COVER STORY

Managing excessive bicarbonates with acidification

By Jim Graham and Kelly Morgan

Huanglongbing (HLB), greening and yellow shoot are names for the most devastating citrus disease in the world. Symptoms of HLB include a distinctive chlorotic mottle on fully expanded leaves. Infected shoots are stunted, and branches gradually die back as the symptoms appear in other sectors of the tree canopy. Fruit from affected branches may be lopsided and remain green at the stylar end of the fruit. Yield is reduced by fruit drop, which is directly related to root loss caused by early infection of the fibrous roots by the phloem-associated bacterium, *Candidatus* Liberibacter asiaticus (Las). HLB reduces fruit size, weight and other fruit quality variables, such as total soluble solids (TSS) content and TSS/acidity ratio.

In Florida, HLB incidence increases each year and is approaching 100 percent infected trees, especially in young groves. The U.S. Department of Agriculture March orange crop estimate was reduced to 102 million boxes, the lowest in the modern history of the Florida citrus industry. Will fruit drop be as high as last season? Since our research established that fruit drop is related to fibrous root loss, this leads to additional questions: Does fruit drop depend on root health status prior to the harvest? If so, what are the major factors affecting root health in Florida citrus groves?

HIGH BICARBONATES AND HLB

Irrigation water in Florida that comes from wells in a limestone aquifer or from lakes or canals that cut into limestone contain dissolved bicarbonates, which is a liming material. Irrigation with such water can increase soil pH with time and cause adverse effects on tree growth, reduce yields and may cause plugging of irrigation emitters. The effect of irrigation on soil pH depends on the concentration of bicarbonates in the water, the amount of the water applied, the buffering capacity of the soil and the sensitivity of the rootstock being grown.

A water test is the surest means of determining if a problem exists. If the pH of the irrigation water is below 7.0, then we may safely assume that it will not be a problem. However, if the pH is above 7.0, the water contains bases such as bicarbonates, and a sample should be sent to a laboratory with a request to specifically test for bicarbonates.

The growers we cooperate with were the first to observe that groves most affected by HLB and fruit drop are irrigated with water high in bicarbonates applied to the wetted zone where fibrous roots are concentrated. Greater HLB symptom expression is also associated with grove soils that have a history of excessive dolomite liming to manage high residual soil copper. Groves with high water and/or soil bicarbonates have off-color foliage, thinning canopies due to excessive leaf drop, twig dieback and more severe HLB symptoms in leaves and fruit.

Leaf and soil nutrient analysis in these groves suggests that bicarbonate stress reduces root uptake of calcium (Ca), magnesium (Mg), potassium

