ECHO® Development Notes

Edited by Dawn Berkelaar and Tim Motis | January 2018 | Issue 138

Yellow Shoot, Green Fruit: Citrus Greening Disease Guidance for Citrus growers in the tropics

from interviews with Tim Gast and Tim Watkins, summarized by Stacy Reader

ECHO's Technical Response Unit recently received a few requests from areas in the Caribbean, for information about what might be causing citrus death. One request came from ECHO network member Jean Eloi, founder of the Hope for Haiti Foundation (www.hopeforhaitifoundation.com), who noticed citrus decline in Haiti:

> *Recently I was introduced to a priest whose community has encountered a problem with their citrus trees. These trees are dying and they have not been able to find out the root cause of their death. Do you have teams working with farmers in that area? If so have they encountered this problem? The citrus trees (grapefruits, oranges and tangerines) are all having similar issues and they were hoping that there is a scientific solution that can be found hence for the problems to be able to be prevented.*

With multiple requests for information about widespread citrus decline, we decided to learn more about its potential cause and practical management tools. We interviewed Tim Gast, Citrus Production Manager at the University of Florida's Southwest Florida Research and Education Center, and Tim Watkins, Head of Agricultural Operations at ECHO Florida's Global Farm. All information in this article was taken from the interviews, unless otherwise cited.

This article focuses on citrus greening disease, otherwise known as Huanglongbing, which has spread to numerous countries. An assortment of other disease and pest pressures can negatively affect citrus trees--citrus leafminers, canker, root rot, and much more. For information and diagnostic help for these other citrus problems, contact your local extension officer or agricultural technician, visit University of California Davis's problem diagnosis page, or visit University of Florida's Citrus Extension Plant Pathology page or Identification guide.

Figure 1. Adult Asian citrus psyllid (*Diaphorina citri*). *Source: Tim Motis*

THE CAUSE

Bacteria in the genus *Candidatus* Liberibacter have caused a decline in citrus trees around the globe. The bacteria clog the sugar transport system (phloem) of a tree, effectively destroying the tree's ability to send synthesized starches from the leaves to the roots. The roots die without access to the simple starches that are their food. The compromised root system is then unable to supply leaves with sufficient water and nutrients. Once a tree is infected, there is no cure for the disease. However, we now have more hope that we can help trees recover from and grow out of the disease than we used to.

Two species of *Candidatus* Liberibacter negatively affect citrus trees: *Ca.* L. asiaticus (native to South Asia) and *Ca.* L. africanus (native to South Africa). Originally, the name 'Huanglongbing' was associated with symptoms caused by *Ca.* L. asiaticus, while the name 'greening' was associated with symptoms caused by *Ca.* L. africanus.

'Huanglongbing' ('yellow shoot disease' in Mandarin) originated in Guangdong province in South China, and was first identified in India in the late 1700s to early 1800s. Many translate directly from its written characters to mean 'yellow dragon disease,' but culturally 'long' is a slang word to mean 'plant shoot.' Yellow coloration of new shoots is one sign of infection in trees.

'Citrus greening,' discovered independently in the 1940s and 1950s in South Africa, was also named for a symptom of infection. Infected trees bear fruit that stays small and green or that fails to mature evenly and ends up misshapen.

For simplicity, we will talk about the disease as 'greening' for the remainder of the article.

The Vectors

A vector is an organism that transfers a disease or pathogen. Two species of small, sucking insects called psyllids are vectors of greening: the Asian citrus psyllid (*Diaphorina*

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citri: Figure 1) and the African citrus psyllid (*Trioza erytreae*). African citrus psyllids are heat sensitive, which limits their range. However, the vector's recent detection in the EU is causing concern (the disease has not yet been detected there). Asian citrus psyllids are present throughout southern Asia and the Arabian Peninsula and in parts of the Americas (CABI Invasive species consortium). Both psyllids are able to carry either of the bacteria that cause greening. The Arabian Peninsula is one of the few parts of the world where both vectors (psyllid species) and both pathogens (*Ca.* L. species) are present. The ranges of the disease and of the psyllids must overlap for psyllids to become vectors.

Adult citrus psyllids feed on plant stems and on both new and mature leaves, but they prefer young leaves. When an uninfected adult psyllid lands on an infected tree and feeds on new leaves, it incubates the Liberibacter bacterium in its gut and becomes a vector of the disease. Later, when it feeds on another tree, it transfers the bacterium and passes on the infection. The most efficient vector is an adult female psyllid who has acquired the bacterium, which incubates in her for 1 to 2 weeks. She later feeds on a shoot (passing on the infection), then lays eggs on the shoot. When nymphs (juveniles) emerge, they feed on the now-infected shoot and ingest the bacteria, which multiply in their guts. As they grow, nymphs continue to eat and infect the same shoot. This constant reinfection weakens the tree.

