Components of a healthy citrus soil

By Sarah Strauss and Ute Albrecht

There is increasing discussion and interest in soil health from both growers and researchers. Soil health is generally synonymous with soil quality. It can impact not just sustainability, but also improve water-holding capacity, nutrient availability, yield and overall grove productivity.

In citrus, soil health is particularly important because of the reduction of root mass and root uptake of water and nutrients due to huanglongbing (HLB) or citrus greening. This problem is exacerbated by Florida's sandy soils, which have minimal water- and nutrient-holding capacity due to low soil organic matter (SOM) content, making it difficult for growers to maintain a sufficient and steady supply of nutrients within the root zone. The impact of citrus greening on the soil microbial community may also affect nutrient uptake, as recent studies have shown that HLB decreases the abundance of many soil microbes involved in nitrogen (N) cycling.

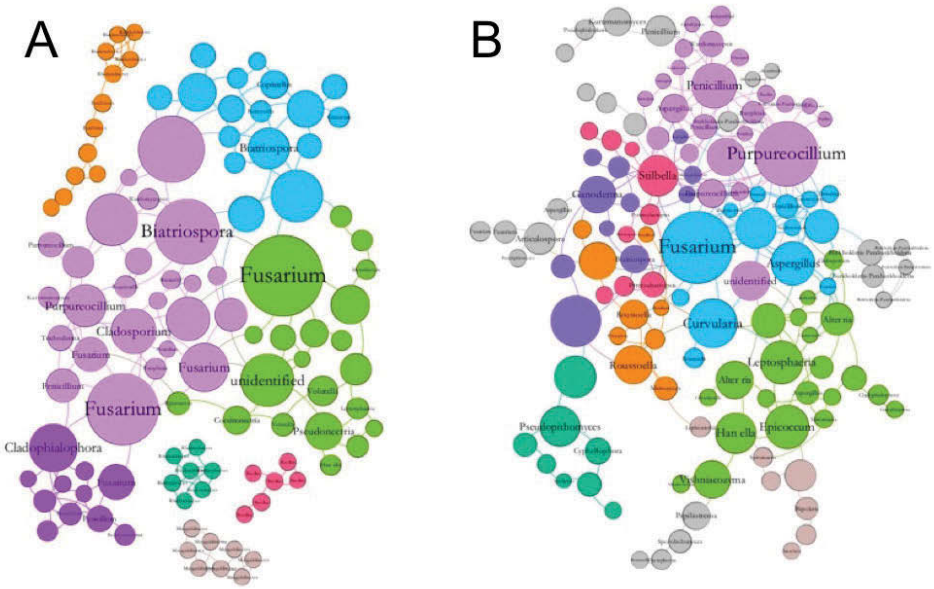

Figure 1. Soil microbial community networks of two citrus groves with different management strategies: high-input management (A) and low-input management (B). Each circle represents a different microbial group. The connections between each circle indicate the interaction between different soil bacteria and fungi. The low-input grove has a more interconnected network compared to the high-input grove, but the impact of these different connections on tree performance is still being determined.

Currently, the majority of research and information regarding soil health was developed for annual crops and soils that are different from Florida soils. In addition, there is still little understanding about what makes one soil healthier than another soil, particularly with regard to soil microbiology. However, several principles can be applied to Florida citrus. Additional research is underway at the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) Southwest Florida Research and Education Center (SWFREC) to examine in greater detail the impact of some of these principles on Florida citrus soil health, particularly with regard to the biological components of a healthy soil.

WHAT MAKES A HEALTHY SOIL?

In general, a healthy soil is one that is able to sustain plants and other organisms. The keys to maintaining this sustainable environment are biological diversity and SOM. The soil microbial community is incredibly rich and diverse, with over 1 billion microorganisms living in only one gram of soil. Those bacteria, fungi and archaea (prokaryotes phylogenetically separate from bacteria) are closely coupled with soil nutrient cycling and many of the traits critical for a healthy soil. Soil microbial diversity can potentially impact crop production through improved nutrient cycling, which may impart some disease resistance.

