

What growers need to know about bicarbonates and root health

By Jim Graham, Evan Johnson and Kelly Morgan

Huanglongbing (HLB), associated with *Candidatus Liberibacter asiaticus* (*Las*), was first detected in Florida in late 2005. 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. Excavation of the root-soil zone in the wetted area under the canopy reveals a deficit of fibrous roots compared to an apparently healthy tree. Yield is reduced directly by the root loss, which leads to fruit drop and eventually to tree decline. HLB reduces fruit size, weight and other fruit quality variables, such as total soluble solids (TSS) content, acidity and TSS/acidity ratio. In Florida, HLB is widely distributed throughout all the citrus-growing regions.

In recent seasons, concurrent with freeze and drought episodes, symptomatic HLB-infected trees have been much more affected by the extremes of temperature and moisture than trees

without HLB. Symptoms exhibited by HLB-infected trees are typical of nutrient- and water-stressed trees with reduced vigor and excessive leaf loss followed by premature fruit drop even when trees are managed with good nutritional and irrigation practices recommended to support health of HLB-affected trees. Stress intolerance of HLB trees is a direct consequence of a more than 30 percent loss of fibrous root density compared to non-diseased trees. This root loss may be compounded by interactions with root pathogens and pests such as *Phytophthora* spp. Progametes of *Phytophthora* spp. are elevated in the rhizosphere soil of HLB trees. When *Las* interacts with *Phytophthora*, fibrous root loss can be greater than that caused by HLB alone, depending on the grove location and time of year.

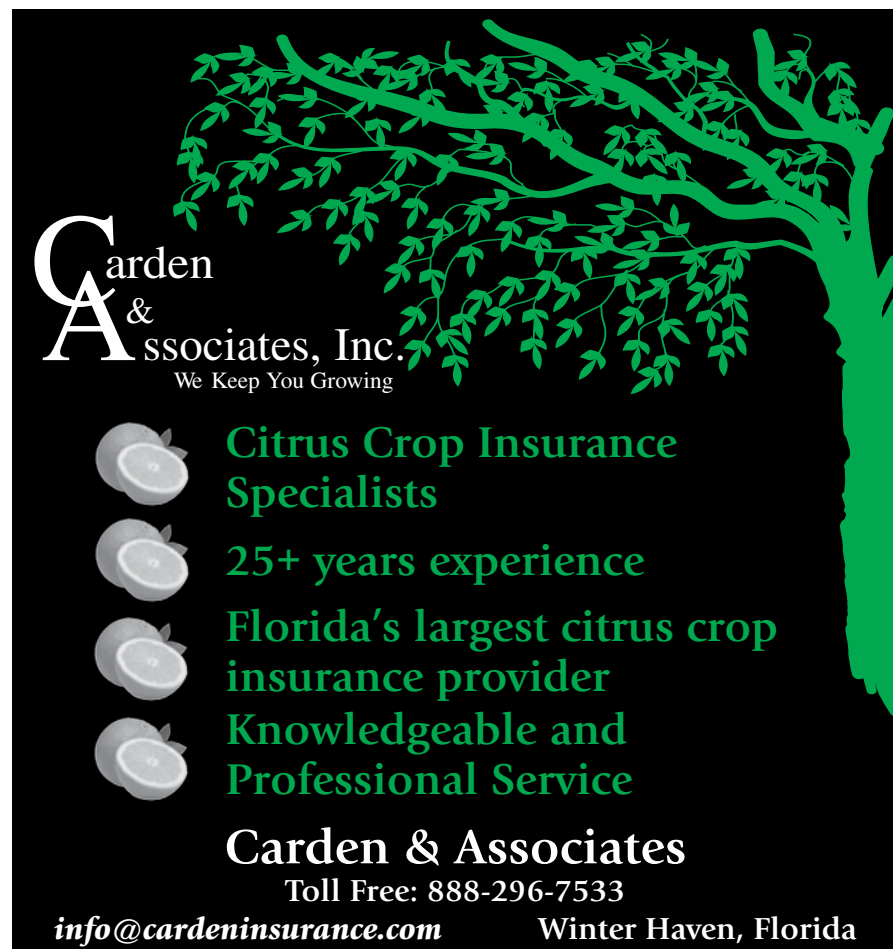
Although not directly studied, HLB associated root loss has been attributed to carbohydrate starvation. Initially, canopy symptoms are not apparent in trees with significant root