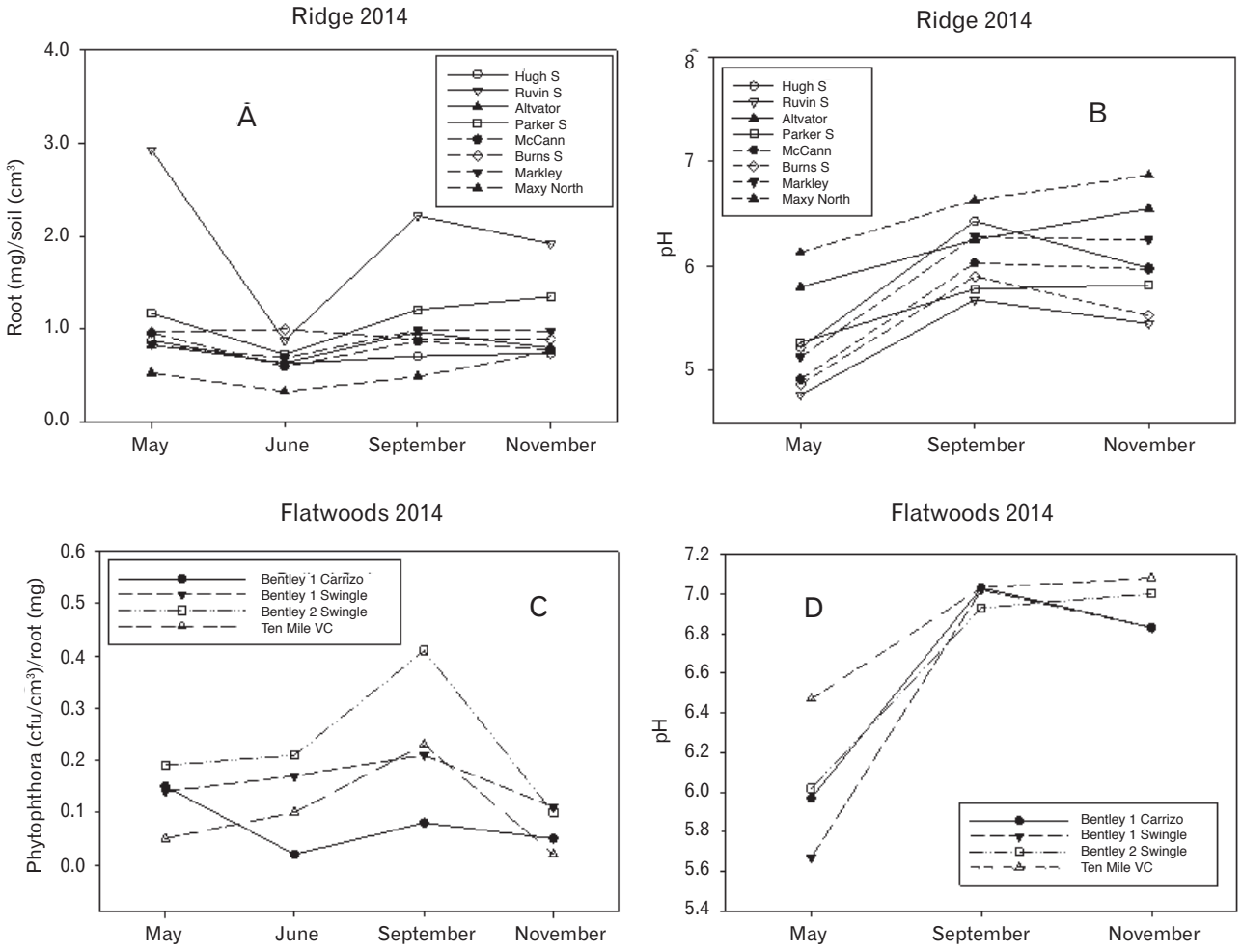

Figure 1. Root density and soil pH responses in south Central Florida groves. Panels A and B show four Ridge groves irrigated with low-bicarbonate water (S, open symbols) without acidification and four Ridge groves irrigated with high-bicarbonate water with acidification (closed symbols). Panels C and D show four Flatwoods groves irrigated with high-bicarbonate water with acidification. Ridge groves within a soil pH range of 5.0 to 6.5 have five to 10 times higher root density than Flatwoods groves with a pH range that was below 6.5 in May 2014, but rose to 6.8 to 7.0 by September 2014 when irrigation frequency decreased during the summer-fall rainy season. Note differences in scales on the y-axis.

(K) and iron (Fe). For example, even when soil Ca status is very high, associated leaf Ca levels are moderate. Severity of HLB symptoms for trees on different rootstocks follows rootstock susceptibility to bicarbonates: Swingle citrumelo > Carrizo citrange > sour orange > Cleopatra mandarin.

BICARBONATE STRESS, FIBROUS ROOT DENSITY AND YIELD

In a 2013 survey of 37 HLB-affected groves, we found a relationship between fibrous root density and reduction in fruit yields for blocks where irrigation water is in excess of 100 parts per million (ppm) bicarbonates and soil pH is greater than 6.5. The greatest decline occurred in Flatwoods groves, which had a 20 percent decrease in yield from 2009–2012 compared to Ridge groves under low bicarbonate stress, which had a 6 percent increase in production over a time period when HLB incidence was rapidly accelerating. Greater yield loss under bicarbonate stress was correlated with lower fibrous root density compared to the non-stress condition.

RIDGE AND FLATWOODS DIFFERENCES

Experience in California citrus and observations in Florida confirm that acidification of the soil or water reduces root zone pH and may promote release of Ca, Mg and Fe for root uptake. Conditioning of irrigation water with acid works quickly to lower root zone pH, but does not work during the rainy season when irrigation is less frequent. Soil conditioning with prilled elemental sulfur applied to the wetted zone creates acidity that releases all season long. When soil pH rises to near the initial pH, the prilled sulfur is reapplied.

