



HORTICULTURE INNOVATION LAB PHOTO / AMANDA CRUMP, UC DAVIS

**A UC Davis researcher works with new postharvest trainers from Kenya, Tanzania and Ghana to prepare amaranth leaves for a solar dryer demonstration. This processing demonstration is part of a Horticulture Innovation Lab project that trained more than 16,000 farmers in improved postharvest practices over two years.**

# REDUCING FOOD LOSSES THROUGH POSTHARVEST TRAINING

Once harvested, 30-80 percent of fruits and vegetables in Sub-Saharan Africa are lost to poor handling. Food quality, safety and nutritional value are also affected by poor postharvest practices.

In an effort to improve postharvest handling of horticultural crops, Feed the Future partners opened a model postharvest center in Tanzania and deployed newly trained experts from seven countries to train farmers.

In October 2012, 36 professionals from Tanzania, Rwanda, Kenya, Uganda, Ethiopia, Ghana, and Benin completed a year-long training in postharvest practices, led by an international team under the Feed the Future Innovation Lab for Collaborative Research on Horticulture.

Through online learning and mentoring, the trainer candidates each completed a series of 10 assignments ranging from assessing commodity systems to developing training programs. The trainings were led by Lisa Kitinoja of the World Food Logistics Organization, with Diane Barrett of the University of California, Davis, and additional training support from the University of Georgia, AVRDC-The World

Vegetable Center, Amity University, UC Davis, and the Postharvest Education Foundation.

These 36 new postharvest trainers became the first graduates of the new Horticulture Innovation Lab Postharvest Training and Services Center, located at AVRDC-The World Vegetable Center in Arusha, Tanzania. The trainers learned about a variety of postharvest technologies, including the use of shade, harvesting tools, packaging, containers, grading, washing, cooling technologies, drying, and processing. They learned how to use various tools, including sizing rings, color charts, chlorine test strips, and refractometers, to measure postharvest quality.

Then new trainers officially opened the center by leading more than 100 local farmers through a day of postharvest instruction and demonstrations. Upon graduating, each of the trainers received a postharvest toolkit to help them get started with their next task—training farmers in their own countries. Ultimately, they are tasked with opening up their own postharvest training and service centers, each offering training, research, equipment retail and fee-based services.

In 12 months following their graduation, the 36 trainers have directly trained 7,474 farmers in postharvest practices and technologies across seven countries, with a potential multiplier effect of an additional 8,900 practitioners.

Designs for more than 80 additional Postharvest Training and Services Centers—including suitable sites, partners and costs—have been developed by trainers who took the year-long course.

Experts affiliated with the Horticulture Innovation Lab also continued to offer training through the center in Arusha for small-scale growers, marketers and processors. Over a two-year period that included the train-the-trainers, more than 16,000 farmers were trained in improved postharvest practices through this project.

“Many of our new ‘postharvest specialists’ are already working together on postharvest research projects or writing new proposals for training programs,” Kitinoja said. “Others have been hired for consulting assignments in the region or awarded fellowships that will allow them to continue their postharvest studies and/or extension work in their own countries.”

# ENGAGING START-UPS TO REDUCE POSTHARVEST LOSSES IN RWANDA

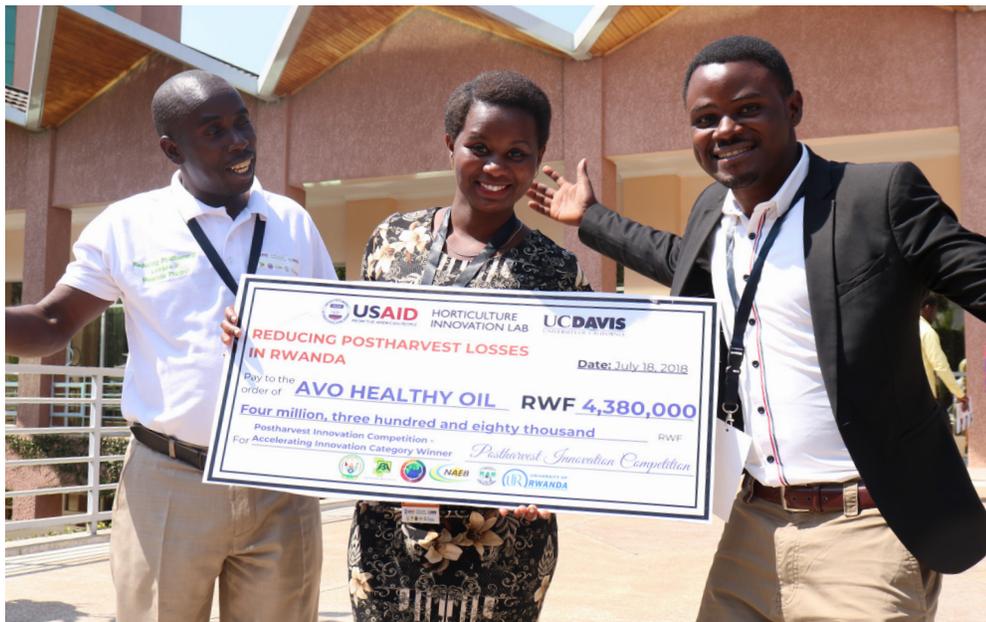
With nearly half of all fruits and vegetables wasted before they can be eaten, reducing losses of fresh produce after harvest requires systematic change. Simple interventions related to postharvest handling can have an impact, but no single isolated intervention will prove effective at mitigating this issue.

