Ohio Agricultural Research and Development Center

Biofertilizers for Organic Production

Brian B. McSpadden Gardener

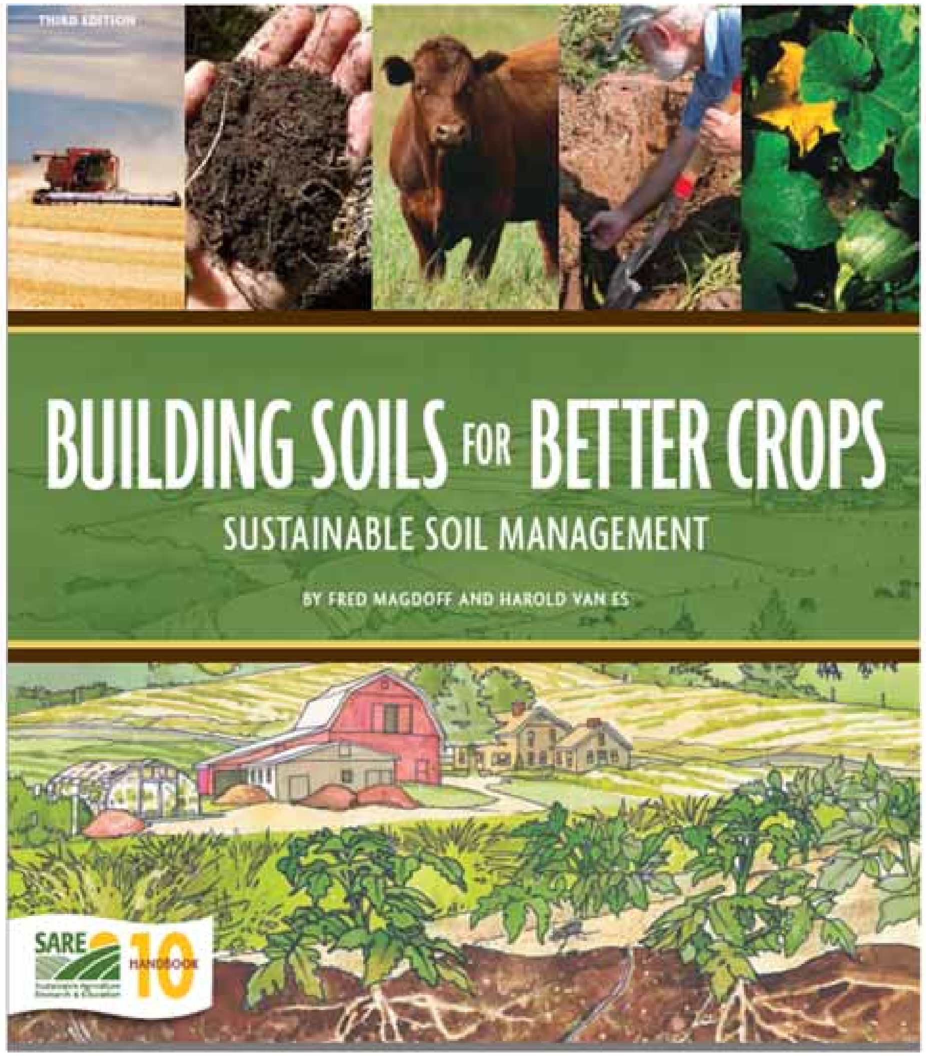
Professor, Department of Plant Pathology
Director, Organic Food Farming Education & Research Program
mcspadden-garden.1@osu.edu

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

Outline

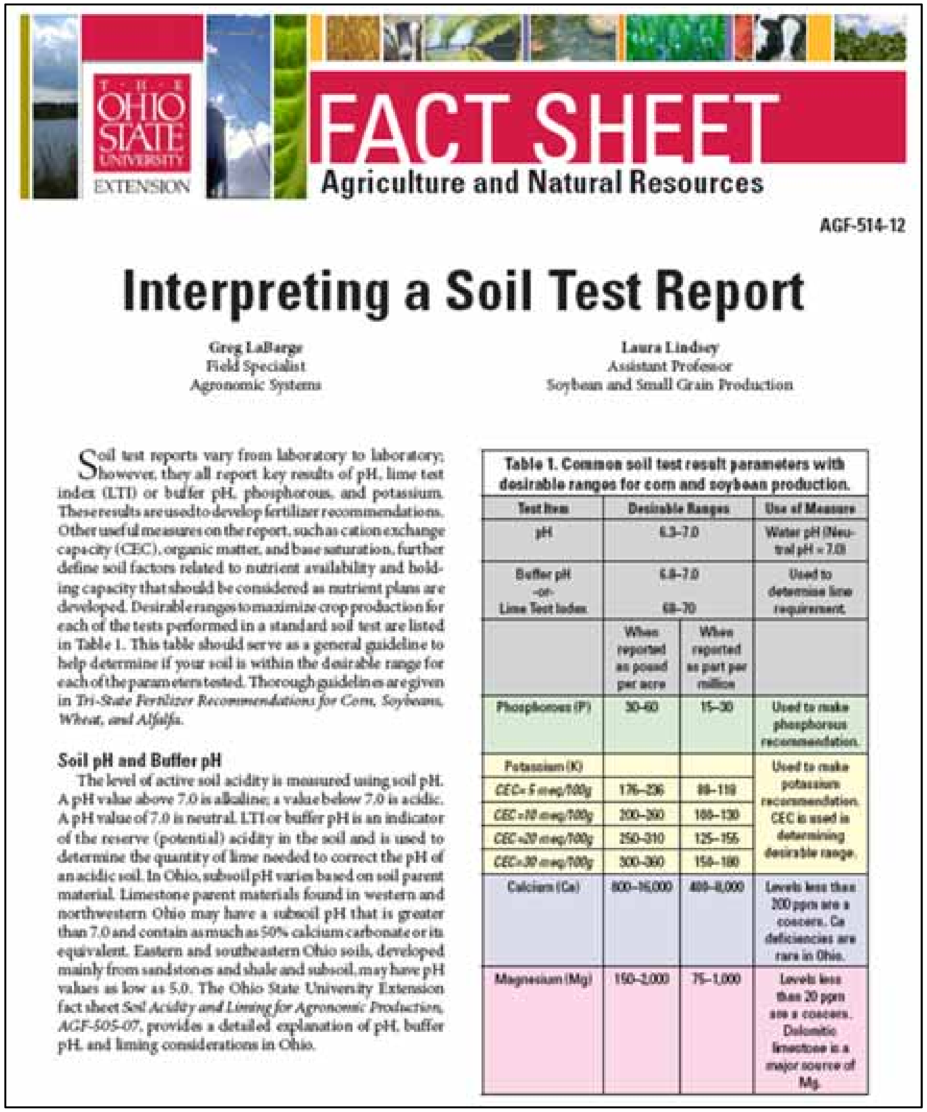
- What are biofertilizers?
- How do biofertilizers work?
- Are biofertilizers really effective?
- When and where should organic growers use biofertilizers?

The Foundation



http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

Good Resources for Soil Testing



THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

AGF-514-12

Interpreting a Soil Test Report

Greg LaBarge
Field Specialist
Agronomic Systems

Laura Lindsey
Assistant Professor
Soybean and Small Grain Production

Soil test reports vary from laboratory to laboratory; however, they all report key results of pH, lime test index (LTI) or buffer pH, phosphorous, and potassium. These results are used to develop fertilizer recommendations. Other useful measures on the report, such as cation exchange capacity (CEC), organic matter, and base saturation, further define soil factors related to nutrient availability and holding capacity that should be considered as nutrient plans are developed. Desirable ranges to maximize crop production for each of the tests performed in a standard soil test are listed in Table 1. This table should serve as a general guideline to help determine if your soil is within the desirable range for each of the parameters tested. Thorough guidelines are given in *Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat, and Alfalfa.*

Soil pH and Buffer pH

The level of active soil acidity is measured using soil pH. A pH value above 7.0 is alkaline; a value below 7.0 is acidic. A pH value of 7.0 is neutral. LTI or buffer pH is an indicator of the reserve (potential) acidity in the soil and is used to determine the quantity of lime needed to correct the pH of an acidic soil. In Ohio, subsoil pH varies based on soil parent material. Limestone parent materials found in western and northwestern Ohio may have a subsoil pH that is greater than 7.0 and contain as much as 50% calcium carbonate or its equivalent. Eastern and southeastern Ohio soils, developed mainly from sandstones and shale and subsoil, may have pH values as low as 5.0. The Ohio State University Extension fact sheet *Soil Acidity and Liming for Agronomic Production, AGF-505-07*, provides a detailed explanation of pH, buffer pH, and liming considerations in Ohio.