To properly monitor potential infection and to understand appropriate treatment, you will first need to identify whether or not psyllids are present on your trees. Adult psyllids are most likely to feed on new growth or shoot tips. They are 2 to 4 mm long (about the size of common aphids). Their brown bodies tilt at an angle as they feed, making them look like thorns (Figure 1). If psyllids have been feeding on a new shoot, you will notice a pinching-like distortion of the leaf edge (Figure 2). Nymphs and eggs are difficult to see without a magnifying hand lens such as those sold by NASCO. With magnification, nymphs appear orange and secrete white tubules; they are typically found on new stem tissue. Eggs are yellow and are most often deposited on new leaves. For more information about monitoring for pests, see *EDN* 136.

Figure 2. Citrus leaf distortion caused by Asian citrus psyllid feeding. *Source: Tim Motis*

Psyllids are the predominant vectors of greening, but humans can also unwittingly cause transmission of the bacteria by propagating with or transporting infected plant material. Use of infected budwood for grafting or budding will spread the disease to the newly grafted trees. Infected trees that are then sold and carried throughout the surrounding region provide more infected hosts for psyllids.

SYMPTOMS

Monitoring for psyllids is extremely important, because there is no simple method for early detection of greening, and significant root death occurs below ground before any signs are apparent above ground. If you live in a region affected by greening, and you see psyllids on your trees, the trees are most likely infected regardless of whether or not you see other symptoms.

Leaves

As the Asian name 'yellow shoot disease' suggests, newly emerged yellow shoots in a citrus tree canopy are a sign of infection. This yellowing is not caused by a nutrient deficiency, but by the buildup of starches synthesized in the leaves; bacteria clog the vascular tissue so that the starches cannot travel down the phloem of the tree to the roots.

Nutrient deficiencies can also cause yellowing, but it is possible to distinguish between them and greening symptoms. A leaf yellowed because of greening will have an asymmetrical blotchy mottled pattern, with small islands of green (Figure 3). By contrast, leaves that are yellowed due to nutrient deficiencies will have symmetrical

Figure 3. Leaf with blotchy mottled greening symptom (left) and a healthy leaf (right). *Source: Tim Motis*

patterns on either side of the leaf midvein. [Nutrient deficiencies are common on trees infected with greening; zinc deficiency is especially common. Corky or raised mid-veins are also common on leaves of infected trees, but alone do not diagnose greening.]

Infected trees may drop their leaves, and their new leaves may be pointed and look like 'rabbit ears.' Mottled leaves along with leaf drop and/or pointy new growth are strong indicators of citrus greening.

Fruit

Fruit from infected trees may appear lopsided or misshapen; it also might stay green even when mature (Figure 4). Additional symptoms may been seen when fruit are cut in half; there may be a yellow stain under the calyx button (where the fruit attached to the tree), a curved central core, and aborted seeds which are hard and brown (Figure 5). Fruit from infected trees may taste salty or bitter.

Figure 4. Citrus fruit with greening symptoms (left) and a healthy fruit (right). *Source: Tim Motis*

Tree

General tree symptoms can give some indication of infection; these include twig dieback (resulting in a less dense tree canopy), stunting, off-season flowering,

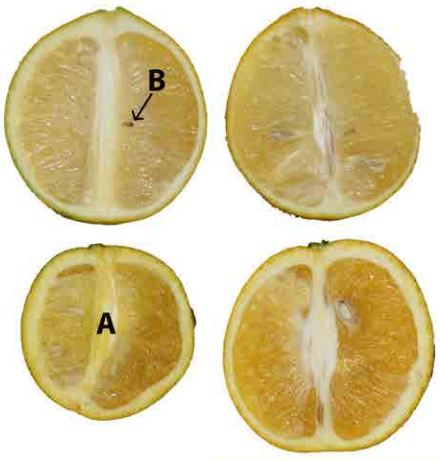

Figure 5. Cross section of citrus fruit with greening symptoms (left) showing a curved central core (A) and immature, brown seeds (B). Healthy fruit (right). *Source: Tim Motis*

and overall tree decline. However, these general symptoms may result from a different disease or from stress, so look for a combination of leaf, fruit, and tree symptoms when monitoring for greening.

University of Florida/IFAS Citrus Extension Plant Pathology has sites where you can view photos of common greening symptoms or compare greening symptoms with nutrient deficiency symptoms and also provide sampling instructions for in-field monitoring.

PROTECTION STRATEGIES

Several strategies can be used to protect against citrus greening. Here, we focus on strategies for farmers with limited access or availability of resources. A short description of some recent, more technical approaches is included at the end of this article under "Additional Resources." A range of organic and inorganic options are presented below. In selecting and applying any of these, consider integrated pest management principles.

Protect in the Nursery

Nurseries that propagate citrus plants or other plants that host citrus psyllids must use preventive measures, to stop the geographic spread of any diseased or vector hosting material and to make sure that citrus propagation material is clean (uninfected). Curry leaf tree (*Murraya koenigii*) and jasmine orange (*Murraya paniculata*), relatives of citrus that are sold as ornamentals, are hosts of Asian citrus psyllids and must be included in preventive measures.

