HS1131

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Dooryard Citrus Production: Citrus Greening Disease [1]

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Citrus greening disease, also known as Huanglongbing (HLB), is the most devastating disease of citrus, affecting all citrus cultivars. This disease has severely limited citrus production in many citrus-growing areas of the world. The disease is caused by the bacterium *Candidatus* Liberibacter spp. and is spread by a tiny insect called the Asian citrus psyllid (*Diaphorina citri* Kuwayama). This insect is not native to Florida and was first found in Florida in 1998, at which time it was considered to be a pest of moderate significance. However, the discovery of citrus greening in Florida in 2005 changed the status of this insect to a pest of great importance.

Why Be Concerned about Greening?

Greening is a very serious disease of citrus that affects all citrus cultivars and causes rapid tree decline. Through the movement of plants and insects around the globe, greening and its insect vector have been accidentally spread throughout much of the world's citrus producing areas. Greening has seriously affected citrus production in a number of countries in Asia (the native home of citrus), Africa, the Indian subcontinent, the Arabian Peninsula, and a number of islands in the Indian Ocean, and was recently discovered in Brazil (2004) and Florida (2005).

Greening is transmitted (vectored) by insects known as psyllids. When psyllids are abundant and environmental conditions are favorable, greening can rapidly spread to existing trees, both commercial and residential, and reduce the productivity of oranges and other citrus cultivars. Mature trees, if infected, decline in health and become non-productive. Young trees that become infected never come into fruit production. In a survey conducted on Réunion Island (an island nation in the Indian Ocean), it was found that over an 8-year period 65% of trees were rendered unproductive within 7 years of planting. Similarly, in Thailand, trees generally decline within 5-8 years of planting. Infected trees become stunted and are sparsely foliated, making them aesthetically displeasing for the home landscape.

Greening is difficult to manage and continued production of citrus has proven difficult and expensive in areas where it is widespread. Nowhere in the world where greening exists has it been

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eradicated. Since greening is transmitted by the psyllid vector which is well established in Florida, the natural (psyllid vectored) spread of greening has occurred very quickly since its introduction into Florida in 2005 (see Fig. 1).

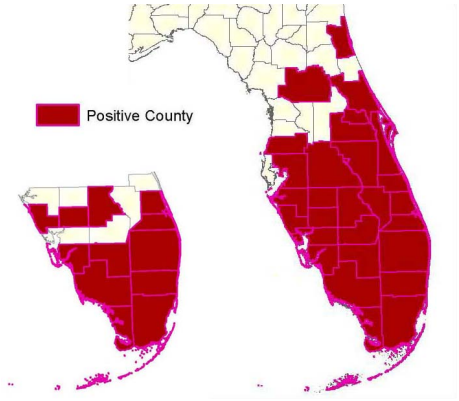

Figure 1. Maps showing the distribution of citrus greening disease in October 2006 (left) and October 2007 (right). In one year the number of counties with infected trees rose from 12 to 28. Maps created by the Florida Department of Agriculture and Consumer Services, Division of Plant Industry.

The Causal Agent of Greening

Greening disease is caused by a bacterium known as *Candidatus* Liberibacter spp. In the plant, this bacterium is limited to the phloem, the living tissue that carries carbohydrates produced by photosynthesis to all parts of the plant. Because the bacterium infects the phloem, once a plant has become infected the bacterium can move throughout the plant. That is, the infection is systemic, and thus cannot be removed by simply pruning away the part of the tree expressing symptoms. To date, researchers have not been able to culture the bacterium in the laboratory. This is severely limiting the progress of research into understanding and finding a cure for this disease.

There are three distinct isolates of the greening bacterium: *Candidatus* Liberibacter africanus from South Africa and *Candidatus* L. asiaticus from Asia, and *Candidatus* L. americanus from Brazil. The African form is believed to be more virulent in cooler climates (below 77°F) and at higher elevations (above 2250 ft). The Asian form, which is found in Florida, is more virulent at higher temperatures (above 80°F) and at lower elevations.