Table 1. Common soil test result parameters with desirable ranges for corn and soybean production.

Test Item	Desirable Ranges		Use of Measure
pH	6.3–7.0		Water pH (Neutral pH = 7.0)
Buffer pH -or- Lime Test Index	6.8–7.0 / 68–70		Used to determine lime requirement.
	When reported as pound per acre	When reported as part per million	
Phosphorous (P)	30–60	15–30	Used to make phosphorous recommendation.
Potassium (K)			Used to make potassium recommendation. CEC is used in determining desirable range.
CEC= 5 meq/100g	176–236	88–118	
CEC =10 meq/100g	200–260	100–130	
CEC =20 meq/100g	250–310	125–155	
CEC=30 meq/100g	300–360	150–180	
Calcium (Ca)	800–16,000	400–8,000	Levels less than 200 ppm are a concern. Ca deficiencies are rare in Ohio.
Magnesium (Mg)	150–2,000	75–1,000	Levels less than 20 ppm are a concern. Dolomitic limestone is a major source of Mg.

THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

SAG-4-08

Soil Quality Test Kit

A simple test for active organic matter as a measure of soil quality

Rafiq Islam, Ph.D., Soil Quality Specialist
The Ohio State University, South Centers, Piketon, Ohio

Alan Sundermeier, Ohio State University Extension, Wood County

There is a need for farmers and growers to be able to evaluate soil quality in the field to help guide sustainability of agricultural management practices. Since soil organic matter (SOM) is the most widely acknowledged core indicator of soil quality, temporal changes in small but relatively active fractions of SOM may provide an early indication of soils' functional capability in response to management practices. We report on a highly simplified method in which neutral dilute solutions of potassium permanganate ($KMnO_4$) reacts with most of the active fractions of SOM, changing the deep purple color of the solution to a light pink color. The lighter the color of the $KMnO_4$ solution after reacting with soil, the greater the amount of active organic matter content, and the better the quality of the soil. A 0.02M $KMnO_4$, air-dry soil (or 10 minutes of sunlight on a thin layer of crumbled soil spread in the field), and 2 minutes of shaking providing optimum ease, consistency, and sensitivity of results when using a simple color chart. Compared to total SOM, the active organic matter measured by the new procedure is closely related to soil quality properties, nitrogen fertilization, and crop yields.

Color comparison of $KMnO_4$ solution after shaking with soil

Poor soil quality	Fair soil quality	Good soil quality	Excellent soil quality
> 0 to 400 AOM lbs/A	> 400–800 AOM lbs/A	> 800–1600 AOM lbs/A	> 1600 AOM lbs/A
> 0–12 lbs available N/A	> 12–20 lbs available N/A	> 20–40 lbs available N/A	> 40 lbs available N/A

Soil quality, active organic matter (AOM), and available N color chart

Outline

- What are biofertilizers?
- How do biofertilizers work?
- Are biofertilizers really effective?
- When and where should organic growers use biofertilizers?

What are biofertilizers?

- Material inputs, *typically* obtained or derived from living creatures, that *directly* alter the biology and/or fertility accessed by the crop plant.

- Mostly produced and packaged off-farm, but all types can be produced on-farm.

Types of Biofertilizers

- Manure and compost-based products
- Slaughterhouse/Fish by-products
- Algal and plant extracts
- Microbial inoculants
- Mined mineral supplements
- Mixtures of the above

Types of Biofertilizers

- Manure and compost-based products
  - Many forms: bulk loads, liquids, dry pellets
  - NPK composition declared (1-5% typically)
  - Will contain carbon and other micronutrients (variable quantities)
  - Will contain microorganisms
  - Nutrient release dependent on soil conditions
    - Temperature, moisture, crop demands, etc…
    - (slow) Compost < dry manure < wet manure (quick)

Types of Biofertilizers

- Slaughterhouse by-products
  - Many forms: bulk loads, powders, liquids, dry pellets
  - NPK composition declared (up to 20% N)
  - Will contain carbon and other micronutrients *especially* Ca and Fe (variable quantities)
  - Will contain microorganisms
  - Nutrient release dependent on soil conditions
    - Temperature, moisture, crop demands, etc…
    - (slow) pellet < coarse grain < fine grain < liquid (quick)

Types of Biofertilizers

- Algal and plant extracts
  - Different forms: Dry biomass, powders, liquid extracts, liquid fermentations, “teas”
  - NPK composition often NOT declared (0.1-5% typical)
  - Will contain carbon and other micronutrients *and* phytohormones (variable quantities)
  - Will *sometimes* contain microorganisms
  - Nutrient release dependent on soil conditions
    - Temperature, moisture, crop demands, etc…
    - (slow) pellet < coarse grain < fine grain < liquid (quick)

Types of Biofertilizers

- Microbial inoculants
  - Different forms: Pellets, powders, dispersible granules, pure and mixed liquid fermentations
  - NPK composition often NOT declared (but up to 5% possible depending on formulation)
  - Will contain carbon and other micronutrients *and possibly* phytohormones (variable quantities)
  - Will *always* contain microorganisms *but type, viability and activity can vary greatly*
  - Nutrient release dependent on soil conditions *and activity of microbes in the formulation*

Types of Biofertilizers

- Mined mineral supplements
  - Different forms: *Typically* bagged powders and granules
  - NPK composition declared (1-20% possible)
  - Will contain significant amounts *specific* nutrients and/or humates (up to 100%)
  - Will *sometimes* contain microorganisms
  - Nutrient release dependent on soil conditions
    - Temperature, moisture, crop demands, etc…
    - (slow) coarse grain < fine grain (quick)

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Modes of Action

(How's it work?)

