Microbe-containing Biostimulants: Current Issues and Future Prospects

National Association of Independent Crop Consultants
January 18, 2019; Savannah, GA

Matt Kleinhenz
Extension Specialist

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES
Today’s Topics

- impacts? (consistent, statistically significant)
- biostimulant science
- place in toolbox
“plant biostimulant” means a substance or micro-organism that, when applied to seeds, plants, or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield.

*courtesy of David Beaudreau, The Biostimulant Coalition
The Emerging Landscape of Products – Broad and (Potentially) Confusing

Humic substances
Humins

B Vitamins
Acids
Fulvic acids

Inorganic salts
Other organic acids

Proteins
Amino acids
Fatty acids / lipids

Beneficial elements (Si, Na, Co, etc.)

Protein hydrolysates
Peptides
Cytokinins

Phosphites
Nitrogenous compounds
Carboxyls

Enzymatic extracts
Chitin / chitosan
Betaines

Other organic matter extracts
Extracts
Polyphenols

Allelochemicals
Botanicals

Mycorrhizae,
Trichoderma, other beneficial fungi

PGPR’s

Seaweed / Kelp
Rhizobium

Complex communities / consortia

Source: Agricen Sciences’ analysis of market analysts, survey papers on Biostimulants
courtesy of the Biostimulant Coalition
Biostimulant Organizations

- Biological Products Industry Alliance
  https://www.bpia.org/

- Biostimulant Coalition
  http://www.biostimulantcoalition.org/
Microbe-containing Biostimulants


Source: http://www.grandviewresearch.com/industry-analysis/biofertilizers-industry

Global biofertilizer market worth 2.31 Billion USD by 2022.
Biopesticide and Biofertilizer Use over Time*

* Together, these products accounted for 9% by number of all inputs on these farms (412 distinct types inputs classified into 14 categories).

Microbial biopesticide use has increased, whereas microbial biostimulant use has fluctuated around 40%.

Data were collected from organic certification records of vegetable producers submitted to the Ohio Ecological Food and Farming Association between 2009-2014.
- Regulations & policy update
- Soil fertility & seed treatment
- Nutrient uptake & plant growth
- Abiotic stress tolerance
- Maximising yields & crops quality
- Increasing shelf life
- Discovering new biostimulants
- Field trials
- Commercialization & market report
- Farmers’ decision making process

Registration & more information: www.agribiostimulants.com
• https://www.acsmeetings.org/
• https://ashs.org
• http://www.apsnet.org/
• Organic Agriculture Research Forum
• many grower-/consultant-oriented technical programs
... “portal to research-and experience-based information regarding microbe-containing biostimulants and biofertilizers (MCBSFs) and their use in commercial vegetable production.”

http://u.osu.edu/vegprolab/research-areas/vegebiostimsferts/
Microbial Biostimulants/Biofertilizers in Vegetable Production ListServ

- to our knowledge, the first listserv to focus on MCBSFs
- launched in April 2016; now with 168 members
- email forum; ask questions, share info on MCBSFs

http://u.osu.edu/vegprolab/microbial_inoculants_in_vegpro/

updated 2-28-18
# Conference Call Participants

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<td>experience with MCBSs</td>
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Discussions recorded, available for listening.

https://youtu.be/XZscnl05RyI

https://youtu.be/hwiMtasdRWk

https://youtu.be/HKS0Qvu05mA

https://youtu.be/2zKC3ppSOUg

https://youtu.be/6xu28f2eNB0

https://youtu.be/Vpf5cDPl110
Presentations at grower and industry programs in FL, IN, OH, IL, NY, NC, CA, KY, and Ontario coordinated by universities and/or grower associations (10/17 – 12/18).
Field Days – Summer 2017
Microbial-based Biostimulants: Big Potential in Small Packages

By: Matt Kleinhenz | Email

There is no shortage of interest in or questions and opinions about biostimulants. Many are working to develop them as key tools in grower toolboxes and to help growers use them effectively. One part of the effort is focused on identifying microbes that enhance crop growth under a range of conditions, including ones that ordinarily reduce yield (e.g., low soil moisture and/or fertility). The other part focuses on identifying methods that allow plant-microbe interactions to be most useful to growers.

