Plant biostimulants — snake oils or beneficial substances?

By Ute Albrecht and Sarah Strauss

Recent years have seen an explosion of products termed "biostimulants" as alternatives to traditional chemical products to improve plant growth and productivity, and to enhance the sustainability of agricultural systems. Although there is currently no legal definition of biostimulants, they are usually defined as "substance(s) and/or microorganisms that when applied to plants or the rhizosphere stimulate natural processes to benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and/or crop quality, independent of their nutrient content." (www.biostimulantcoalition.org)

Biostimulants are available in many formulations and with varying ingredients. Among the most popular ingredients are humic substances, seaweed extracts, and beneficial bacteria and fungi. For many years, these substances were considered to be "snake oils," and skepticism regarding their positive effects on plant growth persists.

However, a large number of scientific studies have shown that many crop systems respond positively to these materials. The positive effects reported include improvement of soil physical-chemical properties, improvement of water and nutrient uptake/use efficiency, improvement of root architecture and lateral root growth, improvement of fruit quality, higher productivity, and higher tolerance to diseases and other biotic and abiotic stresses.

Despite these well-documented effects, the exact mechanisms of action of biostimulants are not always understood. Here we present an overview of the most popular materials, followed by a summary of ongoing biostimulant research at the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) Southwest Florida Research and Education Center.

MOST POPULAR MATERIALS

Humic substances (humic and fulvic acids) are collections of natural components of the soil organic matter with relatively low molecular mass that result from the decomposition of plant, animal and microbial residues, and the metabolic activities of soil microbes.

Compared with fulvic acids, humic acids are darker in color, have a higher molecular weight and carbon content, and a higher degree of polymerization. Most sources of humic substances used in agriculture are non-renewable and include natural deposits of humified organic matter such as peat and mineral deposits such as leonardite and soft coal. More sustainable, renewable sources are humic substances

