbage production and pest management depending on the net removal frequency and microclimat. International Journal of Pest Management (accepted).
- Juma V, M Kasina, L Wasilwa, E Kokwaro, P Kipyab, F Kariuki, M Ngouajio, and T Martin. Tomato (Solanumlycopersicum L.) protection with Agronets affects pest population and yields under Kenyan growing conditions (in progress).
- Achieng'a FC, M Kasina, J Mbugi, L Wasilwa, M Ngouajio, P Kipyab, and T Martin. Infestation of tomatoes (Solanumlycopersicon L.) by pests when protected with Agronets in Central Kenya (in progress).
- Kiptoo, J, M Kasina, P Kipyab, L Wasilwa, F Wanjala, M Ngouajio, T Martin. Management of cabbage (B. oleracea var. capitata L.) pests in Kenya with insect proof Agronets (in progress).
- Guantai, G, M Kasina, J Mbugi, S Mwaniki, L Wasilwa, M Ngouajio, P. Kipyab and T Martin. Comparing efficiency of cover duration and mesh size of pest

exclusion net covers against cabbage (Brassica oleraceae var. capitata) pests in Kenya (in progress).

Theme B: Sustainable production of horticultural crops
Project 2
Training plant diagnosticians: Deployment of Rapid Diagnostic Tools for Phytophthora on Horticultural Crops in Central America

Description:
Plant diseases caused by Phytophthora species present major limitations to food security in the developing world. Late blight on potato caused by *Phytophthora infestans* caused the Irish famine, and *Phytophthora* species also limit production of cacao, taro and other horticultural crops. *Phytophthora* is easily spread through international trade of plant materials and via airborne spores. Since plant pathogens do not carry passports nor recognize national borders, having a network of well-trained network of plant diagnosticians around the world benefits agriculture in the United States and abroad.

Collaborators:

- PI: Jean Ristaino of North Carolina State University
- Kelly Ivors, North Carolina State University
- Carrie Lepaire Harmon, University of Florida
- Peter Bonants, Plant Research International, The Netherlands
- Monica Blanco Menenses, Universidad de Costa Rica
- Jose Melgar, Fundación Hondureña de Investigación Agrícola, Honduras

Achievements:
Plant disease is a limiting factor in agricultural production in Latin America. Plant pathogens cause losses estimated to be as high as $30 billion per year. The risk of introduction of *Phytophthora* species through trade requires continued monitoring and improved diagnostic capabilities. Our objective was to deploy a platform of tools needed to detect, identify, and ultimately prevent the spread of species of *Phytophthora*, with a major focus on common and high threat species of *Phytophthora* on horticultural crops in Latin America. We were funded to teach a *Phytophthora* diagnostic workshop at Zamorano Agricultural University (Honduras) in the fall of 2013, and we deployed a series of technologies including: a protocols book, a Lucid key, and molecular and digital diagnostic identification systems to identify Phytophthora species and improve the diagnostic capabilities for important plant disease clinics in the region. The accurate identification of Phytophthora has important implications for growers in Latin America and the US and will result in the expansion of the Latin American Phytophthora Diagnostic Network (LAPDN).

The international team led a diagnostic workshop in Honduras from Sept 29- Oct 4, 2013 that was attended by 21 plant disease diagnosticians from six Latin American countries. Technologies for conducting rapid and accurate diagnostic assays for Phytophthora in plant and water samples under real-world working conditions were taught over four lab-intensive days. Students learned basic pure culture methods for isolating Phytophthora, morphological identification techniques, and state-of-the-art molecular diagnostics assays including PCR, ELISA and DNA sequences to identify species. The workshop was held at

the Panamerican Agricultural School Zamorano University, which also hosts the Horticulture Innovation Lab Regional Center.
This was the second in a series of plant disease diagnostic workshops held in Latin America. The first workshop, also funded by USAID through the Horticulture Innovation Lab, was held in June 2010 and formed the basis of the Latin American Phytophthora Diagnostic Network, a network of well-trained plant disease diagnosticians throughout the region. Further workshops are planned for Southeast Asia and Africa.

With funding from USAID, the Horticulture Innovation Lab builds international partnerships—like this one between NC State plant pathologists and Latin American scientists—for fruit and vegetable research to improve livelihoods in developing countries.

Capacity building:
Over a dozen host country institutions, agencies, and/or organizations were in direct cooperation or collaboration with the program. In 2014, over twenty host country professionals attended trainings or workshops, with more than twice as many women than men. Previous workshops in rapid diagnostics trained even higher numbers of participants. Host country professionals participated in certificate training programs, conducted trainings for other host country professionals, and were directly involved in project research.

Lessons learned

- There is a large need for improvements in plant disease diagnostics in Central America. Pre and postharvest disease is limiting food production in the region on major horticultural crops and export corps such as coffee.
- There is currently only one practicing plant pathologist in Honduras and he is nearing retirement.
- We trained 21 young plant disease diagnosticians from Central and South American countries with this workshop.
- There is still great need for infrastructure and human capacity building in the region.
- I would like to train more plant pathologists via long term degree programs in the US.
- Zamorano Agricultural University has a plant disease clinic with molecular diagnostic capabilities but there is no funding for a trained plant pathologist to manage the lab. We trained 5 staff members but they do not have the education and background to manage the lab and are misdiagnosing diseases.
- There is a need for sustained funding for supplies and a full time postdoctoral level person to run the diagnostic clinic at the university. This would be a great resource for the student run farm and the Regional Center.
- I think we need a postdoc there to work in the lab and train students and visitors to the regional center. They could work with growers who are having postharvest disease problems.

Presentations and Publications:

- Ristaino, J. B. 2012. A Lucid Key to the common species of Phytophthora. Plant Disease 96:897-903.

- Ristaino, J. B. 2014. Fighting Phytophthora: A Compilation of Laboratory Protocols: Five protocols including: Phytophthora DNA extraction and amplification from dried plant or herbarium specimens; V-8 rye agar; Rye B agar; Isolation of Phytophthora infestans from tomato fruit; fresh lima bean agar. Online publication APS Press.
- Ristaino, J. B. 2013. Rapid Diagnostic Tools for Phytophthora on Horticultural Crops. USAID Hort Innovation Lab Workshop, Sept 29-Oct 4, 2014, Zamorano University, Honduras.
- Ristaino, J. B., Ivors, K., Bonants, P., Blanco-Menenses, M., Gomez-Alpizar, L., Melgar, J. 2011. Deployment of Rapid Diagnostic Tools for Phytophthora on horticultural crops in Central America. Phytopathology S 153.
- Ristaino, J. B and Daub, M. 2013. Teaching tropical plant pathology to a global audience. Phytopathology 103:S2.189.
- Ristaino J.B. 2014. Deployment of Rapid Diagnostic Tools for Phytophthora on Horticultural Crops in Central America. Horticulture Innovation Lab Synthesis Meeting, Tegucigalpa Honduras, March 17-21, 2014.
- Ristaino, J. B. 2009. A Lucid Key to the common species of Phytophthora. American Phytopathological Society, APS Press. A PC computer CD software product.

Theme B: Sustainable production of horticultural crops

Project 3

Empowering women vegetable growers with drip irrigation: Vegetable production in drip irrigation for disadvantaged women in Siem Reap, Cambodia

Description:

Horticulture crop production, a woman's domain in Southeast Asia, is plagued by yield losses because of drought and unequal opportunities for women. Among the many introduced technologies in horticulture, drip irrigation has demonstrated that it can replace the time consuming tasks of hand irrigation and fertilization, increase yield and quality of horticultural crops, reduce pest infestations, and save water. When targeted at women, drip irrigation can also increase women's productivity and income, enhance their welfare by reducing drudgery, decrease their workload, improve health and save time for other practical needs, and empower them with a stronger voice in the family and community.

The project is in a rural site near Siem Reap, Cambodia. The area is home to several grand temples like Angkor Wat, which is a popular tourist destination. Vegetables are marketed in restaurants and hotels serving the tourism community, but only 30% of these vegetables are supplied by Cambodia and less than 10% are supplied locally. There is an opportunity for the women of Siem Reap to supply fresh vegetables to the market which is at most 1 hour away.

We built local scientific and technical capacity for a technician and the women of Siem Reap to work with drip irrigation. In addition, through SANREM Innovation Lab funding we were able to complement the advantages of drip irrigation for conservation agriculture and developed a combined package of technology to save labor, enhance soil quality, boost drought resilience, and improve vegetable quality. We intentionally and almost exclusively targeted female beneficiaries because we are convinced that for women to be empowered, women must be the intentional and almost exclusive targets and focus of horticulture technology innovations. We needed to 'disrupt' the current approach of aspiring just for gender equality by advocating almost exclusively for women, because unless this is done, the men in most cases will overpower the women. The specific objectives of this project were to:

- Reduce the labor burden of the women of Siem Reap through drip irrigation
- Increase vegetable production by the women of Siem Reap through drip irrigation
- Increase the income of the women of Siem Reap through drip irrigation
- Empower the women of Siem Reap through drip irrigation

Collaborators:

- PI: Manuel Reyes, North Carolina A&T State University
- Kjeld Vodder Nielsen, Agricultural Development Denmark Asia
- Buntong Borarin, Royal University of Agriculture
- Pagnasoley Sip,University of Battambang
- Thammasak Thongket, Katsetsart University

Achievements:

Fifteen smallholder women farmers in Siem Reap, Cambodia were served by this project. We provided 500-liter tanks, drip irrigation hardware, training and extension services to the 15 women while conducting a comparison study of drip and manual irrigation. In collaboration with SANREM, we studied synergies of drip irrigation with conservation agriculture technology.

We found that:

- A tank-supplied drip irrigation system saved the farmers a lot of time compared to their manual irrigation system. Most of them have a gasoline-powered pump that filled the tanks from a pond; then the vegetables could be watered by opening the main pipe connected to drip laterals. Labor time for the drip system primarily involved checking emitters and making sure that the laterals were uniformly irrigating the plots.
- Women were relieved of the drudgery and stress of carrying water to manually irrigate vegetables. We believe carrying water repeatedly has long term implications on women's health.
- Although there were no statistically significant differences found in income and yield between drip and manually irrigated systems, it was observed through informal conversations with participating women that they like drip irrigation. Many are requesting that we stop the no-drip irrigation study and just do drip irrigation. However, we do not know if the women will invest in drip irrigation when their hardware needs to be replaced.
- We estimated that the average annual income for a 100-square-meter vegetable plot among the 15 women farmers of Siem Reap was $350. This is at least 1/3 of the per capita income in Cambodia.
- In August 2014, during the fifth growing season, we had 100% retention of participants since the beginning of the study in June 2013. Another indication that the combination of drip irrigation and conservation agriculture technologies is working is that we have an additional 31 smallholder farmers (25 women and 6 men) who are growing vegetables using only these technologies in a similar manner to our original participants. The funding to help spread this combination is provided mostly by SANREM Innovation Lab along with some other smaller donors. The average plot of the adopters is 200 square meters. After the fifth growing season, the original 15 women will not continue with the treatments but will all move to drip irrigation and conservation agriculture technologies. Hence, we have a total of 46 participating smallholder farmers who will have changed their practices from conventional vegetable production to drip with conservation agriculture technologies.
- A team led by Dr. Thammasak from the Horticulture Innovation Lab Regional Center at Kasetsart University conducted a training about preparing seed germination media. Forty women and five men were trained to prepare a rice charcoal-rice ash-cow manure seed germination media. The farmers who adopted the seed germination media reported close to 90% seed germination compared with a seed germination of 50% for those who did not adopt the media. The advantage of

media is high germination rates, though farmers must transplant seedlings early because nutrients in the media are depleted quickly.

- The team from the Regional Center at Kasetsart University also installed six small tunnel-netted greenhouses in six villages, and two big ones (one made of bamboo and the other with plastic pipes) at Siem Reap.
- A team from Royal University of Agriculture led by Dr. Borarin held a postharvest training on handling and packaging of vegetables for the Siem Reap market. The women in the project decided to form a marketing team and decided on a brand name and also drew a logo. The farmers are hoping to sell their first vegetables as a team during the November and December 2014 harvests. Currently we are negotiating with the NGO Agricultural Development Denmark Asia (ADDA) to organize the farmers into a cooperative.
- Drip irrigation and conservation agriculture training was done by field technician Ren Ry who was trained by the NC A&T team the previous year. He was able to lead a team of four women to install drip irrigation and train the additional 25 women and six men who adopted conservation agriculture and drip irrigation technologies. We are expecting the smallholders to earn an average of $700 a year, which is about 70% of the per capita income in Cambodia. Training was primarily funded by the SANREM Innovation Lab which provided hardware for 27 additional farmers; four farmers were funded through a donation.
- Conversations and observations with the 15 women participants cause us to believe they are more food secure now than before we worked with them last year. Their families eat non-marketable vegetables, sell vegetables they can sell, and still have time to get employed or do other home chores. We observed their happiness with our intervention during a marketing and postharvest workshop in August 2014 and from their responses on informal focus group questions.