loss, so starch concentration in roots was determined. Surprisingly, early root loss occurred without a drop in starch. This disappearance of roots could be due to the lack of new growth to replace old roots during the normal cycle of death and regeneration of fibrous roots, or may be associated with premature root death unrelated to phloem plugging, or a combination of the two processes. Also, it is highly likely that *Las* damage alters the concentration of soluble sugars in roots by increasing leakage from roots that attracts and accelerates infection by root pathogens such as *P. nicotianae*.

Early root loss has been observed for sweet orange trees on both Swingle citrumelo and Carrizo citrange rootstocks. Visually, there is little difference in the decline of trees on these rootstocks and no difference in magnitude of root loss has been detected. Rootstock trials have shown differences in vigor of HLB-infected trees on different rootstocks. This suggests that rootstocks may vary in their response to *Las* infection and that some rootstocks may maintain a more functional root system for nutrient and water uptake despite bacterial infection.

Given such a large deficit in roots of HLB-affected trees, it is imperative to maximize the functioning of the remaining roots for nutrient and water uptake while minimizing root stresses. One such stress, bicarbonates in soil, went unrecognized in citrus groves for decades until HLB incidence increased and trees began to show symptoms of stress in groves statewide. Carbon species present in water depends on pH: Carbonic acid (H_2CO_3) is the predominant form at pH less than 6.5; bicarbonate (HCO_3^-) forms at pH range from 6.5 to 8.5; and carbonate (CO_3^{2-}) forms at pH greater than 8.5 (Figure 1, page 8). Extensive surveys of HLB-affected groves indicate that where irrigation water is high in bicarbonates (greater than 100 ppm) and/or soil pH (greater than 6.5) there is greater decline in root health and higher expression of HLB symptoms. Typically, affected groves are under microjet irrigation that concentrates fibrous roots in the wetted zone, and soils have a history of excessive dolomite liming to manage issues such as high residual copper.

Soils statewide have increased in pH and bicarbonate concentrations in



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recent decades due to irrigation with alkaline water from deep wells extending into Florida's limestone aquifers. As soils become more alkaline, some nutrients become more available (e.g., N and Mg) for uptake by plants, and others (e.g., Fe, Mn, Zn and B) become less available for uptake. Groves with soil pH greater than 6.5 and/or well water bicarbonate greater than 100 ppm often have off-color foliage, thin canopies due to excessive leaf drop, twig dieback and more severe HLB symptoms in leaves and fruit.

Furthermore, HLB symptom expression of trees on different rootstocks ranks Swingle greater than Carrizo, Carrizo greater than sour orange, and sour orange greater than Cleopatra — which follows their known intolerance of bicarbonate.

We hypothesized that groves with high bicarbonate stress are suffering from HLB because they support lower fibrous root density compared to groves with lower bicarbonates (less than 100 ppm) in irrigation water and/or soil pH (less than 6.5). To confirm this relationship, we surveyed 37 grove locations in Highlands and Desoto