An international team supported by the Feed the Future Innovation Lab for Horticulture is taking a systems approach to reducing postharvest losses in Rwanda, beginning by understanding the problem, laying the groundwork for improvements, and perhaps most importantly engaging entrepreneurs and industry in leading the way for lasting solutions.

Led by Agribusiness Associates with guidance from Rwanda's Ministry of Agriculture and Animal Resources, the team has analyzed the problem of postharvest losses in Rwandan horticulture across four different value chains: green chili peppers for export; tomatoes for regional domestic markets; sweet potatoes for local markets; and green bananas for local markets. Published this year, the reports combine a value chain analysis with a commodity systems assessment methodology to evaluate postharvest losses.

The team also established three Postharvest Training and Services Centers, each hosted by a key organization in Rwanda's horticulture industry. One center is located at the University of Rwanda in Busugo, another center is hosted by the Rwanda Agriculture Board in Rubona, and a third is part of the National Agricultural Export Development Board at Mulindi. Each of the centers is equipped with postharvest technologies and run by knowledgeable partners who can share improved postharvest practices with nearby farmers and agricultural businesses.

With postharvest tools now available, the team launched the Rwanda Postharvest



**Niyidukunda Mugeni Euphrosine, one of 13 Postharvest Innovation Competition winners, will use award money to purchase processing equipment for her avocado oil extracting company. She also makes soaps and avocado flour. (Horticulture Innovation Lab photo by Rashmi Ekka/Agribusiness Associates)**

Innovation Competition to provide postharvest entrepreneurs with seed funding and skills to start profitable businesses that reduce postharvest losses.

The competition culminated in the first-ever "Rwanda Postharvest Week," in Kigali, which included a conference attended by 100 people, a two-day postharvest training for agronomists and farming cooperative leaders, and a graduation workshop for 33 new postharvest trainers after a year-long e-learning course — in addition to the announcement of the competition winners.

Competition participants ranged from innovators with a prototype, to businesses that have already introduced a product to the market and are ready to accelerate growth. Over the course of two months, participants attended an agribusiness development training, polished a persuasive "pitch deck" slideshow, and submitted financial projections for their enterprise.

Innovations were judged based on their economic opportunity, value to customers, place in the value chain and financial sustainability. The competition's winning projects ran the gamut from a cold storage service provider to the makers of a traditional chili sauce, tree tomato jam and pumpkin oil.

Winners of the competition were 13 burgeoning enterprises that received a cumulative total of \$50,000 (44,054,000 Rwandan francs) in seed funding for their postharvest technologies and start-up businesses.

Through the competition, entrepreneurs learned how to combine their business savvy to extend innovative solutions in the postharvest sector, creating value in crops that might otherwise be lost or wasted. By engaging entrepreneurs, this Horticulture Innovation Lab team is seeding sustainable change in Rwanda's horticulture industry.



# YOUNG ENTREPRENEURS IN GUINEA HELP FARMERS ACCESS INNOVATION

Golden rings of pineapple have already started to dry around the edges, fragrant as they soak up the sun's heat beneath a sheen of clear plastic — on the way to becoming dried fruit.

Fatoumata Cissoko knows this routine of drying pineapple slices well. At 29, she runs a small dried fruit business in West Africa and has already spent three years trying out different drying methods on her parents' farm in Guinea. She is confident of the entrepreneurial opportunities that are found after harvest — when fruit can be processed, dried, stored and sold later at favorable market prices — and she is working to expand her knowledge and share it with more farmers.

“The best thing about agriculture is being able to harvest the fruit of your work,” Cissoko said. “Farmers are happy when I bring them new things, like the possibility of drying their fruits and vegetables that they cannot sell. And that is a great satisfaction for me.”

She is part of a small team that has started a new Horticulture Training and Services Center as a way to boost rural entrepreneurship and agricultural prosperity. This effort is part of the long recovery from the Ebola outbreak. The burgeoning center is housed on a campus of Guinea's national agricultural research institute, *Institut de Recherche Agronomique de Guinée*. For this new center, the institute is partnering with the Feed the Future Innovation Lab for Horticulture, led by researchers at the University of California, Davis.

Cissoko is one of several young entrepreneurs who are working to turn the center into a hub for rural innovation who were trained to extend rural innovation in Guinea with Winrock International and Cultivating New Frontiers in Agriculture.

Together with her colleagues, Cissoko is helping to build a center that will reflect the needs of the rural farming community in



**Above, pineapple slices dry in a chimney solar dryer. At left, Fatoumata Cissoko works to prepare compost for a demonstration garden at the new Horticulture Training and Services Center on the IRAG campus in Kindia, Guinea. (Horticulture Innovation Lab photos)**

the Kindia district and surrounding region. Eventually, the center will offer training to farmers and demonstrate how new technologies work.

To efficiently dry pineapple slices — as well as other fruits and vegetables — the team has built a chimney solar dryer from wood and plastic tarps, designed by UC Davis researchers.

To test whether the food is dry enough to store safely without mold growth, the team is manufacturing DryCards, a low-cost tool that indicates levels of dryness by changing color. It's convenient for farmers, who can seal a reusable DryCard with a sample of their dried product in an airtight container to test for dryness before storage.