Be sure to obtain clean budwood for grafting and budding. Research institutions, government-led programs and other entities actively protect and maintain budwood to preserve healthy stocks of grafting material. Ask your local extension agent or field technician for sources of locally available material. Fruitmentor™ offers an incomplete list of international sources of budwood. When importing plant material be aware of laws requiring phytosanitary certificates, import permits, or plant quarantine.

Screens on greenhouses can help exclude psyllids, especially if combined with positive pressure ventilation, in which greenhouse air pressure is kept higher than outside air pressure. When a door is opened, air rushes out at a rate faster than an insect can fly, excluding insect pests (Mears and Both 2002). Where positive pressure ventilation is not feasible, screens with a hole size of 530 x 530 microns (32 x 32 treads/inch) will exclude psyllids (Stansly and Rogers 2006).

Experts recommend that you treat nursery trees every six months with a systemic, soil-drench neonicotinoid, such as those with active ingredients thiamethoxam or imidacloprid. Neonicotinoids are broad-spectrum insecticides that quickly spread to every part of the tree and deter insects from feeding. Some formulations can be applied to the foliage, but a soil drench is said to be most effective (Rogers *et al.* 2016). Personnel applying chemicals must be trained in the application and safety measures required for pesticides use (e.g. personal protective equipment). These insecticides may not be widely available or affordable to small-scale farmers. Farmers may also wish to use insecticides less likely to impact beneficial insects such as bees. For such cases, see content in the next section for foliar-applied psyllid control options.

Monitor your nursery regularly, looking for infection symptoms and for the presence of psyllids. If you identify tree seedlings with greening, remove them immediately and burn the diseased plant tissue.

Tree removal

Regionally, if greening is detected early, eradication of affected trees may be necessary to protect the local industry. If you discover greening in an area that has an infection rate less than 2%, keep pulling out trees. Both Texas and California citrus industries in the United States still practice eradication programs in an effort to remove diseased material and slow down disease transmission. However, past a certain point, eradication ceases to be an effective protection strategy. According to Tim Gast, economic models and studies show that in areas with more than 4 to 5% infected trees, you will not get ahead of the disease through tree removal.

MANAGEMENT STRATEGIES

"We used to say, 'It's dead as soon as the tree gets it, it's done. In a couple of years, it's gonna die.' But that's not the truth," said Tim Gast as we were talking about citrus management. He gave us at ECHO hope that, with proper management strategies, we can help trees grow out of citrus greening disease and be productive again. He informed us that every two years, citrus trees replace all of their leaves; the trees are also constantly putting on new phloem. As we give citrus trees targeted support, chances are that they will grow out of the disease. "I've seen thousands of trees grow out of it," Tim encouraged us. Infected trees must be properly cared for and managed to minimize stresses such as overwatering, insufficient watering, over fertilization, under fertilization, sunburn, frost burn and excessive pest pressure.

Psyllid Control

Young trees

Young trees tend to flush more frequently than mature trees, attracting psyllids and making young trees more susceptible to infection and re-infection.

Shoots and leaves can be treated two times per flush, once as the new leaves emerge and again just after they harden off. Because temperatures and rainfall fluctuate in the tropics, the timing of flushes may be unpredictable, so be prepared to treat trees at any time. There are commonly used foliar applications that either kill psyllids or deter them from eating. Oil and soap dilutions sprayed on tree leaves kill psyllids while diatomaceous earth, wood ash, and kaolin clay applications deter insects from feeding on leaves.

Tim Motis, co-editor of *EDN*, shared a simple recipe to control psyllids:

> After observing a number of citrus greening psyllids on my lemon tree at home, I decided to spray a combination of liquid dish soap and vegetable oil. I added 2 teaspoons (10 ml) of dish soap and 1 teaspoon (5 ml) of vegetable oil to a gallon (3.8 l) of water, in a one-gallon sprayer. After shaking the sprayer to mix the ingredients, my 7 and 11 year old boys took turns spraying the leaves. The tree was short enough for them to reach most of the canopy, and I helped reach leaves at the very top. When I inspected the leaves a day or so later, every psyllid I found was dead. This simple recipe, used in conjunction with a hand-operated sprayer, is very doable for one or two trees in my yard.

On a larger scale, many citrus growers treat young trees every six months with a systemic, soil-drench neonicotinoid to deter psyllids. The soil drench is applied during drier periods, to prevent the treatment from leaching beyond the root zone. In place of soil drenches, neonicotinoid foliar sprays are also an option.

Mature trees

During cold and/or dry seasons, the growth rates of both trees and psyllids typically slow down. Psyllids become lethargic during a prolonged dry or cold period, providing the opportunity to manage them as a population--for example, by spraying trees with soap or oil sprays as described above.