In addition, greater soil diversity may result in beneficial changes to the soil microbial community

composition. This includes increased abundance of plant-growth-promoting bacteria, which can significantly improve root growth, particularly lateral root branching and development of root hairs, or changes in the abundance of N cycling microorganisms. High soil microbial diversity can also impact soilborne disease incidence by providing microbial competition and limiting the abundance of some plant pathogens. However, there is not a specific level of diversity that equates a "healthy" soil, and it is still unclear what conditions are necessary to increase the abundance of specific beneficial organisms.

SOM is one of the main determinants of soil microbial diversity and is critical for overall soil health. Organic matter is generated through the decomposition of plant material and microorganisms, provides energy (carbon) to soil microorganisms, and can improve soil stability and water-holding capacity.

A recent greenhouse study in collaboration with Davie Kadyampakeni (UF/IFAS Citrus Research and Education Center) examined the impact of added SOM (biochar and compost) to citrus. It was found that additional organic matter improved water retention and uptake in Florida sandy soil. In citrus, this may lower irrigation water needs due to reduced percolation or drainage losses.

Soils with greater amounts of SOM are generally considered "healthier." However, like with microbial diversity, there is not a certain percentage of SOM that is necessary for soil to be considered "healthy" or "unhealthy."

WHAT INFLUENCES SOIL HEALTH?

As the formation of SOM is tied to soil microorganisms, the factors that influence soil microbial diversity and composition are closely related to SOM and soil health. These factors include soil pH, plant species, soil carbon (C) and N, land, crop, and water management. Soil pH can strongly influence the composition of a soil microbial community, as bacterial and fungal taxa prefer a specific pH range. Plant species can also significantly impact the soil microbial community, as the exudates released by plant roots

provide resources for microbial groups. In some cases, these exudates are specific to a plant type. The availability of soil C and N, both as part of SOM and independently, is critical for soil microbes, just as it is for plants. The concentrations and types of C and N influence not only the abundance of soil microbes, but also the diversity.

In all ecosystems, but particularly for agroecosystems, determining the impact of each of these factors separately is difficult, as they are influenced by land and crop management practices. For example, in a field study of two citrus groves with the same soil type and rootstock/scion but different management strategies, there were significantly different soil microbial communities and different interactions between the soil microbes (Figure 1, page 10). It remains unclear which specific management practices and/or soil properties are responsible for these differences.