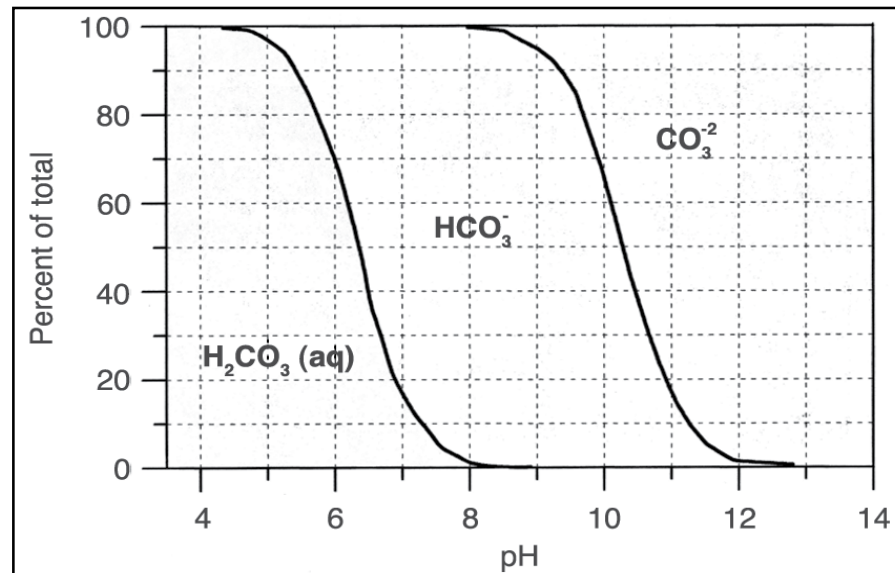


Figure 1. Percent of carbon species in solution for various pH ranges. H_2CO_3 = carbonic acid, HCO_3^- = bicarbonate and CO_3^{2-} = carbonate. Figure from Boman, B.J., P.C. Wilson and E.A. Ontermass. Understanding Water Quality Parameters for Citrus Irrigation and Drainage Systems. IFAS Circular 1406.

counties with varying liming history and deep vs. shallow wells mostly on Swingle and Carrizo. Lower root density is significantly related to well water pH greater than 6.5 and to soil pH greater than 6.2. Yield records from

these blocks reveal that groves under high bicarbonate stress production have declined 20 percent over the last three seasons (2009–2012) in contrast to Ridge groves with low bicarbonate stress, which have increased 6 percent in production even though HLB incidence has accelerated (Table 1). The yield losses are correlated with less fibrous root density, which reduces root system capacity for water and nutrient uptake. Evidence from research on other crops indicates that bicarbonate impairs the root's ability to take up important nutritional cations including Ca, Mg and K, as well as micronutrients, especially Mn and Fe.

We recently learned that there is a long history of management of high bicarbonates and pH of irrigation water for Carrizo rootstock groves in the Central Valley of California. In February 2013, we took Florida growers to California to tour Paramount Citrus groves and learn more about conditioning water and soils with high bicarbonates and soil alkalinity. The primary means they use are sulfuric acid injection from storage tanks managed by contractors and use of sulfur burners to generate acidity from elemental sulfur (Figure 2, page 9). In California, the target is to reduce pH of water used for irrigation to 6.5 in each irrigation cycle.

In Florida, Bryan Belcher of Davis Citrus Management has acidified irrigation water with sulfuric or N-furic acid (a mixture of urea and sulfuric acid) by injection at the well in the same way as fertigation. N-furic has the advantages of being safer to handle and providing some additional

Table 1. Relationship between bicarbonate status, root mass density and change in yield from 2009–2012*

Grove status	No. of blocks surveyed	Root mass density (mg/cm ³)	Change in block yield from 2011–2013
Low pH stress Ridge	14	0.6	Increased 6%
High pH stress Ridge	10	0.4	Decreased 3%
High pH stress Flatwoods	13	0.2	Decreased 20%

*Yield data kindly provided by Davis Citrus Management.

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N due to the urea component, but the disadvantage is higher cost of treatment compared to sulfuric acid. Since irrigation is not necessary when it rains, acidification treatment only occurs during the dry season when the bicarbonates are loading into the wetted area under the tree. When the rain begins, these bicarbonates are flushed from the rhizosphere.