The team is also demonstrating other horticultural technologies, including drip irrigation and plastic mulch. Researchers at the center are identifying which tools and agricultural services are marketable in



the region, with sensitivity to the needs of French-speaking Africa. By bolstering young entrepreneurs like Cissoko with business training and access to new innovations, the center is not only advancing rural farmers, but also enabling successful youth entry into agriculture. Supporting the advancement of this new generation is critical during a time when unemployment is growing across Africa, particularly among youth.



# REDUCING DRUDGERY, IMPROVING SOIL FOR VEGETABLE FARMERS

Most commonly used with field crops, conservation agriculture combines three practices that help farmers invest in soil health, specifically:

- minimal soil disturbance (“no till”),
- continuous mulch cover, and
- rotating diverse crops.

These practices can also reduce labor and reduce water evaporation from the soil.

Manuel Reyes, professor at North Carolina Agricultural and Technical State University, has helped farmers in many countries improve their soil and use water efficiently. In doing so, he has also partnered with three Feed the Future Innovation Labs, funded by the U.S. Agency for International Development.

Beginning in 2010, Reyes started working with farmers in Cambodia on conservation agriculture for field crops, with an international team supported by the SANREM Innovation Lab. Two years later, the team worked with 56 households over 149 hectares to use conservation agriculture principles.

After testing conservation agriculture practices with vegetable crops in the United States, Reyes expanded his conservation agriculture work in Cambodia to focus on vegetable farmers. Now with additional funding from the Horticulture Innovation Lab, he added drip irrigation to conservation agriculture practices for vegetable farmers. This research sought to find whether combining these practices could reduce labor needs, increase yield, increase income and ultimately receive support from vegetable farmers.

For field trials in Cambodia, women farmers grew a variety of vegetables, including string beans, cucumber, Chinese cabbage, kale, tomatoes and eggplant. Unlike the first few years of using conservation agriculture with field crops, this trial with vegetables found no significant differences in yields or income between the various treatments.



Women farmers in Cambodia are combining drip irrigation with conservation agriculture to grow vegetables with less drudgery, while improving soil health.

HORTICULTURE INNOVATION LAB PHOTO / MANUEL REYES, NC&T

But what did change with the new practices was the farmers' labor. The researchers estimate that growing vegetables on 100 square meters with traditional methods and hand watering requires hauling about 1,300 pounds of water per day during the dry season — and even twice as much during very dry seasons. Drip irrigation and conservation agriculture freed the women farmers from carrying water, tilling and weeding.

Many of the women farmers were so pleased with the new practices that they asked to end the experiment early, to avoid the extra labor of tilling, hand-watering and weeding required to maintain the field tests.

The next step? Reyes is working with these Cambodian women farmers on a new Horticulture Innovation Lab project, this time on marketing their vegetables and building a local brand that promotes their conservation practices.



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# HOW ONE FARMER'S INVENTION IS REDUCING FOOD WASTE

In many developing countries, more than half of all fruits and vegetables are never eaten, but instead are damaged or spoiled after harvest. These post-harvest losses can mean that farmers need to sell their fresh produce immediately at whatever price they can get, before they lose the crops that represent investments of labor, water, and agricultural inputs. Improving how fruits and vegetables are handled after harvest can significantly prolong freshness — and cooling is key.

“The three most important aspects of postharvest handling are: temperature, temperature, temperature,” said Michael Reid, postharvest specialist with the Horticulture Innovation Lab. “In the developing world in particular, affordable cooling technology is mostly absent.”

Cooling can be an expensive challenge — even for American farmers.

As a farmer in upstate New York, Ron Khosla knew this problem too well and could not afford to buy a walk-in cooler for his small farm. So he invented a solution: an electrical device called a CoolBot that tricks an air conditioner into getting colder, turning a well-insulated room into a cold room for less than it costs to buy a refrigeration unit.

“I was hoping for a cheap, do-it-yourself solution that I could maintain, but mostly I just needed to keep my leafy greens and strawberries cold,” Khosla said. He later started a small business to sell the CoolBot called Store It Cold, LLC.

Khosla's CoolBot invention caught the eye of postharvest researchers, including Reid who in 2010 first partnered with agricultural scientists from Uganda, Honduras, and India to test this new device in their climates and with local materials.

Since that first project, the Horticulture Innovation Lab has tested CoolBots for cold storage in Tanzania, Zambia, Uganda, Thailand, Cambodia, Bangladesh, India and



Above, a CoolBot connects to an air conditioner to further lower the thermostat without freezing over so that a well-insulated room can cool fresh produce effectively.

At left, Amrita Mukherjee checks the temperature of potatoes stored in a CoolBot-equipped room in Bangladesh. (Horticulture Innovation Lab photos by Britta Hansen, above, and Amanda Crump, left)

Honduras. Reid has also tested options for solar-powered CoolBots.

One Horticulture Innovation Lab partner — Jane Ambuko of the University of Nairobi — received a grant to pilot this technology among horticultural farmers for the Kenya Feed the Future Innovation Engine.

“I see the CoolBot making a whole lot of difference,” Ambuko said during a TEDxNairobi speech. “But for it to make that desired difference we have to make it cost-effective and affordable for the smallholder farmers.”