The difference between Flatwoods and Ridge groves in sustainability of acid treatment of irrigation water was evidenced in our 2014 grove survey (Figure 1). In the central Ridge (Highlands County), we sampled

four low-bicarbonate groves without acidification of the irrigation water and four high-bicarbonate groves with acidification of the irrigation water (Figure 1, page 9). Root mass density was similar for groves with or without acidification (Figure 1A, page 9). Soil pH in the low-bicarbonate and acidified groves ranged from low 5.0 to mid 6s (Figure 1B, page 9). Leaf analysis confirmed the improved color and absence of twig dieback of the acidified groves are associated with optimum leaf nutrient levels. Phytophthora populations in the Ridge groves were zero or low and decreased over the 2014 season (data not shown).

In contrast, the Flatwoods groves (Hardee County) with high-bicarbonate irrigation water had a root mass density five to 10 times lower than in the Ridge groves (Figure 1C, page 9). Soil pH in the acidified groves at the beginning of the survey in June was in the low 6s, but rebounded to high 6s during the rainy season (Figure 1D, page 9). Foliage improved in color and vigor, but not as much as for Ridge groves, and was associated with low leaf manganese (Mn) and zinc (Zn) levels. Phytophthora soil populations remained at damaging levels in Flatwoods groves — and even increased — until after fall application of mefenoxam fungicide reduced populations (Figure 1C, page 9).

Conditioning the irrigation water can be achieved by injection of acids or combinations of acids and urea to reduce bicarbonates in irrigation water to below 100 ppm.

MANAGEMENT RECOMMENDATIONS

Observations confirm that trees respond well to reducing soil stresses with a balanced, lower and more frequent application of water and nutrients, i.e. "spoon feeding" (Figure 2). Where excess bicarbonates in irrigation water or soil have been identified by water and soil testing, the goal is to reduce soil bicarbonate stress to sustain root functioning in nutrient uptake and root longevity. To assess bicarbonate stress, check soil pH in the wetted zone and test well water for pH, bicarbonates, salinity, cations and anions.

Conditioning the irrigation water can be achieved by injection of acids (e.g., sulfuric or phosphoric) or combinations of acids and urea to reduce bicarbonates in irrigation water to below 100 ppm. Injecting products that combine acids and urea reduces corrosion of injection equipment, makes the acids safer to use and supplies a small amount of nitrogen.

Figure 2. Four-year-old Valencia on Kuharske Carrizo rootstock fertigated since planting.

After correcting water and soil bicarbonate stress, then consider management of root pathogens. The 2014 Flatwoods survey confirmed that Phytophthora soil populations are at damaging levels, and when treated, should be managed aggressively to sustain root health. If Phytophthora populations exceed 10 to 20 propagules/cm^3, maximum label rates of fungicides are recommended. Rotation of the two fungicide modes of action for Phytophthora is furthermore recommended: Aliette/phosphite should be applied after spring shoot flush, mefenoxam after spring/early-summer rains begin, Aliette/phosphite after midsummer shoot flush and mefenoxam after fall shoot flushes. Because root flushes on citrus trees follow shoot flushes, fungicide applications should be timed to protect root flushes. For additional information regarding current management recommendations, consult the 2015 Florida Citrus Pest Management Guide (www.crec.ifas.ufl.edu/extension/pest/).

CURRENT RESEARCH

Survey of commercial groves under bicarbonate stress on the Ridge and Flatwoods will continue. Replicated trials of acid injection and sulfur application rates were initiated in 2014 and will continue through 2016. These studies will provide additional information on the most effective treatments for water and soil conditioning, provide further evidence for soil conditions contributing to root decline of HLB affected trees and hopefully lead to improved root health and yields of HLB affected trees.

SUMMARY

Surveys of groves after 1 to 1 1/2 years of treatment indicate that acidification reduces HLB-induced fruit drop and improves tree appearance. Soil pH/bicarbonate management of irrigation water and soil may reduce stress on fibrous roots and increase nutrient uptake and root longevity. Growers are advised to check soil pH (wetted zone) and test well water for pH, bicarbonates, salinity, cations and anions. Acidification of the rhizosphere will release Ca and Mg from bicarbonate and make soil Mn, Zn and Fe more available for root uptake.

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