Capacity building:
Fifteen women's groups are the core focus of capacity building with the project. They specifically received training on the installation, operation, and maintenance of drip irrigation systems, in addition to other agronomic training relevant to their crops.

A doctoral student from North Carolina A&T conducted research in Cambodia as part of the project, and several Cambodian partners, including employees of ADDA, were trained in conservation agriculture and drip irrigation practices. The project driver was also trained as a field technician.

Lessons learned
We learned the benefit of synergizing Innovation Lab work, especially now that USAID is focusing on Feed the Future countries. Multiple Innovation Labs have projects at the same Feed the Future sites in many of those countries. The connections established through the four years of investment by SANREM Innovation Lab in conservation agriculture and four years of investment by the Horticulture Innovation Lab in postharvest technology were excellent foundations upon which this project capitalized.

In hiring personnel, there are prospects to provide opportunities to gifted, talented, skilled and trained Cambodians who just did not have a chance to complete a college degree. Our field technician was a 'tuktuk' driver with a high school degree, but he had his own computer and was very skillful with current technologies (search, Facebook, email, Excel, and many more), proficient with smartphone technology, spoke very good English and was thus a good translator, had his own tuktuk, knew the villages in Siem Reap very well because he grew up there, knew how to work with foreigners because he entertained tourists, and was proficient in practical farming. We opened our doors to Ren, and now we have a passionate technician who knows how to install drip irrigation and knows the principles of conservation agriculture and can conduct hands-on training with farmers.

Partnership with ADDA was a big plus. They are very skilled in organizing women, and have been organizing self-help women groups in Siem Reap since 2004. But they need new, science-based agricultural technologies to supplement the skills and income of the women in self-help groups. The Horticulture and SANREM Innovation Labs provided science-based drip irrigation, conservation agriculture, and postharvest technologies to 3 of the 146 self-help groups they have formed.

Conservation agriculture is very applicable to smallholder vegetable farming. It is excellent for weed control, is easy to implement on small land sizes, and can produce synergies when combined with drip irrigation.

Presentations and publications:

- Edralin, D.I. 2014. The use of low cost drip irrigation materials by conservation agriculture women farmers in Siem Reap, Cambodia. Oral presentation at the 2014 annual meeting of the American Society of Agricultural and Biological Engineering, Montreal, Canada, July 2014.
- Edralin, D.I. 2014, S. Ry, and M. R. Reyes. 2014. The Effect of Mulch on the Quality of Low Cost Drip Irrigation in the Dry Season and Yield of Vegetables in Cambodia. Poster presentation at the 2014 annual meeting of the American Society of Agricultural and Biological Engineering, Montreal, Canada, July 2014.
- Edralin, D.I., S. Ry, and M. R. Reyes. 2014. Vegetable Production in Drip Irrigation and Conservation Agriculture for Disadvantaged Women in Siem Reap, Cambodia. Poster presented at the 2014 annual SANREM meeting, Arlington, VA, May 2014.
- Edralin, D. I. and M. R Reyes. 2014 "Vegetable Production in Drip Irrigation and Conservation Agriculture for the Disadvantaged Women in Siem Reap, Cambodia," Presented at the Horticulture Innovation Lab Annual Meeting, Tegucigalpa, Honduras. (March 2014). Poster and one page summary.
- Edralin, D.I. and M. R. Reyes. 2013. Conservation agriculture with drip irrigation in Siem Reap, Cambodia. 2013 Water Education Summit. Chattanooga, TN, September 2013.

Theme C: Postharvest Practices

Project 1

Extension of Appropriate Postharvest Technology in Sub-Saharan Africa: A Postharvest Training and Services Center

Description:
This project trained 36 people from 7 sub-Saharan African countries as postharvest trainers, and also established a Postharvest Training and Services Center (PTSC) in Arusha, Tanzania. The PTSC offers training programs, conducts adaptive research, and offers demonstrations of postharvest technologies and best practices. Trainings are targeted at women's groups, smallholder farmers, and small-scale food processors. In addition, the PTSC was the site of the 2012 postharvest Training of Trainers program.

Collaborators:

- PI: Diane Barrett, University of California Davis
- Co-PI: Lisa Kitinoja, World Food Logistics Organization
- Jinru Chen, University of Georgia
- Ngoni Nenguwo, AVRDC – Regional Center for Africa
- Bernard Moonga, Moses Banda, University of Zambia (UNZA) Dept. Food Science

Achievements:

- Trained 36 postharvest trainers and extension specialists from 7 sub-Saharan African countries. These trainees subsequently trained over 16,000 members of farmer groups and women's cooperatives, plus an additional 15,000 people through the multiplier effect.
- Designed, set up and launched a Postharvest Training and Services Center (PTSC) in Tanzania
- A postharvest shop (operated in conjunction to the PTSC) was opened outside of Arusha, Tanzania. The money generated will be used to support the PTSC and its programs.
- The "Small scale handling postharvest manual: A manual for horticultural crops" was translated into Swahili, and is now available as a free download.
- More than 600 farmers and small-scale food processors attended trainings and demonstrations at the PTSC, and 1000 other people came to visit the center.
- The PTSC was highlighted as a case study by the Global Knowledge Initiative/Rockefeller Foundation 2014 postharvest loss project.
- Lizanne Wheeler (project consultant) conducted adaptive research on improved traditional containers, consumer packages, insulated pallet covers for shipping, and solar drying in cloudy weather.

Capacity building:

- 36 young people from Rwanda, Ghana, Kenya, Tanzania, Benin, Ethiopia and Uganda were trained as postharvest trainers. Each trainee completed 10 assignments (reading, fieldwork, written reports) on Commodity Systems Assessment,

postharvest systems research techniques, postharvest demonstration and extension program design, and cost-benefit analysis.

- 32 of the trainees attended a weeklong closing workshop at the PTSC in Arusha, where they received additional training.
- 637 farmers and food processers (230 men, 407 women) attended classes and demonstrations at the PTSC. The demonstrations focused on simple technologies that can easily be replicated at local homes and farms (i.e. use of shade, harvesting tools, improved packages and more)
- 1000 people visited the PTSC, in addition to the 600 who took classes there.
- Graduate students from UC Davis, the University of Georgia and AVRDC conducted research for the project.

Lessons learned:
It is important to have back-up plans: the first partner organization identified as a host for the PTSC wasn't able to come through, so they had to come up with a secondary site and host.

Presentations and publications:

- "Postharvest Innovation Series No 1-20" developed (Illustrated guides to making tools and equipment)

Theme C: Postharvest Practices

Project 2

Sustainable Development of Horticultural Crops in Zambia by Introducing Postharvest Technologies and Practices for Food Security, Income Generation and Support of the Tourism Industry

Description:
The goal of this project is to build on gains made in the Livingstone, Zambia, horticulture program and the related Immediate Impact Project, and further extend economic opportunities to small-scale farmers in Zambia.

This project strengthened the value chain for fresh market vegetables through a focus on postharvest handling. Building upon our successful introduction of locally produced commercial vegetables into southern Zambia's Livingstone region, we worked to expand local production of fresh vegetables for the tourism and supermarket industries, with the goal of reducing postharvest losses by 40 percent. As local production displaced more expensive imported vegetables, significant economic opportunities for small-scale farmers were achieved.

This proposal strengthened the value chain and scaled up production to supply markets in the Livingstone area. As the major constraint to scaling up is the lack of cold-chain systems, this project focused on introducing a strong postharvest and cold-chain program to reduce postharvest losses and increase profitability along the value chain, ensuring food security and promoting rural livelihoods and diversified income streams.
Using an innovative, market-first, science-driven approach with a focus on applied postharvest technologies, farmers were trained in good agricultural management practices, postharvest and storage systems, and entrepreneurship; they were also linked to sustainable markets. Innovative technologies including low-cost coolers, quality control in postharvest technology and appropriate cold storage systems at the farm. Our private sector partners include Sun International Hotels, David Livingstone Hotel, Freshmark/Shoprite and SPAR supermarkets. Many secondary micro-enterprises to support the farmers will be created.

Collaborators:

- Principal Investigator: Dr. Jim Simon, Rutgers University, USA
- Co-Principal investigator: Dr. Steve Weller, Purdue University, USA
- Co-Principal investigator: Emil Van Wyk, ASNAPP-Zambia, Country Director, Zambia
- USA Collaborators:
- Dr. Rodolfo Juliani, Dr. Bill Sciarappa, Dr. Ramu Govindasamy, Albert Ayeni, Rick VanVranken, William Reichert, Dan Giurleo; Rutgers University
- Dr. Lisa Kitinoja; PostHarvest Education Foundation
- Richard Tracy; World Food Logistics Organization
- South Africa: Elton Jefthas, Craig Fulton; Agri-Business in Sustainable Natural African Plant Products (ASNAPP-South Africa)

- Zambia: Emil Van Wyk, Muunga Mapenzi, Ockert Jacobus van Wyk, Lupiya Sakala, Natasha Mwila, Kelly Bauer Bennett; Agri-Business in Sustainable Natural African Plant Products (ASNAPP-Zambia)
- Bernard Moonga, Moses Banda; University of Zambia (UNZA) Dept. Food Science

Achievements:

- The project trained 924 farmers (839 women) in Good Agricultural Practices. 1524 people total participated in trainings. In addition, the project trained 15 lead farmers (3 men, 12 women). These lead farmers then trained 87 other farmers (75 women) in agri-business entrepreneurship.
- Project communities produced 129,480 tons of fresh produce, and within the last year of the project, earned $205,259. The success of this project led to the introduction of hot pepper and African Birds Eye Chili production for the fresh and dry markers by additional communities.
- The Kazuni community, which focuses exclusively on the production of vegetable seedlings in high tunnels, produced 1,890,000 seedlings in 2014. These seedlings were then sold earning a total value of $19,000.
- With the World Food Logistics Organization, the project conducted a cold chain analysis for Zambia. The project then used the information from this analysis to design effective trainings.
- A CoolBot and a Shadebot were built at the Nsongwe Women's Community to help with postharvest. The Shadebot was particularly popular, since it was affordable and easy to replicate. The CASH project (USAID funded) built 40 additional Shadebots in the region after seeing how successful the initial Shadebot was.
- Three new private sector partnerships formed.
- This project leveraged additional funds and provided the foundation for the successfully awarded and ongoing $4.98 million Global Development Alliance (GDA) from the USAID-Zambian Mission to ASNAPP in support of CASH (Commercial Agriculture in Sustainable Horticulture). The success of the project at this stage, coupled to the wide attention this project has received and the recognition by the industry that Livingstone could be an ideal site for both a packing house and distribution center, has led to the newest award (August, 2014) of $1 million (US) to design and build a packing house/bulking center and cooling facility with funds provided by DFID. This is an exciting development, because one of the major gaps identified was the lack of cooling facilities, storage conditions and more in this region. While this new initiative is only for the design and actual construction, with proper and continued technical support, this region could grow substantively as a producer as well as a repackaging and distribution center for produce and supplies to/from Lusaka to the north and points in Zimbabwe, Botswana, Namibia, Mozambique and Malawi.

Capacity building:

- Farmers received training in the following areas:
- Seedling production - 103 farmers (17 male, 86 female) were trained in the production of transplants to enable them to produce quality and healthy vegetable

seedlings during November 2013 (3 male, 32 Female total 35 farmers). Follow up trainings in January 2014 (5 male, 28 female: total 33 farmers) and in February 2014 (9 male, 26 female: total 35 farmers).