In the wake of these successes, Feed the Future Partnering for Innovation also chose to invest in scaling up the CoolBot among

exporters and agricultural associations in Honduras.

And Khosla's small business has been growing. In early 2016, it had grown to employ six people and had sold more than 27,500 CoolBots in 51 countries.

“I'm thrilled and so grateful to be a part of helping lots of people. Working with USAID has gotten us known in other countries, and I'm looking forward to the day when we have enough in-roads in India and Africa where we can work directly with farmers there,” Khosla said. “People didn't believe the CoolBots worked at first. But now we get the most amazing letters from people whose business has doubled or quadrupled. Good postharvest care makes such a difference. Once they try it, then they see.”



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# INVENTING A LOW-COST SOLUTION TO REDUCE MOLDY FOODS

## 'DryCard' wins Africa postharvest prize, takes guesswork out of drying

How do you see dryness? Drying food is one way many farmers preserve their harvest, but knowing when food is dry enough to store can be difficult — and mold growth on dried foods is a pervasive problem. For farmers, mold growth can mean postharvest losses and lowered market value. For consumers, aflatoxins from moldy foods can suppress the immune system, increase disease rates, and cause lifelong stunting in children.

To that end, researchers from the University of California, Davis researchers Michael Reid and James Thompson invented a low-cost, easy-to-use tool that farmers can use to measure food dryness, called the DryCard™.

The DryCard is the size of a business card and combines cobalt chloride paper, which indicates dryness by changing color, with a color guide on a laminated piece of paper. Repackaging the cobalt chloride paper with the color guide increases the usability of the strips and allows farmers to access this dryness indicator at just pennies per card.

To check that food is dry enough for safe storage, farmers can seal a DryCard and a sample of dried product in an airtight container. After a brief wait, the card indicator changes color based on relative humidity within the container. Matching the color of the indicator with the guide on the card shows whether food is dry enough to prevent mold growth. The DryCard is reusable as long as it is stored safely away from water.

In March, the DryCard was selected as a top emerging technology for improving postharvest practices in Africa — beating more than 200 technologies to win the



By combining a strip of cobalt chloride paper with a color index, the DryCard indicates by color whether dried foods are dry enough to store safely, reducing the risk of mold growth.

grand prize at the All Africa Postharvest Technology and Innovation Challenge. Top technologies and innovations were invited to pitch to an audience of about 600 participants, including researchers, investors, extension agents, government executives, and farmers.

“I have never seen such strong interest in a technology like this,” said Elizabeth Mitcham, director of the Horticulture Innovation Lab, who represented the card during the competition. “This technology has high potential to make an impact—and not only with dried produce and vegetable seeds, which was our original intent. A lot of the interest we have seen is from organizations that work with staple crops too.”

In the wake of the competition and resulting publicity, interest in the DryCard has been high. In response to requests for samples, the Horticulture Innovation Lab

has distributed more than 1,400 cards to organizations in 17 countries. The team is also in talks with local entrepreneurs who are interested in manufacturing and marketing the cards in their own countries.

Bertha Mjawa is one of the first researchers to test out and promote the DryCard in Africa, with her Postharvest Consult and Capacity Building Company in Tanzania. Over the course of 5 months, Mjawa and her team sold 2,500 DryCards to 500 local farmers and organizations.

“The DryCard makes a promising solution for African farmers due to its cost effectiveness, clear indicators and ease of use,” Mjawa said. “Both farmers and agricultural experts can benefit from this technology.”

For updates, samples and more information about the DryCard, visit <http://drycard.ucdavis.edu>.



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# TARGETING SOIL HEALTH TO REDUCE NEMATODES ON GUATEMALAN FARMS

In Guatemala, potato farmers are losing their spuds to a microscopic menace – potato cyst nematodes.

In the Western Highlands, nematodes have been blamed for cutting crop yields in half over the past 20 years. Small-scale farmers are responsible for 75 percent of Guatemala’s potato production, digging ditches in steep cliffs to plant the tubers by hand. They save smaller potatoes for their family and sell larger, more valuable potatoes at markets.

The nematodes tunnel into the roots of potato plants to feed, where they grow into fat, circular-shaped cysts. Their presence reduces the quantity and size of potatoes, robbing farmers of income and nutrition. Pesticides to eradicate nematodes are neither readily available nor culturally sanctioned in the region.

Researchers supported by the Feed the Future Innovation Lab for Horticulture have been working with smallholder farmers near Huehuetenango and San Marcos to rid crops of this tack-sized pest, which thrive in degraded soils. Improving soil health creates a complex soil food chain where the nematodes are suppressed and beneficial organisms prosper.

Plant pathologist Brent Sipes leads an international project team of collaborators from the University of Hawai‘i at Mānoa, the Universidad de San Carlos de Guatemala and Michigan State University. The team used a research method called Fuzzy Cognitive Mapping to gather data about how farmers perceive the nematode problem. Research has shown that promoting best intervention practices without understanding their socio-cultural relationships reduces adoption rates of new technologies.

“Cognitive mapping helps us understand how the community is thinking, to tailor our workshops and teaching so that we



**Potato cyst nematodes thrive in depleted soil and are blamed for major reductions in potato yield in Guatemala’s Western Highlands. After analyzing farmer perceptions, researchers recommend they use chicken litter compost and biopesticides to reduce this pest pressure among potatoes. (Horticulture Innovation Lab photo by Erin McGuire/UC Davis)**

can target misconceptions and linkages that they do not see,” Sipes said.