Why the fuss? The science is promising. Years of experiments in controlled environments suggest that the potential upside in production will be real, i.e., that inoculated crops will outperform non-inoculated ones. While some are already convinced, others need more proof collected on farms and in more 'real-world' situations. They also point to the dozens of products and the lack of information about them and see a need to create grower-friendly resources similar to ones available for biostimulants. It can be difficult to know when or even if a biostimulant is working. So, reliable protocols for assessing their effects in field and high tunnel systems are needed.

Discussion helps and there is plenty taking place. I have been fortunate to hear from many growers, suppliers, grower advisors, and researchers regarding their views on biostimulants, especially as we discuss the current situation and steps that may help more growers obtain greater value from their investments in biostimulants. Some of the comments shared most often are summarized below.

Grower Perspectives on Microbial-based Biostimulants

- They can't hurt and they may help ... they act as insurance
- Their (low) cost makes their possible upside appealing
- Everyone can't be wrong. Popularity = efficacy
- I hear good things about beneficial microbes and their effects on crops and farms. I want to promote soil life but it's...
Researchers share five ‘fast facts’ to help growers understand biofertilizers

By Matthew D. Michelson

An increasing number of products containing microbes as the primary active ingredient are being marketed to growers looking to enhance crop growth, by nutrient acquisition, uptake, or utilization, or enhance crop traits such as disease resistance, yield, and/or oil yield. However, the effectiveness of many products is unetermined, leaving growers and retailers to assess efficacy and potential product return on investment.

A team led by The Ohio State University is working with that process by conducting on-farm and on-farm evaluations and creating new resources and educational opportunities to help growers understand product action, use, and evaluation. Products are tested under a range of conditions — for 21 sites in seven states have been employed in experiments involving seven crops. Data, products, and information for farmers are available at webvegetal.org/research/vegetable microbes.

Microbe-containing crop bio stimulants or biofertilizers are popular among growers and a growing source of income for product manufacturers and suppliers. Yet, many questions are unanswered. How should they be used? Are they effective? Do they offer a consistently positive return on investment? While more research is needed to address these questions, the following five ‘Fact Facts’ can help growers make informed decisions about using these products.

Fact One: There are numerous and diverse important uses for these products. We have ranked the number of products and companies offering them since March 2016. Currently, we know of 345 U.S.-based, microbe-containing crop bio stimulants offered by 155 companies in the U.S. The number of products and companies in this category have risen 16- and 19-fold, respectively, in three years. Also, individual products contain an array of microbes (e.g., multiple types of bacteria, fungi, or both) on a much smaller subset (e.g., single species of bacteria). Some products also contain components designed to feed the microbes, crop, or both.

Fact Two: Overall, labeling and third-party documentation of efficiency are weak. Compared to fertilizers, pesticides, and other input categories, regulation of microbe-containing crop bio stimulants is minimal and inconsistent, with much data-free state variation. Labels can lack complete or accurate descriptions of packaging contents or detailed instructions for use. Currently, there is no systematic, third-party, state, regional, or national testing system or mechanism for developing efficiency information (unlike biostimulants). Companies appear to differ significantly in their amount and rigor of third-party testing they conduct. As one consequence of this, ‘Wild West’ scenario, the best evidence of efficiency on farms is often not publicly available, more formally focused, research-based reports featuring these products are rare.

Fact Three: They are increasingly popular among organic and other growers in the U.S. and globally. Projections are for the U.S. biofertilizers market (including products in which microbes do not of the conditions under which they are used. With support from USDA SAF, special company, and others, we and our collaborators work to develop resources that better understand, select, use, and evaluate microbe-containing crop bio stimulants.

Fact Five: Ways in which these products work (e.g., modes of action) can lead to application efforts being more viable than with other inputs. We have developed plots may grow a little faster, flower a little sooner, and appear to be healthier (e.g., in color) in a range of conditions but not yield considerably more. Of course, these differences will be apparent only when an untreated check is available for comparison. Replicated, documented, and consistent efforts will allow users to know exactly what they should expect from an experiment and to ascertain it is what they want to pay for.

In replicated trials, statistically significant yield increases are rare and usually don’t exceed 6.5%. It remains an area of research and is unrelated to inoculation with a single product, even different trials in different environments and involving different crops. Companies and researchers may report many responses from many trials into groups resembling one in the figure. Often, the graph for a product is as important to growers as the average yield response, which is the most commonly reported statistic. The graph and, by association, the most frequently occurring yield response, may be a more reliable indicator of what growers should expect from the product. When inspecting a product, consider asking for either the distribution of yield responses across trials and the most frequently occurring yield response to determine the range. There is a tangible, transferable, and widespread application for the idea that purposeful inoculation of seeds, crops, and/or soil with beneficial microbes (e.g., bacteria, fungi) may enhance farm service and enterprises (e.g., nurseries, co-op).