- Irrigation management – During November 2013, January 2014 and April 2014 training was provided to 130 farmers (9 male, 121 female) in the use of a tensiometer when scheduling the irrigation of crops. Practical demonstrations were done as well.
- Postharvest technology – During January, April, and June, 2014 training was provided to 155 farmers (21 male, 134 female) in the postharvest handling, washing and cooling of products. Food safety and hygiene also formed a key component of the training. The training was conducted in partnership with Rutgers and Sun International Hotel. In January and June 2014, trainings were given to ASNAPP team and grower leaders with a focus on a new ShadeBot © concept, which was introduced to growers to highlight the importance of keeping all harvested fresh produce out of the sun.
- Crop Rotation- 30 farmers (1 male, 29 female) were trained during May 2014 on the importance of crop rotation, crop scheduling and the impact of not rotating relative to insect and disease impact and overall yields.
- Marketing - 49 farmers (5 male, 44 female) were trained in marketing during April and July 2014. Emphasis was placed on quality products, consistency, timeliness and types of packaging. The concept of supply and demand in relation to price was explained as well.
- Compost making - 15 farmers (0 male, 15 female) were trained in April 2014 on how to make compost and were showed the most effective ways to apply and use it.
- Record Keeping – 87 farmers (12 male, 75 female) were trained during May and July 2014 in entrepreneurship and general record keeping. Emphasis was placed on accurate record keeping, time management, the allocation of labor, and the calculation of profits and losses.
- Land preparation - 62 farmers (4 male and 58 female) were trained in how to sharpen a hoe and to make most effective use of a hoe while preparing land. The importance of the layout of the land, including making ridges and land usage, was emphasized.
- Planting techniques – 115 farmers (1 male and 114 female) were trained during January and May 2014 in planting techniques that conserve moisture and increase the efficiency of irrigation.
- Safe handling of chemicals – 58 Farmers (2 male and 56 Female) were trained during March and June 2014 on the safe handling of chemicals. Emphasis was placed reading the label and keeping the chemicals isolated. Training in mixing and spraying the chemicals along with the use of protective clothing was demonstrated. The training was done in collaboration with Syngenta, a company dealing with agriculture inputs.
- Harvesting of vegetables – 104 farmers (16 male and 88 female) were trained during February and June 2014 in postharvest technologies following the construction of the CoolBot. Emphasis was placed on the operation of the CoolBot, harvesting, grading and packing of vegetables. Time of harvest, use of shade and other good

management practices were also highlighted to improve postharvest handling and to reduce postharvest losses.

- Business and entrepreneurship training – 35 Lead farmers (7 male and 28 female) were trained during February 2014 with collaboration from Sun International by ZPI during a 3 day workshop.
- Sowing of seeds – 35 farmers (4 male and 31 female) were trained in correct sowing methods and rates for amaranths, spider plant and nightshade during January and February 2014.
- The project also trained farmers on how to repair and maintain existing irrigation and high tunnels. Although these technologies were already in the communities before the project started, producers did not know how to repair them when they broke.
- In addition, 6 students (2 Zambian, 4 American) participated in the project this year.

Presentation and publications:

- Postharvest Guidelines for Fruit and Vegetables in Zambia
- Postharvest Focus in Zambia
- Food Safety Protocols
- Sustainable Agricultural Guidelines for Zambia
- Presentation at the Horticulture Innovation Lab Annual Meeting

Theme C: Postharvest Practices
Project 3
Developing training materials to improve postharvest practices

Description:
Knowledge of postharvest handling practices necessary to satisfy market requirements is a serious constraint that limits the success of small-scale producers of horticultural crops in participating in the value chain at various levels. Improving the ability of smallholder farmers to produce horticultural crops with the required levels of quality and safety for markets will support the Feed the Future strategy for Honduras and Guatemala by improving growers' income and increasing available nutrient-rich foods. In this project we developed training materials that both tell and show users the what, why and how of postharvest handling practices that are necessary in order to ensure the quality and safety required to successfully market fresh horticultural crops in markets at different levels. In addition, the training materials were designed so that they can be easily incorporated into postharvest curricula at higher education institutions in Horticulture Innovation Lab host countries.

Collaborators

- PI: Jeff Brecht, University of Florida
- Octavio Menocal, Steven Sargent, and Maricruz Ramirez, University of Florida
- Marita Cantwell, UC Davis
- Alejandro Castillo, Texas A&M University
- Lisa Kitinoja, Postharvest Education Foundation
- Eleni Pliakoni, University of Kansas
- Jaime Vincent Leon Chavez, USAID US-Brazil Trilateral Cooperation in Food Security Program
- Ivanna Verjarano Moreno, Escuela Agricola Panamericana Zamorano
- Ana Silvia Colmenares de Ruiz, Universidad del Valle
- Fernando Maul

Achievements:
PowerPoint presentations on 12 different postharvest topics were created by international Subject Matter Experts, some presentations with narrations completed at this time. Each topic was created with three modules tailored to different audiences in Honduras and Guatemala: 1) subsistence producers transitioning to selling crops; 2) smallholders desiring to sell product locally to markets or cooperatives; 3) medium size producers desiring to sell product to quality conscious commercial customers in population centers in their country or export. Module 3 can also be used for university students or extension agents who will be training farmers.

The presentations on several topics were re-created using Prezi. The two versions of the presentations will be useful for testing the effectiveness of different approaches to imparting knowledge – not only the linear structure of PowerPoint versus the compartmentalized

approach of Prezi, but also individual self-directed learning versus facilitated and group learning approaches.
Lessons learned:
Creating materials to be used for training and to impart knowledge related to the universal practice of producing and distributing food for consumption requires an understanding of the specific situation in the countries where the training materials will be used, including each country's unique traditions, practices, raw materials that are available, and cultural considerations.

It became clear to us near the end of the project timeline that these presentations may never, and need never, be considered complete. New and better visual aids will be found; the way in which information identified by the SMEs can be presented will be re-imagined and new and possibly more effective ways will be found to present the information to different audiences.

Presentations and publications:

- J.K. Brecht, M.A. Ritenour and L. Cisneros Zevallos. Postharvest Training Materials for Smallholder Producers of Horticultural Crops That Support Transitions to Commercialization. Poster presentation at Annual Horticulture Innovation Lab Annual Meeting in Tegucigalpa, Honduras, 17 March 2014.

Theme C: Postharvest Practices

Project 1

Innovative potato storage for smallholder farmers in Bangladesh

Description:
Potatoes are the second largest crop in Bangladesh after rice, but production is focused in the winter months, and most of the crop is harvested in a very short period, which leads to depressed prices and profiteering at farmers' expense by large traders who purchase potatoes at low prices and store them in large commercial cool stores for sale usually at higher prices throughout the year. To increase the profitability of smallholder potato farmers in the southern areas of Bangladesh, we tested small-scale systems for short-term storage ambient storage and for longer-term storage (insulated coolrooms refrigerated by an air conditioner controlled by a 'CoolBot' controller). In addition to testing storage of the primary target crop, potatoes, we also conducted storage trials with sweet potatoes and a range of vegetables.

Collaborators:

- PI: Jim Thompson,University of California, Davis
- International Potato Center
- Bangladesh Agricultural Research Institute (BARI)
- Bangladesh Research Advisory Council (BRAC)

Achievements:
One year remains of this three-year project. In the first year of the project, we identified communities of smallholder farmers interested in the possibility of storing table and seed potatoes. Although potatoes are primarily a "man's crop," women are major participants in one of the communities that we work with.

Eleven ambient storage houses were constructed by BRAC to a design prepared by BARI. The ambient storages are ventilated storage buildings, in which potato can be stored loose on bamboo shelves for 3 to 5 months. The buildings are constructed under the shade of trees with adequate air circulation with locally available materials such as bamboo and straw, and reinforced concrete pillars.

After the potato storage season, there is a window of opportunity to use the cool rooms to store other horticultural crops, and in the second year of the project, we tested the benefits of storing tomatoes, eggplant, and bottle gourd in ambient and cool storage rooms. The products were held at 12.5 C, the proper storage temperature for these warm-season vegetables, and the results of cool storage were dramatic reductions in ripening, shriveling and loss due to rots compared to storage in the ambient storage rooms. In the third year of the project we plan to evaluate the potential for storage of a wide range of horticultural crops, with the goal of choosing those where short-term cool storage will result in improved returns to the growers.

In the second year of the project, our storage experiments included evaluation of the benefits of "curing," where potatoes are held at intermediate temperatures for two weeks to

stimulate production of periderm over wounds resulting from harvest and handling operations. The major issue in the second year continued to be access to electricity, and the need to use generators in most of the rooms to provide the needed cooling.

At one site, Potuakhali, a coolroom was devoted to storage of sweet potatoes, which performed much better in cool storage than roots held in ambient storage rooms. Storage under ambient conditions resulted in sprouting, shriveling due to water loss, and early rotting of the tubers; roots stored in the coolroom were still saleable after four months' storage.

Capacity building:
The primary capacity-building effort in this project was the funding of researchers from Bangladesh to attend the annual UC Davis Postharvest Short Course. Difficulties with the issue of visas reduced the number of trainees that were budgeted, but two completed the two-week short course.

Lessons learned:
Most of the "lessons learned" have to do with the challenges of working in Bangladesh. Our project was facilitated greatly by the hiring of a UC-funded junior specialist in Bangladesh who took primary responsibility for the project. The dual administration of this position (which was supported by the CIP administration in Dhaka) proved to require constant attention to ensure that she had the resources and support required. Challenges abounded, including the difficulty of sourcing materials and equipment, and the difficulties and delays in connecting to the grid noted above. Communication was facilitated by the use of Adobe Connect for 'chat' sessions. The relative unreliability and low speed of Internet connections, even in Dhaka, made it impossible to use video conferencing or other more interactive communication tools.

Publications:

- Posters at the Annual Horticulture Innovation Lab meetings
- Presentations to farmer groups in Bangladesh
- A poster at the ASHS annual meeting in Orlando FL, July 2014
- A translation into Bengali of the UC Davis Small-Scale postharvest technology manual
- Published information for Bangladeshi small-scale farmers on optimal harvesting, handling and storage practices for potatoes and sweet potatoes.

Theme D: Food safety

Project 1

Delivering Vegetable Safety Education through Established Social Networks

Description:
Themes like food security and food safety are very important for agriculturalists and are required to support the volume and quality of food that humanity needs. There are a number of markets around the world where knowledge about proper food handling and sanitary regulations is not adequate to provide these foods in proper condition.
Of even more concern is the situation in rural households using food or food products for their own consumption without restriction and appropriate care.

From July 31st-September 1, 2014, a group of 23 students and 2 professors were trained at the Kellogg center of Zamorano University in Honduras. All of them received information on food safety, and they also had the opportunity to do laboratory analysis.

Elements of food security, food safety and postharvest plant during production, processing and storage were covered with the objective of increasing awareness of the food safety hazards and quality defects associated with microbial contamination of produce during production, processing, and storage by small-scale vegetable producers. All participants received a certification at the end of the course, and all technical information was provided in a USB flash drive. Additional workshops were given to groups of farmers in two agricultural communities outside of Zamorano.

Collaborators:

- PI: Jeffrey LeJeune, The Ohio State University
- Sanja Ilic, The Ohio State University
- Julio Lopez Montes, Zamorano University, Honduras
- Nidzy Islady Amador Trujillo, Zamorano University, Nicaragua
- Carla Turcios, Zamorano University, Honduras
- Patricia Arce, Zamorano University, Honduras

Achievements:
The Horticulture Innovation Lab Program, UC Davis, and The Ohio State University with Zamorano University, have executed a series of trainings, which have strengthened the knowledge of vegetable producers on food safety hazards, food security, and good agricultural practices with the aim that participants provide their own safe and healthy food and that access and availability of data are improved. 234 participants have received the training to date.

Capacity building:
In addition to the other trainings conducted by the project, in March 2014, a "Train the Trainer" workshop was held where over 50 people were prepared to hold their own food safety trainings at their respective institutions.

Lessons learned:

Research moves slowly in Latin American countries. It is difficult to get subawards/invoices from our research partners. Microbial food safety issues are a growing concern for producers in Latin America! This statement may seem obvious, but it is only obvious to the informed: Although most growers were aware of the hazards of pesticides, our preliminary studies indicated that vegetable growers in Latin America had little to no awareness of food safety threats posed by bacteria, parasites and viruses. Once the possible pathways for contamination of fruits and vegetables were described, there was a genuine interest, both from the producer and consumer standpoint to make these products safer. We now observe among producers requests for information, rather than simply an exercise in us, the foreigners, trying to impose our standards, values or practices on endogenous production systems.

Publications:

- Good Agricultural Practices Training/Capacitación Buenas Prácticas Agrícolas. The Ohio State University College of Food, Agricultural and Environmental Sciences Concepts and Challenges to Integrating Food Safety Training. Dr. LeJeune, Washington DC, Post-Harvest Showcase, July 24, 2014.