One finding was that many farmers were distrustful of certified potato seeds which they blamed for attracting nematodes to their crops.

“If we go in and say that they should use certified potatoes and they have anecdotal evidence that suggests certified potatoes are to blame for the problem, they might be polite to us, but likely won’t trust our interventions,” Sipes said.

Through the mapping, the team identified two effective interventions to recommend to farmers: incorporating composted chicken litter into their soil and applying *Trichoderma* and *Purpureocillium lilacinum*. These fungi attack nematode eggs and are a biopesticide treatment sold by Popoyán, a Guatemalan company.

In one community where farmers believed chicken litter attracts nematodes, the researchers instead encouraged them to mix composted horse litter into their soil.

From the cognitive mapping, researchers also learned that farmers relied on cooperatives to learn new farming practices. Thus the team is sharing their techniques with two prominent potato cooperatives, so these strategies can be shared more widely and long after the project has ended.

Sipes reflected that soil in the region is so depleted that it may take years to restore its health.

“In the long term, I hope that we have an impact in teaching farmers about the incorporation of more organic matter and soil health,” he said. “I hope that by knowing that they have a nematode problem, they make better choices.”



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# STUDENTS HELP STUDENTS LEARN STATE-OF-THE-ART SCIENCE

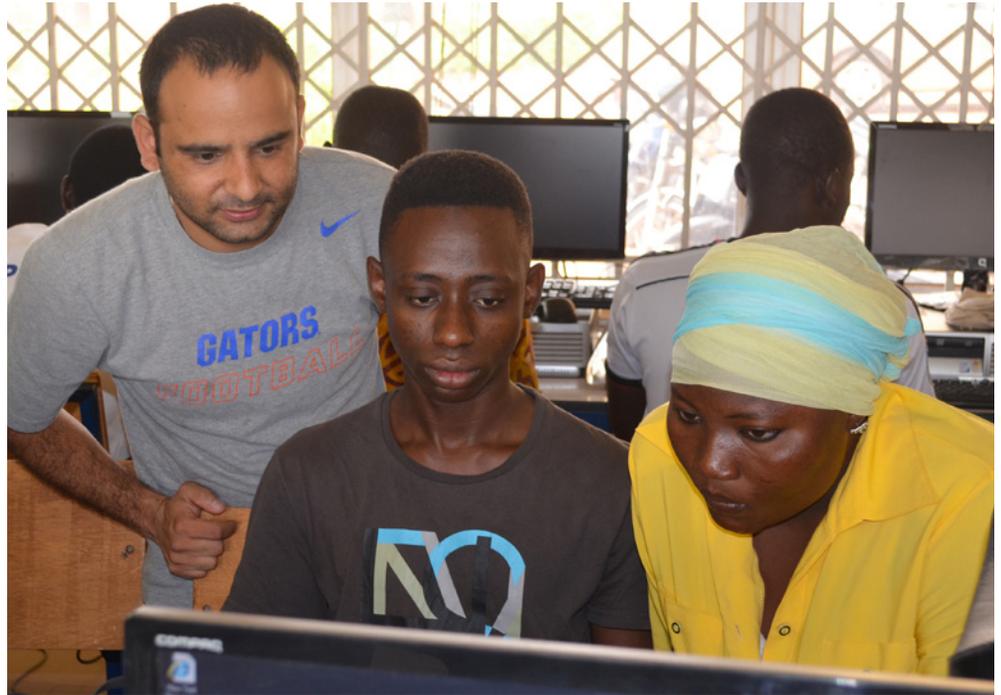
In a classroom in Ghana, graduate student Dev Paudel from the University of Florida bent over computers with students and research assistants as they learned the basics of R, a free, open-source programming language for statistical analysis that he had installed on the computers earlier that week. As participants in this Kayaba Management Foundation training, the class members would next analyze the results of a needs survey of more than 300 farmers and vegetable vendors from nearby communities. Their goal?

“If we can use state-of-the-art statistical tools (including R) in Ghana, we can generate research findings that would be accepted by both policy makers and the international investor community,” said Hussein Yunus Alhassan, CEO of the Kayaba Management Foundation and chief instructor at Tamale Polytechnic. His new foundation is laying the groundwork for locally led research that supports the horticulture sector in northern Ghana, markets for horticulture value chains, and women’s empowerment.

As a doctoral graduate student, Paudel uses statistical analysis software frequently. His previous experience as a horticulture development officer in Nepal was an early step in his international development career.

Paudel’s work in Ghana — including his first trip to Africa — is supported by the Trellis Fund, an innovative program that pairs U.S. graduate students with organizations engaged with local farmers in developing countries. The Trellis Fund is part of the Feed the Future Innovation Lab for Collaborative Research on Horticulture, led by the University of California, Davis.

The Horticulture Innovation Lab’s two main goals for the Trellis Fund are complementary: strengthen smaller organizations with the horticultural expertise that a graduate student can offer,



From left, Dev Paudel walks Shiraz Ibn Haliq and Issahaku Fauzia through a computer exercise to learn about open-source statistical analysis with the Kayaba Management Foundation in Ghana. (Horticulture Innovation Lab photo by Hussein Yunus Alhassan)

and provide experience to the graduate student that could expand their career horizons toward international development. The connections with smaller organizations and young professionals also strengthen the Horticulture Innovation Lab’s network for future projects.