Inoculation would complement steps fostering the development and activity of naturally occurring beneficial microbial communities. Being enthusiastic about opportunities created by inoculation is easy; so far, it rarely results in higher yield, it may result in higher yield, and it is often thought of as ‘cheap enough’.

However, the goal is to ensure that inoculation offers more growers a greater return on investment more often. Achieving that goal definitely requires more information and may require better products.

Based on these five fast facts, researchers offer these recommendations. First, stay tuned to reports from the microbe-containing crop bio stimulant industry and trusted scientists. Second, experiment with bio stimulants using reliable bio stimulant manuals such as “SAFE How to Conduct Research on Your Farm” and visit with others involved in this research. The Ohio State University Vegetable Production Systems Laboratory manages a library for vegetable producers to access information and field experience with microbial-based bio stimulants. To join, see more about vegetable research across vegetable bio stimulants.

Matthew Michelson is a professor in Horticulture and Crop Sciences at The Ohio State University. Walents, Dr. Julie Ladd, Stephanie Must, Thong Wang, and Nicole Wright contributed to the content of this article.

References
1. www.ohioagriculture.org/industry-analysis/biofertilizer industry
2. Langelier, J. et al., 2016. M.S. Thesis. The Ohio State University: Microbial inoculants in sweet corn (Zea mays) yield, nitrogen, and nitrogen use efficiency in different soil environments.
3. www.ohioagriculture.org/industry-analysis/biofertilizer industry
4. www.ohioagriculture.org/industry-analysis/biofertilizer industry
5. www.ohioagriculture.org/industry-analysis/biofertilizer industry

Articles in university and industry publications (local-national readership/circulation)
Example First Name,

Don't miss your chance to register for the Biostimulants World Congress Digital Week (8-11 October 2018), hosted by New Ag International and KNect365 Life Sciences, a 4-day series of live educational webcasts and downloadable resources developed especially for crop innovation and regulation professionals.

Check out our Thursday webinar.

THURSDAY OCTOBER 11™, 2018 - 11am EDT / 4pm BST / 5pm CEST

Best Practices to Effectively Utilize Biostimulant Technology

The use of biostimulants in agriculture has been growing rapidly despite considerable uncertainty regarding their mode of action and appropriate use. Many biostimulants are believed to function through their ability to mitigate the negative effects of mild to moderate plant stress and improve crop resilience under resource competition, thereby enabling the full realization of yield potential.

Professor Patrick Brown
Department of Plant Sciences
University of California-Davis, USA

To optimize crop response to biostimulants it is therefore critical that users understand the sensitivity of their crop to stress events and have a sound understanding of the purported mode of function of the biostimulant being used. In this seminar we will explore current hypotheses on the mode of action of many biostimulants and the principles that underlie their effective use.

REGISTER FOR PROF. PATRICK'S WEBINAR
Development Strategies for Biostimulants
4-week online course | 2 hours per week
4 February - 11 March 2019
Online Academy

Understand the value of biostimulants as the future of state-of-the-art crop development

http://www.ati-global.co.uk/event/development-strategies-for-biostimulants
Literatures

- refereed scientific
- trade
Today’s Topics

- impacts? (consistent, statistically significant)
- biostimulant science
- place in toolbox
Containing one or more microbes as a leading, if not THE primary active ingredient, sets these products apart.
in widespread trialing, effects have been case-specific (i.e., inconsistent) and yield increases, if any, have rarely exceeded 5%
Common Profile of Results of Microbial Biostimulant Yield Trials

- average = 5.98%
- # below = 249
- # above = 150
Common Profile of Results of Microbial Biostimulant Yield Trials

- Average = 5.98%
- # below = 249
- # above = 150
Yield enhancement, if any, occurs on a case by case basis, probably influenced by soil status and application and other factors.
... prevailing narrative in the scientific literature is that response to inoculation (e.g., percent growth enhancement) is most often greater in low-fertility environments. Other narratives exist.
Microbial Biostimulants in Organic Farming Systems: Patterns of Current Use and an Investigation of Their Efficacy in Different Soil Environments

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science in the Graduate School of The Ohio State University

The Ohio State University

2017

Master’s Examination Committee:

Dr. Matthew Kleinhenn, Advisor

Dr. Enrico Bonello

Dr. Richard Dick

Dr. Michelle Jones

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Plant biostimulants: Definition, concept, main categories and regulation

Patrick du Jardin

Plant Biology Unit, Gentheux Agro-Bio Tech, University of Liège, Belgium. 2, Passage des Déportés, B-3000 Gentheux, Belgium

A plant biostimulant is any substance or microorganism applied to plants with the aim to enhance nutrient efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content. By extension, plant biostimulants also designate commercial products containing mixtures of such substances and/or microorganisms. The definition proposed by this article is supported by arguments related to the scientific knowledge about the nature, modes of action and types of effects of biostimulants on crop and horticultural plants.

Furthermore, the proposed definition aims at contributing to the acceptance of biostimulants by future regulations, especially in the EU, drawing the lines between biostimulants and fertilisers, pesticides or biocontrol agents. Many biostimulants improve nutrient and they do so regardless of their nutrients contents. Biofertilisers, which we propose as a subcategory of biostimulants, improve nutrient use efficiency and open new routes of nutrients acquisition by plants. In this sense, microbial biostimulants include mycorrhizal and non-mycorrhizal fungi, bacterial endosymbionts (like Rhizobium), and Plant Growth-Promoting Rhizobacteria. Thus, biostimulants applied to plants can have a dual function of biocontrol agent and of biostimulant, and the claimed agricultural effect will be instrumental in their regulatory categorization. The present review gives an overview of the definition and concept of plant biostimulants, as well as the main categories. This paper will also briefly describe the legal and regulatory status of biostimulants, with a focus on the EU and the US, and outlines the drivers, opportunities, and challenges of their market development.

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Figure 3.3 Percent yield increase of wheat due to inoculation with *Azospirillum brasilense* was based on mean values reported for 10 soil types, and charted against the yield of the non-inoculated control for each soil type. Yield response to inoculation appears to have a quadratic relationship with the control yield for a given soil type. This graph was generated using data from a study of dryland wheat at 297 field sites including 10 soil types (Díaz-Zorita and Fernández-Canigia 2009).
Example: growth of mycorrhizal fungi greatest in soils intermediate in nutrient availability

soil health-biostimulant relationships are neither settled science nor practice.
Today’s Topics

• impacts?
  (consistent, statistically significant)

• biostimulant science

• place in toolbox
Microbe-containing Biostimulants

- continue a two-century old expectation that increasing the numbers of beneficial microbes in the crop root zone, including with inoculants, is worthwhile.

- PGPR commercialization began in 1895 in U.S. and UK with inoculating legumes with rhizobia.
enthusiasm over the potential benefits of inoculation or treatment with MCCBs

research-based resources to guide the process in ways resulting in worthwhile ROIs

The Problem
(Microbe-containing) Biostimulants

- currently, minimally and inconsistently regulated in the U.S.;
  ‘weak’ testing system

“Wild West” of input categories and industries
(Microbe-containing) Biostimulants

- no clear mechanism to develop research-based, third-party, user-friendly info analogous to that for (bio-)pesticides (e.g., IR-4) and other (more regulated) inputs
Facts Slowing the Progress of Certain Types of User-Focused Research involving (Microbe-containing) Biostimulants
The Emerging Landscape of Products – Broad and (Potentially) Confusing

diversity

Humic substances
Humins
Acids
Fulvic acids
B Vitamins
Other organic acids
Inorganic salts
Amino acids
Fatty acids / lipids
Proteins
PGPR’s
Protein hydrolysates
Cytokinins
Other
Peptides
Mycorrhizae, Trichoderma, other beneficial fungi
Phosphites
Nitrogenous compounds
Polyamines
Carboxyls
Betaines
Seaweed / Kelp
Rhizobium
Complex communities / consortia
Enzymatic extracts
Chitin / chitosan
Other organic matter extracts
Extracts
Laminarin, alginites, other polysaccharides
Polyphenols
Allelochemicals
Botanicals

Source: Agrigen Sciences' analysis of market analysts, survey papers on Biostimulants
courtesy of the Biostimulant Coalition
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<th>Important Dates</th>
<th>Number of OMRI-listed Products</th>
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2.3- and 2.2-fold increases in # of products and companies, resp., in last 3 years

Abundance
The Ohio State University

Information in the database was obtained from OMRI, manufacturer documents and Material Safety Data Sheets (MSDS).