Theme E: Marketing

Project 1

Sustainable African Indigenous Vegetable Production and Market-Chain Development for Improved Health and Nutrition and Income Generation by Smallholder Farmers in Kenya, Tanzania and Zambia

Description:
This research project sought to support and strengthen the African indigenous vegetable (AIV) industry using a market-first approach to overcoming constraints along the value chain, leading to improved production practices, supply, postharvest handling, distribution and consumer acceptance of AIVs in Kenya, Tanzania and Zambia. Key pieces of the project were developments of strong public-private sector partnerships that ensured activities supported the needs of consumers and markets. These partnerships involved germplasm evaluation, development of sustainable production techniques, seed production/saving techniques, improved market access and stakeholder capacity building through outreach programs at all levels of the AIV value chain. This project characterized both nutritional attributes of AIVs, as well as created awareness of health and nutritional benefits of AIVs through household and market surveys and educational programs about nutrition. The project bridged information gaps through research and through the cooperation of promotional activities with the private sector, farmer groups, government, research and non-governmental organizations to build confidence in AIV production and to enhance farmer adoption. Project activities built capacity of African universities and institutions involved in research and training of extension personnel who serve the farm community. Improved indigenous vegetables will provide nutritional complements to diets. The approach aimed to promote biodiversity and sound environmental management while providing affordable, edible foods that can be grown and processed locally and are tailored to local dietary needs. Activities resulted in improved income generation, new microenterprises across the value chain, improved availability of nutritious AIVs for consumption and overall improved quality of life. This project built on two previous projects, one in Kenya and one in Zambia.

Collaborators:

- PI: Stephen C. Weller, Purdue University, USA
- Maria Marshall, Purdue University, USA
- James Simon, Rutgers University, USA
- Pamela Obura, USAID/AMPATH Project, Moi University, Kenya
- Chris Ojiewo, AVRDC-The World Vegetable Center, Tanzania
- Petrus Langenhoven, Agribusiness in Sustainable Natural African Plant Products (ASNAPP), Zambia

Achievements:
Baseline Household Survey:

Zambia: A baseline survey was done for Lusaka and Livingstone. Two hundred surveys were done; data was entered by ASNAPP staff and analyzed by Dr. Maria Marshall (Purdue University). We had a total of 100 respondents in Livingstone (29 female and

71 male) and another 100 respondents in Lusaka (39 female and 61 male). Major markets for AIVs were identified based on the survey.

Kenya: During the months of June-August 2013 a consumer survey was conducted with the help of Frances Einterz using a choice experiment model to determine consumer willingness to pay for quality when purchasing three key AIVs: amaranth, nightshade, and spider plant. A group of 340 consumers across 3 cities in Western Kenya in 6 different markets were surveyed. Some important lessons were learned from the survey to understand the consumers' preferences and purchasing patterns of AIV which notably varied among the regions. Results indicated that if farmers are able to invest in post-harvest handling and get their produce to market quickly they stand to make a bigger profit by charging higher prices, especially for spider plant.
A vendor survey was conducted during the same period of 2013. The results of the survey helped understand the vegetable markets of Western Kenya. Vegetable markets across Western Kenya are remarkably prevalent and well-stocked. One striking similarity across all cities was the rigidity of gender roles across formal and informal markets. Women were in control of the informal markets whereas men held the positions of power in supermarkets. According to the survey, the tendency seemed to be attributed to the differences in education levels of men and women.

Research:

Kenya: Throughout the project period various scientific experiments were executed on AIV performance, pests and seed production/quality. Pest insects were identified and patterns of prevalence of pests were found. Effects on AIV physiology were identified. We experimented with improved solar dryers for processing African Indigenous Vegetables in western Kenya and found the method was efficient for drying.
Tanzania: The research was similar to that described for the variety and herbicide trials in Kenya and Tanzania. The experiments included the various lines of amaranth, nightshade and spider plant and their response to 3 types of fertilizer: commercial, chicken manure and no fertilizer. Results over the 2 years of these studies have been positive in that the new improved lines of the 3 AIVs from AVRDC have outperformed the local varieties in yield and quality in all seasons tested. The results from the first years of the study are presently being analyzed and a full report and paper will be prepared in year three.

Partnership:

The project achieved partnerships with members of the private sector including Mace Foods (Eldoret Kenya), Sylva's Catering and Sun International on implementing research, market surveying and training.

Other:

AIV project sites were visited by honored guests during the project period. The United States Ambassador to Zambia, Mark Storella, visited the Nsongwe Women's Association in March 2013 during a cross-border bike ride to promote international tourism, economic growth, and wildlife conservation in Zambia and Zimbabwe. As part of her expedition to Africa and Zambia in particular, Former First Lady to the United States of America, Mrs. Laura Bush graced the Nsongwe Women's Association with a visit to their

horticulture research and demonstration site in Livingstone on June 29, 2013. See press release in appendix.

Capacity building

- Zambia: A total of two hundred and five farmers were trained (23 male and 182 female) in the following areas: Land preparation, seed placement, crop establishment, weed management, pest and disease identification and management.
- Tanzania: Six capacity building activities were implemented during 2012 and 2013 including seed increases and distributions, farmers' capacity building through training in various areas of vegetable production and utilization, awareness creation as a means of technology promotion, AIVs recipe cookbook preparation, and a field day and seed-fair. A total of 149 farmers and 260 farmers and horticultural students participated the farmers' field day and seed fair respectively.
- Kenya: 743 Kenyan people have received training on AIV production, pest management, harvesting and seed saving.
- Student Training: 11 students have participated in the project from 4 countries; USA (5 students), Kenya (4 students), Tanzania (1 student), and Honduras (1 student). David Byrnes from Rutgers University applied for and received a Borlaug Fellowship to conduct selection and breeding studies at the World Vegetable Center, Arusha, Tanzania for a 6 month period in 2014 in the amount of $15,000. Marcia Croft from Purdue University received a Borlaug Summer Institute at Purdue Fellowship, which covered the costs of 2 years of her Ph.D. degree at Purdue University, a value of $60,000.

Lessons learned:

The Kenyan survey showed that the key socio-economic constraints along the AIV value chain were high priced fertilizer, poor quality seed and a lack of cash to buy fertilizers. The most frequently cited biophysical constraints were drought, pests and low soil fertility. Some important lessons were learned from preliminary data analysis. The city in which interviews were conducted made a difference in terms of consumer preferences. Nightshade was very popular in Eldoret, whereas spider plant was more common in the eastern border town of Busia; these differences are likely impacted by ethnic and cultural differences between these two places. Women were significantly more likely to choose high quality vegetables and be willing to pay a premium price for them than men, but in general both male and female consumers were very aware of the health benefits of these vegetables. Over 60% of consumers listed health benefits as their primary reason for purchasing AIVs. In general, consumers were more likely to prefer small leaves for amaranth and nightshade and rank nightshade as their favorite of these three AIVs. Customers were significantly more likely to choose the highest quality spider plant than either of the other vegetables, however, suggesting that quality in this species may be highly valued. Results indicate that if farmers are able to invest in post-harvest handling and get their produce to market quickly they stand to make a bigger profit by charging higher prices, especially for spider plant.

Presentations and publications:

- Lotter, D.W., M.I. Marshall, S. Weller, and A. Mugisha. 2014. African Indigenous and Traditional Vegetables in Tanzania: Production, Post-Harvest Management and Marketing. African Crop Science Journal 22:3, pp.1-9.
- Yang, R-Y. and C. Ojiewo. 2013. African Nightshades and African Eggplants: Taxonomy, Crop Management, Utilization, and Phytonutrients. African Natural Plant Products Vol II, pp. 137-165
- Cordeiro, L.S. 2013. The Role of African Indigenous Plants in Promoting Food Security and Health. African Natural Plant Products Vol II, pp. 273-287
- Croft, M.M., M.I. Marshall and S.C. Weller. 2014. Consumers' preference for quality in three African indigenous vegetables in Western Kenya. Journal of Agricultural Economics and Development Vol. 3:2, pp.1-11
- Keller, G.B., H. Mndiga and B.L. Maass. 2005. Diversity and genetic erosion of traditional vegetables in Tanzania from the farmer's point of view. Plant Genetic Resources 3:3, pp. 400-413
- Herforth, A.W. 2010. Promotion of Traditional African Vegetables in Kenya and Tanzania: A Case Study of An Intervention Representing Emerging Imperatives in Global Nutrition. Cornell University
- Keatinge, J.D.H., R.-Y Yang, J.d'A. Hughes, W.J. Easdown and R. Holmer. 2011. The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals. Food Security 3:4, pp. 491-501
- Yang, R-Y., S. Fischer, P.M. Hanson and J. D. H. Keatinge. 2013. Increasing Micronutrient Availability from Food in Sub-Saharan Africa with Indigenous Vegetables. African Natural Plant Products Vol II, pp. 231-254

Theme E: Marketing
Project 2
Safe Vegetable Production in Cambodia and Vietnam: Developing the HARE-Network to Enhance Farmer Income, Health, and the Local Environment

Description:
In Cambodia and Vietnam, horticulture remains an important undeveloped business sector supported by small-scale farmers. Our goal is to empower smallholder farmers (59% of whom are women) with integrated experiential education and training for sustainable vegetable production that limits postharvest losses, increases food safety, increases market access and, importantly, increases income. We have designed an innovative participatory approach to meet these goals by networking experts in horticultural production through marketing. Stakeholders include farmers communes, regional universities, local governments and national communications companies. This broad network provides continuity needed for continuation of farmer outreach training and education beyond the lifetime of Horticulture Innovation Lab funding. The successful completion of the project in Vietnam will serve as a model for implementation of the participatory action network in other, more challenging, countries like Cambodia and Laos with similar, but less developed, horticulture business sectors. Importantly, completion of this project will address essential capacity-building needs of Cambodia including an assessment of capabilities, research training, outreach development and promotion of communication between policy makers, universities and the agribusiness community. A direct impact from this project is that Cambodian and Vietnamese vegetable farmers will gain income.

One extension of this project worked with savings groups in Cambodia that were trained in financial literacy and cell phone-related savings technology. The savings and lending groups were also introduced to improved horticultural technologies investigated by Horticulture Innovation Lab projects and provided with the opportunity to invest in these technologies. We collected data on the demand and use of these technologies in rural farming systems. Those groups which were interested in saving for a new technology were connected to Horticulture Innovation Lab partners for technology delivery and training. This model enables information to flow in two directions, as farmers and savings groups gained access to "leapfrog technologies," and Horticulture Innovation Lab partners learned how rural farmers in Cambodia reinvent new technologies to accommodate on-the-ground realities. This project also helped determine which horticulture technologies are in demand among Cambodian farmers, and what specific conditions create demand for these technologies

Collaborators:
- PI: Carey Trexler, University of California, Davis
- Johan Six, Glenn Young, Mark Van Horn, and David Miller, University of California, Davis
- Nguyen Quoc Vong, Nguyen Thi Bich Thuy, Pham Thi Huong, Pham Bao Duong, Pham Van Hung, and Thong Kong, Hanoi University of Agriculture, Vietnam
- Borarin Buntong, Asikin Yoeu, Lyda Hok, and Lor Lytour, Royal University of Agriculture, Cambodia

- Lam Thanh Hien, Phan Thi Giac Tam, Thai Anh Hoa, and Pham Thi Minh Tam, Nong Lam University, Vietnam

Achievements:
Group Formation: 148 people were formed into twelve saving groups with an average of 12 members per group within a period of six months. 125 of these members were women who were mainly either farmers or members of farming households.
Financial Benefit: The groups were able to save $15,798 with an average of $1,317 per group after one year of project. On top of that, they placed on average $36 into a social fund set aside for emergencies.

Adoption and Adaption: In November 2013, RUA hosted a workshop that brought farmers from savings groups and high value vegetable marketers together to learn about horticultural technologies and market opportunities in Phnom Penh. Farmers selected protective nets among their top three picks of technologies. Following the workshop, one farmer provided land to test the protective nets on his farm. The other technologies selected were soil solarization and compost. A farmer in a savings group tested the nets on his field using his preferred design of the net covering four rows of Chinese kale. Results were compared with the same crop grown outside of nets that received four pesticide applications. There was a 62% increase in production using the nets. Other examples of vertical learning occurred as technologies such as drying beads, used to keep seeds dry for the next planting season, were not adopted. Group members identified alternative, locally produced technologies that served them just as well. A variety of horizontal learning activities have also taken place among group members. For example, farmers and marketers came together in workshops, focus group discussions and field visits to share information on production of niche market crops, market demands and prices. In another case, discussions were held with those in the community interested in starting local production of the pest nets. The introduction of a new technology creates a ripple effect. Seeing the effectiveness of the nets, farmers have begun to test new crops such as tomatoes. A member of a savings group is now considering a business making the nets locally.