“Trellis promotes horticultural science to organizations that are often smaller than we might otherwise work with. They become part of our Horticulture Innovation Lab family, and many become good partners for us in the future,” said Elizabeth Mitcham, director of the Horticulture Innovation Lab.

The first 47 completed Trellis projects included 7,400 farmer participants, 219 demonstration plots and 238 training meetings. Those projects involved 47 students from five U.S. universities, who served as consultants for projects spanning

15 Feed the Future focus countries in Africa, Asia and Central America.

Though their 6-month Trellis Fund project is officially complete, Paudel, Alhassan and the Kayaba Management Foundation team continued to work together remotely with the goal of publishing a journal article based on their robust analysis of farmer needs from the survey.

“Working with students and research assistants is great because they are really open to new ideas and grasp things very easily,” Paudel said. “This was a challenging course for some of them, particularly those who did not have training in basic programming skills. However, they are practicing their skills with the survey analysis now. I believe this training will be advantageous to the students as they leap into their new careers.”



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Training participants prepared a variety of fruits and vegetables on trays for the chimney solar dryer they built as part of the postharvest short course. (Horticulture Innovation Lab photo by Michael Reid)

# SUPPORTING POSTHARVEST IN TANZANIA'S HORTICULTURE SECTOR

In Tanzania horticulture is one of three value chains that Feed the Future activities focus on for greatest impact. Horticultural crops are particularly sensitive to poor postharvest practices, with estimates that half of fruits and vegetables grown in many sub-Saharan Africa countries are lost during postharvest phases.

To enable Feed the Future partners—including educators, industry professionals, and government employees—to better support horticultural development, the Horticulture Innovation Lab led a project to increase training infrastructure and provide training-of-trainers for improved postharvest practices of fruits and vegetables.

At the Horticultural Research and Training Institute in Tengeru (HORTI Tengeru), Horticulture Innovation Lab team members designed a field packing shed and charcoal cooler, which were later built and installed by partners at the World Vegetable Center. The site had an insulated room, which the Horticulture Innovation Lab converted into a working cold room, with the addition of a CoolBot and air conditioner. These postharvest facilities now allow for packing, cooling and storage of crops harvested from HORTI Tengeru's acres of field trials, for improved sales at a market nearby.

In July, the Horticulture Innovation Lab provided a five-day course in postharvest handling of horticultural crops to more than 40 professionals from all over Tanzania, including university professors, technical trainers, industry leaders, and government representatives.

The course was led by Michael Reid and Angelos Deltsidis of the Horticulture Innovation Lab, with Marita Cantwell of the UC Davis Postharvest Technology Center, and Ngoni Nenguwo of the World Vegetable Center. The course was hosted at the Postharvest Training and Services Center on the World Vegetable Center campus in Arusha. Juma Shekidele of HORTI Tengeru also provided assistance in organizing the course.

Each day the course started with lectures covering postharvest principles and practices for crops with commercial potential in Tanzania, including eggplants, tomatoes, bananas, mango, papaya, citrus, avocado, leafy greens, green beans, cherimoya, onions, cut flowers, cucumber, potatoes and carrots.

Hands-on activities were also part of the course. Participants conducted exercises to

examine maturity, produce quality, cooling, packaging, and water loss. Each participant also received a postharvest toolkit and learned how to use the tools with different fruits and vegetables through the exercises.

The course included a module on solar drying, in which attendees constructed and tested the UC Davis-designed chimney solar dryer. The dryer proved its effectiveness in demonstrations; despite heavily overcast conditions, products dried rapidly.

The class also took a couple of short field trips, visiting the local wholesale market, an export packing operation and HORTI Tengeru to see the postharvest facilities and horticultural field trials.

After the course's conclusion, evaluations included many positive comments from participants. Weeks later participants also reported incorporating the chimney solar dryer and other demonstrations into farmer field days in other parts of Tanzania.

"I will use and teach this course to my farmers who produces tomatoes and onion," reported one participant. Many commented that the course should be offered repeatedly in the future.



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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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# CAMBODIAN FARMERS REACH NEW BUYERS WITH A FRESH APPROACH

Leaning into her tuktuk in Siem Reap, Eang Chakriya opens a cooler and takes out fresh wax gourds and other vegetables that have been carefully packed and chilled, showing them to a group of neighbors. Emblazoned on the tuktuk (a kind of motorized rickshaw) are images of farmers and the marketing motto, “Grown Right, Handled Right, Community Right.”

Chakriya sells nutritious vegetables directly to consumers in Cambodia as part of a farmers’ cooperative working with the Feed the Future Innovation Lab for Horticulture, led by the University of California, Davis.

The project’s research team is examining incentives that help farmers improve their agriculture practices. The researchers’ hunch is that farmers will adopt conservation agriculture practices (or “Grown Right” practices) if the team also helps them to adopt two other types of profitable practices that will increase their success: improved postharvest handling techniques and novel marketing practices.

So far, the idea seems to be working.

Leading this project, researchers from Kansas State University introduced farmers to conservation agriculture practices: mulch use, diverse crop rotation, and no tillage. Combined with drip irrigation, conservation agriculture can help farmers grow vegetables on small plots with reduced time and labor.