Information is incomplete for some products; information will be added as it becomes available and as resources allow.

The interface is interactive and designed to become more so in time. Currently, facets of information can be sorted and searched and links can be selected to obtain additional information. Links to technical reports on and use-re its entirely by clicking on the “view” link located directly to the f fhe product name. Columns can be hidden from view by clicking on the menu arrow that appears to the right of the column name. To unhide a column, hit the F5 key or

Microbe-containing products differ in the microbes and other ingredients they contain and in methods used to apply them. For various reasons, two products containing the same or similar organism(s) may perform differently in the

Please click here to provide feedback on and suggestions for improving the interface.

Please click here if you have trouble accessing or using the interface.

This interface was developed with the support of The OSU Department of Horticulture and Crop Science and the Center for Applied Plant Sciences.

To view in original mode, click here. To return the Vegetable Production Systems Laboratory website, click here.

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• [http://u.osu.edu/vegprolab/microbe-containing-products/](http://u.osu.edu/vegprolab/microbe-containing-products/)
• 344 OMRI-listed MCBSs; first searchable and sortable online portal focused on delivering information for growers, grower advisors, members of industry, researchers
• 2316 pageviews representing 33 countries and 48 US states (2015-2018)
Number of distinct species (bacteria and fungi) contained in OMRI-listed biostimulants.

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<th>Bacteria</th>
<th>Fungi</th>
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<td></td>
<td>Rhizobia</td>
<td>Other bacteria</td>
<td>Mycorrhizal fungi</td>
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<tr>
<td>Rhizobia</td>
<td>14</td>
<td>61</td>
<td>31</td>
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Number of products with the microbial compositions listed.

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<th>fungi only</th>
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<td>One genus</td>
<td>25</td>
<td>44</td>
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<td>8</td>
<td>22</td>
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<td>Multiple genera</td>
<td>28</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>73</td>
<td>34</td>
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A MAJOR REASON

Stages in Product Pipeline and Adoption and Relative Effort given to Each

1. Discover or identify, characterize
2. Formulate, package, deliver
3. Select and use on working farms with demonstrated efficacy (ROI)
Strength of evidence regarding effectiveness on farms

- host-/crop-specificity

• Rhizobia legumes ... yes
• Mycorrhizal Fungi Brassica ... no
Strength of evidence regarding effectiveness on farms

- Azotobacter
- Bacillus
- Mycorrhizal Fungi on most crops ...

+ Azospirillum
+ Pseudomonas
Strength of evidence regarding effectiveness on farms

- dozens of other microbe-crop combinations
• multiple modes of action, some incompletely characterized, leading to subtle, ‘finicky’ application effects

... difficult to quantify and assign value and to publish, if needed
Table 1
Effects of biostimulants on crop productions, from their cellular targets in plants to whole-plant physiological functions, to agricultural/horticultural functions, and ultimately to expected economic and environmental benefits (Dobbelære et al., 1999; Huang et al., 2010; Shabala et al., 2012).

<table>
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<th>Humic acids</th>
<th>Seaweed extracts</th>
<th>Protein hydrolysate</th>
<th>Glycine betaine</th>
<th>Plant Growth-promoting Rhizobacteria</th>
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<tr>
<td><strong>Activate plasma membrane proton-pumping ATPases, promote cell wall loosening and cell elongation in maize roots (Zea mays) (Jindo et al., 2012)</strong></td>
<td><strong>Asphodelium nodosum</strong> extracts stimulate expression of genes encoding transporters of micronutrients (e.g., Cu, Fe, Zn) in oilseed rape (Brassica napus) (Billard et al., 2014)</td>
<td><strong>Enzymatic hydrolysate from alfalfa (Medicago sativa) stimulates phenylalanine ammonia-lyase (PAL) enzyme and gene expression, and production of flavonoids under salt stress</strong> (Ertani et al., 2013)</td>
<td><strong>Protects photosystem II against salt-induced photodamage in quinoa</strong> (Shabala et al., 2012), likely via activation of scavengers of reactive oxygen (Chen &amp; Murata, 2011)</td>
<td><strong>Azospirillum brasilense</strong> releases auxins and activates auxin-signalling pathways involved in root morphogenesis in winter wheat (Triticum aestivum) (Dobbelære et al., 1999)</td>
<td></td>
</tr>
</tbody>
</table>

