Microbial Biostimulants in Grower Toolboxes

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Sustainable and organic growers have come to rely on a diverse array of inputs and this trend does not appear to be weakening. Actually, as grower numbers increase, along with the range of the scale and setting of their operations, markets they serve, approaches they use, and the experience and training they possess, demand for more and different inputs is likely to remain strong.

The Rise of Microbial Bioproducts

Strong evidence is available to support this prediction, especially where products containing microbes are concerned. To begin, the scientific literature contains two general types of reports. The first group consists of hundreds of articles demonstrating that various microbes can positively affect plant growth or nutrient acquisition, or negatively affect pathogens, insect pests, or weeds under tightly-controlled lab or greenhouse conditions. The number of different types (i.e., genera) of microbes tested in this group is very large. The second, much smaller group, contains reports showing similar effects under more production-like field conditions. However, effects in this group generally have been less dramatic and consistent and true for a smaller number of different types of microbes.

Still, the science is promising and many have noticed. For example, one report placed the value of the global microbial bioproduct industry at nearly $7 billion in 2016. Also, a recent study centered in Ohio revealed that 51% of organic vegetable farmers used a microbial biostimulant at least once between the years of 2009-2014 (in any one year in that period, a microbial biostimulant was used on about 40% of organic vegetable farms). The same study estimated that microbe-based biopesticide and biostimulant use together accounted for over 9% of all inputs used by growers. Industry and other reports show that the number of microbial bioproducts and companies offering them is marching upward. Moreover, other reports show that some growers value beneficial microbes as partners in production so much that they work to manufacture their own inoculants on farm, a process that can have many pitfalls. Still more but anecdotal evidence, such as conference session titles and attendance and publication numbers, points to a clear conclusion: namely, that microbe-based products are big business and that they have secured key positions in growers' toolboxes. Of course composts, compost teas, and similar products that contain microbes or rely on them during production have long been important to growers as well.

Two Types of Microbial Bioproducts and What Sets Them Apart

Shovel. Tractor. Plow. Seeder. Transplanter. Ask growers, grower advisors, and other people in the industry to define them and describe them and two things are likely to be true. First, most will get it right. Second, answers will be similar from person to person. Ask the same people to define and describe "stimulant" and "pesticide" and much of the same will happen. However, put "microbial" and "bio" in front of those two words and the accuracy of and similarity in peoples' descriptions mostly evaporate. That is reasonable considering the labeling and packaging of microbial biostimulants and microbial biopesticides, how they come to market, and how they are often discussed.

Commercial microbial biopesticides advertised to be used

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What to Look For

Here are five key questions to ask yourself when considering your next microbial biostimulant purchase.

- Do I have a clear goal in mind in using this product?
- Is this product likely to work on my crop(s) and under my production conditions?
- Does the product label include a full list of microbial and other ingredients and their concentrations or levels?
- Does the product label include clear and complete information on how to store, handle, and apply the product?
- Does or will the company provide data or other convincing information, perhaps third-party test results, about product performance?

Being able to answer 'yes' to all or most of these questions will make success with the product more likely.

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specifically in insect, disease, or weed management in the U.S., at minimum must: 1) have a legal definition and 2) be released to the market only after testing in a formal and regulated third-party system. Biopesticides also require an EPA label and, overall, biopesticide labels contain relatively thorough instructions for their use and descriptions of their expected effects. Words such as "pathogen control," "antagonism," "competition," and/or "antibiotic" often appear on biopesticide packaging.

In contrast, microbial biostimulants currently have no legal, universally accepted definition in the U.S., are largely unregulated, and do not require third-party testing before coming to market. Hence, publicly available third-party data describing their effects are limited. These products are known to contain living microorganisms (often bacteria, fungi, or both – see figure) able to enhance crop growth and alleviate environmental stresses when applied to soil, seeds, roots, or above-ground tissues. Words such as "nitrogen fixation," "phosphorous solubilization," "drought tolerance," "root extension," and/or "nutrient or water availability" often appear on microbial biostimulant packaging.

With crop protection the primary role of biopesticides, other functions fall to crop biostimulants and biofertilizers. Some consider biofertilizers to be a type of biostimulant while others do not distinguish between them. This muddled terminology has unwanted effects on growers, people they rely on, and others. The debate cannot be settled in this article. So, to clarify, products containing microbes as a primary active ingredient and advertised to regulate plant growth, enhance plant tolerance to abiotic stress (e.g., low root-zone moisture), and improve plant acquisition of nutrients (e.g., nitrogen, phosphorus, iron) are referred to here as microbe-containing crop biostimulants and they are the primary focus of this article.

A searchable and sortable online interface we constructed contains information on 173 OMRI-listed microbe-containing biostimulants advertised to perform one or more of the functions mentioned above (see http://u.osu.edu/vegprolab/microbe-containing-products/). Labels for these products differ significantly in the amount and type of information they contain. Some labels do not list the microbes they contain or their "titre" (the concentration of microbes in the product). Other types of 'minimalist' labels also lack information on how to apply the product or they contain vague descriptions of its likely effects. Other, more user-friendly labels, however, contain much more detail. Many include the taxonomy and concentration of the microbe(s) in the product and guidelines on its use. Still, too little research-based, third party information about all the products, especially their efficacy on specific crops and soils, appears to be publicly available. Indeed, nearly all agree that additional testing, and communicating its outcomes more widely and effectively, is essential to selecting and using microbe-containing biostimulants more effectively.