Capacity Building
Throughout the project 4 institutions, agencies and organizations were in direct cooperation. 10 professionals from the host countries attended workshops. 4 U.S. faculty members provided training in host countries. 6 host country professionals were involved in providing training to other host country professionals. 3 research projects and technologies of potential benefit to U.S horticultural industries were implemented.

Student Training: 37 students from Vietnam, Cambodia, and Laos pursuing either bachelors or masters degrees have participated in the project since 2010.

Lessons Learned
- The following observations of this short study of less than two years offer anecdotal information that calls for follow-up with more rigorous research:
- The weekly meetings have opened up new information channels among members who have increased their financial management skills.

- The commitment mechanism not only serves to strengthen the group but works to increase member savings and willingness to invest.
- Savings groups develop strong trust and self-confidence among members, especially as resilience and household food security are improved.
- Savings groups are an effective platform used by RUA and UCD to deliver training on horticultural technologies and to study how the technologies are adopted and adapted by these groups.
- There is a qualitative difference working with savings groups in which all members share a common interest. In this case, the common interest is that when farmers win, everyone wins. Although savings groups in agricultural communities do not consist solely of farmers, on average 85% are farmers, and the rest are a mix of farm laborers, input suppliers, transporters, food processors, machinery repairers, and marketers. Groups also include members of farm families seeking to subsidize farming through off-farm employment and merchants and service providers who possess a strong self-interest in the well being of farm families.
- Interviews with loan group members reveal that the majority of the loans are enterprise loans. At a distant second are income smoothing loans to be repaid at harvest time.
- Focus group discussions revealed a common entrepreneurial purpose to scale up their industry. When members of these shared interest agricultural savings groups were asked what would happen if they won the lottery, their most common response was that they would buy more land or acquire better equipment and plant more vegetables. This is sharply different than the response among multi-interest groups that respond with dreams of leisure.

Theme F – Nutrition

Project 1

Strengthening the value chain for orange- and purple-fleshed sweet potatoes

Description:
Orange and purple-fleshed sweet potatoes are promoted in this project as an opportunity for households in Northern Ghana to increase nutrition in their diets and to develop products for market. This project worked with sweet potato farmers, youth and communities through a series of workshops and cooking demonstrations, including how orange and purple sweet potatoes can be integrated into culturally appropriate foods.

Collaborators:

- PI: Eunice Bonsi, Tuskegee University
- Conrad Bonsi, Prosper Doamekpor, Desmond Mortley, Robert Zabawa, Tuskegee University
- Thomas Gill, Leland Glenna, Janelle B. Larson, Sjoerd W. Duiker, Pennsylvania State University
- Kwame Offei, University of Ghana
- Wisdom A. Plahar, Food Research Institute, Ghana
- Hans Adu-Dapaah, Crop Research Institute, Ghana
- Stephen Nutsugah, Savanna Agricultural Research Institute, Ghana
- Fafali Azaglo, Selasie Farms and Groceries, Ghana
- Joseph Apedo, farmer leader, Ghana
- Hawa Musah, Ministry of Food and Agriculture, Ghana
- Nana Ayim Poakwah, Hunger Alliance of Ghana (HAG), Ghana

Achievements:
Key achievements of this project included the establishment of a framework for orange and purple sweet potato dissemination and adoption through the collaboration of 14 host country institutions, agencies, and organizations in agricultural production, post-harvest, and markets. By working with project partners in several areas of the orange and purple sweet potato value chain, this project was able to do the following:

- Advance technology for the adoption of solar dryers to enable local sweet potato processing through evaluation of two solar dryers.
- Evaluate packaging techniques for preserving solar dried sweet potato chips.
- Demonstrate the production of orange fleshed sweet potato bread and evaluate sweet potato flour for color and consistency.
- Demonstrate how orange and purple sweet potato can be incorporated into local foods.

Capacity building:
This project trained 10 women in incorporation of orange sweet potato into traditional breads and five women were trained to incorporate these sweet potatoes into traditional

mpotompoto. Eight participants were engaged in a demonstration on the use of solar dryers to dry sweet potato chips.
This project also provided partial funding to one male and one female Ghanaian student in Development Studies (Master's and Bachelors, respectively).

Lessons learned
After preliminary evaluations of several solar dryers, two dryers were selected and built for evaluation. Of the two, the Tuskegee University Modified Tunnel Solar Dryer (TU-MTSD) with plastic sheeting provided the best results in root crop drying. This dryer can be built using local materials and is less costly than other models. Additionally, it can be used for multiple root crops and vegetable varieties according to seasonal production.

Presentations and publications

- Bonsi, E. A., W. A. Plahar and R. Zabawa. (2014). Nutritional Enhancement of Ghanaian Weaning Foods Using the Orange Flesh Sweet potato (Ipomea batatas). African Journal of Food, Agriculture, Nutrition and Development. 14(5): 2036-2056.
- Bonsi, E. A., E. C. Chibuzo and R. E. Zabawa. (2014). The Preliminary Study of the Acceptability of Ghana Bread Made with Orange Sweet potato Puree. Journal of Human Nutrition and Food Science. Accepted for Publication.
- Bonsi, E. A., R. Zabawa, D. Mortley, P. Doamekpor, C. Bonsi, K. Acheremu, F.C. Amagloh and F.K. Amagloh. (2014). Food Diversification to Improve Health: The Sustainable Technology for Orange and Purple Sweet Potatoes (STOPS) Project, Ghana. Acta Hort. (ISHS). Accepted for Publication.

Theme G - Enabling Environment

Project 1

Developing a participatory extension model to enhance smallholder production and marketing

Description:
Although the growing market for horticultural products in Uganda offers an opportunity for smallholder farmers to improve their incomes, their access to these markets is still limited. This project has developed a participatory extension model to rapidly improve smallholder linkages to horticultural markets through merging and supplementing two agricultural development models - Farmer Field Schools (FFS) with the Participatory Market Chain Approach (PMCA). We worked with Farmer Groups established in our pilot project in Nkokonjeru, Uganda. Specific objectives were to strengthen farmer groups' capacity to produce indigenous leafy green vegetables and tomatoes for the market and to improve farmers' ability to use their farm as an income-generating asset. Research in small plots and on farmers' fields of economically appropriate soil fertility management technologies, micro-dosing, improved varieties, irrigation, and safe pesticide use helped identify ways to increase vegetable yields and quality. In addition, curriculum enhancement with a local university (Uganda Christian) and Uganda's primary agricultural university (Makerere), as well as with governmental and NGO agricultural extension, strengthened the region's capacity to carry out and sustain research and extension activities for horticultural crops.

Collaborators:

- PI: Kate Scow, UC Davis
- Lauren Pincus, Abe Solomon, Mark Van Horn, Heidi Ballard, and Stephen Boucher, UC Davis
- Sam Mwebe, Rural Agency for Sustainable Development,
- Michael Masanza, Uganda Christian University
- Dennis Yiga, Peter Lusembo, National Agricultural Research Organization (NARO-MUZARDI)
- Harriet Nsubuga Mpanga, Agribusiness Initiative Trust
- Peter Ebanyat, Makerere University

Achievements:

- Successfully developed and completed a participatory and integrated extension approach of combining Farmer Field Schools (FFS) and Participatory Market Chain Approach (PMCA).
- Trained over 460 farmers in production, marketing, and postharvest of Indigenous Leafy Vegetables (ILVs).
- Identified local markets where more than half the project participants now sell fresh greens (70% women) now making 5 times the income from greens as they did before the project.

- Developed recommendations for "integrated soil fertility management" (IFSM) practices for one of Uganda's main indigenous leafy greens based on student research and research of farmer groups on shared plots.
- Tested the effects of adding biochar to soil on growth of indigenous leafy greens and other crops.
- Trained and built experience for seventeen undergraduate students, five high school graduates, and twenty agricultural professionals in agricultural research, extension, and ILVs.
- Sponsored and supervised research of three graduate students in soil science, agricultural extension, and horticulture & agronomy.
- Incubated innovations in vegetable seed, marketing, and irrigation, leading to one new research project and three new enterprises.
- Provided training in postharvest practices for leafy greens for two professionals
- Improved the diet and perceived health of 33% of the participants in the program.

Capacity building:
The project trained over 460 farmers in production, marketing, and postharvest of Indigenous Leafy Vegetables (ILVs). They also sent one project participant to the postharvest master training course held by Lisa Kitinoja and Diane Barrett in Tanzania. This led to new postharvest research on 3 low-cost technologies for storing nakati on-farm. 10 students from Uganda Christian University, Makerere University business school and Kyambogo University worked as research assistants on this project.

In 2013, the project involved 9 undergraduates (6 women) from Uganda Christian University, and a master's student from Makerere University. An additional master's student from Makerere graduated this year. A PhD student from UC Davis has conducted her dissertation research on this project.

The project also built capacity at RASD, as staff learned how to do rapid market appraisals and gained additional experience conducting farmer field schools and participatory market chain analysis.

The project worked with the Nkokonjeru Seed Packers group (established earlier in the project) to expand their seed production from nakati seeds to other crops. They were trained on wet-processed tomato seed production and dry-processed (eggplant, pepper) seed production.

Lessons learned
Small markets matter. There is an enormous potential to improve the livelihoods of many smallholder vegetable producers through selling in local markets (in contrast to a focus solely on regional markets, supermarkets, hotels), as it is much easier for rural producers to capitalize on untapped local demand than to participate in larger marketing sectors. In fact, failing to recognize the importance of small local markets can miss what may be the greatest opportunity to improve the well-being of the majority of farmers, particularly women farmers. Participation in these small markets can contribute to small but substantial changes in living standards, particularly for women farmers who have limited capital, time, and labor

to devote to additional agricultural activities. Also given that harvesting of greens can continue over extended periods of time rather than being a one-time event, these markets give the farmers access to a continuous income stream, at least during the rainy seasons.

Production practices need to be linked to market opportunities. Market knowledge can be very useful in guiding production decisions, hence the importance of extension approaches that link both markets and production. For example, availability of indigenous leafy greens in markets during the dry seasons is quite limited due to the fact that these are rain-fed crops. Prices of greens can triple during the dry season making growing greens lucrative in these times. Introducing irrigation and water storage technologies can open up the possibility of growing greens and serving these markets during the dry season. Several farmer groups began to explore potential business endeavors involving irrigation technologies to help produce greens in the dry season.

Participatory market chain assessment involving farmers leads to unexpected business opportunities and partnerships. A major output of our project stemmed from the discovery of the lack of availability of good quality seeds. Seed production was thus identified as a potential market and this led to mobilization of some farmer groups to develop a seed business which, in turn, led to contracts with seed companies.

Farmers learn best and become empowered in an environment that is participatory and hands on. The Farmer Field School (FFS), given its participatory nature, was effective at raising farmers' awareness of soil fertility management and new vegetable production methods. Farmers reported learning the most from their facilitator, their peers, and at a farmer field day that highlighted individual FFS groups' field research. Those FFS groups that integrated additional group activities into their venue, such as savings schemes or shared marketing ventures, were more likely to persist after the formal project ended.

Postharvest practices for leafy greens are challenging. Indigenous leafy green vegetables wilted rapidly after harvest, making it difficult to transport them for long distances to larger regional markets. The most successful postharvest practices were simple ones (e.g. using shade, covering, moisture).

Farmers need to organize into farmer groups to take advantage of markets and production innovations for vegetables. Strong farmer group organizations help substantially in empowering farmers in both marketing and production of indigenous leafy greens. Traders who came to buy greens needed to be able to find centralized locations where greens from different farms were consolidated. Given issues of limited trust between farmers and traders, strong leadership of groups is needed to ensure fair prices, sufficient produce availability, and means to arbitrate unfair practices.

Most vegetable production does not utilize sufficient fertility. Not only indigenous leafy green vegetables but vegetables in general receive little, if any, mineral fertilizers and there is considerable potential for boosting yields with better soil management. Combining the use of organic and mineral sources of fertilizers (as part of integrated soil fertility management) shows the greatest promise in increasing yields while improving soil quality.