| Physiological function (i.e. action on whole-plant processes) | Increased linear growth of roots, root biomass | Increased tissue concentrations and root to shoot transport of micronutrients | Protection by flavonoids against UV and oxidative damage (Huang et al., 2010) | Maintenance of leaf photosynthetic activity under salt stress | Increased lateral root density and surface of root hairs |

| Agricultural/horticultural function (i.e. output traits relevant for crop performance) | Increased root foraging capacity, enhanced nutrient use efficiency | Improved mineral composition of plant tissues | Increased crop tolerance to abiotic (e.g., salt) stress | Increased crop tolerance to abiotic (e.g., high salinity) stress | Increased root foraging capacity, enhanced nutrient use efficiency |

| Economic and environmental benefits (i.e. changes in yield, products quality, ecosystem services) | Higher crop yield, savings of fertilisers and reduced losses to the environment | Higher crop yield, 'biofortification' of plant tissues (increased contents in S, Fe, Zn, Mg, Cu) | Higher crop yield under stress conditions (e.g., high salinity) | Higher crop yield under stress conditions (e.g., high salinity) | Higher crop yield, savings of fertilisers and reduced losses to the environment |
Microbe-containing Biostimulants

Work in 5 Main Ways (can be related)

1. Increase nutrient availability
2. Plant hormones (produce, trigger)
3. Limit plant stress
4. Extend root systems
5. Suppress pathogens, induce resistance
Success (i.e., growth promotion) in research (especially in ‘artificial’ settings).

≠

Success (i.e., greater profit) on farms.
• unclear product-product interactions

... reductionistic, input substitution or holistic model?
• category’s credibility problem hampers the recruitment of committed investigators, especially early-career, and sufficient funding
Selected U.S.-based Microbial Biostimulant Investigators

• Ute Albrecht, *University of Florida*
• Patrick Brown, *University of California-Davis*
• Tim Coolong, *University of Georgia*
• Lori Hoagland, *Purdue University*
• Sam Wortman, *University of Nebraska-Lincoln*

• David Holden, *Holden Research and Consulting*
• John Kempf, *Advancing EcoAgriculture*
Biostimulants

Three Factors Influencing Research Topics and Directions
main interest in the soil-microbe-crop continuum
<table>
<thead>
<tr>
<th>basic/fundamental</th>
<th>applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>microbial ecology</td>
<td>targeted use of microbes in production</td>
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</tbody>
</table>

interests, roles/responsibilities define activities
Applied Biostimulants Research Questions

• best application procedures, including 4 R’s?
• host-specificity, if applicable?
• soil and cropping conditions?
• interactions with other inputs, (e.g., pesticides) and practices?
• appropriate evaluation metrics?
• thresholds for acceptance (ROI)?
Direction reflects funding, support. Overall, applied biostimulant research relatively difficult to fund.
PROJECT SUMMARY

Title: Examining and Utilizing the Microbiome in Controlled Environment Agricultural Systems to Improve Productivity, Food Safety and Sustainability

PD: Christopher G. Taylor  Institution: The Ohio State University
CO-PD/PI's: Bhavik Bakshi, Maria Soledad Benitez Ponce, Alison Bennett, Joshua Blakeslee, Shauna Brummet, Luis Canas, Jessica Cooperstone, David, Francis, Rachel Gabor, Sanja Ilic, Melanie Lewis Ivey, Michelle Jones, Matthew Kleinhenz, Chieri Kubota, Subbu Kumarappan, Jiyoung Lee, Peter Ling, Tea Meulia, Frederick Michel, Sally Miller, Uttara Samarakoon Basnagala, Matthew Smith, Ye Xia

The widely recognized, unmatched potential of Controlled Environment Agriculture (CEA) to address growing food security-related concerns will be achieved only when lingering challenges in CEA are adequately addressed. Although more reliable, productive, and efficient than open field systems, the potential of CEA is limited by high costs and the need for ever-greater efficiency and improved sustainability, knowledge gaps in understanding the impacts of its associated microbiome on crop, human, and business metrics, and the shortage of qualified labor. We will address all four issues directly using a transdisciplinary approach integrating our research, extension, and education capacities along with our long-standing relationships with CEA stakeholders. Decades of experience in engineering, plant physiology, biochemistry, and genetics, microbiology, food science and safety, modeling, economics, and other areas will be directed to cutting-edge science grounded in current and emerging private-sector challenges. Studies completed in working and experimental CEA systems and engaging investigators and stakeholders differing in age, experience, discipline, affiliation, and perspective will help insure that research is highly credible and useful, no matter the audience. Moving forward in our understanding of how various inputs shape growth, yield, nutrition, and water quality is a goal, along with documenting the composition and function of CEA microbiomes as a necessary first step in learning how to alter them for peoples’ benefit. The collecting and distributing of science-based knowledge, improving CEA system literacy in stakeholders, and preparing the next generation CEA workforce along with a strategy to fund new ideas are hallmarks of this project.