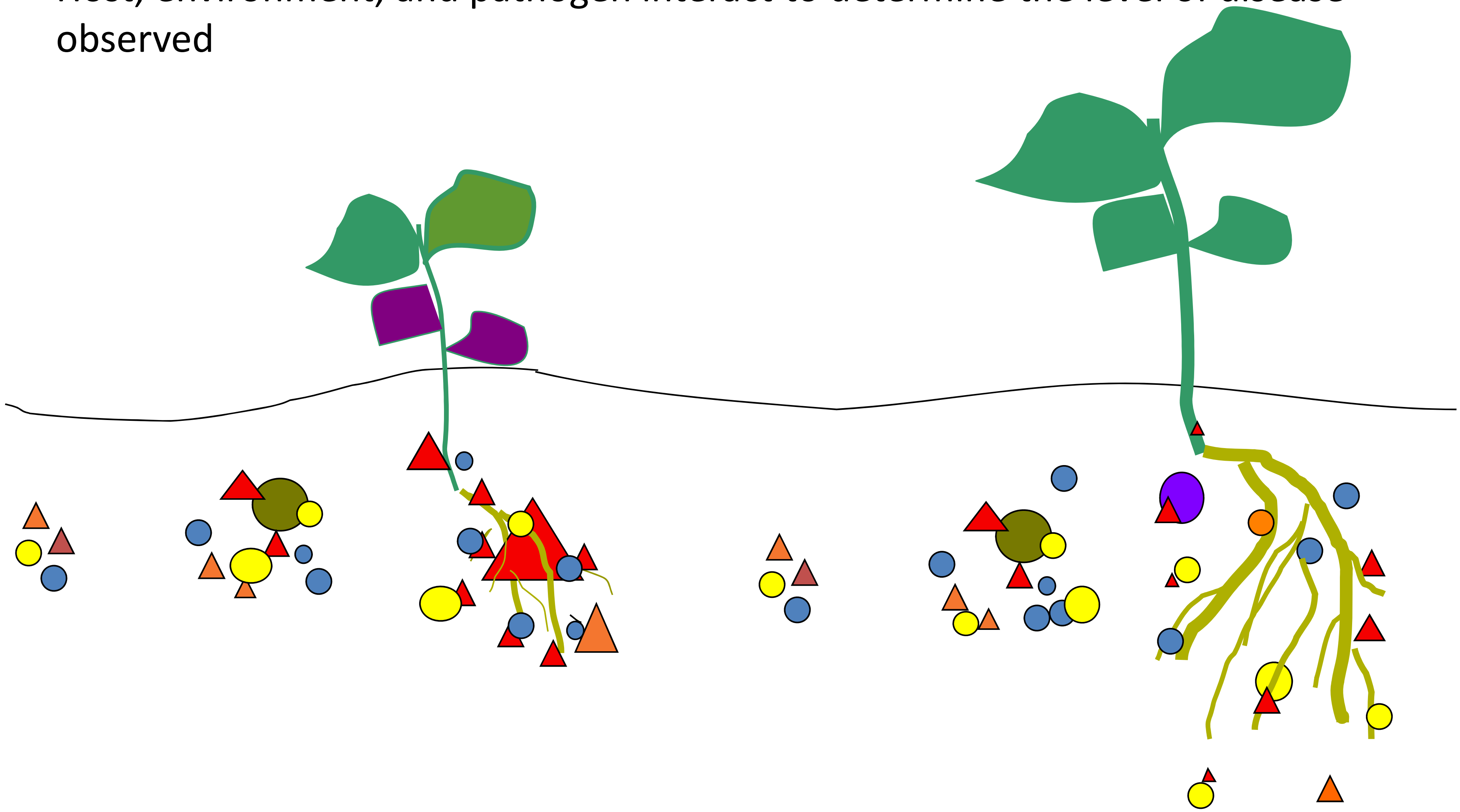
- Three Different Effects
  - Supplementing / rebalancing soil fertility
  - Stimulating soil life
  - Stimulating the crop directly
- More than one effect per product possible
  - More than one ingredient
  - Interdependency of bio- and and available fertility

Consider a General Ecological Model

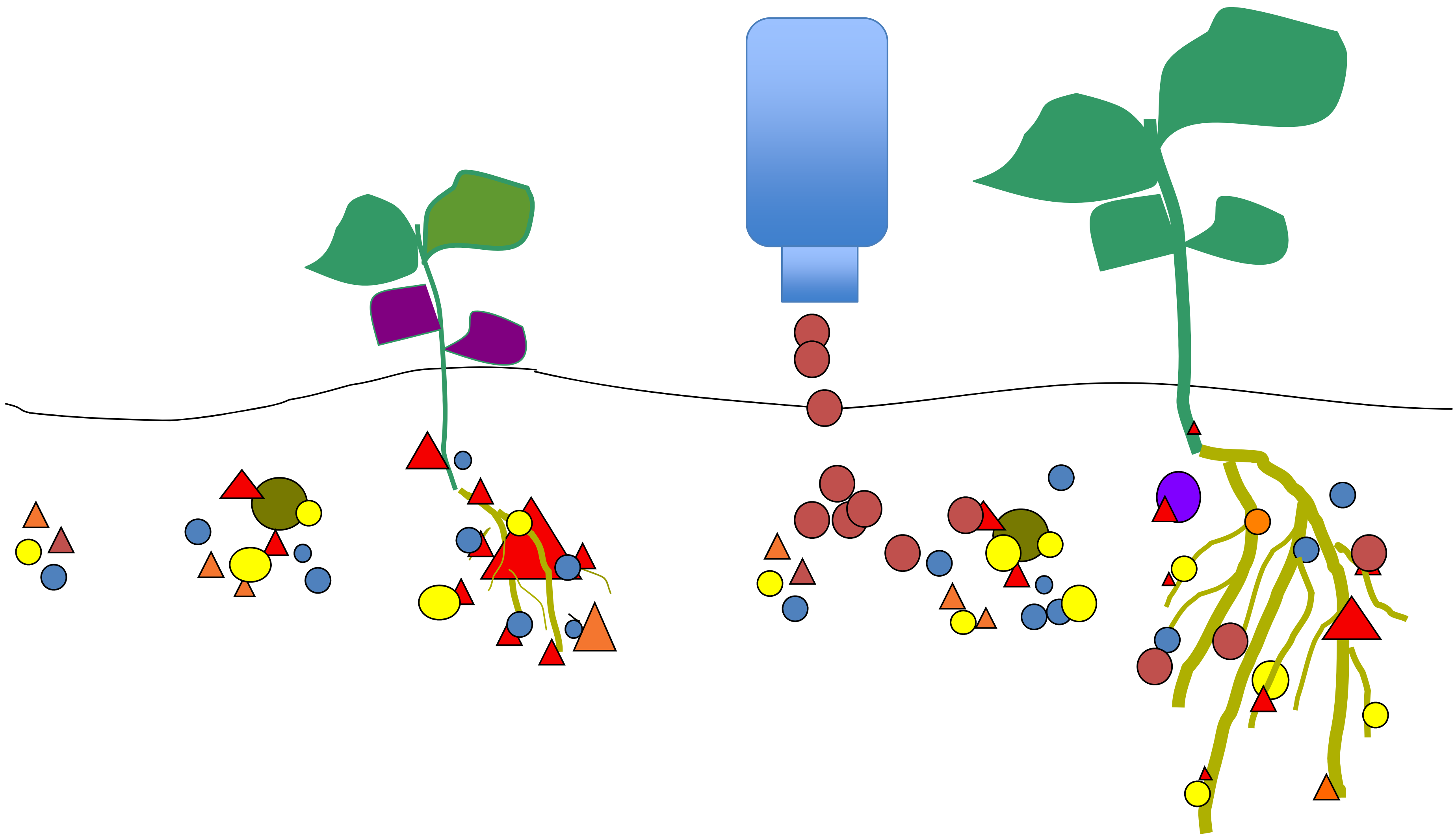
Microbial communities develop around each plant