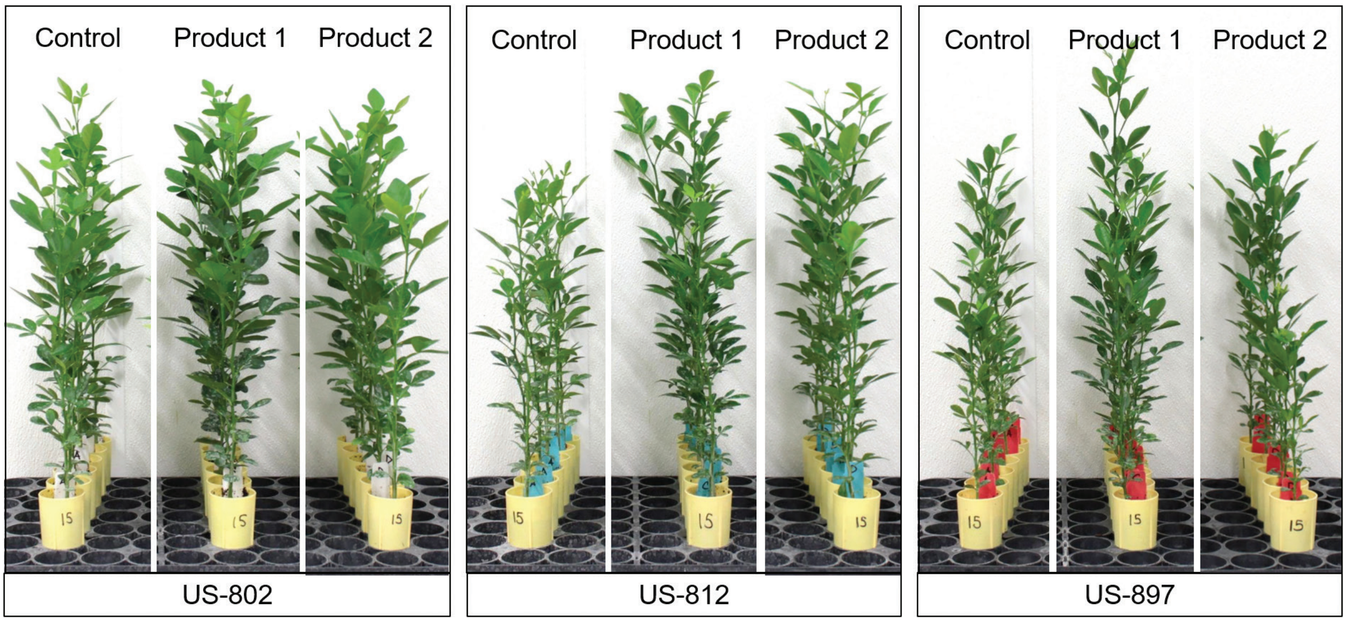

Figure 1. Positive growth response of two biostimulant products on 18-week-old citrus rootstock seedlings. Responses vary depending on the rootstock genotype (US-802, US-812 and US-897). Product 1: composite product containing humic acids (10 percent), fulvic acids (5 percent), seaweed extract (20 percent), nitrogen (13 percent) and potassium (5 percent). Product 2: microbial product composed of *Bacillus* spp. Products were applied as a soil drench 10, 12 and 14 weeks after seeding.

derived from compost and vermicompost. Plant physiological responses are often better with humic substances isolated from peat, compost or vermicompost compared with those from brown coal.

Most reported positive effects of humic substances on plants are improvement of root nutrition and lateral root development. Increase of the soil cation exchange capacity is one of the reasons for these effects.

Beneficial bacteria that promote plant growth or plant growth-promoting rhizobacteria (PGPRs) include free-living bacteria that inhabit the zone around the root, bacteria that colonize the root surface and bacteria that live within the roots.

In addition to the ability of some PGPRs to fix nitrogen, they are known to produce siderophores — small iron-chelating compounds that reduce the growth of deleterious soil-borne pathogens. PGPRs can also influence plant growth directly by producing plant hormones such as auxins, cytokinins and gibberellic acid, and indirectly by inducing hormonal changes in the plant host. Many PGPRs emit volatile organic compounds, which may improve plant growth and productivity, and induce resistance to bacterial pathogens present in the rhizosphere.

Most reported positive effects of humic substances on plants are improvement of root nutrition and lateral root development.

While beneficial bacteria can have significant impacts on plant growth, their performance and relationship with native soil bacteria, particularly in citrus, is still largely unknown.

Beneficial fungi with plant biostimulant activity are found in the group of symbiotic fungi, particularly arbuscular mycorrhizal fungi (AMF), which penetrate plant roots where they form nutrient-exchange structures called arbuscules. The result of this root symbiosis is the formation of a highly branched network of AMF hyphae in the soil. This network enables the plant to extend the reach of the root system beyond the depletion zone, allowing for enhanced uptake of nutrients and water. One of the difficulties associated with reliance on the benefits of AMF is their susceptibility to different crop management practices, such as disruption by soil tillage, lack of plant host diversity in monoculture, and suppression by high levels of fertilizers and fungicides.

Other plant-beneficial fungi are found within the genus Trichoderma, a group of hyphae-forming fungi found in the soil or on dead wood and bark. Trichoderma form close symbiotic associations with plants and were shown to promote root-branching and nutrient uptake. Due to their ability to parasitize other fungi, they are often used as biocontrol agents for fungal diseases of plants.

Seaweeds have long been known for their beneficial effects on plant growth. Most seaweed products are soluble powders or liquid formulations derived through different extraction procedures. The biological activity of these extracts depends on the raw material and the extraction process.

One of the major components of seaweed extracts are polysaccharides, which may account for 30 to 40 percent of the dry weight and include alginates and laminarins. These polysaccharides possess plant growth-promoting activities and are known to elicit plant defense responses against fungal and bacterial pathogens.

Seaweeds have long been known for their beneficial effects on plant growth.

In addition, seaweed extracts are rich in phenolics, compounds with antioxidant activity that play an important role in scavenging highly reactive and plant cell-damaging free radicals. Seaweed extracts may also contain phytohormones, which can directly influence plant growth and development. Other positive attributes of seaweed extracts are their soil-conditioning and metal-chelating properties as well as their ability to positively influence the water-retention capacity of soils.

BIOSTIMULANT RESEARCH IN CITRUS

At the UF/IFAS Southwest Florida Research and Education Center in Immokalee, the effects of different biostimulant materials on citrus grown under greenhouse and field conditions are currently under investigation. As root health is critical to tree performance, especially in the HLB era, UF/IFAS researchers are interested in deciphering the effects of biostimulant substances on the root/soil microbial community, and possible interactions with the rootstock genotype.