Presentations and publications

- Invited talk at RUFORM meeting in Mozambique, July 2014 titled "Increasing the Capacity of Smallholder Farmers to Produce and Market Vegetable Crops in Uganda"
- Presentation to Weller Horticulture Innovation Lab Final Meeting, July 2014, titled "Increasing the Capacity of Smallholder Farmers to Produce and Market Vegetable Crops in Uganda"
- Invited talk at conference "Ecosystem Services Modeling to Manage the Emerging Infectious Plant Diseases of Africa", Bellagio, Italy, April 2014, titled "Increasing the Capacity of Smallholder Farmers to Produce and Market Vegetable Crops in Uganda"
- Invited talk at Purdue University, October 2013, titled "Increasing the Capacity of Smallholder Farmers to Produce and Market Vegetable Crops in Uganda"

Theme G - Enabling environment
Project 2
Developing energy solutions for horticultural production

Description:
As part of a larger capacity-building effort, this project will integrate activities at the Horticulture Innovation Lab Region Centers in Thailand, Honduras and Kenya into the ongoing work at the University of California, Davis (UC Davis) D-Lab. UC Davis D-Lab faculty mentors and graduate student teams will collaborate with the Horticulture Innovation Lab Regional Center partners through a structured approach for performing feasibility studies, technical and market assessments, and design development on innovative horticulture-focused energy technologies. Through this process, the Horticulture Innovation Lab Centers will gain new methods for evaluating and developing horticulture innovations, better enabling them to attract investment and initiate dissemination of these technologies.

Collaborators:

- USA: PI: Kurt Kornbluth, Michael Reid, Jim Thompson, UC Davis
- Honduras: Jorge Espinosa, Arie Sanders, Alfredo Reyes, Zamorano University
- Thailand: Poon Kasemsap, Siwalak Patheveerat, Kietsuda Leuengwilai and Nonglak Samantart, Kasetsart University

Achievements:
D-Lab courses established at Zamorano University (Honduras) and Kasetsart University (Thailand). In partnership with the host universities, the D-Lab team created curriculum for both courses, and developed an instructor's logbook (in Spanish) for the Honduras course. The courses enabled students at both universities to test low-cost, innovative technologies under local conditions, and strengthened partnerships between UC Davis, Zamorano, Kasetsart, and local communities and organizations in Honduras and Thailand.

The materials generated by the Zamorano and Kasetsart D-Lab courses were shared with the USAID IDIN network. Students participating in these courses evaluated technologies under their local conditions and submitted reports of their results to their peers and professors.

In addition, UC Davis D-Lab students tested the following technologies:

- Simple solar dryer for fruits, vegetables, and grains
- Tools for the dry chain
- Simple photovoltaic pumping
- Small-scale transportation and cooling
- Innovative insulation
- Facilitated solarization
- Peltier block cooling
- D.C. split air conditioner/CoolBot for a solar-powered cool room

Capacity building:

Two host country organizations worked in direct collaboration on the various projects. Nine host country professionals took part in workshops and training conferences. Eight host country university faculty and other professionals were involved in providing training to other host country professionals. Ten host country professionals were directly involved in conducting Horticulture Innovation Lab research activities, and the work resulted in five technologies of potential benefit to U.S. horticultural industries including zeolite beads, mobile irrigation, efficient cook-stoves, cool room insulating technologies, and product storage bags.

23 UC Davis graduate students completed the D-Lab "Energy and Development" course in the winter, and 19 UC Davis graduate students completed "D-Lab II: Designing for the Market". In the winter, students worked on practical feasibility studies of energy technologies with developing country partners. In the spring, students designed and tested low-cost, easy to scale energy technologies for their developing world clients. These classes were offered again in 2014, with 30 students participating in winter 2014, and 19 participating in the spring.

45 Zamorano undergraduates participated in the inaugural Zamorano D-Lab course. 29 students participated in the Kasetsart course.

Lessons learned
Most of the "lessons learned" are described in the 'achievements' section above. The overall lesson that we have learned is that there are ample opportunities to use innovative technologies to improve the production and postharvest handling of horticultural crops.

Publications

- Posters at the Annual Horticulture Innovation Lab meetings
- Horticultural Innovation Lab Information sheets on the UC Davis chimney dryer and the CoolBot refrigeration system
- D-Lab 1: Winter 2013
    - Energy Hub (Uganda)
    - Electricity Feasibility Study (Ghana)
    - Solar Irrigation (Uganda)
    - Seed Saving Feasibility Study (Thailand)
- D-Lab II: Spring 2013
    - Solar Fruit Drying (Ecuador)
    - Rubber Tapping Knife (Thailand)
    - Mobile Irrigation System (Uganda)
    - Off-Grid Zeolite Bead Regeneration (Thailand)
- D-Lab I: Winter 2014
    - Essential Oil Extraction Market & Technical Analysis (Nepal)
    - Mobile Irrigation Market Analysis (Uganda)
    - Mobile Irrigation Technical Analysis (Uganda)
    - Cool Chain Analysis (Kenya)
    - Post-Harvest Grain Storage (Zambia)
    - Energy Microgrid (Sudan)

        - Cool Room Insulation (Kenya)
- D-Lab II: Spring 2014
        - Agricultural Mobile Irrigation System (Uganda)
        - Cool Room Insulation (Kenya)
        - Solar Cooker (Chad)

Theme G - Enabling environment
Project 3
The Trellis Fund

Description:
The Horticulture Innovation Lab's Trellis Fund provides small-scale, in-country development organizations access to U.S. graduate student expertise, providing benefit to both the student and the in-country institutions. Trellis Fund projects address a variety of horticultural development topics, including irrigation, fertilization, other aspects of production, pest management, postharvest practices, nutrition, or marketing issues in relation to fruits, vegetables and high-value horticultural crops.

Collaborators:

- Kenya:
  - Johnson Nyasani, KARI
  - Jane Ambuko, University of Nairobi
- Uganda:
  - Charles Bagenda Kasangaki, Hoima District Farmers Association
  - Amos Kerera, WECA Farmers Association
  - Veronica Kfambe Night, URICT
  - Andrew Baguma, Mwino Group
- Nepal:
  - Angus Douglas, KISC-Equip
- Tanzania:
  - Don Lotter, St. John's University
- Ghana:
  - Peter Kwapong, University of Cape Coast
- Guatemala:
  - Myriam LeGault, Ronaldo Lec Ajcot, Instituto Mesoamericana de Permacultura
- Bangladesh:
  - Amin Uddin, Helen Keller International
- Senegal:
  - ADC SuperCrown
  - Groupement Ande Liguey
- Mali:
  - Sokona Dagnoko, IPR/IFRA

Achievements:
In 2013, Trellis involved 15 graduate students from 3 universities (UC Davis, University of Hawaii at Manoa, and Cornell University). Students worked with partner organizations in 9 countries. This was the first year that Trellis had projects in Bangladesh, Senegal, Mali, and Ghana. Project ranged from using neem in IPM to introducing a new chili variety to working with homestead gardeners to mitigate soil salinity. Trellis projects trained 2555

farmers (698 men and 1857 women), and estimate approximately 49% of participants adopted a new practice (averaged over all of the projects).
Capacity building:
In 2013-2014, Trellis trained 2555 farmers (72% women), and estimates a 49% adoption rate for the new practices or technologies introduced. In addition, 15 US graduate students received training on agricultural development, workshop facilitation, gender empowerment, and more.

Lessons learned:
We had major problems getting money to the organizations this year (partially due to someone in the budget office going on leave). In the future, we will factor in a lot more time for the contracting process.

In addition, we worked with several large organizations this year, and they were generally – though not universally - more difficult to work with. We will focus on smaller organizations as much as possible in future rounds of Trellis.

Presentations and publications

- Trellis partner Dr. Sokona Dagnoko (IPR/IFRA, Mali) presented the results of her Trellis project at the RUFORUM meeting in Mozambique. Student Carly Summers is currently working on an article about her experience for the MEAS case studies series.

Capacity building

Capacity building is a pillar of Horticulture Innovation Lab projects. In Fiscal Year 2014, 227 people took part in short-term trainings; 52% of them were women. 121 of them were trained at an affiliated Center, and 106 people received training directly from projects. Since 2009, Horticulture Innovation Lab projects have provided short-term training for 32,068 people, over half of whom are women. One hundred students completed training with us in FY 2014, bringing the total number of long-term students we have supported to 424. We worked with 249 additional students in our projects (this year?). Nearly 60% of our long-term students have been women and two-thirds of students are undergraduates.

We collaborated with the University of Minnesota's Humphrey School of Public Affairs and supported the efforts of five graduate students to assess legal and policy barriers faced by women in horticulture in four countries.

In addition to student training, the Horticulture Innovation Lab is committed to building institutions. We have worked with over 100 partners throughout the world. Our projects provide critical research funding and professional development to in-country researchers and extension educators. In addition to universities and research institutions, Horticulture Innovation Lab supports small developing country organizations through our Trellis Fund. The Trellis Fund provides small-scale, in-country development organizations access to U.S. graduate student expertise, providing benefits to both the student and the in-country institutions. With a focus on impact and expansion of locally proven ideas, the Trellis Fund matches the organizations with students and provides modest funds to support the organization's farmer outreach program.

Technology transfer and scaling partnerships

The Horticulture Innovation Lab has several promising technologies to scale. In the past four years, we have worked transferred technologies to over 600 organizations and our project partners have formed 140 public-private partnerships.

Scientists from US and developing country institutions are developing and adapting a range of innovative technologies aimed at significantly improving the profitability of horticultural production in Africa and other parts of the world. Current studies include low-cost cold storage and transportation systems, portable and reusable drying beads for seeds and other dried products, improved solar drying technologies, cell-phone extension services, barrier nets that reduce the need for pesticides and create a microclimate for row crops, and high tunnels to mitigate climate challenges and extend production and marketing seasons. The goal is to test 'disruptive' technologies that can overcome developing country constraints of small farm size, limited capital, and poor infrastructure. Our researchers are exploring innovative uses of modern materials and technologies to overcome the challenges of production and marketing of horticultural crops. Among the technologies that we are exploring for future are opportunities for innovative uses of energy (including photovoltaics) for overcoming barriers that limit the participation of smallholder farmers in the horticultural value chain. Horticulture Innovation Lab is establishing Centers of Innovation in collaboration with leading research institutions around the world, where these technologies can be deployed, adapted to local conditions, tested on smallholder farms and extended to local stakeholders.

Given the complexity of horticulture, innovative "leapfrog" technologies can reduce constraints and input costs that limit the ability of smallholder farmers to achieve maximum profitability in the production and marketing of high-value horticulture products. Horticulture Innovation Lab projects have researched and adapted proven technologies and have come up with a number of novel leapfrog technologies and innovations that will reduce poverty and hunger.

The work of innovation in horticulture is to make something better, more efficient, more nutritious, more productive or more profitable. The Horticulture Innovation Lab believes that specific technologies and innovations have the ability to solve problems and challenges and 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 Lab focuses on technologies that reduce on-farm costs, use labor more efficiently, empower women, build partnerships, and sustainably use natural resources.

We know that often the simpler a technology is, the more likely its uptake and adaption to local conditions will be. Access to materials, final cost, and actual and perceived benefits all play an important role in farmer adoption. Our research addresses all of these aspects of technology design and dissemination.

The Horticulture Innovation Lab's "technology toolbox" is a selection of tested and proven technologies including those that have been developed and/or demonstrated in Horticulture Innovation Lab projects. Currently Horticulture Innovation Lab scientists are adapting a

range of innovative technologies aimed at significantly improving the profitability of horticultural production for smallholder farmers.

Through the Horticulture Innovation Lab Regional Centers, these technologies will be deployed, adapted to local conditions, tested on farms and extended to local stakeholders. Each of the centers will add local innovations to the toolbox and will continue to research and adapt these technologies for local use while following rigorous research methods and community participation.

In addition to the technologies in the toolbox, our projects are developing other methodologies which will be ready for scale. These include "soft" technologies such as techniques for farmer education and farmer savings.

Steps Taken:
There are four specific types of scaling that the Horticulture Innovation Lab works on, these are:

- Geographic scale; from one geographic region to another
- Vertical scale; from local to policy level, also called integration
- Horizontal scale; to more people within the same geographical region
- Functional scale; from one part of the value chain to another

The Horticulture Innovation Lab scales technologies on a number of fronts:

1. Research projects are coming to a close in 2014 and many of them have in the last year identified scaling new technologies as a priority before terminating their projects. Many technologies like the drying beads, agro nets, the Coolbot, the solar dryer, and savings groups have already taken steps to scale their technologies. This is explored in more detail in sections iv and v.
2. The Regional Centers integrate with new and existing Horticulture Innovation Lab research projects, synchronize with new and existing USAID/BFS funded value-chain projects and Mission-led horticulture projects, build strategic relationships with partners, conduct research, and build local management, research, and horticulture capacity. Each Center will continue to focus on innovation and technology; working in parallel with each ME funded research project to test and modify new technologies, host workshops and activities and serve as a regional resource for project PIs.
3. The annual meeting allows cross project collaboration and learning from invited guest speakers. The 2014 Annual Meeting focused on scaling-up technologies, and our keynote guest Robert Adams from UC Davis led an interactive team-oriented workshop on the principals of methods of scaling technologies. It was through this that each project team came up with a scaling plan for their technologies/research or interventions.

