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Letter to the Editor

# Announcement of the International Citrus Microbiome (Phytobiome) Consortium.

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Plants host rich and diverse microbial communities near, on, and inside their tissues. The microbial communities associated with plants are known as the plant microbiome or phytobiome, which is comprised of a diverse array of microorganisms such as bacteria, archaea, fungi, oomycetes, viruses, and nematodes, that are associated with different plant habitats including the rhizosphere, phyllosphere, and endosphere (Fig. 1) (Turner et al. 2013; Berg et al. 2014; Lebeis 2014; Schlaeppi and Bulgarelli 2015). The phytobiome is an emerging field of research aimed at generating a systems-level understanding of plant-microbe interactions which influence plant health and plant productivity. The study of phytobiomes is currently in its infancy, and most research focuses on profiling plant microbiomes in different hosts and environments.

Recent advances in cultivation-independent next generation sequencing techniques have provided valuable tools to investigate plant microbiomes, enabling thorough descriptions of these plant-associated microorganisms. The latest approaches overcome the limitation of culturing since only a small portion of microbes can be cultivated. The microorganisms in the rhizosphere, phyllosphere, and endosphere of various plants, including the model plant Arabidopsis and crop plants such as maize, rice, wheat, sugar beet, lettuce, and pea, have been characterized (Guttman et al. 2014). These studies have significantly advanced our understanding of the composition and structure of plant microbiomes. In general, the phyllosphere microbiomes are of a higher variability and lower diversity than the belowground (soil and the rhizosphere) microbiomes, and the endophytic microbiomes have higher diversity than the epiphytic microbiomes. Together these studies indicate that abiotic factors as well as plant–microbe, microbe–microbe, and plant–plant interactions contribute to plant microbiome composition and structure.

The interactions between the microbiome and plant are highly complex and dynamic. The interactions among plant and microbes can be beneficial (mutualistic), neutral (commensalism), or detrimental (parasitic). Consequently, the plant microbiome dramatically affects plant health and productivity (Turner et al. 2013; Berg et al. 2014; Schlaeppi and Bulgarelli 2015). The plant microbiome is known to induce or prime plant defenses against a broad range of pathogens and insect herbivores. The plant microbiome also plays essential roles in disease-suppressive soils. Additionally, the plant microbiome is a crucial player in global biogeochemical cycles, participating significantly in biochemical cycling of the products of photosynthesis (Turner et al. 2013). Therefore, manipulation of plant microbiomes is believed to have the potential to interfere with plant disease development, promote plant production, and ease chemical inputs, leading to more sustainable agricultural practices (Turner et al. 2013).

The citrus microbiome remains largely unexplored. Although the productive lifetime of citrus trees is usually less than 50 years, they can live for more than a century. The long lifespan of citrus likely leads to fluctuation in microbiome composition, which adapts to the changing environment and citrus physiology over time. Citrus is grown worldwide. More than 140 countries produce citrus, with most grown in subtropical regions. The worldwide distribution of citrus and the wide variations in soil, temperature, rainfall, pH, citrus varieties, different disease challenges (e.g., citrus Huanglongbing), and production practices almost certainly leads to a wide range of microorganisms comprising the citrus microbiome. Consequently, we aim to investigate the citrus microbiome at the global scale.

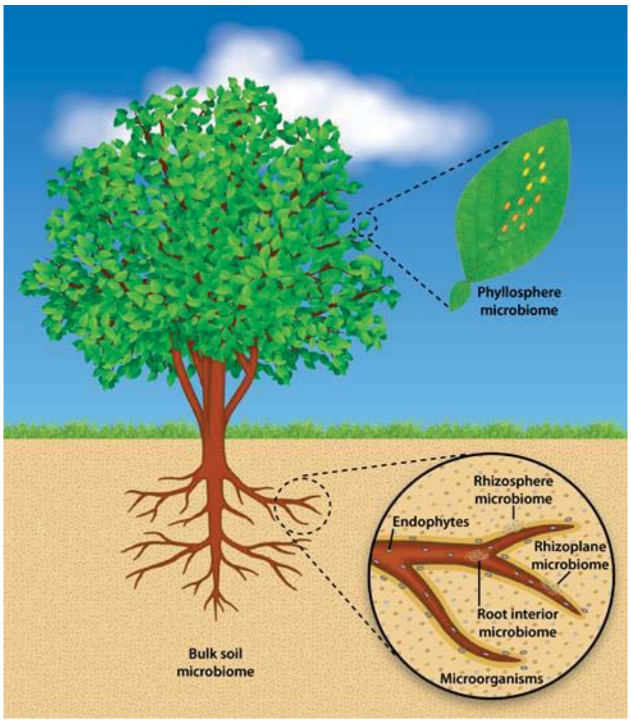


**Figure 1.** Model of the plant microbiome (phytobiome). The plant microbiome consists of microorganisms (e.g., bacteria and fungi) in the phyllosphere (above-ground portions of plants); the rhizosphere (the area surrounding the plant root), the rhizoplane (the root-soil interface), and the endosphere (internal compartments).

For this purpose we have formed the International Citrus Microbiome (Phytobiome) Consortium. The consortium will endeavor to synergize colleagues from all citrus-producing countries. It will be comprised of expertise in microbiology, bioinformatics, citrus, biogeography, and soil, all working together to understand the citrus microbiome from a systems biology perspective. We have proposed the following objectives for the International Citrus Microbiome (Phytobiome) Consortium:

1. Profile citrus microbiomes in different countries.
2. Determine the effect of citrus age on the citrus microbiome.
3. Investigate the effect of different rootstocks and scions on the citrus microbiome.
4. Study the effect of different biotic (diseases) and abiotic stresses (e.g., drought) on the citrus microbiome.
5. Determine the effect of different citrus management strategies (herbicides, mulching, fertilizing, etc) on the citrus microbiome.
6. Functionally characterize the citrus microbiome using RNA-Seq, proteomics and metabolomics approaches.
7. Isolate and characterize beneficial microbes.
8. Manipulate the citrus microbiomes to improve plant production and health.

Currently, the International Citrus Microbiome (Phytobiome) Consortium consists of colleagues from USA, China, Brazil, Spain, Australia, South Africa, India, Italy, Oman, Kenya, and France. We welcome colleagues to join the consortium, and to collectively contribute to this important area of research.

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