Challenges

Why are microbial biostimulants difficult to select, use, and evaluate? Here are some of the challenges frequently encountered:

SELECTION

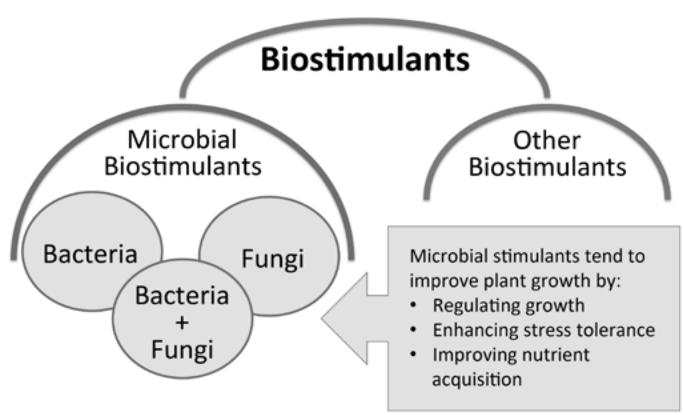
- large number of products available
- incomplete label and product efficacy information
- many different production conditions

USE

- incomplete or vague instructions
- microbes can perish before, during, or soon after application
- microbes generally must contact roots to function
- conditions do not bring out product ability or function

EVALUATION

- few accepted protocols
- incorrect product selection, product misuse or deactivation



Microbial biostimulants contain bacteria, fungi, or a mix of both as primary active ingredients, and promote plant growth in a number of ways.

Highlights

- The value of the microbial biostimulant industry and farmers' use of its products continue to rise sharply. Still, focused action is needed to ensure that microbial biostimulants are used more effectively more often.
- Complications in diversified sustainable-organic vegetable production and limitations in microbial biostimulant development and marketing make gaining from these products noticeably and reliably difficult.
- Collaborative efforts linking growers, manufacturers, researchers and educators increase grower success with microbial biostimulants, especially long-term.

Past Successes

Good examples of this type of testing and outreach are available, including some with microbial bioproducts. In the big picture, the rise of the microbe-based bioproducts industry and the prominent position of its products in farmers' toolboxes are examples of the development-adoption process that can occur with some types of inputs. The first inoculations of legumes with rhizobia in commercial settings are reported to have occurred in the U.S. and U.K. in 1895. Since then, a wealth of information demonstrating returns on investment that growers can expect from inoculating legumes with rhizobia has been developed and shared extensively with growers. Also, the inoculant production process has been refined greatly. As a result, legume-rhizobia inoculations are routine. Overall, the legume inoculation process (including inoculant production) can be considered as a success story for growers, inoculant suppliers, the extension-research and consultancy communities, and others. The inoculation of certain perennial crops or plants with mycorrhizae and the use of specific biopesticides, such as *Bacillus thuringiensis* (Bt), made from and/or containing microbes are similarly routine and successful.

Rhizobia and mycorrhizae biostimulants and a number of biopesticides are success stories. However, they cover only a small fraction of crops and grower needs. Now, many growers, private- and public-sector consultants and advisors, and investigators wonder what other crop-inoculant combinations will be shown to be similarly productive and reliable -- and what may be needed to identify them and to assist growers in using them well. Study and outreach on this topic is a focus of the Microbial-based Solutions for Agriculture Team at The Ohio State University and similar teams at other institutions and organizations.

Looking Forward: Microbial Biostimulants in Vegetable Production

Over the years, a number of bacteria, fungi, and other types of microbes have been found to act as crop biostimulants, especially in tightly-controlled conditions more common to university and company labs and greenhouses than to most working farms. Some commercialized products containing these same microbes have had tantalizingly similar effects on crops on farms, heightening peoples' expectations that microbe-containing biostimulants may impact sustainable-organic production more meaningfully going forward.

Product-related testing and outreach may be especially important to sustainable-organic vegetable growers. They operate year-round, sometimes looking to harvest in winter. They operate at every scale, in open field and semi-controlled environments, and for a tremendous range of markets. Likewise, organic vegetable growers must optimize conditions for direct-seeded and transplanted crops that differ widely in climatic, nutritional, soil moisture, and other requirements, as well as in maturity, which ranges from weeks to months. Vegetable crops also vary in root and other characteristics that may affect their ability to form productive relationships with specific microbes. For example, mycorrhizae do not appear to colonize *Brassica* crops. Identifying productive combinations of crops, microbes, product application factors, and growing conditions may be especially complicated. Still, it is equally important given that mismatched crops, products, soils, settings, or application methods are wasteful.

The Vegetable Production Systems Laboratory at The Ohio State University is cooperating with vegetable growers, grower associations, product manufacturers, extension-research colleagues, and many others in developing resources for selecting, using, and evaluating the effects of microbe-containing crop biostimulants. The team looks to reduce some of the confusion involved in those steps because with many products, crops, settings, etc. have come many questions. Learn more about the effort by contacting one of the authors of this article and/or stopping by http://u.osu.edu/vegprolab/research-areas/vegebiostimsferts/. When you visit, consider joining the microbial listserv or leaving a question or comment.

Authors' note: A number of other publications informed our development of this article. A list of these references is available at http://go.osu.edu/tilth-biostims-spring-17.