The Asian Citrus Psyllid

The greening bacterium is transmitted by two species of psyllids. The species *Trioza erytreae* (del Guercio), occurs in Africa, Yemen, and islands in the Indian Ocean, and is the vector of the African form of the disease. The other species, *Diaphorina citri* – the Asian citrus psyllid (Fig. 2), is adapted to warm humid climates and is found throughout Asia, the Indian subcontinent, Saudi Arabia, South America, Central America, and Florida. This species is the vector of the Asian form of greening disease that is found in Florida. This insect feeds and multiplies on all species of citrus as well as a number of ornamental citrus relatives listed in this article. By feeding on an infected tree, the psyllids can themselves become infected with the bacterium. They can then fly to a healthy tree and infect it through feeding. Once infected, the psyllids remain capable of transmitting greening for their entire lives.

Figure 2. Adult Asian citrus psyllid.

Adult psyllids (Fig. 2) measure about 1/8 in long and have mottled grey-brown wings which they hold "roof-like" above their bodies. Adult psyllids can usually be found aggregated on young, tender new growth (flush) where they feed and mate (Fig. 3). The females must feed on young flush after mating to produce mature eggs. The females lay their eggs in the folds of the unexpanded young leaves, or near the base of leaf buds that are just beginning to grow. If no new flush is present, the adults can be found feeding along the center vein on the undersides of leaves.

Figure 3. Adult Asian citrus psyllids aggregating on new growth.

Adult psyllids have a lifespan of about 30 to 50 days when temperatures are between 68 to 86°F, but this increases as temperatures become cooler. During winter, when temperatures are typically 55 to 60°F, the adult psyllid lifespan increases to approximately 88 days. Thus, during the winter adult psyllids can live for a long time, feeding on mature leaves, until new growth develops in the spring when their populations can increase very quickly. Psyllid eggs are very small, about 0.01 inch long (Fig. 4). Once the eggs hatch, the nymphs (young psyllids) range in size from 0.01 inch just after hatching, to 0.06 inch just prior to reaching the adult stage (Fig. 5). Nymphs are yellow and have red eyes. Their small size can allow them to be mistaken for aphids. However, psyllid nymphs produce a white, waxy secretion (Fig. 6) that is easily seen and makes them easily distinguishable from aphids.

Figure 4. Asian citrus psyllid eggs massed at the tip of a young expanding shoot.

Psyllids have what are known as piercing-sucking mouthparts which allow them to penetrate the phloem of their host plant and feed on the carbohydrate-rich plant sap.

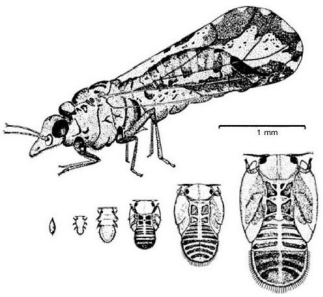

Figure 5. Diagram showing the developmental stages and relative size of Asian citrus psyllids from egg (bottom left) to mature nymph (bottom right) to adult (top).

Figure 6. Asian citrus psyllid nymphs showing white secretions. Note the red eyes.

Psyllid feeding causes new leaves to emerge twisted and curled (Fig. 7). Severe feeding damage can reduce shoot elongation and result in shoots with a bushy appearance (Fig. 8), or shoots may completely fail to develop (Fig. 9).

Figure 7. Newly expanding leaves displaying twisted and curled distortions caused by Asian citrus psyllid feeding.

Figure 8. Bushy, abnormal shoot development caused by Asian citrus psyllid feeding during shoot development.

Figure 9. Shoot tip death caused by Asian citrus psyllid feeding.

Long distance movement of greening can occur through the movement of infected plant material, including cuttings as well as potted trees. Epidemics of the disease have been documented when infected plant material is brought into an area where the psyllid vector is present to spread the disease. The movement of all citrus plant material into and out of Florida, whether by commercial companies or individuals, is restricted by state regulations and should not be done under any circumstances. It is also recommended that citrus plant material not be moved within the state because this will facilitate the spread of greening.

What Plants Are Affected?

The greening bacterium can infect virtually all citrus species, cultivars and hybrids, as well as several citrus relatives. Sweet oranges, mandarins (tangerines), and mandarin hybrids (tangelos) are highly susceptible to greening. Lemons, grapefruit, pummelos, and sour orange are also affected and are rendered non-productive when infected. Mexican lime, trifoliate orange and some trifoliate orange hybrids are more tolerant and may show only some leaf symptoms.

In addition to cultivated citrus and its relatives, greening can infect a number of citrus related (family Rutaceae) ornamental plant species. The greening bacterium can infect and multiply in orange boxwood (*Severinia buxifolia*, Fig. 10), and orange jasmine (*Murraya paniculata*, Fig. 11). These plants are also excellent host plants of the Asian citrus psyllid. Thus, having these ornamentals in the landscape can allow psyllid populations to build up and increase the risk of spreading the disease to other ornamental and citrus plants. Movement of these ornamentals is restricted under Florida regulations and they should not be moved out of areas where greening is present (see Fig. 1).