With researchers from Cambodia’s Royal University of Agriculture, the World Vegetable Center and UC Davis, the project team also provided consultation and farmer training in improved postharvest handling — to harvest, sort, pack, transport and store the vegetables to maintain freshness longer. A team from the Horticulture Innovation Lab’s Regional Center at Kasetsart University in Thailand also helped the farmers construct a packing shed to prepare and store their produce, complete with a cold room, evaporative cooler and sorting table.



Eang Chakriya, above and left, sells vegetables grown using conservation agriculture practices under the “Grown Right, Handled Right, Community Right” banner on behalf of a local farmers cooperative.

The cooperative is using marketing techniques that are new in Cambodia to help farmers get the most profit from their crops. For example, farmers connect directly with urban customers, driving their fresh produce into city residential neighborhoods. The produce they sell has been chilled during storage and transit, which helps maintain quality and nutritional content. The farmers also clearly identify the produce as locally grown and emphasize that their crops are an outcome of good environmental practices.

One advantage of these improved practices has been intensified production with more crop rotations per year.

“We’ve increased yields per unit area because of conservation agriculture and the number of times they can plant in the year — from two plantings to up to six plantings per year,” said Manuel Reyes, a Kansas State University research professor who also works with the Feed the Future Innovation Lab for Sustainable Intensification. “Before they finish harvesting, the farmers are already planting the next crop’s seedlings, so they are saving a lot of time overall.”

Confident in their ability to sell high-quality vegetables directly to consumers at higher prices, the cooperative has offered to buy vegetables from its members at a 10 percent premium over other buyers. Today, farmers are enjoying increased incomes from vegetables grown on their conservation agriculture plots, with earnings as high as \$1,323 over 10 months.



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# DRYING BEADS HELP BANGLADESH FARMERS ACCESS BETTER SEED

Finding reliable vegetable seed in humid Bangladesh can be a challenge — a situation that can ruin a crop before a farmer's hard work even begins. But Bangladesh seed companies are rapidly adopting a new technology that can improve seed germination and plant vigor, through improved seed processing and storage. Called "drying beads," this reusable tool can help seed companies provide farmers with higher quality seed, improving the local seed industry and helping farmers maximize the potential of their own hard work.

Many of the country's leading vegetable seed companies have adopted drying beads through a multi-part training led by Rhino Research and supported by the Feed the Future Innovation Lab for Horticulture, based at the University of California, Davis. Participating organizations include Lal Teer Seed Limited, Metal Seed, Getco, A. R. Malik & Co., Ispahani Agro Limited, Bangladesh Agricultural Development Corporation and others.

"We concluded that these beads are drying our seeds faster and deeper, obtaining a better quality that results in a longer storage potential, and all this with lesser costs," said Tabith M. Awal of Lal Teer Seed Limited in Bangladesh. "Therefore Lal Teer made the executive decision to move ahead with implementing these beads for all our seeds and crops as soon as possible."

This year, more than 200 tons of vegetable seed have been dried and stored with drying beads—helping an estimated 100,000 farmers in Bangladesh access quality seed.

The in-depth training, offered for a week at a time and repeated 3-7 times over several months, has focused on 14 seed leaders in Bangladesh. They have trained more than 70 employees, who in turn have trained more than 500 seed production farmers in how to use drying beads and maintain seed quality.

In a sealed container, the zeolite-based drying beads can dry seeds to very low moisture contents—preventing mold growth, restricting insect habitation, and



**Above:** Korshed A. Chowdhury leads a training on using drying beads to process seed with a group of farmers, seed company employees and agricultural workers in May 2017.



**Left:** Vegetable seed drying with drying beads in airtight containers.

preserving seed quality. The beads can be regenerated in an oven for repeated use.

Seed farmers in Bangladesh first dry their seed in the sun — and that's where many of them stop (a survey showed about 22% also used fan drying and 8% used heated air). Companies that have adopted drying beads use them in containers to transport the seed from the farmer to company storage, where they can collect the fully dried seeds and return a container with fresh drying beads to the field.

Horticulture Innovation Lab researchers have previously shown drying beads are

effective for seed storage, and developed an overarching "dry chain" concept. "Make it dry, keep it dry" is the motto of the dry chain, which specifies how to maintain quality and safety of dried products — not just seed.

"What is really remarkable is the explosion of different ideas in how to use the drying beads," said Johan Van Asbrouck of Rhino Research. "But we are starting with seeds, maximizing the potential of the crop at a farmer's level. If you don't have quality seed, you start penalized and will not have the crop you could."



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# ‘DRY CHAIN’ PARTNERSHIP HELPS FARMERS STORE SEED BETTER

A partnership between university scientists and a private technology company has sprouted both new concepts and new tools that can help vegetable farmers in developing countries access better seeds.

For many smallholder farmers, buying and trading vegetable seeds can be risky. The benefits of purchasing seed can be high, with improved crop varieties offering disease resistance, increased vigor and improved taste. But the risks of receiving poor-quality seed are also significant, particularly in tropical climates. Seed will deteriorate rapidly if it is not properly dried and stored. The resulting poor germination reduces yields, which for vegetable farmers can mean staggered harvests and inconsistent crop quality.

“If you buy seed and it’s all dead, you aren’t going to buy very much more seed,” says Kent Bradford, seed biologist at the University of California, Davis. “To get improved varieties into farmers’ hands, you must have a system where people can buy and trade seed successfully.”