Balance of pathogens ▲ and beneficials ● determines plant health

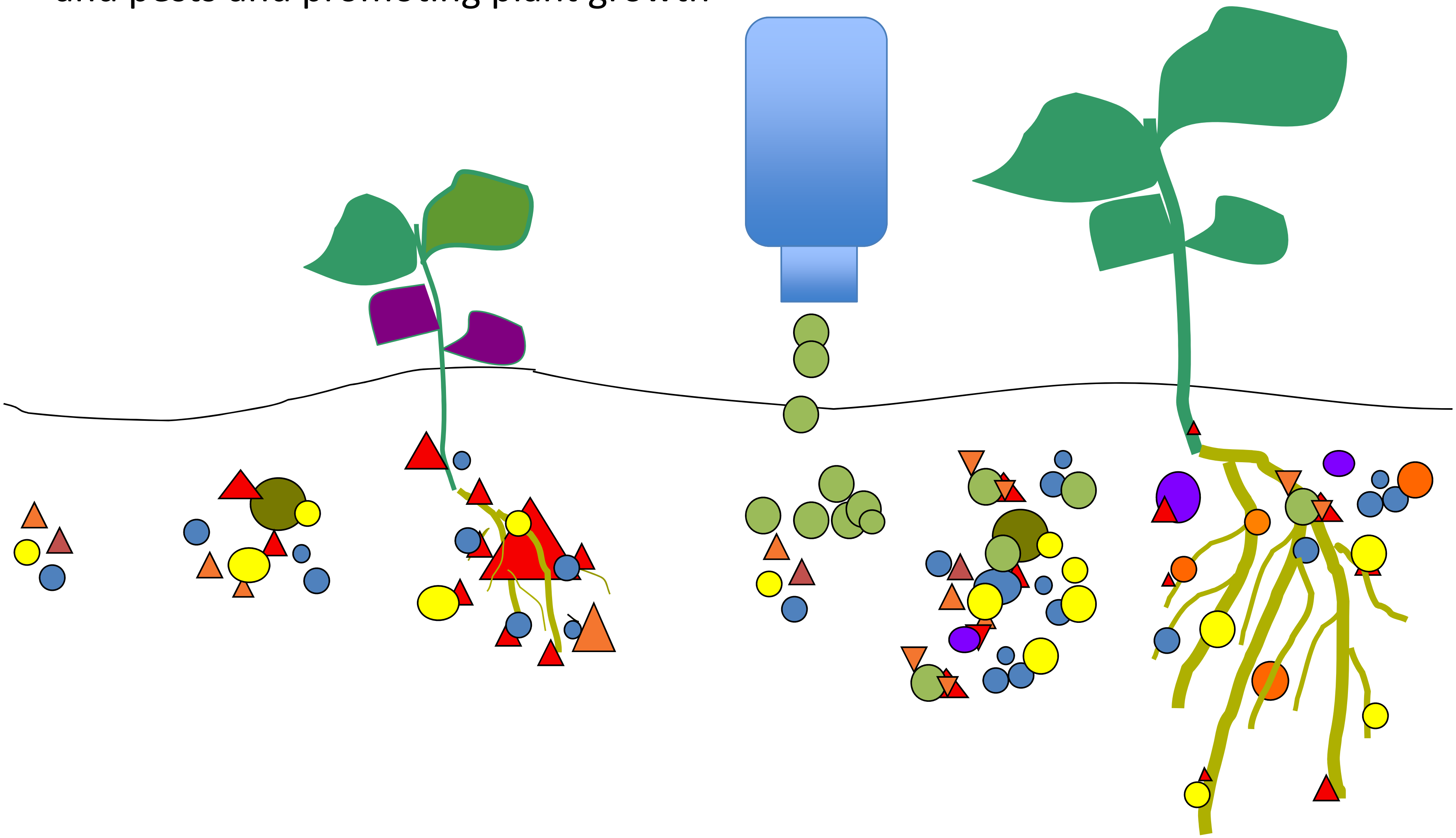
Host, environment, and pathogen interact to determine the level of disease observed

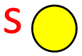


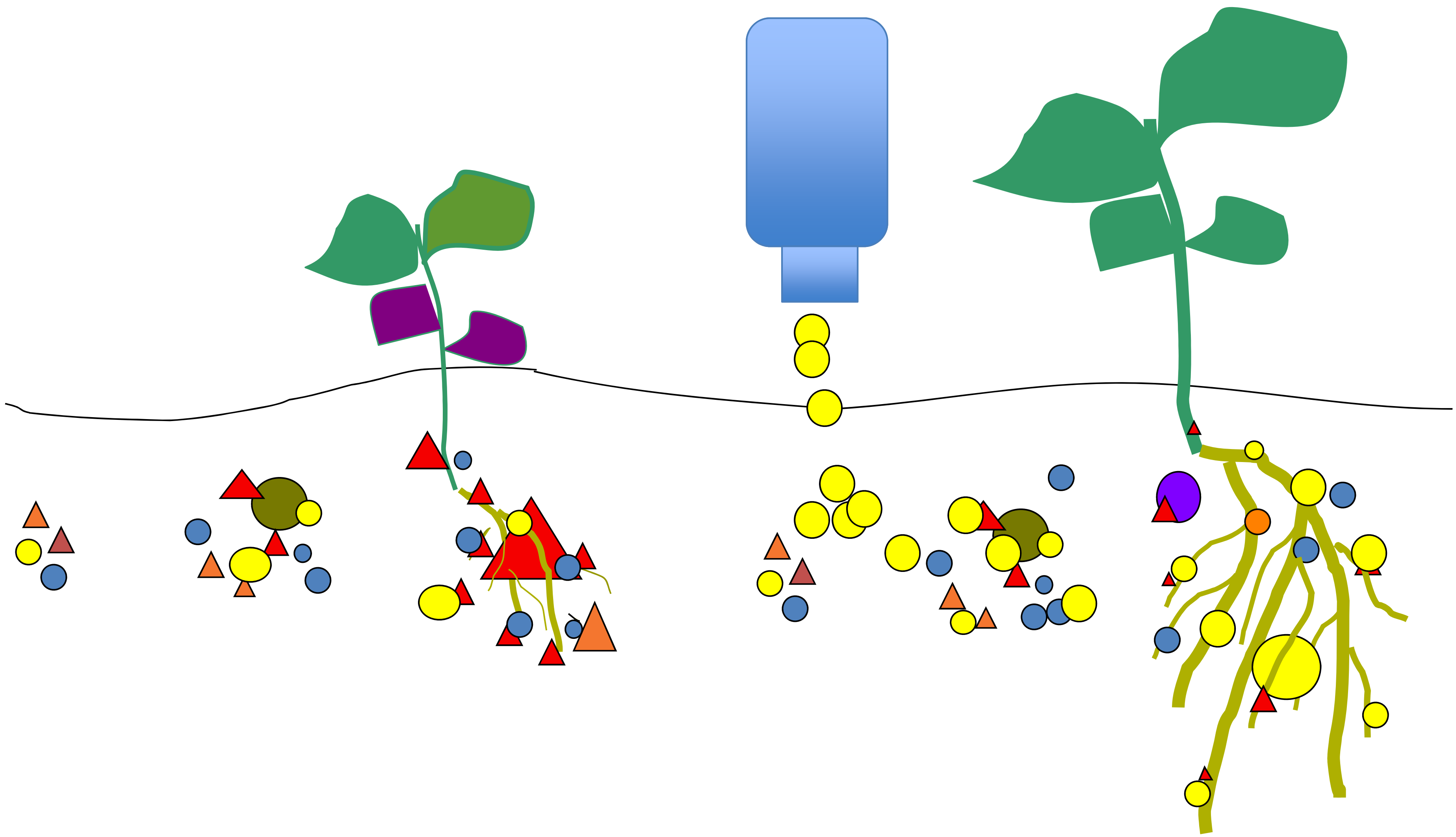
Inoculants may include essential mineral mineral nutrients ● that needed to support plant growth and development



Inoculants may include useful carbon, nutrients or other compounds that promote soil life thereby enhancing nutrient cycling and suppressing pathogens and pests and promoting plant growth



Inoculants may include beneficial microorganisms  that promote plant growth and/or health through a variety of mechanisms



Modes of Action

- Supplementing / rebalancing soil fertility
  - Sufficiency model vs. Albrecht/CEC model
    - How much does the crop need?
    - How much can the soil hold and deliver?
  - Both tend to focus on nutrient "pool size" as opposed to "cycling dynamics"
    - Amount, form, release, and uptake all matter
  - Both approaches require good soil testing to implement

Modes of Action

- Stimulating soil life
  - Soil life is very dynamic (day = 1-10+ generations)
  - Microbial growth and activity is sensitive to moisture, temperature, carbon, and nutrients
  - Weather, crops, and tillage *all* affect microbial community structure
  - Supplementing indigenous populations can
    - "jump start" nutrient cycling and crop growth
    - provide "biological buffering" against various stresses

Modes of Action

- Stimulating the crop directly
  - All active ingredients can affect the crop plant to some degree
  - Nutrients and carbon can alter root and/or shoot activity
  - Phytohoromones can alter crop growth dynamics
  - Addition of microbes can stimulate host immunity
  - “Beneficials” can increase available nutrients and protect plants from pests and diseases