a. Title of Project: Strengthening the sustainability of the U.S. greenhouse industry through effective use of biological products.
   (This is a resubmission of NIFA proposal #2018-03403, which was ranked High Priority)

b. Type of project to be submitted: Coordinated Agricultural Projects (CAPs)

c. Anticipated amount of funding to be requested: $6,200,000 (4 years)

d. Economic/environmental/social significance of the problem being addressed and
   Potential economic/environment/social benefit to solving the problem being addressed:

   The continued success and future growth of the U.S. greenhouse industry is dependent on improving the sustainability of greenhouse production systems. The current retail value of the greenhouse industry in the U.S. is well over $12 billion. While the demand for ornamental plants continues to rise steadily, edibles such as herbs and vegetables, represent the largest growth area for the industry, bringing great opportunity and challenges (Greenhouse Grower Magazine 2017 State of the Industry Whitepaper). The widening gap between production costs and revenues is emerging as a significant barrier to the profitability of the U.S. greenhouse industry. Similarly, traditional production systems, which rely on the use of synthetic pesticides and fertilizers, do not align with worker and customer expectations regarding sustainability.

   Commercial greenhouse production systems have traditionally relied heavily on the use of chemical pesticides and intense fertilization to control pathogens and insects and to ensure the timely production of quality crops. Traditional crop production and protection protocols can place growers, workers, and the environment at risk. While effective, costly synthetic fertilizers and pesticides undermine worker and environmental safety agendas. They also drive wedges between edible and ornamental crop suppliers and the growing community of buyers applying different standards when exerting their purchasing power. For an increasing number of customers and retailers, healthy, attractive products are insufficient; they must arrive in that condition having been grown using sustainable worker- and environmentally-responsible approaches. Conserving and protecting resources, including water, while meeting traditional crop quality standards is essential. Adjusting management programs to make better use of biological products (biostimulants and biopesticides) is an attractive solution to both the profitability and worker and customer expectations issues. However, despite much promise, management programs built around the use of bioproducts have been unreliable thus far. Our work over the last three years has revealed reasons for this and possible solutions.

   First, we (the Bi4o Greenhouse Team) were awarded a NIFA SCRI planning grant to assess the U.S. greenhouse industry’s interest in and knowledge of different classes of biological products, including biopesticides and biofertilizers. Among other findings, our industry survey confirmed that most greenhouse growers were interested in using biological products as part of a more sustainable crop production system. Next, our follow-up 2016 strategic planning workshop -- attended by a significant cross-section of the industry and its associated university research and extension community -- identified five obstacles that have limited the use of biological products in commercial greenhouses. These included slower action, higher costs, lack of experience with biological products, inability to use them with current management practices, and a lack of efficacy data. Our research and dialogue with the industry and the project’s Stakeholder Advisory Committee are ongoing. Through them, we have come to recognize that
Summary
Microbe-containing Biostimulants

• growers, investigators, and grower advisors have a mix of positive and negative views on these products
Microbe-containing Biostimulants

Thought process leading growers to at least experiment with if not use them regularly.

1. Some microbes are good, others are bad, and others people aren’t sure about.
2. Companies have identified potentially helpful microbes and packaged them in ways allowing inoculation (“pill”, yogurt, probiotic).
3. Products are very unlikely to cause harm and they just may help. And, most of the time, per-acre costs are not prohibitive.
4. So, inoculation is worth it.
Today’s Topics

- impacts?
  (consistent, statistically significant)
- biostimulant science
- place in toolbox
Microbial-based Crop Biostimulants: Their Place in the Toolbox

- still being discovered
- defined farm-farm, crop-crop; use multiple approaches
Microbe-containing Biostimulants

- obvious potential and popularity; great assets
- strengthening their position in growers’ toolboxes will require patience and information
Microbe-containing Biostimulants

- fast-moving, still-evolving industry and category of inputs ... wise to pay attention
QUESTIONS?

THANK-YOU and GOOD LUCK!

QUESTIONS?