Biological controls

Several common generalist insect/arthropod predators consume Asian citrus psyllid nymphs. Lacewings, spiders, and especially ladybugs all feed on psyllid nymphs. An introduced wasp, *Tamarixia radiata*, is a highly effective predator, killing up to 95% of nymphs (Michaud 2004). Female wasps lay eggs on the bodies of psyllid nymphs; after hatching, wasp larvae consume the body fluid of the psyllids, killing them.

Supply Nutrient and Water Requirements

Blockage of the phloem in an infected tree causes it to lose between 50 and 70% of its feeder roots. As a result, roots have limited ability to send water and nutrients to the leaves. In order to facilitate healthier conditions for growth, we must supply nutrients and water to an infected tree's disjointed parts. (Note that the disease affects the tree vertically but does not spread rapidly throughout the tree horizontally except when psyllids reinfect different shoots of the same tree.)

Figure 6. Mandarin 'Orah' variety from Israel cultivated in China. Trees are kept short for ease of maintenance. White material on the leaves is lime, which is applied to help prevent sun burn on the fruit. *Source: Tim Gast*

Root Fertilization

Feed roots by supplying macro and micronutrients, to support the root system while you wait for the tree to put on new phloem. Aged manure, compost and synthetic fertilizers are all options. What you choose to use will depend on availability and access. Fertigation--micronutrient supplementation through an irrigation system--is very effective but may not be readily available.

The amount of fertilizer and frequency of application will depend on the type of fertilizer you choose, the climate of your region, and the sizes of trees. Contact your local extension officer or field technician for guidance.

Irrigation

Infected trees need more frequent irrigation than healthy trees, because greening compromises the root system, reducing water supply to the leaves. Irrigate trees as the soil dries out, but be careful not to overwater. Wet soil or poor drainage can cause root rot, which can easily kill an already weakened tree.

Shoot Fertilization

Shoot health can be supported by applying organic or inorganic foliar nutrient sprays. If using synthetic foliar sprays, refer to product instructions. Homemade foliar sprays require labor inputs but can utilize local resources and can be ready to use in as little as two weeks. *West Africa Note* 1 includes a recipe for organic liquid fertilizer made from manure, green matter, soil and water. Fermented fish can be used to make a foliar feed high in nitrogen. Natural Farming techniques include instructions for making foliar sprays. If you make a foliar nutrient spray for your crops, please share your experience and insight with the ECHO Community.

Keep Trees short

At a grove in China, Tim Gast observed that the grower kept trees short for ease of maintenance, which was entirely done by hand (Figure 6). There, laborers apply agricultural chemicals with backpack sprayers that are able to reach the short trees. Greening is endemic to the region he visited, but he did not see greening symptoms in the grove. They also utilize geese for weed management (Figure 7). Here at ECHO Florida, we have found that chickens and sheep effectively control weeds under a number of tree species.

Figure 7. Geese removing weeds at a grove in China. Grove manager says that they do have to supplement geese feed in winter months when weeds are not vigorous. *Source: Tim Gast*

Variety Selection

Certain citrus varieties, including Nova Tangelo, Dancy Tangerine and Sugar Bell Tangerine, are more tolerant of greening, showing fewer symptoms of the disease than other varieties. You may create resiliency in your orchard by choosing tolerant varieties. If your region has greening and psyllids, but you do not know which local citrus varieties are tolerant, observe trees to see which are asymptomatic. Harvest a few fruits from those trees (with permission) and evaluate the taste, shape and evenness. Share your observations with your community and with

researchers or extension workers in your region.

CONCLUSION

Citrus trees are discouragingly susceptible to a myriad of diseases, including citrus greening. But farmers and researchers are making hopeful new observations and discoveries. ECHO has been encouraged by recent conversations with local fruit growers. We hope that understanding how best to steward your citrus trees helps them to survive and, one day, thrive.

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ADDITIONAL RESOURCES

General Citrus Problem Information

University of California Davis has a comprehensive citrus disease diagnostic chart which lists citrus symptoms, likely causes, and recommended control methods.

Arizona Cooperative Extension has a home diagnostic sheet that includes helpful images of symptoms related to citrus problems.

Pathogen and Vector Information

Hall, D.G., M.L. Richardson, E.D. Ammar and S.E. Halbert. 2013. Asian citrus psyllid, *Diaphorina citri*, vector of citrus huanglongbing disease. *Entomologia Experimentalis et Applicata* 146: 207–223. doi:10.1111/eea.12025

The California Department of Food and Agriculture Plant Health & Pest Prevention Services provides a condensed overview of the asian citrus psyllid history, distribution, life cycle and role as a vector and also gives suggested control methods. The Department also provides a list of plants that are hosts to the Asian citrus psyllid.

Florida Department of Agriculture and Customer Services offers options on biological control of Asian citrus psyllids and, depending on levels of stock, will ship *Tamarixia radiata* to eligible applicants who file a release application.