Under the Horticulture Innovation Lab, Bradford and an international team have partnered with Rhino Research, a seed technology company in Thailand, to improve the science and tools available for drying and storing vegetable seed. The team initially sought to better maintain seed quality by exploring zeolite-based “drying beads.”

Produced by Rhino Research, the drying beads absorb moisture from the air. When sealed with seeds in an airtight container, the beads reduce the seeds’ moisture content to very low levels. They can be re-used repeatedly, after being reactivated in an oven.

In Thailand, India, Nepal and Bangladesh, the team developed protocols for how to best use drying beads with vegetable seed and trained more than 3,600 people in their use. The team’s preliminary economic analyses showed that using drying beads could increase earnings within the onion



Kent Bradford, right, discusses how to use drying beads to save horticultural seed with scientists and entrepreneurs at a meeting in Kenya held by the Horticulture Innovation Lab.

HORTICULTURE INNOVATION LAB PHOTO

seed industry in Nepal by an additional \$5.85 million per year.

But working with smallholders in developing countries presented additional challenges. While the cost of drying beads can be recovered through repeated use, the up-front costs were not reasonable for many small-scale farmers. Accustomed to working with seed companies, the team also assumed the importance of drying seeds was “fairly common knowledge,” but quickly learned that was not the case.

“But when we started talking in terms of the ‘dry chain’ for seeds, then the idea clicked,” Bradford says. “When we compare the importance of drying seeds and keeping them dry throughout storage to the ‘cold chain’ [i.e. keeping perishable goods cold during storage and transport], then our ability to communicate with people goes up.”

A “dry chain” requires that seed be dried, and the dryness monitored and maintained throughout all stages of storage. Many actors along the seed dry chain—from seed production to storage, transportation, sales and on-farm use—need to maintain that dryness to ensure seed quality.

Following the new dry chain concept, the Horticulture Innovation Lab team also developed a suite of tools appropriate for the different participants along the chain, using what they learned from working with the drying beads. The team’s next steps will begin with a commercial-scale drying system—the FlexiDry, which also uses drying beads—and continue down the dry chain to small containers with inexpensive sensors that enable farmers to maintain and monitor dryness during seed storage.



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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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# D-LAB TEACHES INNOVATION SKILLS TO AGRICULTURAL STUDENTS

How do you teach innovation? A partnership under Feed the Future is empowering university students to solve real-world agricultural problems while learning the nuts and bolts of how to innovate.

“We set out to teach the students some skills in metal work, the design process and appropriate technology—and they end up learning empowerment and teamwork,” explained Jorge Espinosa, with the Panamerican Agricultural School, Zamorano, in Honduras.

Espinosa is an instructor for Zamorano’s version of D-Lab, a concept course originally started at the Massachusetts Institute of Technology. Now replicated and adapted for students at multiple universities, the D-Lab model focuses on “Development through Dialogue, Design and Dissemination.”

Espinosa’s work with D-Lab started at the University of California, Davis, where Kurt Kornbluth leads students through two D-Lab classes each year that result in feasibility studies and prototypes, with a focus on external clients’ needs. One of Kornbluth’s clients was the Horticulture Innovation Lab, which was seeking solutions for smallholder farmers, such as ways to keep fruits and vegetables cool during transport to market.

“After serving as a D-Lab client, we saw potential value in offering D-Lab courses to students at universities in Honduras and Thailand where we have Regional Centers that act as hubs for our work,” said Britta Hansen, of the Horticulture Innovation Lab. “Not only could D-Lab provide skills to students—tomorrow’s agricultural leaders—but it could also support our partners in adapting new solutions to local farming challenges.”

Each university that offers D-Lab must adapt the course to meet its needs and standards. With its learn-by-doing ethos, Zamorano seemed like a good match for D-Lab.



HORTICULTURE INNOVATION LAB PHOTO / ERIN MCCUIRE, UC DAVIS

**Instructor Jorge Espinosa discusses how to recycle an old saw blade with college students studying agriculture at the Panamerican Agricultural School, Zamorano, for a project during a D-Lab course in Honduras.**

“[Zamorano] is very hands-on, but it can be mechanical, like a recipe. I think that is the magic of D-Lab, that the students are not given recipes,” Espinosa said. “We have adapted it to not be a class, but a work experience—a learn-by-doing module, Zamorano style.”

So far 70 Zamorano students have participated in six D-Lab modules, intended to foster student creativity and provide a space to make mistakes and learn from them.

In a curriculum review, 71 percent of Zamorano’s D-Lab students reported they would “definitely respond more creatively” when approaching future problems, and 87 percent reported being very comfortable with presenting new ideas in D-Lab. Overcoming an aversion to failure proved to be an essential component of the course. On average, students built

more than three prototypes for every one prototype that worked as expected, with 80 percent learning “very much” from failed prototypes.

“What I am taking [from D-Lab] is the magnificent experience of practically inventing something,” reported one student. “Like [Espinosa] said to us once: There are no mistakes, there are only opportunities to develop... You always learn in the end.”

In addition to the D-Lab course at Zamorano, the Horticulture Innovation Lab team has started a D-Lab at Kasetsart University in Thailand, with 29 students in its first class. The Horticulture Innovation Lab Regional Centers continue to support and improve D-Lab courses at these universities.



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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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