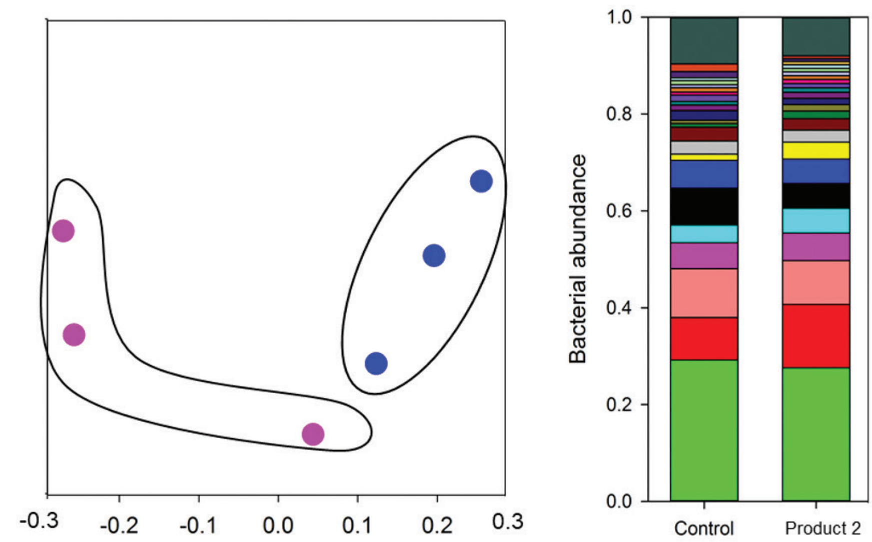

Figure 2. Impact of *Bacillus* spp. applications (Product 2) on the root/soil microbial community of US-802 seedlings. On the left, each dot represents the overall bacterial community composition of a sample. The closer together the dots, the more similar the bacterial community composition. Pink dots are the control, and blue dots are seedlings treated with Product 2. On the right is an example of the number of different bacterial taxa that are found in the soil of the control and amended seedlings. Each color represents a different bacterial taxa.

A greenhouse experiment conducted over 18 weeks used three different rootstock seedlings (US-802, US-812 and US-897). Researchers observed positive growth responses to a microbial product composed of a consortium of *Bacillus* species and to a composite product containing humic acids, fulvic acids and seaweed extract, as well as additional nitrogen (N) and potassium (Figure 1, page 12). The total biomass of plants treated with either product increased significantly in response to the treatments, as did the shoot-to-root ratio, indicating a higher nutrient use efficiency of these plants. However, part of the positive response to the composite product is likely related to the additional N component.

Besides clear differences in the growth response, a significant interaction of product type and rootstock genotype was observed. Neither of the two materials applied changed the number of lateral roots or the total root length of the rootstock seedlings. However, the specific root length (SRL — the ratio of total root length and root biomass) was significantly reduced in response to both products. This suggests that more nutrients were available or used more efficiently in treated plants, and that there was no need for allocating resources to root foraging.

It is important to note that root architecture also varied considerably between the three different rootstocks, with US-802 seedlings having the lowest SRL and US-897 the highest, independent of the treatment. In addition to changes in plant growth, changes were also observed in the root/soil microbial community patterns in response to the treatments (Figure 2). Here, too, significant differences were observed among rootstock genotypes, independent of any treatment.

Several field studies are currently in progress, including young trees as well as mature trees in commercial operations. Thus far, no above-ground differences have been observed between plants receiving biostimulant products and those that do not, which is not surprising, considering the trials were initiated only within the last year.

It is important to note, however, that we did not observe a reduction in HLB incidence in response to biostimulant treatments in two young Valencia tree trials which were started more than one year ago. Preliminary data from a trial involving 8-year-old Valencia trees on Carrizo rootstock revealed a significantly higher metabolic activity of roots receiving monthly applications of seaweed extracts to the root zone compared with untreated trees. Assessment of other physiological parameters and of changes in the root/soil microbial community is in progress. These studies will aid in deciphering possible impacts of biostimulants on root health and the root/soil environment before effects become visible in the above-ground portion of the tree.

SUMMARY

Many biostimulant products of varying composition are currently on the market. Despite the potentially positive effects on different crops reported in the scientific literature, there is little knowledge regarding biostimulant effects on commercially grown citrus. Biostimulant effects will vary depending on the rootstock/scion combination, the source and composition of materials, the dose and manner of application, environmental conditions and management practices.

In general, biostimulants are more effective under stress conditions. Although greenhouse experiments in a controlled environment are valuable for the preliminary assessment of different substances, ultimately field trials are necessary to decipher effects under the specific conditions of the grove and assess economic feasibility.

Ute Albrecht and Sarah Strauss are assistant professors at the University of Florida Institute of Food and Agricultural Sciences Southwest Florida Research and Education Center in Immokalee.