University of Florida IFAS offers an Integrated Pest Management page on Asian Citrus Psyllid and Citrus Greening Disease as well as a species highlight on *Tamarixia radiata*. They also have an updated 2017-2018 Citrus Production Guide: Huanglongbing (Citrus Greening) with recommended management practices.

CABI (Centre for Agriculture and Biosciences International) has an Invasive Species Compendium with datasheets on citrus huanglongbing (greening) disease, Asian citrus psyllid, and African citrus psyllid. These sheets include useful distribution maps of the disease and vectors, which can help you discern the likelihood of the vector and/or disease reaching your area.

Recent and Upcoming Technical Advancements

A recent article from Growing Produce shared that University of California Davis citrus experts are working with farmers to develop detection methods that can chemically profile leaves early in the infection process.

Many researchers around the world are breeding, grafting and culturing citrus plant tissue in an effort to identify and/or develop tolerant or resistant citrus tissues. There has been some success; for example, the preferred rootstock for many nurseries in the United States: 'US-942,' is 'HLB tolerant'. The University of Florida's '#4' rootstock is considered resistant to greening, but is not available yet. A recent article in Science Daily summarizes the hope of imparting greening tolerance with use of new citrus rootstock varieties.

The UF/IFAS Citrus Research and Education Center is the site of much research on citrus and greening. UF/IFAS Extension is investigating the interactions of soil microbial populations, applied both directly and indirectly, to understand if changes in the soil microbe population can benefit citrus trees.

United States Department of Agriculture has evaluated varieties for tolerance and resistance to HLB and is also testing a new trap to trick psyllids with sound.

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2017 ECHO International Agriculture Conference: Topic Summaries

by ECHO Staff

This article summarizes several of the plenary sessions presented at the 2017 ECHO conference in Florida. If you were unable to attend the conference, or would like to review some of the talks, many of them can be viewed on ECHOcommunity. Other 2017 presentations that appear there include "Tropical and subtropical fruit crops for small to moderate farm holdings," "Dialogue education and farmers," and "Integrating practical nutrition education into community agricultural programs." Talks given in previous years are also available on the website.

Moringa-coated sand filters as a sustainable solution for clean water (Dr. Stephanie Butler Velegol)

Moringa seeds can be crushed and used to clean dirty water. However, water treated in this manner must be used right away, or else the small amounts of organic matter

that remain in the water will allow bacteria to grow.

Dr. Stephanie Velegol has been working for seven years to make the process of water treatment with moringa more effective for the long-term. She shared some exciting information:

- **The antibacterial mode of action.** Moringa seeds contain 1% of an antimicrobial cationic protein peptide that has a positive charge. Pathogens have a negative charge and are attracted to the protein. Dr. Velegol described the mechanism by which bacteria are rendered inactive: the bacterial membranes fuse and the bacteria can no longer reproduce.
- **"Sticky killer sand."** Sand filters do a good job of filtering out particles in water but cannot remove bacteria like *E. coli*. Dr. Velegol has shown that the active proteins from moringa seeds can be adhered to the surface of sand. This "functionalized sand," or *ƒ*-sand (also referred to as "sticky killer sand"), can then be used in sand filters; as water filters through, microbes have sustained contact with the *ƒ*-sand. Here are some details about the process:
    - Experiments showed that **mixing crushed seeds (in water) with sand for five minutes is long enough** for the proteins to adhere to the sand's surface.
    - **"Sticky sand" also sticks to plastic and glass, because of the latter's negative charge**; this can be an easy and helpful test to check whether or not sand is functionalized.
    - **A sand water filter made with "sticky killer sand" works on bacteria like *E. coli*** that are 1 µm in diameter, that are hardest to remove with a filter.
- A 1 m x 1 m filter, using seeds from six trees, can remove 99.99% of 1 um particles and can treat water for 1000 people. Models have demonstrated that such a filter will be functional indefinitely. It will clog up long before it ceases to be effective.
- Moringa seed can yield multiple products. The seed can first be pressed for oil. The seed cake that is left can be used to produce *ƒ*-sand; the remainder of the seed cake can then be used for animal feed.

Questions remain, of course. In experiments, very large quantities of *E. coli* were introduced into the test sand filter, and none were detected in the water that came through. But what if, at lower and more realistic concentrations, the *E. coli* bacteria are less attracted to the charged sand? It is also not clear whether the filter can remove viruses. Because of these unknowns, Dr. Velegol was hesitant to recommend that an *ƒ*-sand filter replace other methods of water treatment. However, she agreed that after filtration, other methods of water treatment (e.g. UV light, iodine, or chorine) could be used at a lower dose. Dr. Velegol's work was recently published and is now available.

An ex-post evaluation of 10 years of Conservation Agriculture (CA) promotion in Zimbabwe: *Lessons for food security interventions* (Putso Nyathi)

Christian Care promoted Conservation Agriculture (CA) in five districts of Zimbabwe from 2006 to 2014, in areas that receive little rainfall for five or six months. In her plenary talk, Ms. Putso Nyathi began with a brief overview of CA principles, which include minimum tillage, maintenance of soil cover, and crop rotation. Then she described Christian Care's program, which also included introduction of open-pollinated varieties (OPVs); use of cover crops; and extension with lead farmers.