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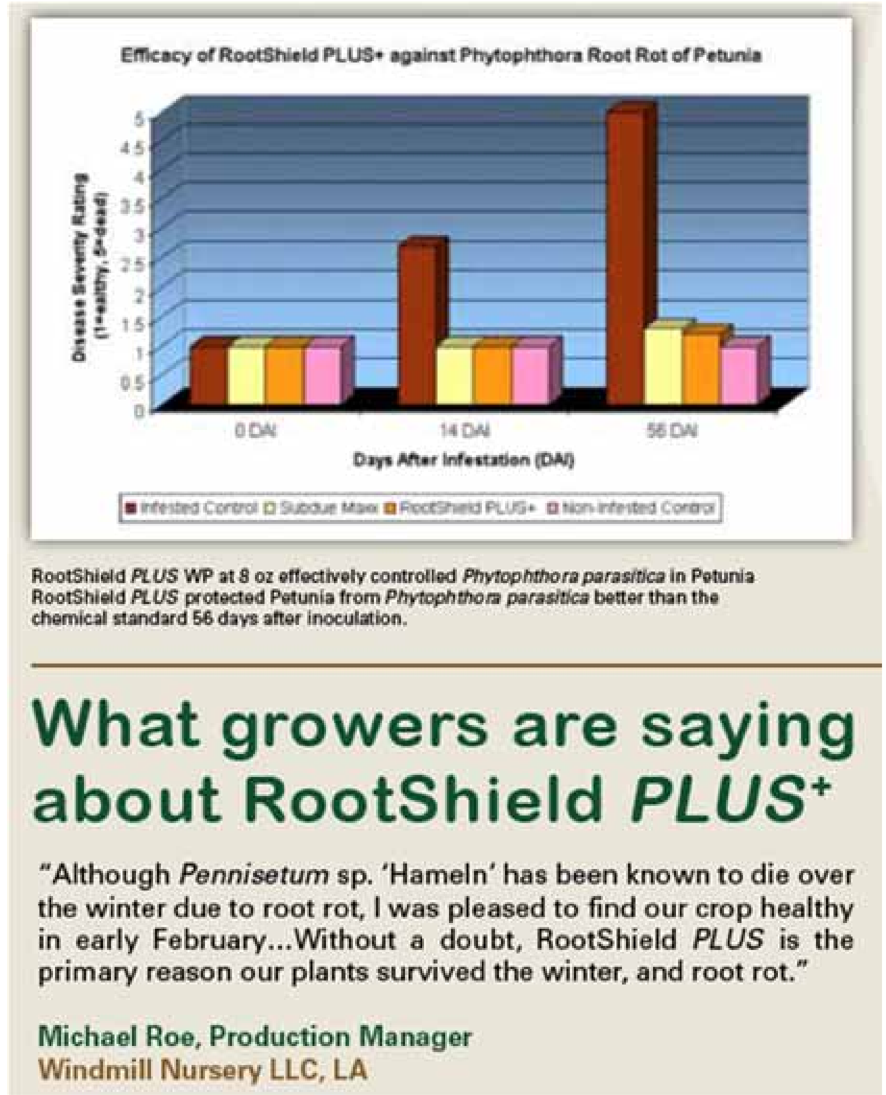
- When and where should organic growers use biofertilizers?

Show Me the Data

(and summarize it too)

- Data from industry
  - Graphs and tables showing significant improvements in growth, health, and/or yields
  - Testimonials by satisfied users
  - Good starting point for assessments of utility on your operation



Show Me the Data

- Data from Extension, ARS, and other University researchers
  - To the extent that NPK is a component, responses are consistent with the nutrient sufficiency model
    - **Manures, slaughterhouse/fish bioproducts, and mined minerals** are considered mostly in terms of nutrient chemistry
    - Grain size, incorporation, pH, and soil moisture delivery relevant to nutrient release rates
    - For manures care must be taken to minimize food safety risks

Show Me the Data

- Data from Extension, ARS, and other University researchers
  - For **composts**, value for soil improvement is multifold
    - Can enhance tilth and seed bed quality
    - Improve water relations
    - Provides slow release of nutrients (50/25/25 rule)
    - Can temporarily stimulate greater soil life

Show Me the Data

- Data from Extension, ARS, and other University researchers
  - For **algal and phytohormone containing products**, responses are more crop and environment dependent
    - Can sometimes enhance water holding capacity of soil
    - Can alter plant growth
    - May improve look of foliage
    - Can sometimes enhance plant immunity to pests and diseases
    - Cost effectiveness sometimes questioned

Show Me the Data

- Data from Extension, ARS, and other University researchers
  - For **microbial products**, responses are more crop and environment dependent
    - Over 100 years of scientific and industry experience demonstrates value to growers
    - Rhizobium inoculants of legumes will enhance yields in systems where N fertility is not oversupplied
    - Mycorrhizae will improve nutrient (especially P) relations especially in stressed soils

Show Me the Data

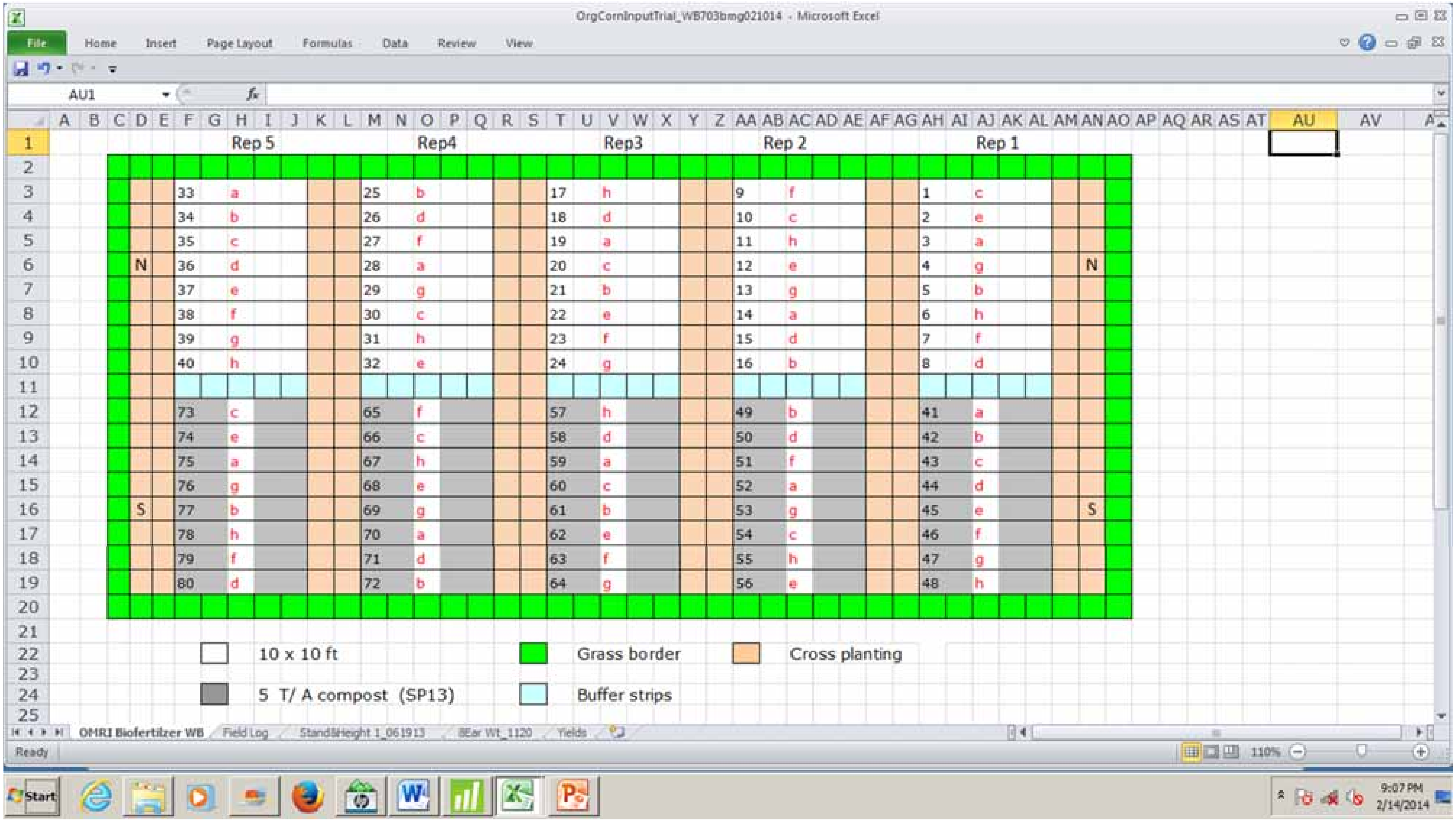
- Data from Extension, ARS, and other University researchers
  - For **microbial products**, responses are more crop and environment dependent
    - Registered biopesticides tend to have solid data set supporting efficacy
    - Mixed inoculants have not been demonstrated to be superior and sometimes lack good QC of ingredients
    - Products marketed as biostimulants / beneficials vary greatly in quality, scientific data support, and value

