

# Best Bet Biopesticides for Organic Production

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# Outline

- Biopesticides
  - Types, Mechanisms, Applications
- 3 Steps towards Finding the Best Bets
  - Surveys and Studies
- Guidance for Organic Growers
  - Current advice and future activities

# What are biopesticides?

- **Pesticides that are derived from natural sources like plants, animals, and microorganisms**
  - Typically less hazardous to people and the environment than the most widely used chemical pesticides
  - Over 400 ingredients and ~\$2 billion sold each year around the globe ( = approximately 5% of the total pesticide market) and growing by 10% per year
  - Certified organic farmers may opt to use *approved* biopesticides to control pests and diseases



McGrath, Vallad, McSpadden Gardener 2010. eXtension

# Types of Biopesticides

by Active Ingredients

- Multifactorial microbial generalists
  - *Trichoderma* spp. (Diverse targets)
  - *Bacillus* sp. (Diverse targets)
  - *Streptomyces lydicus* (Diverse targets)
- Hyperparasitic microbial specialists
  - *Coniothyrium minitans* (targeting Sclerotinia diseases)
  - *Pasteuria* (targeting root knot nematode)
  - Entomopathogenic nematodes (targeting grubs)

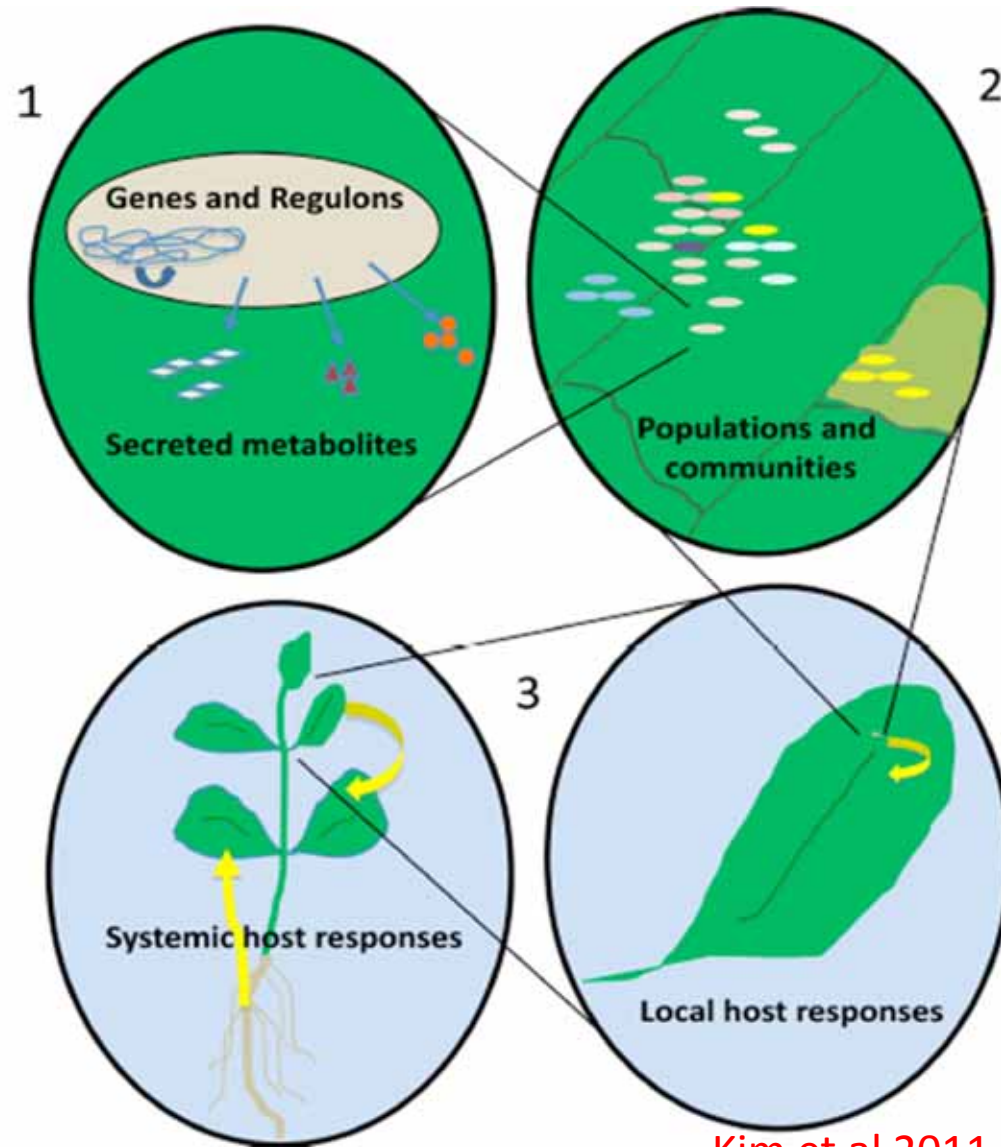
# Types of Biopesticides

by Active Ingredients

- Biochemical Co-formulates
  - Antibiotic-containing fermentation products (Diverse targets)
  - Plant and seaweed extracts (Plant targets)
  - EPA List4a biochemicals (Diverse targets)
- Plant Incorporated Protectants (GMO-based)
  - *Cry* genes (targeting Lepidoptera pests)
  - Chitinase genes (targeting fungal diseases)
  - Resistance and effector genes (diverse disease and pest targets)

# Mechanisms

## Multifactorial Nature



Kim et al 2011 *Appl. Environ. Microbiol.*

# Mechanisms

## Continuum of Direct to Indirect

Type	Mechanism	Examples
Direct antagonism	Hyperparasitism/predation	Lytic/some nonlytic mycoviruses <i>Ampelomyces quisqualis</i> <i>Lysobacter enzymogenes</i> <i>Pasteuria penetrans</i> <i>Trichoderma virens</i>
Mixed-path antagonism	Antibiotics	2,4-diacetylphloroglucinol Phenazines Cyclic lipopeptides