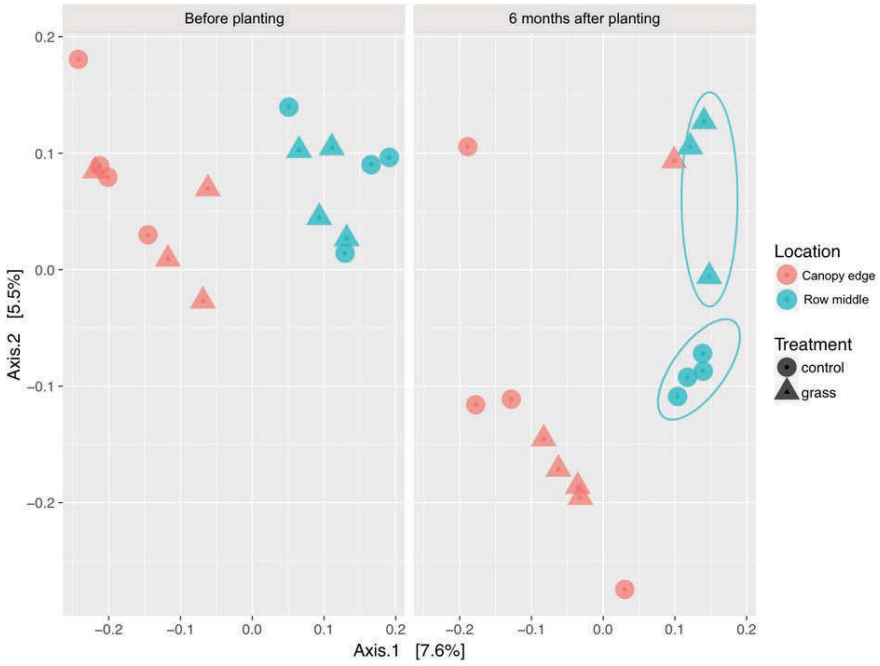

Figure 2. Soil bacterial community composition before and six months after Bahiagrass (triangles) was planted in a commercial grove row-middle compared with a no-treatment/grower-standard control (circles). Samples were collected from the row middle (blue) and edge (red). Each point represents the bacterial community composition of a sample. Samples close together are more similar to each other.

FLOODING IMPACTS ON SOIL HEALTH

Flooding, both from summer rains and hurricanes, is a continual factor for Florida citrus soils. While the impacts of flooding specifically on soil health and soil microbial activity have not been well-documented for Florida, the largest concern in flooded soils is the lack of oxygen. The abundance of soil microorganisms that require oxygen, which includes both plant pathogens and beneficial organisms, are significantly reduced under flooded conditions.

However, there are also microorganisms that survive and even thrive during periods without oxygen, either by using different metabolic pathways or through dormant states. Some of these microorganisms, particularly the "water molds" (oomycetes) Phytophthora and Pythium, can cause considerable root rot after prolonged periods of flooding and are detrimental to plants. Flooding generally changes the overall soil microbial community composition, but this change may not be long-term. Additional studies are needed to further examine the resiliency of Florida soil microorganisms after flooding.

METHODS TO IMPROVE SOIL HEALTH

The U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) recommends four soil-health planning principles: 1) reduce soil disturbance, 2) increase plant diversity, 3) maintain living roots throughout the year and 4) keep soil

covered. Although these principles were primarily designed for annual crops, some can be adapted for Florida citrus, and all aim to increase SOM levels.

While it initially appears difficult to increase plant diversity within a citrus grove, the row middles are excellent places where this may be accomplished. Weedy row middles, while potentially a source of plant diversity, can result in soil disturbance by periodic chemical mowing. However, cover crops planted in the row middles provide increased plant diversity, additional inputs of SOM, and can impact the soil microbial community composition and diversity within the citrus root zone. Depending on the cover crops, they may also provide additional soil nutrients.

In a preliminary trial, we planted Bahiagrass as a cover crop in row middles of a commercial citrus grove. Just six months later, we found a significantly different bacterial community composition in soils under Bahiagrass compared to the grower standard (Figure 2, page 12).

The type of species used as a cover crop may also impact the soil microbial community composition. A preliminary trial in Southwest Florida, although not conducted on citrus, examined different summer cover crops (sunn hemp and sorghum-sudangrass) and found considerable changes in the bacterial community composition compared with the control. These cover crops could be planted to citrus row-middles as well.

We are in the process of developing a long-term field trial to assess the impact of mixtures of cover crops planted in row-middles on soil nutrient availability, microbial community composition, root and tree health, and yield. Cover crops in row-middles also address the recommendations by USDA-NRCS to maintain living roots throughout the year and to keep the soil covered.

While not part of the specific recommendations from USDA-NRCS, an additional method to improve SOM is to apply compost. The addition of compost when planting trees can provide an initial increase in SOM and microbial diversity. A Southwest Florida field study indicated that long-term (over 10 years) repeated application in a Florida citrus grove resulted in increased SOM.

Many questions remain regarding Florida citrus soil health and the best methods for its improvement. The ideal combination of cover crops for citrus row-middles that will maximize SOM inputs, improve soil nutrient availability and increase production is still unknown. In addition, due to Florida's low SOM (often only 1 percent or less) and unique climate, increasing SOM is a long-term process, regardless of whether compost and/or cover crops are used.

New methods are continually being developed to measure soil microbial diversity, and it is unclear whether general diversity, specific microbial taxa, or specific microbial functions are more critical for healthy soils. However, taking steps to increase SOM in Florida citrus soils will be a significant step to improving soil health.

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