Show Me the Data

- Recent data from OSU

Demonstration Plots

Mixed Composition Biofertilizers



Soil and Growing Conditions

- Baseline soil fertility average for region, no evidence for imbalances
- Previous crop of alfalfa/clover mix
- Silt loam with ~50% to 95% crop needs for N provided by compost addition and rotation based on yield target of 150 bu/A of corn

Fal2012SoilTest			Bray P-1		Ammonium Acetate Extract					
			ug/g	ug/g	ug/g	ug/g	meq/100 g		Base Saturation	
ID	**pH**	**LTI**	**P**	**K**	**Ca**	**Mg**	**CEC**	**% Ca**	**%Mg**	**% K**
703 CORN	6.17	68.0	41.4	109.9	1127.8	194.6	9.9	56.7	16.3	2.8

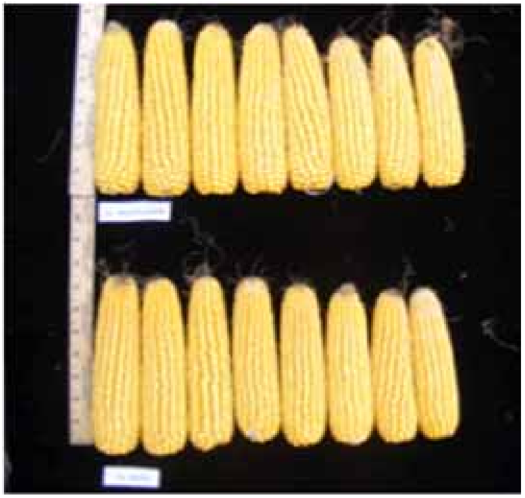
Procedures and Measurements

- Prepped and managed certified organic field according to SOPs
- Applied biofertilizers at planting and V4 per manufacturer’s instructions
- Assessed corn stands and plant height at V3
- Evaluated ear size and weight at harvest
- Compared moisture adjusted yields

- *Note: Good growing conditions and lower than average weed pressure in the plot*

Results from 2013 Demo Plots

- No significant differences noted in stand or seedling height
  - Biofertilizers did not accelerate early season growth in these plots
- No differences noted in ear size or weight
  - Biofertilizers did not dramatically affect yield-relevant growth characteristics in these plots



Potential Benefits at Harvest

Low Fertility Plots

Tmt	N	Yield (bu/A)
f	5	157.8 A
d	5	157.4 A
c	5	153.9 A
e	5	153.3 A
NC	5	152.7 A
b	5	152.4 A
g	5	151.5 A
a	5	147.3 A

High Fertility Plots

Tmt	N	Yield (bu/A)
e	5	166.3 A
c	5	165.4 A
a	5	161.8 A
f	5	161.1 A
NC	5	161.0 A
d	5	159.1 A
b	5	158.8 A
g	5	158.5 A

- Majority of biofertilizers outperformed NC (~3%)
- Elevated rates of V3 sprays may have reduced yields (<2%)
- Yields differed by baseline fertility (~5%)

Preliminary Take Home Messages

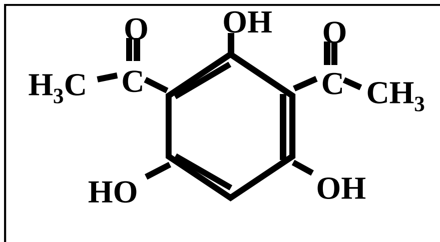
Mixed Composition Biofertilizer Demonstration

- Under good growing conditions, yield benefits likely to be < 5%
- Standard rates of biofertilizers may provide yield responses equivalent to larger equivalents of N applied as spring compost
- Elevated rates of post emergent seedling sprays may be counter productive
- More site years of data required before return on investment can be accurately calculated

Microbial Inoculant Development

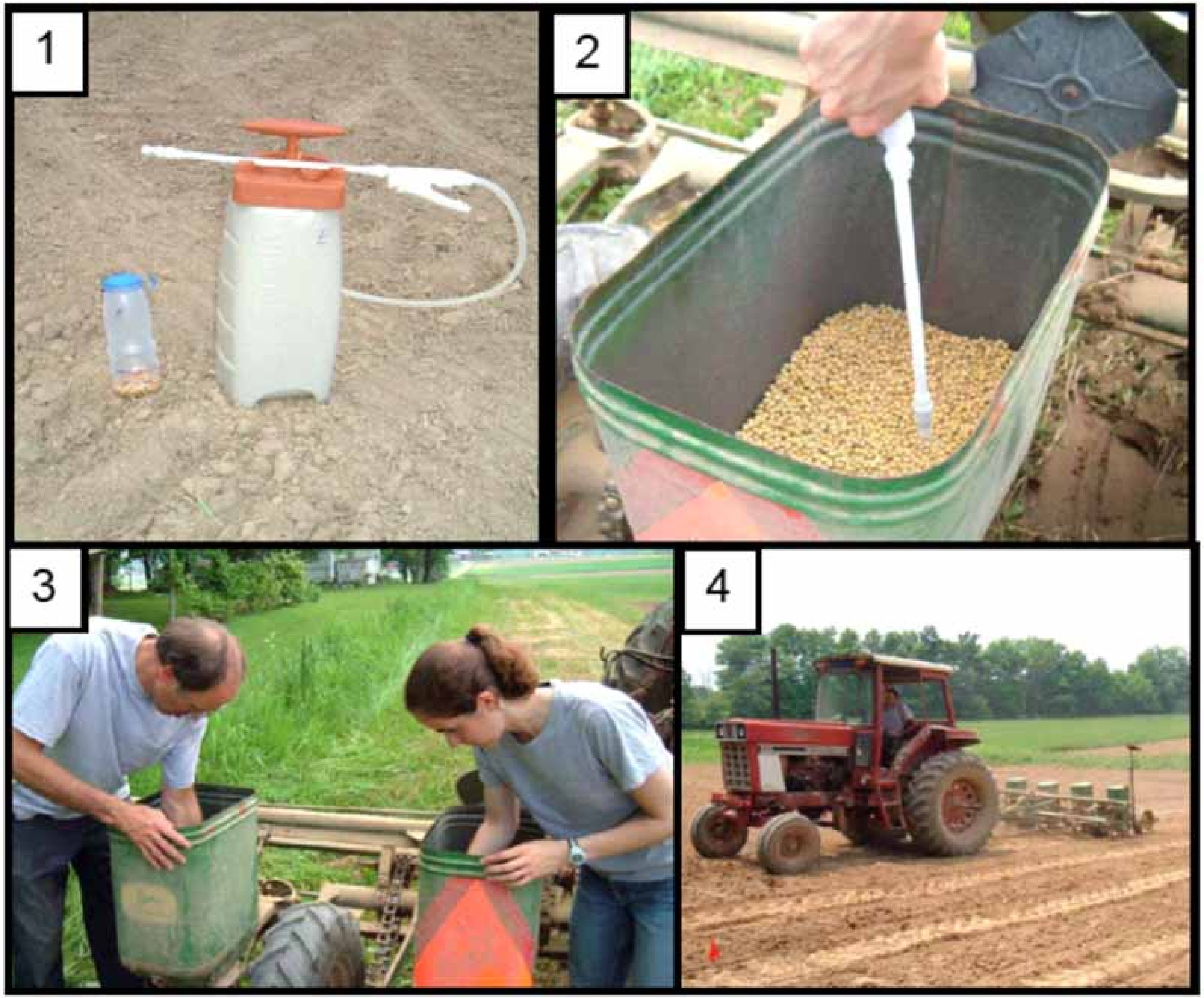
DAPG-producing *Pseudomonas* spp.