Our labs and grower cooperators are also evaluating acidification of soil by amendment with elemental sulfur applied in prilled or finely ground form. Sulfur (S) releases acid when it interacts with *Thiobacillus* bacteria in soil to form acid (H+) ions. This process of acidification with S is slower than treatment of the water, but provides for longer lasting reduction in soil pH. Sulfur can be applied in prilled form with a fertilizer spreader or with a herbicide boom as a slurry. Sulfur can also be added to dry and fertigation formulations to lower the pH by as much as one unit after repeated ground applications.

Acidification of the soil and water will release Ca, Mg and K from the bicarbonate that is available for root uptake. The increase in nutrient availability should be reflected in higher concentrations of Ca and Mg in leaves in the fall following the application



Figure 2. During a Syngenta-sponsored tour of the California Central Valley citrus production area in February 2013, Florida growers saw demonstrations of different methods for acidification of alkaline irrigation water.

of acidification treatments. If only Ca increases, then Mg (Epsom) salts will need to be added to the fertilization program. The ratio of Ca and Mg in leaves should be maintained at 10:1 to keep these two nutrients in proper balance. Other micronutrients such as Mn, Zn and Fe will also become more available for uptake by HLB-infected trees with reduction of soil pH to less than 6.5. Improved uptake of these elements should further reduce HLB symptoms. However, as with foliar application of nutrients, reductions in symptom expression should improve tree vigor and productivity, but does not eliminate *Las* from the tree.

Additional research is needed on the effect of soil pH and bicarbonates on the health and productivity of trees infected with HLB. Some of these

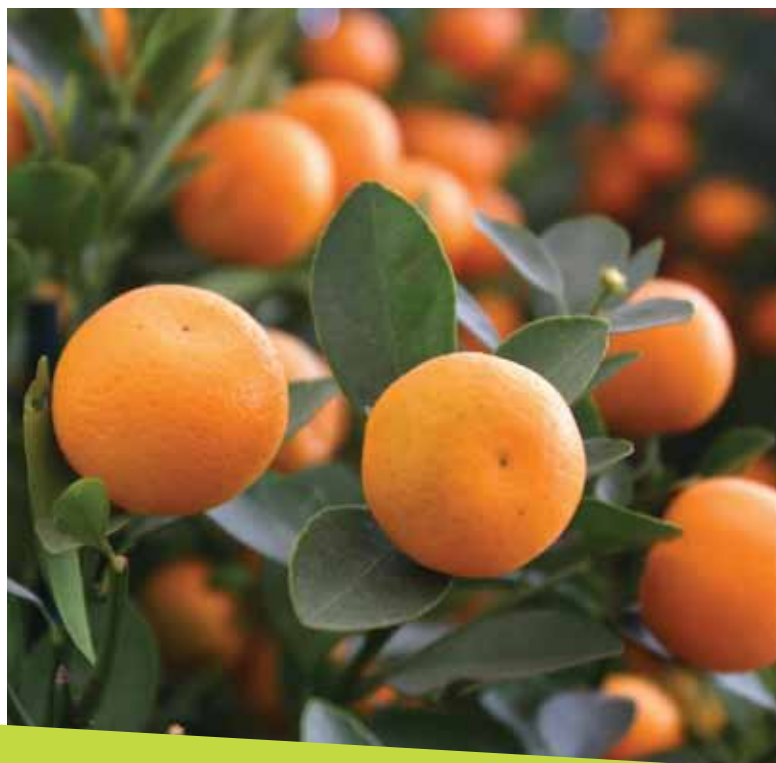
studies are now being initiated in the greenhouse where trees can be maintained free of the disease (by excluding psyllids) for comparison with HLB-infected trees. Results of these experiments will evaluate tree health reduction (reduced root density and leaf nutrient concentrations) associated with HLB infection and elevated soil pH and bicarbonate concentrations. Comparison of infected and non-infected trees with and without increased soil bicarbonate concentrations will allow for improved recommendations on water and soil treatment to reduce HLB symptom expression and improved tree productivity.

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