Partnerships made (6 in 2014):

- A to Z international, APRETECTRA in Benin and KOAN in Kenya (Ngouajio)
- Royal University of Cambodia, Agriculture Development Denmark Asia ADDA and SAMREM (Reyes)

- Mace foods, Eldoret Kenya, Sylva's Catering, Sun International (Weller and Simon),
- CABI Kenya, iDE Bangladesh, AgLearn, (Bradford).
- Partnerships have been made with the CIP team in Dhaka, with our farmer collaborators, with the BRAC solar team, and with BARI postharvest researchers.
- Partnerships have been made with the directors of the Innovation Centers, with the D-lab students, and with in-country collaborators.

Technologies transferred (6 in 2014)

- CoolBot- over 20 new users established directly by Horticulture Innovation Lab projects, leveraged funds and new partnerships.
- UCD Solar Dryer- transfer to Uzbekistan, Bangladesh, Guatemala, Ghana, Tanzania, Nepal,
- AgroNets
- Phytophthora Diagnostics- Training done at the Regional Center at Zamorano
- Zeolite Beads
- Shade Bot

Technologies scaled (2 in 2014)

- UCD Solar Dryer
- CoolBot and affordable coolroom design

Technologies ready to scale (2 in 2014)

- Affordable solar pumping with readily available materials
- Zeolite Beads

Regional Centers

In collaboration with partner institutions, the Horticulture Innovation Lab Regional Centers will serve the regions of East Africa, Central America and Southeast Asia to showcase technologies and innovations that can improve horticulture in their respective regions. The Central America center is located at The Panamerican Agricultural School, Zamorano, Honduras, the East Africa center is at the Practical Training Center with the Kenya Agricultural Research Institute (KARI) in Thika, Kenya and the Southeast Asia center is at Kasetsart University in Bangkok, Thailand.

The centers connect horticultural researchers, extension workers, farmers, non-governmental organizations and relevant private sector partners within their respective regions. The centers each serve as a regional repository for horticultural technologies and knowledge, provide training programs, facilitate the evaluation and adaptation of horticultural technologies, and develop mechanisms for sharing ideas within and across borders. The centers work with national agriculture research and extension systems, agricultural universities, NGOs and the private sector to provide ongoing training for the local horticultural industry and for trainers both at the centers and across the region. The centers draw on local experts who have received technical training through advanced degree programs or train-the-trainer courses. The centers provide testing grounds for horticultural technologies and physical facilities for workshops and training sessions. Each center houses a number of horticulture technologies that have been researched and validated by Horticulture Innovation Lab researchers and in-country partners. The most suited technologies are on display and used for trainings and research.

Key accomplishments FY14:
2013-2014 has been a year of growth for the Horticulture Innovation Lab Regional Centers. The Regional Center at Zamorano directed by Julio Lopez

In Thailand, faculty have been researching and testing materials to insulate a low cost cold room, as well as testing affordable ways to convert a household AC unit into a powerful cooler. Our partners and researcher investigating the drying beads continue to work to expand their network and sales. The AgLearn project continued with training Bangladesh, and Cambodia.

Specific to each center, Central America:
The Regional Center at Zamorano has been successful in establishing postharvest technologies, integrating Zamorano students into the daily activities of the center and hosting visits from a number of private companies, NGOS and other academic institutions. Above all, the center is focused first on training farm families to meet their daily needs; when they have the ability to produce at the subsistence level the center works through a collaborative business process with the families to connect them to markets and improve production and business practices to sustainably meet their financial needs.

Achievements:
Integrated Management of Crops and Climate Change continues to be a core course, required of all students in their 3rd year. The course is taught at the Regional Center by Staff member Ivanna Vejarano (Center Instructor). Students are trained in vegetable production,

new technologies, IPM, climate change adaption, postharvest, and agronomy. Students get credit and time to work on their individual research plots which are also a part of the center. Onion, peppers, lettuce, tomato, celery, beets, horseradish and carrots are currently under cultivation. This course is integrated with a USAID funded climate change adaption project also implemented by Zamorano.

The center houses 4 protective structures, 2 mesh houses, 1 large macro tunnel and 1 smaller micro tunnel. These are used for the production of high value solanaceous crops. The center has found that these structures are a viable technology for medium sized producers. These farmers have a difficult time producing these crops in open fields due the many pests present.

Installation of soil and water conserving methods of vegetable production using live barriers.

10 x 10m Bio Intensive home garden research. The Center is looking at how families with little land can grow enough food to supplement their diet. These demonstration plots have 7 different fruit and vegetable crops.

Research plot of taro root to test and demonstrate feasibility on water logged soils, and as an alternative crop. The Regional Center will have plots for teaching and showing farmers and students the value and techniques to growing taro and how to process the root to be ready for the market.

New Technologies in 2014:

- Zero Energy Cool Chamber ZECC
- UC Davis solar dryer and traditional stack dryer
- Coolbot

Visits:

- Horticulture Innovation Lab Annual Meeting 2014- field day at the Regional Center at Zamorano
- Lizanne Wheeler from Sonora Pacific and WFLO
- Dr. Marita Cantwell from UC Davis
- Ohio State University
- University of Wisconsin
- North Caroline State University
- Kansas State University
- Ministry of Agriculture SAG Honduras
- Kolping Foundation

Trainings:

- June 2014 2nd annual International Course of Postharvest of Vegetable and Fruits. (47 participants)
- Field Schools with participants from iDE, NSV, INPRHU-Nicaragua, INTA
- Promoters field schools (19 participants)

- Technical field schools (35 participants)
- CCRD-USAID trainings on climate change adaption
- Zamorano students trained (170 men and 100 women)

Specific to each center, Asia:
The Regional Center at Kasetsart University spans the entire university, involving faculty from departments such as Food science, Agronomy, Horticulture and Agriculture Engineering. In 2014 the center established a central site with a number of technologies set up for demonstration and research. This new move has helped the center to reach more trainees, and involve more students in research and training. The center has also been able conduct many trainings outside of Thailand, as the center has built strong partnerships with RUA in Cambodia and Helen Keller International in Bangladesh. We expect these and many more partnerships to evolve in 2015.

Center activities in Cambodia:

- 10 academics and extensionists trained on pest exclusion net use, net house design, and cold storage.
- 16 women and 2 men were trained on how to design and build net houses with local net materials. They were also trained in the basics of growing vegetables in the nets for market, including seedling production, planting, irrigation, care, weeding, and harvest maturity.
- 10 male farmers were trained in IPM
- 11 women and 9 men were trained in postharvest pathology for horticulture crops, in collaboration with RUA.
- 34 women and 4 men were trained in guava production, and are currently testing a new variety of guava provided by KU.

Center activities in Bangladesh

- 30 women and 9 men were trained on how to build and use the UC Davis Solar dryer. The dryer was set up in two communities for demonstration purposes. Staff at Helen Keller International/Bangladesh were trained in the design, use and upkeep of the dryers.

Center activities in Thailand

- Conducted postharvest and technology training at the AVRDC international vegetable course 2013.
- Mark Bell gave a workshop on extension training at the AVRDC international vegetable course 2013.
- Trained extensionists from Nepal, Cambodia and Bangladesh on the construction and use of low cost solar irrigation systems and soil solarization.
- Trained extensionists from Nepal, Cambodia and Bangladesh through the AgLearn program on the use of zeolite drying beads for improved seeds storage.
- Cold storage was tested with growers in southern Thailand.
- Regional Center hosted representatives from USAID during the Scaling GLEE.
- Trained extensionists from Nepal, Cambodia and Bangladesh on the Horticulture Innovation Lab's technology toolbox.

- Trained extensionists from Nepal, Cambodia, Indonesia and Bangladesh on the construction and use of the UC Davis Solar Dryer.

Specific to each center, Africa
The Regional Center at KARLO is housed at the Practical Training Center and is a collaboration between KARI and FPEAK, a private sector group.

Achievements:

- Opening a postharvest training and services center. The Center is in the process of aligning itself with the curriculum development at the Practical Training Center. The Innovation Lab-trained staff Dr. Charity Gathambiri has developed a practical training course for postharvest.
- Strengthening the value chain for African indigenous vegetables. The demonstration units for establishing the identified crops have already been demarcated and prepared, and are waiting for the planting season in October.
- Developing a variety of solar dryers. The center is developing additional solar dryers for testing under the conditions prevailing where the center is located. The simple cabinet dryer has attracted a lot of interest and stakeholders are already trying it for mangoes and vegetables. A zero energy dryer will also be established here. As part of the curriculum being developed at the PTC, solar drying technology will be demonstrated both at the center and the mobile units that will be put together
- Demonstrating low-cost cooling technology. The structure for the CoolBot-run cold room has been erected at the center and in the next phase, the CoolBot equipment will be affixed. The power line for the CoolBot has already been extended to the structure.
- Demonstrating nets and floating row covers. Production units using low-lying nets and medium height structures will be established to demonstrate pest exclusion technologies as a practical part of IPM. With the upcoming issue of *Tuta Absoluta* it would be interesting to see how effective nets are in keeping off the pests.
- Increasing smallholder use of grafting and tunnels for tomatoes and peppers
- The tomato grafting technology for hybrids is generating a lot of interest. The center will establish a demonstration unit where farmers will be trained on how to do this.

Regional Center capacity building:
The regional centers are continuing to work on student training. Both KU and Zamorano have trained students on production, postharvest and new technologies.

Lessons Learned

- Strong and dedicated leadership is necessary for a Center to thrive.
- A supportive staff able to execute the Director's visions is absolutely necessary to a centers' success.
- Building relationships across countries will strengthen the regional networks.
- Aligning goals and priorities (as able) with local USAID Missions helps to get their buy-in.

- Searching for external funding sources helps to build the sustainability of each center.
- Involving students in research and implementation enriches our projects.
- Visits and hands-on support from the Horticulture Innovation Lab Program Officer and members of the ME increase the likelihood of success.
- Attending regional meetings, conferences and high-level workshops helps to increase the visibility and viability of each center.

Issues

Some projects were demoralized when changes in USAID funding structures, based on political decisions, negatively impacted their work after they had already started to implement their projects. Projects reported that some of the research partners in multiple countries were slow to send invoices or sub awards.

Future Directions

Technical Leadership:

UC Davis and its partner institutions are well poised to continue as the Management Entity of the Horticulture Innovation Lab. In this next five year period, the University of Florida will replace Cornell University as our Partner Institution along with North Carolina State University and the University of Hawaii at Manoa. We have five years of experience leading Phase I of the Horticulture Innovation Lab, as well as strong relationships with university and organizational partners worldwide. In addition, the partners' faculty expertise and diversity of crops addressed by their research, teaching and outreach makes us ideal partners to promote horticulture research and education in the developing world.

Themes in Phase II:

The Horticulture Innovation Lab remains committed to building international research partnerships to sustainably reduce global poverty and hunger. In order to achieve this goal, we will focus on the following areas:

- Horticultural value chain research:
    - We will support research projects along the entire horticultural value chain. We will also work on special projects of interest to the USAID Mission Value Chain projects.
    - Innovation and scaling:
    - We will work with our projects and the Regional Centers on the dissemination and scaling of innovative horticultural technologies. In addition, we will fund 3 projects specifically focused on scaling technologies from Phase I projects.
- Capacity building:
    - We will build the capacity of researchers, institutions, students, and other actors in the horticultural sector worldwide. Capacity building is integrated into all Horticulture Innovation Lab activities. We will also continue our Trellis program with five rounds during Phase II.
- Nutrition sensitive horticulture:
    - All of our research projects will be nutrition sensitive, and will assess the impacts that their project is making on the nutrition of the participants.
    - Empowering women and the most vulnerable:
    - In many regions, women and other vulnerable people are the primary producers and marketers of horticultural crops. The Management Entity will work with collaborators to ensure that all Horticulture Innovation Lab projects are gender sensitive and encourage the meaningful participation of women.
- Sharing information:
    - We will make our projects' research results easily accessible to multiple stakeholders, from local community members in project focus areas to university scientists. In addition, we will work with our project partners to help them effectively package and disseminate information for wide impact. We will collaborate with others to disseminate materials that are of use to them, including regional projects and USAID partners.