Figure 10. Orange boxwood (*Severinia buxifolia*).

Figure 11. Orange jasmine (*Murraya paniculata*).

Greening Symptoms

As research continues, we are learning that the symptoms of greening are not constant over time, within a tree or between locations, thus it is important to be familiar with all of the manifestations of this disease. Citrus greening symptoms are most easily detected on leaves, but can also be found on fruit from severely infected trees.

Leaf Symptoms

The leaf yellowing symptom on a single branch or shoot from which the Chinese name yellow shoot (huanglongbing) comes is seldom seen in Florida (Fig. 12). The more typical symptom in Florida, particularly early in the development of the disease, is what is known as blotchy mottle (Fig. 13). This is a variegated chlorosis or yellowing of the leaf that is not symmetrical about the center vein of the leaf. That is, the symptoms on the two halves of the leaf are not mirror images of one another, but rather are random across the leaf. An easy test to help determine if the symptoms are symmetrical or not is to draw two circles on the leaf surface on either side of the center vein as shown in Figure 14. If the areas within the two circles have a similar appearance, the symptoms are symmetrical and do not indicate greening. However, if the areas within the two circles are not similar, the symptoms are not symmetrical and may indicate greening.

Figure 12. Yellow shoots (arrows) caused by citrus greening disease on a sweet orange tree.

It is very important to distinguish greening symptoms from mineral nutrient deficiencies which also cause leaf yellowing. Mineral nutrient deficiencies, such as those caused by zinc, iron, manganese, and calcium can resemble greening symptoms (Fig. 15). However, mineral nutrient deficiency symptoms are symmetrical about the center vein of the leaf.

Figure 13. Citrus leaf expressing the typical blotchy mottle symptom of citrus greening.

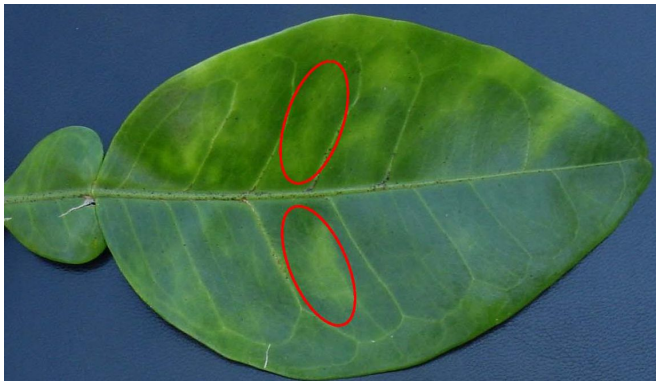

Figure 14. A leaf expressing the blotchy mottle symptom of citrus greening. Note that the symptoms are not the same in the circles drawn on opposite sides of the leaf mid-vein (asymmetrical).

With time, the yellowing usually spreads throughout the tree and affected trees may show twig dieback and productivity will decline. Additionally, leaves may develop what is known as vein corking (Fig. 16). This symptom is typified by bright yellow leaf veins that are raised and have a corky appearance.

Fruit Symptoms

Fruit symptoms. As an infected tree declines, the fruit may begin to display disease symptoms as well. Symptomatic fruit are commonly misshapen and appear lopsided (Fig. 17). A yellow stain in the peel just below the point of stem attachment, dark-colored

Figure 15. Leaves showing mineral nutrient deficiency symptoms (A-D) and greening disease symptoms (E). Nutrient deficiencies are manganese (A), iron (B), zinc (C), and magnesium (D). Note the uniformity (symmetry) of the mineral deficiencies; the left and right halves of the leaves are mirror images of one another. The greening leaf (E) does not show this symmetry.

Figure 16. Leaves exhibiting the yellow corky vein symptom of greening disease. Note how the center and lateral veins appear raised above the surrounding leaf tissue and have a cork-like appearance.

aborted seeds, uneven peel coloring, and a bitter, salty taste are other symptoms (Fig. 18).