Ms. Nyathi spent most of her talk describing an evaluation that was conducted after the program ended, to assess the impact of the effort. A team collected data using household interviews, focus group discussions, key informant interviews and field visits. The team found high adoption of CA principles; 95% of respondents continued to use minimum tillage methods, and around 80% continued mulching and rotating crops. There was good evidence that the practice of CA had led to increased food security; one respondent commented, "Even where there were no granaries before, they are now there because of CA." However, the evaluation team found that farmers only devoted about one quarter of their cropland to CA, with the rest planted using conventional practices. Though group seed banks had been promoted, household seed banks proved more sustainable. Only cowpea was planted as a cover crop, due to limited understanding of gmccs and to lack of seed availability.

Ms. Nyathi discussed some of the reasons farmers adopted CA practices. The main driver for adoption was higher yields. The evaluation also revealed barriers to adoption; for example, using a hoe was too labor-intensive. Ms. Nyathi suggested the introduction of other, mechanized options for minimum tillage.

Ms. Nyathi shared a few other interesting results of the CA promotion. First were the program's impacts on women, which were both positive and negative. On the one hand, many women became lead farmers and as a result, women had more access to agricultural extension; use of the hoe (known as a woman's tool) made CA accessible for women; and the increased production from CA benefited the whole household. On the other hand, the weeding and mulching meant more work for women.

The other interesting finding had to do with the extension farmers. Though no longer paid once the program ended, the lead farmers continued to give technical and moral support when asked. Government extension for CA also continued after the program.

Conservation Agriculture has been promoted and practiced by farmers for well over 10 years in southern Africa. Ms. Nyathi gave a very helpful presentation of a rigorous evaluation that took a critical look at the impact of this widely promoted farming practice.

Integrated Development Done Right: *Farmer-led Research on Agroecology and Nutrition* (Dr. Rachel Bezner Kerr)

Dr. Rachel Bezner Kerr shared results of 17 years of multi-faceted, farmer-led research in Malawi and Tanzania. The research resulted in dramatic improvements in infant, child, and family nutrition and food security, through promotion of crop diversification, soil improvements, nutrition and cooking education, and open dialogues about family dynamics and gender roles. Dr. Bezner Kerr's research has evolved through five stages, with each successive stage incorporating feedback from inclusive and participatory discussion groups.

Participating communities experience high rates of chronic malnutrition due to factors that include severe poverty, high unemployment, low wages, and poor soil fertility. Traditional diets are high in

carbohydrates, but low in protein, vitamins, and minerals with little money available to purchase food. In addition, unequal gender dynamics divert food and income away from infants and nursing mothers during critical developmental stages.

Dr. Bezner Kerr described many results of the farmer-led research. Legumes (e.g., pigeon pea, groundnut, soya, cowpea) were rotated with or planted among maize, to increase available soil nitrogen and organic matter levels, and to suppress weeds, conserve water, reduce erosion, diversify diets, and supply livestock fodder. Increased chicken and pig production helped supply more protein and increase incomes. Compost helped improve dry season vegetable gardens and efficient wood stoves reduced fuelwood consumption.

Discussion groups helped encourage community and family dialogue about gendered labor roles, financial decision making, and childcare to highlight how the attitudes of grandparents and husbands impact nutrition outcomes. Special community events, such as cooking and recipe competitions (with men cooking!), dramas, and music reinforced the benefits of working together to strengthen families and helped to adjust gender roles.

Dr. Bezner Kerr's talk included fascinating examples of the wide-ranging interactions of agriculture, nutrition, and gender relations. For example, one graph showed correlations between farm diversification and improved child growth. Dr. Bezner Kerr shared, "models show that legume intercrops, number of crops cultivated, and discussing farming with a spouse are significant predictors of food security and dietary diversity after holding other factors constant." Analysis of research in Tanzania showed a "significant relationship between household food insecurity, gender inequity, and depression."

Post-Conflict Agriculture (Dr. Joshua Ringer)

Dr. Ringer has worked with smallholder farmers in Myanmar, Vietnam, and the Philippines, in locations where armed conflict has torn apart the physical and social structure of society. Many smallholder farmers that live in areas of conflict, or that have lived through conflict, have been displaced. They may have lost loved ones, their homes, and their livestock. Dr. Ringer shared the importance of grieving with farmers over their losses, but cautioned against viewing farmers as victims. Development efforts should maintain people's respect and dignity, and should build on steps farmers have already taken. Those affected by conflict often develop avoidance and escape strategies in order to survive. Agricultural development alone is not enough; for families who have lived through situations of conflict, spiritual and personal needs also must be addressed in order for healing to happen.