- A widespread plant-associated bacteria
  - Found in soils all over the world
  - Naturally present at 100 to 1,000,000 cells/g root
- DAPG is a multifunctional natural product
  - Produced on roots, but quickly degrades
  - Toxic to many plant pathogens
  - Can stimulate root growth and induce plant host defenses
- Application can increase crop productivity
  - Wheat yields in WA (Cook et al 2002)
  - Corn stand and yields in OH (McSpadden Gardener et al 2005a, Rotenberg et al 2007)
  - Soy yields in OH (McSpadden Gardener et al 2005b, 2005c, Raudales et al. 2009)



2,4-diacetylphloroglucinol
(DAPG)

Figure 1: Inoculating seed with DAPG-producing *Pseudomonas* strain for yield enhancement.



Field Trials on Organic Farms

Soybean (2005)

Table 1: Effects of inoculation of soybean seeds with DAPG-producing pseudomonads on organic farms.

Site	Cultivar	Treatment	DAPG-producers log cells / gram root	Yield bu/A
1A	Kottman	Treated	4.3	44.3
		Untreated	3.6	42.8
1B	Kottman	Treated	4.3	28.7
		Untreated	3.3	24.1
2	Vinton	Treated	5.3	38.7
		Untreated	4.6	35.0
3	Vinton	Treated	5.1	29.2
		Untreated	4.4	28.7
All sites combined		Treated	4.8	35.2
		Untreated	4.2	32.6

- Positive yield responses in ~70% of field trials
- Overall yield increases of ~ 5% on average

Translational Research

- Beneficial strains isolated from Ohio soils
- Ability to promote crop growth has been proven across several years in replicated field trials
- Unique formulation and delivery system that mimics natural processes to maintain viability and stimulate rapid growth


Take Home Messages

Translational Research

- Biofertilizer and microbial inoculant products are continuing to be developed
- Public private partnerships at OSU have led to the development of innovative and useful new products
- Independent testing and field validation will be continually needed to determine ROI for input users under diverse growing conditions

Outline

- What are biofertilizers?
- How do biofertilizers work?
- Are biofertilizers really effective?
- When and where should organic growers use biofertilizers?

Choosing Biofertilizers

(The 5 Gotta Knows)

- Know the NOP rules
- Know your soil
- Know your growing conditions
- Know your limits
- Know your options

Choosing Biofertilizers

- Know the NOP rules
  - **§ 205.203 Soil fertility and crop nutrient management practice standard**
  - "maintain or improve the physical, chemical, and biological condition of the soil and minimize erosion."
  - Manures: 120/90/0 day pre harvest rules
  - Composts: allowable feedstock, suitable heating and mixing, very low low coliform and Salmonella counts

Choosing Biofertilizers

- Know the NOP rules
  - **§ 205.206 Crop pest, weed, and disease management practice standard**
  - Use of a tiered approach in deciding how to deal with pest, weed, and disease problems.
  - Prevention
  - Mechanical and physical methods
  - Application of allowed materials
    - **Look from OMRI certification or check with your certifier**

Choosing Biofertilizers

- Know your soil
  - **Test *every one to three years* depending on intensity and complexity of production**
  - Obtain baseline data on soil type, structure, fertility, and organic matter
  - Track the data in one's organic system plan (crop, input, management, and harvest history)
  - Identify trouble spots to test and manage separately

Choosing Biofertilizers

- Know your growing conditions
  - Compare your productivity to neighbors, county averages and your own past history
  - Diagnose the causes of observed problems
  - *Determine if higher productivity is likely achievable*

Choosing Biofertilizers

- Know your limits
  - Determine if the application of biofertilizer inputs “fits” your operation and management style
  - Evaluate costs and likely benefits of an input
- Know your options
  - Identify multiple products that might fit your operation
  - Cost compare different sources for those products
  - Evaluate return on investment to ensure profitable use

Quiz Time

(What do you expect from a Professor?)

- What are biofertilizers?
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- Are biofertilizers really effective?
- When and where should organic growers use biofertilizers?

Summary

- Biofertilizers are a broad class of inputs that may include different types of ingredients
- As their name implies, biofertilizers *can* stimulate the biology and fertility of a farm
- The *value* of such products will depend heavily on your overall nutrient management plan, field history, and current quality of your soil

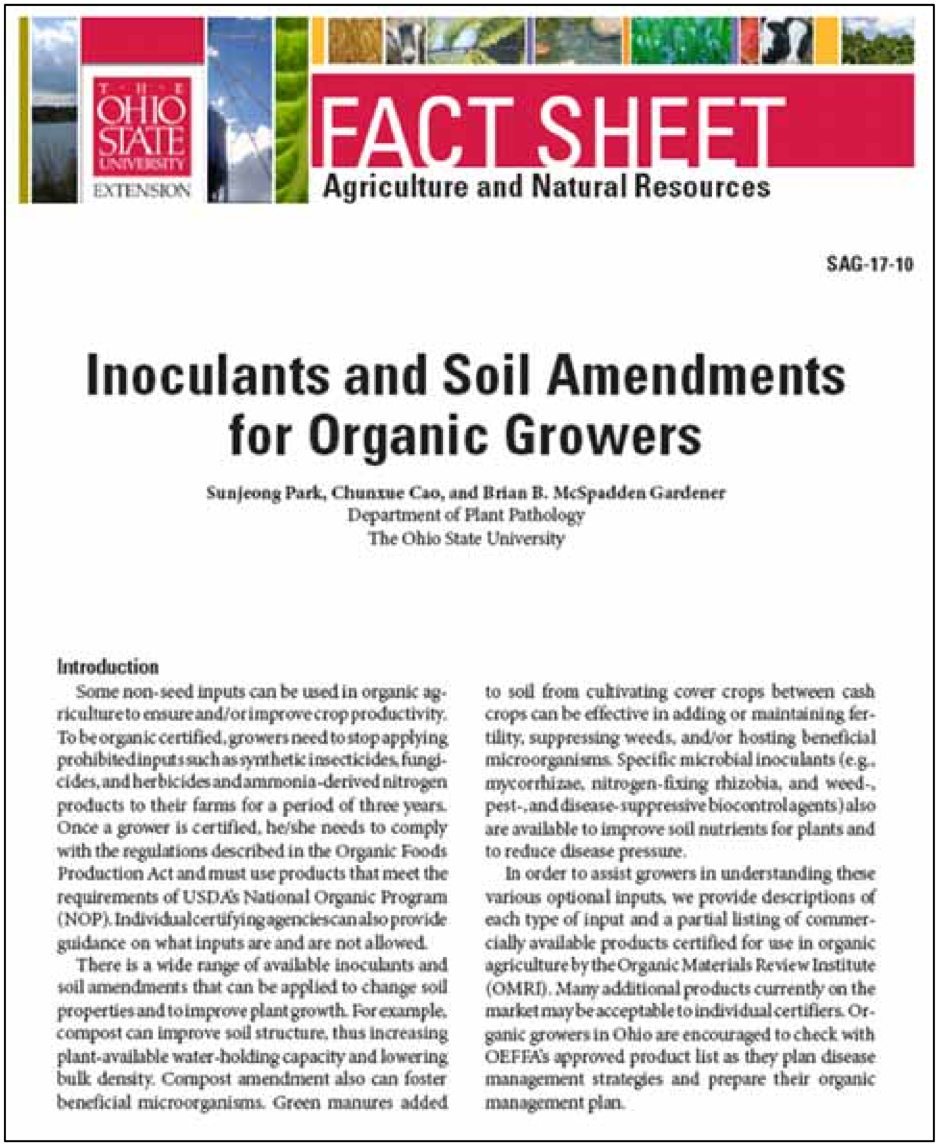
Summary

- Apply *approved* biofertilizers
  - Wherever crops are regularly experiencing a definable stress
  - To supplement and/or rebalance soil chemistry & biology
    - Preferably where weeds are already well managed
  - *Only* when and where the NOP rules allow
  - *Only* according to label specifications

Summary

- Ask useful questions
  - What are the active ingredient(s)?
  - How should the material to be stored and handled?
  - What consistency of a quality or yield response can one expect?
  - What is the expected return on investment?

