Root Health Management[1]

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Developing and maintaining a healthy root system is important for establishment and long-term productivity of trees. The roots take up nutrients and water from the soil to transport them to the tree canopy (leaves and fruit). The root system also acts as an anchor for the tree, which is important during high wind conditions, such as thunderstorms and tropical storms. At the same time, the leaves provide carbohydrates to grow and maintain a functional root system. In a healthy tree, the carbohydrate supply is balanced between new leaves, fruit, and roots. When root health is compromised, the root system has reduced nutrient and water uptake capacity, which can subsequently affect growth of new leaves and fruit.

Root health can be compromised by pests, pathogens, and environmental (abiotic) factors. Citrus root pests include *Diaprepes* root weevil, burrowing nematode, sting nematode, and others. Historically the most damaging root pathogens in citrus have been *Phytophthora* spp. that cause root, crown, and foot rot. The most common detrimental environmental factors for roots in Florida citrus are soil pH, salinity, and flooding. An increase in soil pH above 7.0 results in precipitation of phosphorus, calcium, magnesium, and other plant nutrients, reducing the concentration of nutrients in solution available for uptake by the roots. Salinity and water logging can cause root decline and death. These biotic and abiotic causes of root health decline can be reduced by site-specific decisions made during the preparation for planting or when they become problematic in a grove. Management of root health problems depends on cultural and, when necessary, chemical management tools.

The root system has two main types of roots, structural and fibrous, that serve different essential functions for the tree. The structural roots provide the anchoring scaffold for the root system and act as the major transport corridors for nutrients, water, and carbohydrates. The fibrous root system forms the interface with the soil where water and nutrients are absorbed. Both kinds of roots are important for root and tree health and are affected differently by pests, pathogens, environmental factors, and their interactions. Structural roots often extend outward to the edge of the wetted zone or canopy and then continue down and outward beyond the canopy. Fibrous roots only grow in high density clusters from structural roots where water and nutrients are most abundant. In irrigated trees, the fibrous roots are concentrated in the wetted zone of the irrigation system. For example, microsprinkler irrigation concentrates 80% of the fibrous roots in the top 10 inches of the wetted zone under the canopy. It is important to understand this because root health management should be focused on these areas of high fibrous root density.

Introduction of *Candidatus Liberibacter asiaticus* (Las), the cause of Huanglongbing (HLB), into Florida greatly complicates citrus root health management. Las infection causes severe damage to fibrous roots that exacerbates the effects of the other root pests and pathogens and can reduce the efficacy of treatments. Root health management has

1. This document is CMG15, one of a series of the Department, UF/IFAS Extension. Original publication date January 2019. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

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become more challenging and more important because most citrus trees in Florida are now affected by HLB.

Huanglongbing and Root Health

HLB severely affects root health causing 30%–50% root loss early in disease development and greater than 70% root loss once canopy decline begins (sectored leaf drop and dieback). This root loss results from a shortened lifespan, about 4 months, for fibrous roots compared to 9–12 months for healthy roots. The shortened lifespan is accompanied by increased root growth, leading to an imbalance in carbohydrate demand in the tree and reducing the total uptake capacity of the root system. Structural roots also dieback from HLB, but the timing and impacts are poorly understood. Currently, there is no proven management option for prevention of HLB-associated root loss. Treatments that stimulate root growth are not recommended because they may increase the root-canopy imbalance. Instead, growers should focus on altering soil applications to adapt to the limited uptake capacity and, when economically feasible, attempt to prevent further damage to the existing roots to maintain or improve root longevity. This includes irrigation and fertilization in small and frequent doses to balance the water and nutrient supply with uptake capacity and adjustment of soil pH below 6.5 to avoid additional stress on the root system.

Managing Root Health

A healthy root system improves productivity of trees and improves their tolerance of major stresses, such as freezes, drought, and high winds. Starting a grove with a healthy root system allows for rapid tree establishment and growth. Maintaining a healthy root system in existing groves lengthens the productive life of the trees.