Agricultural development and extension can play a vital role in stabilizing and rebuilding food production in post-conflict situations, if done carefully. Aid workers and agricultural extension workers must gain the confidence of farmers and engage them in a true participatory manner to develop solutions to their problems. Agricultural networks will need to be rebuilt. Marginalized and traumatized farmers may need encouragement to rebuild.

Recovery starts with meeting people's most basic needs, including food, shelter, sanitation and personal safety. Then chronic development issues can be addressed. Villagers must work together to rebuild food production, to raise animals again, to adopt new technologies presented by extension officers and NGOs, to preserve their resource base, and to regain access to markets.

Dr. Ringer suggested that practitioners work with key farmers to develop agricultural options that can be incorporated into farming systems. Farmer field schools and farmer self-help groups can improve opportunities for agricultural development. Dr. Ringer commented on the importance of planning for the long-term (at least ten years). He suggested small-scale on-farm field experiments that can be evaluated and adapted.

[*Related: In her conference plenary session in 2013, Robin Denney shared her experience in post-conflict areas, including challenges, different agricultural development approaches, and how faith influences recovery. Also, some of the strategies to help prepare for and respond to disaster from EDN 122 might be helpful in post-conflict situations.*]

ECHOES FROM OUR NETWORK

Edible Insects

Patrick Trail, working with ECHO Asia in Chiang Mai, Thailand, shared some feedback after reading the recent *EDN* article about edible insects. He wrote, "It is not uncommon to find a variety of edible insects in many of the markets here in Thailand, and across many SE Asian countries, though typically in small quantities and mostly wild harvested. However, [at our] local Maejo Agricultural University, one can tour the newly constructed Center for the Production of Black and Yellow Soldier Fly. Using mostly organic market waste, black soldier fly larvae are being raised on a large scale and are being fed to broiler chickens as a supplemental feed. For more information or to set up a tour, please contact our office.

"Dr. Arnat Tancho has also recently published a manual guidebook on the production of BSF, though currently only Thai translation is available. Its title in English (translated from Thai) would be 'Black Soldier Fly Production' from Maejo University."

Patrick also told us about a recent encounter with a very real agricultural pest problem that relates to a lack of insect consumption. He wrote, "On a recent trip to Bali, Indonesia, we went in to do a rapid assessment of some agricultural challenges, including a major infestation of the sugarcane white grub (*Lepidiota stigma*:

Figure 8) in northeastern Bali. It is currently ravaging farmers' fields, consuming the roots of banana, sweet potato, cassava, and several others, to the point that farmers have been abandoning their fields. Farmers are having very little success with managing the grub, and have become overwhelmed by this voracious insect pest.


Figure 8. *Lepidiota stigma* grub (left) and adult (right).
Source: Patrick Trail

"After interviewing several farmers, it seems that *L.stigma* is neither an invasive species, nor recently introduced; it has always been present on the island. However, just one generation ago when times were tougher, people would collect the large grubs and consume them. Today, people don't have any interest in eating the larvae, and their numbers have grown to destructive levels in farmers' fields. I never guessed that part of our proposed IPM strategy would include advice to 'eat more grubs,' but perhaps that can and will be more common in the future!"

FROM ECHO'S SEED BANK

Tree Lucerne: Multipurpose forage crop for the highlands

by Gene Fifer

ECHO promotes many animal fodder crops for use in the tropics and subtropics, for arid and humid areas, but few of them are frost tolerant, drought tolerant, and thrive at high elevations. Tree lucerne *(Chamaecytisus palmensis),* also known as tagasaste, is a long-lived, leguminous shrub that can survive temperatures as low as -9°C (16°F), produce forage during extended dry seasons, and thrive at elevations up to 3000 meters. It is suited to poor, sandy soils and sends roots down as deep as 10 m.

Tree lucerne is native to the Canary Islands but is widely adapted to Mediterranean climates, semi-desert conditions (such as those found in Western Australia), and dry tropical highlands. It contains high levels of protein (21.5% CP; Assefa *et al.* 2008), making it an excellent fodder for ruminants, in both free range systems and cut-and-carry systems. Tree lucerne is a popular forage for dairy farmers in the highlands of both Kenya and Ethiopia.

Tree lucerne offers multiple benefits in addition to fodder. It can be used as a windbreak, as a firebreak, for erosion control, and for soil improvement through symbioses with nitrogen-fixing bacteria. It is a valued bee forage for honey production and produces an excellent fuelwood.

Seed is now available from ECHO's seed bank in packets of 25 to 30 seeds. Scarify or boil seeds in water for one minute before planting. Seedlings grow quickly but must be protected from grazing (by livestock and wildlife) until well-established.

Figure 9. Tree lucerne flowers and leaves.
Source: ECHO Staff

Reference

Assefa, Getnet, C. Kijora, A. Kehaliew, S. Bediye, and K.j. Peters. "Evaluation of tagasaste (*Chamaecytisus palmensis*) forage as a substitute for concentrate in diets of sheep." Livestock Science 114, no. 2-3 (2008): 296-304. doi:10.1016/j.livsci.2007.05.017.