Related Resources



FACT SHEET

Agriculture and Natural Resources

SAG-17-10

Inoculants and Soil Amendments for Organic Growers

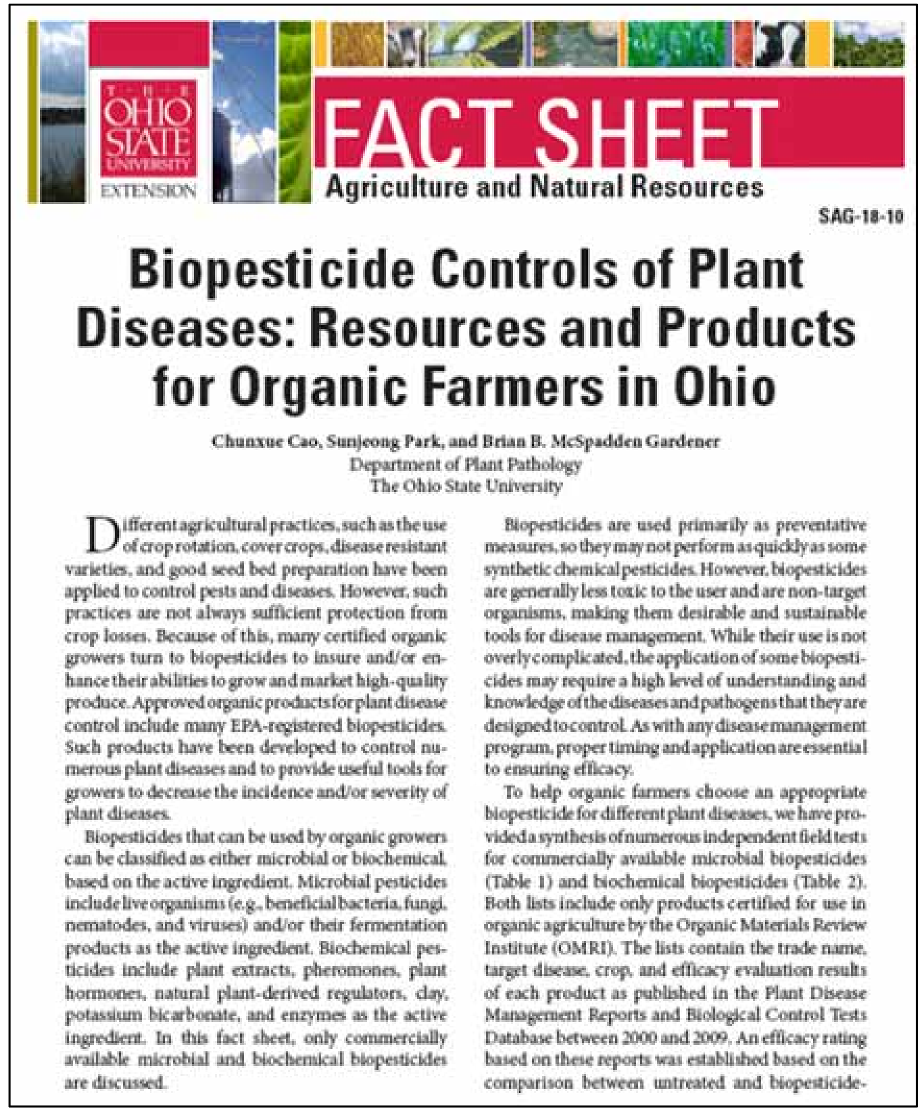
Sunjeong Park, Chunxue Cao, and Brian B. McSpadden Gardener
Department of Plant Pathology
The Ohio State University

Introduction

Some non-seed inputs can be used in organic agriculture to ensure and/or improve crop productivity. To be organic certified, growers need to stop applying prohibited inputs such as synthetic insecticides, fungicides, and herbicides and ammonia-derived nitrogen products to their farms for a period of three years. Once a grower is certified, he/she needs to comply with the regulations described in the Organic Foods Production Act and must use products that meet the requirements of USDA's National Organic Program (NOP). Individual certifying agencies can also provide guidance on what inputs are and are not allowed.

There is a wide range of available inoculants and soil amendments that can be applied to change soil properties and to improve plant growth. For example, compost can improve soil structure, thus increasing plant-available water-holding capacity and lowering bulk density. Compost amendment also can foster beneficial microorganisms. Green manures added to soil from cultivating cover crops between cash crops can be effective in adding or maintaining fertility, suppressing weeds, and/or hosting beneficial microorganisms. Specific microbial inoculants (e.g., mycorrhizae, nitrogen-fixing rhizobia, and weed-, pest-, and disease-suppressive biocontrol agents) also are available to improve soil nutrients for plants and to reduce disease pressure.

In order to assist growers in understanding these various optional inputs, we provide descriptions of each type of input and a partial listing of commercially available products certified for use in organic agriculture by the Organic Materials Review Institute (OMRI). Many additional products currently on the market may be acceptable to individual certifiers. Organic growers in Ohio are encouraged to check with OEFFA's approved product list as they plan disease management strategies and prepare their organic management plan.



FACT SHEET

Agriculture and Natural Resources

SAG-18-10

Biopesticide Controls of Plant Diseases: Resources and Products for Organic Farmers in Ohio

Chunxue Cao, Sunjeong Park, and Brian B. McSpadden Gardener
Department of Plant Pathology
The Ohio State University

Different agricultural practices, such as the use of crop rotation, cover crops, disease resistant varieties, and good seed bed preparation have been applied to control pests and diseases. However, such practices are not always sufficient protection from crop losses. Because of this, many certified organic growers turn to biopesticides to insure and/or enhance their abilities to grow and market high-quality produce. Approved organic products for plant disease control include many EPA-registered biopesticides. Such products have been developed to control numerous plant diseases and to provide useful tools for growers to decrease the incidence and/or severity of plant diseases.

Biopesticides that can be used by organic growers can be classified as either microbial or biochemical, based on the active ingredient. Microbial pesticides include live organisms (e.g., beneficial bacteria, fungi, nematodes, and viruses) and/or their fermentation products as the active ingredient. Biochemical pesticides include plant extracts, pheromones, plant hormones, natural plant-derived regulators, clay, potassium bicarbonate, and enzymes as the active ingredient. In this fact sheet, only commercially available microbial and biochemical biopesticides are discussed.

Biopesticides are used primarily as preventative measures, so they may not perform as quickly as some synthetic chemical pesticides. However, biopesticides are generally less toxic to the user and are non-target organisms, making them desirable and sustainable tools for disease management. While their use is not overly complicated, the application of some biopesticides may require a high level of understanding and knowledge of the diseases and pathogens that they are designed to control. As with any disease management program, proper timing and application are essential to ensuring efficacy.

To help organic farmers choose an appropriate biopesticide for different plant diseases, we have provided a synthesis of numerous independent field tests for commercially available microbial biopesticides (Table 1) and biochemical biopesticides (Table 2). Both lists include only products certified for use in organic agriculture by the Organic Materials Review Institute (OMRI). The lists contain the trade name, target disease, crop, and efficacy evaluation results of each product as published in the Plant Disease Management Reports and Biological Control Tests Database between 2000 and 2009. An efficacy rating based on these reports was established based on the comparison between untreated and biopesticide-

Link to Related Information

- Building Soils for Better Crops www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

- Soil Quality Test Kit ohioline.osu.edu/sag-fact/pdf/Soil_Quality_Test_Kit.pdf
- Interpreting a Soil Test Report ohioline.osu.edu/agf-fact/pdf/Interpreting_a_Soil_Test_Report_AGF-514-12.pdf
- Tri-State Fertilizer Recommendations ohioline.osu.edu/e2567/
- Ohio Livestock Manure Management Guide, ohioline.osu.edu/b604
- Testing Compost, ANR-15-03 ohioline.osu.edu/anr-fact/0015.html

- Inoculants and Soil Amendments ohioline.osu.edu/sag-fact/pdf/0017.pdf
- Biopesticide controls of plant diseases ohioline.osu.edu/sag-fact/pdf/0018.pdf