Root Health in New Plantings

The best way to manage root health is to prevent problems from starting. This requires careful consideration and planning before ordering trees and planting a new grove. The largest contributor to root health that will affect pests, pathogens, and the tree itself is the soil and water at the site. The most cost-effective way to manage root health is proper field preparation for planting and choosing rootstocks based on site-specific knowledge of the soil and irrigation water. Flooding and water table problems that affect root health also can be managed with land preparation including drainage and bedding (see Grove Planning and Establishment chapter). Many of the soil, pest, and pathogen problems can be addressed by choosing the best-adapted rootstock. To select a rootstock you need to know the site history, such as existing nematode problems or previous infestations of *Diaprepes*. It may also be important to know what has been done in the past to modify soil pH. If recent efforts were made to change the soil pH with liming or sulfur, it is likely that the soil will slowly shift back to its native pH with time. To avoid the perennial expense of adjusting the pH in your grove, a rootstock with an appropriate pH tolerance should be selected. Rootstock selection can be difficult because there is limited knowledge about soil preference, pest and pathogen resistance for some rootstocks (especially newly released rootstocks). To help in the selection process, a summary of what is known for commercially available rootstocks can be found in the rootstock selection section of this guide and the Citrus Rootstock Selection Guide (http://www.crec.ifas.ufl.edu/extension/citrus_rootstock/templates/guide/). Some locations may have multiple pest, pathogen, and environmental problems. In these cases, a rootstock that addresses all the problems may not be available. It is important to consider which problems are the most severe at the site, and which can be most easily and economically managed by land preparation or on a regular long-term basis. In situations where multiple problems cannot be addressed by proper rootstock selection, alternative crops should be investigated.

Root Health for Existing Groves

Unlike new plantings, existing grove root health problems have to be managed instead of avoided. However, like new plantings, root health in existing groves requires site-specific management. The first step is to identify the problems present in the grove. Take soil samples for pH and nutrient analysis as well as *Phytophthora* and nematode counts. Determine the pH, salinity, and bicarbonate content of irrigation water. Bicarbonates are leached from limestone in the aquifer and act as a buffer raising the pH of the water and irrigated soil. Groves should be scouted for the presence of *Diaprepes* root weevil and if they are known to be a problem see Citrus root weevils chapter. Once the root health problems are identified, develop a decision making process to determine which problems are the most severe and should be managed first. For example, if *Phytophthora* spp. are at damaging levels on roots but there are also problems with soil pH and *Diaprepes*, addressing soil pH or *Diaprepes* may effectively reduce *Phytophthora* populations in a grove soil because these factors interact with *Phytophthora* to make it worse than it would otherwise be. Therefore, pH or *Diaprepes* should be treated first and *Phytophthora* counts should be reassessed to determine if chemical applications for *Phytophthora* spp. are still needed.

HLB-induced root damage also interacts with *Phytophthora* spp. by increasing the exudation of sugars from roots. This sugar exudation attracts *Phytophthora* zoospores increasing infection. HLB also reduces the efficacy of fungicides (phosphite, focetyl-Al, fluopicolide, and mefenoxam) for control of *Phytophthora* spp. Timing is essential to maintain efficacy of *Phytophthora* management applications. Propagule counts should be monitored carefully for developing problems, so late summer or fall root flushes (root flushes follow leaf flushes) can be protected. For more information, see the *Phytophthora* foot rot, crown rot, and root rot chapter for more detail.

Soil pH and bicarbonates in irrigation water have gained attention because HLB has reduced the tolerance for pH incompatibilities on rootstocks mismatched with grove soil such as Swingle on high pH soils. In many cases, especially in the flatwoods, management of pH and bicarbonates resulted in increased root density of trees with HLB. For yet to be determined reasons, groves on ridge soils do not respond as well to pH and bicarbonate management. Soil pH or high bicarbonate irrigation water can be treated with ground applied sulfur or by acidifying irrigation water with injections of sulfuric or N-phuric acid. For Swingle rootstock, the ideal pH range is 5.5 to 6.5. Recent field experiments have determined that maintaining soil pH in the 5.5 to 6.5 range increases nutrient uptake and root density. It is important to test the pH before and after treatment as over-acidification leads to release of toxic amounts of copper and other metals and depletion of essential nutrients such as calcium and magnesium from the soil. Extra care needs to be taken when using sulfur to avoid over-acidification. Sulfur acidification is dependent on microbial breakdown of elemental sulfur and can take a year or more before soil pH drops. The soil pH is very likely to drop below the optimum range if other acidification methods are used before the sulfur takes effect.

Depending on soil tests of nutrients such as calcium, supplemental application may be necessary to replenish those lost from leaching and to prevent copper toxicity to roots. When pH management is necessary, sources of calcium that don't counteract pH management should be chosen, for example, gypsum ($CaSO_4$) instead of lime can add calcium without increasing the soil pH.