Technical Approach:
We will issue six types of RFPs during Phase II, each with a different scope and focus. All RFPs will be competitive, and applications will be evaluated by a combination of ME and external reviewers. Proposals must be collaborations between a U.S. university researcher and focus country partners.

In year one, we will issue RFPs for three major projects, one each for research on Postharvest, Nutrition, and Gender equality ($1.5-$2 million each over five years). These awards will be open to anyone with a PI status at a U.S. university. We will also issue RFPs for scaling of Phase I technologies (three two-year projects, $220,000 each) and Spin-off Projects addressing new research needs identified by a Phase I project (three two-year projects, 300,000 each). Both of these RFPs will be open to any PI previously funded by the Horticulture Innovation Lab. In year one, we will also fund a Mission service project on aquaculture and horticulture in Cambodia ($200,000 over two years). This project will be a collaboration with WorldFish and other local Mission projects and the Nutrition Innovation Lab.

In year two, we will fund two additional Mission service projects on issues identified by the Missions and their value chain partners. These projects will take place in two yet to be determined countries ($300,000 over two years). Finally, we will fund four focus projects on postharvest, marketing, food safety, production, capacity building, or mixed animal agriculture, starting in year two (four three-year projects, $375,000-$450,000 each). We have also set aside $750,000 for a five-year investment in Burma.

We will continue funding our three Regional Centers, with an increase in funding to allow each of them to hire a person dedicated to facilitating Center activities. We will work over the first three years of Phase II to ensure sustainability of the Centers by the end of Phase II. We will be monitoring the progress of the Regional Center at KARI Thika for progress over the first six months of the new project. If progress continues to be unacceptable, we will close that center and search for a new location in Africa for a Regional Center.

Appendices

A. List of awards given to U.S. universities to include project name, dates and funding (current year and total).

1. Rutgers University; "Sustainable Development of Horticultural Crops in Zambia by Introducing Postharvest Technologies and Practices for Food Security, Income Generation and in Support of the Tourism Industry"; $58,743 allocated FY13-14; $250,000 total award
2. UC Davis; "Seed Systems - Improving Seed Quality for Smallholders"; $265,129 allocated FY13-14; $999,936 total award
3. The Ohio State University; "Delivering Vegetable Safety Education through Established Social Networks in Latin America"; $23,330 allocated FY13-14; $149,448 total award
4. Tuskegee University; "Sustainable Technology for Orange and Purple Sweet potato (STOPS) in Ghana"; $13,272 allocated FY13-14; $250,000 total award; HBCU
5. Purdue University; "Sustainable African Indigenous Vegetable Production and Market-Chain Development for Improved Health and Nutrition and Income Generation by Smallholder Farmers in Kenya, Tanzania, and Zambia"; $0 allocated FY13-14, $995,725 total award
6. The University of Florida; "Postharvest Training Materials for Smallholder Producers of Horticultural Crops that Support Transitions to Commercialization"; $0 allocated FY13-14; $153,046 total award
7. The University of Wisconsin; "Semillas de Esperanza"; $0 allocated FY13-14; $489,923 total award
8. Michigan State University; "Low cost pest exclusion and microclimate modification technologies for small-scale vegetable growers in East and West Africa"; $0 allocated FY13-14; $500,985 total award
9. North Carolina State University; "Regional Capacity in Phytophthora diagnostics in Latin America"; $0 allocated FY13-14; $39,042 total award
10. The North Carolina Agricultural and Technical State University; "Vegetable Production in Drip Irrigation for Disadvantaged Women in Siem Reap, Cambodia"; $0 allocated FY13-14; $15,000 total award; HBCU
11. UC Davis; "Safe Vegetable Production in Cambodia and Vietnam: Development of the HARE-Network to Enhance Farmer Income, Health, and the Local Environment" $0 allocation FY13-14; $659,728 total award
12. UC Davis; "Increasing the Capacity of Smallholder Farmers to Produce and Market Vegetable Crops in Uganda and Democratic Republic of Congo"; $0 allocated FY13-14; $497,986 total award
13. UC Davis; "Extension of Appropriate Post-harvest Technology in Sub-Saharan Africa: A Postharvest Training and Services Center (PTSC)"; $0 allocated FY13-14; $491,519 total award

B. Three distinct success stories

HORTICULTURE INNOVATION LAB PHOTO / ROBERT ZABAWA, TUSKEGEE UNIVERSITY

Tuskegee University's Eunice Bonsi (right) is working with food processors and bakers to formulate flours, breads, purees and weaning foods using orange and purple sweet potatoes.

Above, a plate full of sweet potato includes orange and purple varieties, as well as palava sauce made with sweet potato leaves.

FROM VINE TO FLOUR: BRIDGING GAPS IN SWEET POTATO VALUE CHAIN

In Ghana, white-fleshed sweet potatoes already play an important role in food security, but orange-fleshed varieties have the potential to alleviate vitamin A deficiency while being incorporated into familiar foods.

Vitamin A deficiency is the leading cause of preventable blindness in children and increases the risk of severe infections. In Ghana, vitamin A deficiency affects 72 percent of the country's children under 5 years of age.

Though interest in orange-fleshed sweet potato has been on the rise, widespread production and consumption of these vitamin A-rich varieties in Ghana still remains limited due to lack of awareness, limited availability of clean-planting materials and limited inclusion in the diet.

As part of Feed the Future, Dr. Eunice Bonsi of Tuskegee University leads an international team working to increase the consumption of orange- and purple-fleshed sweet potatoes in Ghana, through activities that strengthen the crops' value chain in three of Ghana's sweet potato growing regions. Other team members include the University of Ghana, Pennsylvania State University, the Savannah Agriculture Research Institute (SARI), Ghana's University for Development Studies and a number of other organizations.

The team established sweet potato vine multiplication sites at SARI and at research facilities in the Northern and Upper East regions in Ghana. Lead farmers have planted the clean vines for demonstration and now serve as distributors of disease-free germplasm. Farmers were also trained in best management practices.

The team conducted focus groups on orange and purple sweet potato palatability and preferences with local schools and non-governmental organizations. They also established demonstration gardens at schools and NGO sites. Through a newly developed partnership with local 4-H, the group is also working to promote the new varieties to youth.

Researchers from SARI and Ghana's University for Development Studies analyzed products already available in Ghana that use orange- or purple-fleshed sweet potatoes. The team has promoted the potatoes' inclusion in traditional recipes, some of which have been served at SARI's cafeteria.

The team formulated a weaning food that incorporates the vitamin A-rich sweet potatoes, and have trained women entrepreneurs to process these colorful sweet potatoes into flour, purees and dehydrated chips. Local bakers are now using locally grown, orange sweet potato puree to make bread—and marketing it as more nutritious than other breads.

Incorporating orange-fleshed sweet potatoes into Ghanaian fields, village bakeries and infants' diets adds nutritional value to existing foods.

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HORTICULTURE INNOVATION LAB PHOTO / BRENDA DAWSON

Workers with the Kenya Agricultural Research Institute check on vegetables in AgroNet field trails at KARI Kabete, during a project with the Horticulture Innovation Lab.

MOSQUITO NET CO PARTNERS WITH RESEARCHERS AGAINST AG PESTS

Bed nets are nothing new to international development, but a leading company in mosquito netting has turned its attention—and its nets—to improving agriculture.

Under Feed the Future, a collaborative research project has brought together A to Z Textile Mills in Tanzania with agricultural researchers to test its nets for growing fruits and vegetables.

The project is funded through the Feed the Future Innovation Lab for Collaborative Research on Horticulture, with researchers from Michigan State University, CIRAD of France, Egerton University in Kenya, Abomey-Calavi University in Benin, the Kenya Agricultural Research Institute (KARI) and the National Agricultural Research Institute in Benin (INRAB).

The team is fine-tuning how smallholder farmers can use the nets to reduce insect pests and improve micro-climates in vegetable plots. Similar to its long-lasting insecticidal bed nets, A to Z's "AgroNets" were developed with and without chemical treatments and for re-use over multiple seasons.

"This technology is, for the first time, adapted to smallholder farmers and available in Africa because of the mosquito net industry," said Thibaud Martin, a CIRAD scientist based in Kenya. "This technology is truly an effective alternative to chemical use."

In the project's first six months, A to Z provided and delivered 1.5 tons of netting to Benin, Kenya and CIRAD partners.

"Partnership with A to Z was critical to the success of this project," said Mathieu Ngouajio, professor at Michigan State University and a leader of the Horticulture Innovation Lab project. "They have made all the fine-tuning that we needed on the nets and supplied our team with the material for field studies. Without that type of support, it would have been impossible to achieve project goals."

After two years of research, results in Kenya show the nets can indeed reduce pests and increase yields in tomato, cabbage, kale, onion, French bean, melon and carrot crops. Farmers have also tried the nets with other crops such as sweet peppers, amaranth, spider plant and strawberries.

"Use of AgroNets on cabbages, tomatoes (both field and nursery), French beans, and melons is not only efficacious against pests, but also offers great business potential for A to Z," said Hubert Coffi, agronomist with A to Z's research unit, the Africa Technical Research Centre.

In Benin, adoption of the nets by farmers has been particularly high. More than 75 percent of farmers in the project adopted the nets for use with nursery production.

Since the project started, the team has received additional funding from CIRAD, INRAB, Ecohort, Katarina University, SupAgro Foundation, and the French embassies in Benin and Kenya.

"Moving toward agriculture is for us a key strategic pillar for the coming years because it will help us to expand and diversify our operations and revenue stream while creating more jobs," said Dr. Johnson Odera, director of the Africa Technical Research Centre.

"We still believe in the future of agriculture in Africa, and we want to be part of this success story," he said.

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HORTICULTURE INNOVATION LAB PHOTO / STEPHEN WELLER, PURDUE UNIVERSITY

Farmers with the Nsongwe Women's Association in Zambia tend to a field of vegetables, including spiderplant, as part of a Horticulture Innovation Lab project in Zambia, Kenya and Tanzania.

GROWING THE SCIENCE BEHIND NUTRITIOUS, LEAFY VEGETABLES

As part of Feed the Future, an international team of researchers has been strengthening the value chain of African indigenous vegetables—with nutrition always in mind.

Their work began in western Kenya with a food and farm training program established by the AMPATH health system. Doctors there knew patients who were well-nourished would respond better to medical treatment for HIV/AIDS, so the program sought to encourage clients to grow, eat and sell nutritious crops.

Three common leafy African indigenous vegetables—amaranth, black nightshade and spider plant—were identified as promising crops for the training program.

"We realized the potential was enormous to expand African indigenous vegetable production and meet increasing consumer demand, while addressing important nutrition and income deficiencies," said Stephen Weller, project leader and horticulture professor at Purdue University.

Assumptions about these vegetables were many, but confirmed science was limited. With funding from USAID, the Feed the Future Innovation Lab for Collaborative Research on Horticulture built a project team to address research gaps in production practices, seed availability, storage, value addition, market linkages and nutritional evaluation. Led by Purdue University, the team includes partners from Rutgers University, ASNAPP, the World Vegetable Center, Eldoret University, Sokoine University, Kenya Agricultural Research Institute and Horti Tengeru.

To measure available nutrients, the team developed protocols for sampling the vegetables from field experiments at different stages of maturity, with testing at Sokoine University in Tanzania.

"Knowing the best stage to harvest these vegetables is crucial," said John Msuya, associate professor at Sokoine University. "While African indigenous vegetables are said to be rich in micronutrients, they also consist of substantial amounts of anti-nutritional factors—phytate, nitrate and oxalate—which can occur naturally."

Results showed most of the nutrients tested increased as plants aged from 21 to 35 days, and the anti-nutritional factors never reached critical thresholds. Dried leaf samples were also analyzed at Rutgers University for nutritional composition.

"We were pleased to find that nightshade, amaranth and spider plant are indeed rich in vitamins and minerals," said Jim Simon, professor at Rutgers University. "These leafy greens are as nutritionally dense as spinach in iron, calcium and potassium—and rich in vitamins such as provitamin A."

Food processing companies in Kenya and Zambia have used the results in nutrition labeling on packaging aimed at American and European markets, as they add these vegetables to their product lines.

Program results have been incorporated into training modules for more than 1,700 farmers, including USAID's Kenya Horticulture Competitiveness Project.

How to better grow more African indigenous vegetables—and the value of eating them too—has been shared continuously with AMPATH's clients.

"So many of the vulnerable AMPATH clients, who are both nutritionally and economically at risk, have had an opportunity to be directly involved in production, consumption and marketing of these crops," said Pam Obura, senior researcher with Purdue University and AMPATH. "Even the landless have been able to produce them in sack gardens for their own consumption."

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