How to Detect Greening

Detecting greening in dooryard citrus can be difficult, particularly if the trees are in poor health from other causes. The blotchy mottle symptom (Fig. 13) is the most diagnostic symptom of the disease, and is usually the best symptom for identification. It has been observed that symptoms become difficult to detect during the summer months when the trees are actively growing, thus carefully examining your trees during the fall, winter and spring offers the best

Figure 17. A greening-affected (left) and healthy (right) 'Valencia' orange fruit at the same stage of development. Note the much smaller size of the greening-affected fruit and its lopsided development.

Figure 18. Fruit showing symptoms of greening disease. The fruit on the left shows lopsided development, yellow staining below the point of stem attachment (yellow arrow), and dark aborted seeds (black arrow). The fruit on the right shows abnormal peel color development and is also misshapen.

chances for detecting the disease. When you are examining your tree for disease symptoms, have a guide with which to compare suspect leaves. The University of Florida publication "Nutritional Deficiencies and HLB/Citrus Greening" is a laminated sheet with color photos of leaves with greening symptoms and nutrient deficiencies that is available at all county cooperative extension offices free of charge.

Leaf symptoms may appear anywhere on the tree, so you may need to move branches out of the way and look inside the tree. If the disease is more advanced in your tree you may see fruit symptoms.

If you suspect that your tree is infected with greening you should mark the suspect branch on the tree and call the Florida Division of Plant Industry (DPI) helpline at 1-800-282-5153. DPI will send a trained inspector to examine your tree, and they can submit samples to their diagnostic lab for further

testing. You should not remove samples and take them to your county cooperative extension office.

Managing Greening and Psyllids

Psyllid Control

Psyllid control. In order for psyllid control measures to be 100% effective at eliminating the chance of disease spread, the psyllid population would need to be reduced to zero. Such a scenario is simply not possible. The best we can hope to achieve is suppression of psyllid populations through careful management; however, options are limited for homeowners.

Encouraging beneficial insect predators of psyllids by limiting pesticide use is the best option for residential citrus trees. Psyllid nymphs are preyed upon by ladybeetles (Fig. 19) and the parasitic wasp *Tamarixia radiata* (Fig. 20) that has been released in Florida. Together, these predators can consume over 90% of psyllids that hatch (Michaud, 2004). Additionally, limiting pesticide use will help to prevent disruption of natural predators of other pests, such as scales, mealybugs and whiteflies that are generally found at low levels in citrus. For homeowners choosing to use pesticides on their dooryard citrus trees, the options are very limited. Horticultural spray oils that are used to control a broad spectrum of insect pests will have some efficacy on psyllid nymphs. Thus, some psyllid control will be achieved when these products are applied for other pests, but they do not have any systemic activity in the plant. That is, they will only be effective against what is present at the time of spraying and they will not prevent new psyllids from moving onto the tree after spraying.

Figure 19. Beneficial ladybeetles that prey upon psyllid nymphs and other insect pests.

Figure 20. A psyllid nymph body (light brown area) that was parasitized by the predatory wasp *Tamarixia radiata* (dark brown in center).

Greening Bacterium Control

At the present time there is no method for controlling the greening bacterium itself. Once a tree becomes infected with greening there is no way to prevent it from spreading throughout the tree, causing the tree to decline and become unproductive. Furthermore, an infected tree that is allowed to remain standing will do little more than serve as a source of inoculum to spread the disease to healthy trees. Removing an infected tree is currently the recommended practice for both residential and commercial citrus trees. Because the disease is systemic, pruning away symptomatic branches is not effective since other parts of the tree may already be infected but not yet symptomatic.

Eliminating the ornamental plants orange jasmine and orange boxwood from the landscape will also help since both of these species are hosts for the psyllid and the greening bacterium. Reducing the number of potential host plants will directly help to reduce psyllid populations and the amount of inoculum available.

Greening is one of a few citrus diseases that can truly limit citrus production. Now that the disease and its vector are present in Florida it is important to limit its spread as much as possible so that we all may continue to enjoy Florida citrus. There is no cure for greening once a tree has become infected, and an infected tree serves as a source of inoculum to infect other trees. Homeowners and commercial citrus growers are strongly urged to remove infected trees once they are positively identified. It is also

recommended not to plant ornamentals which are alternate hosts of the greening bacterium and psyllid. Homeowners are strongly encouraged not to move citrus or citrus-related plant material within the state. Doing so can spread the bacterium and psyllid even more quickly. Additionally, homeowners should not bring any citrus-related plant material into Florida from other states or countries because these materials may contain pests and diseases not yet present in Florida.

Additional Information

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