BOOKS, WEB SITES AND OTHER RESOURCES

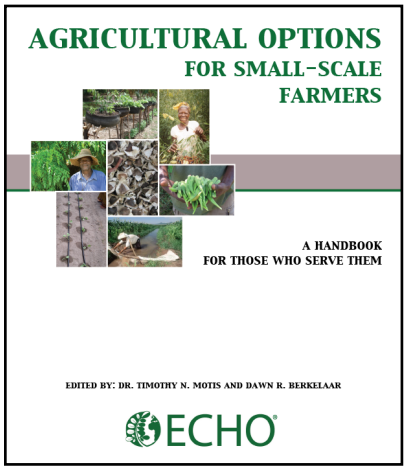
New epublication Release: Agricultural Options for Small-Scale Farmers

ECHO is pleased to announce availability of the ebook ***Agricultural Options for Small-Scale Farmers: A Handbook for Those Who Serve Them***.

This book, first published in 2012 as a paper book, is filled with practical options for those working to assist small-holder farmers and urban gardeners in the tropics and subtropics. How can we help the farmer who must survive on a small parcel of degraded land without access to water or a means to purchase fertilizer? Information is abundant, but which interventions will really make a difference? The best way to gain the necessary perspective is to connect with like-minded people who have the benefit of experience.

Since 1981, an extensive network of missionaries and development workers in over 180 countries has shared ideas through *ECHO Development Notes* (*EDN*).

The first 51 issues of *EDN* were compiled in a previously published book, *Amaranth to Zai Holes* (also known as *A to Z*). Agricultural Options for Small-Scale



Farmers, a sequel to A to Z, draws mostly from content in issues 52 to 100 of *EDN*, but also contains some ideas from earlier issues and from Technical Notes written by experienced practitioners.

Chapter 1 covers foundational concepts, such as the weaving of agriculture and community development; insights about doing research in the field; and factors and issues to consider before investing valuable resources in specific project interventions. Chapters 2 through 8 build on that perspective, presenting practical, project-oriented options on a variety of topics: restoring unproductive soils; coping with scarce rainfall and with crop pests; promoting underutilized crops to improve human nutrition; diversifying small farms; multiplying and storing seed; and addressing human health issues related to agriculture.

This ebook is available for purchase from Amazon in English, Spanish and French, for $19.95 each. The paperback version is available from our ECHO Bookstore and is sold at ECHO conferences internationally.

We hope that the perspective and practical project options found in this ebook will help improve the livelihoods of smallholder farmers around the world. Please let us know how the book's content contributes to your efforts to serve those in your community (email echo@echonet.org). We also invite you to utilize ECHO's network portal (www.ECHOcommunity.org) and to participate in our forum (ECHO Conversations) as together we work towards solutions to hunger.

UPCOMING EVENTS

ECHO Florida Events:

Location: ECHO Global Farm, USA
Presented by: ECHO

Tropical Agriculture Development: The Basics
July 23-27, 2018

Introduction to underutilized and tropical crops: Growing, harvesting, preparation
September 10-14, 2018

Introduction to Permaculture
April 30-May 4, 2018

Tropical Agriculture Development: 101 (geared towards University students)
April 9-13, 2018

- email rgill@echonet.org for more information

Please watch ECHOcommunity for further information. More information and registration details can be found on www.ECHOcommunity.org.

ECHO Asia Event:

2018 Asia Pacific Sustainable Agriculture & Development Conference
February 6-9, 2018
Location: Asia Pacific Theological Seminary (APTS), Philippines
Presented by: Samaritan's Purse Canada, ECHO Asia, and The SEED Project

ECHO East Africa Events:

Best Practices in Pastoralist Areas
March 6-8, 2018
Location: Sportsman's Arms Hotel, Nanyuki, Kenya

Best Practices to Improve Nutrition in Dryland Areas Symposium
August 7-9 2018
Location: Naura Springs Hotel, Arusha, Tanzania

ECHO West Africa Events:

Guinea (Conakry) Workshop (in French)
February 21-23, 2018
Location: Kissidougou

Ghana Workshop (in English)
Mid February
Location: Tamale

Niger Workshop (in French)
March 13-15, 2018
Location: Niamey

Liberia Workshop (in English)
April 3-5, 2018
Location: Monrovia

Mali Workshop (in French)
April 17-19, 2018
Location: Bamako

West Africa Regional Forum (in French)
May 8-11, 2018
Location: Ouagadougou, Burkina faso

Nigeria Workshop I (in English)
May 22-25, 2018
Location: Jos

Nigeria Workshop II (in English)
May 29-June 1, 2018
Location: Ibadan

Please contact Noemi Kara (knoemi@echonet.org) for more information on these trainings.

PLEASE NOTE: At ECHO we are always striving to be more effective. Do you have ideas that could help others, or have you experimented with an idea you read about in *EDN*? What did or did not work for you? Please let us know the results!