	Lytic enzymes	Chitinases Glucanases Proteases
	Unregulated waste products	Ammonia Carbon dioxide Hydrogen cyanide
	Physical/chemical interference	Blockage of soil pores Germination signals consumption Molecular cross-talk confused
Indirect antagonism	Competition	Exudates/leachates consumption Siderophore scavenging Physical niche occupation
	Induction of host resistance	Contact with fungal cell walls Detection of pathogen-associated, molecular patterns Phytohormone-mediated induction

# Strengths and Limitations By Type

- Multifactorial microbial generalists
  - Strengths
    - Promote more rapid/vigorous plant establishment and provide protection against diverse seedling pathogens
    - Diverse active ingredients available with multiple modes of action
  - Limitations
    - Modest and variable responses when used alone
      - Mitigated by integration with plant health management plan or system
    - Low activity per CFU and low control over population size
      - Mitigated by high inoculum rates, inoculating fresh cultures, or selecting for stable colonizers



# Strengths and Limitations By Type

- Hyperparasitic microbial specialists
  - Strengths
    - Specificity for target pest/pathogen
    - Lowers pathogen inoculum if persistent
    - Can be partially curative
  - Limitations
    - Requires high inoculum / endemic disease pressure to be valuable
      - Mitigated by applying only with high disease/pest pressure or persistent colonization of plant root zone
    - Must be compatible with full package of control methods
      - Mitigated with appropriate practices and inputs

# Strengths and Limitations By Type

- Biochemical co-formulates
  - Strengths
    - Can provide broad spectrum protection
    - Diverse actives with different modes of action
    - Some act as biostimulants of plant growth
  - Limitations
    - Limited activity of allowable EPA List4A ingredients
      - Mitigated by complementation with multiple materials
    - Inundative applications may lead to resistance
      - Mitigated by mixing or alternating actives/MOA

# Strengths and Limitations By Type

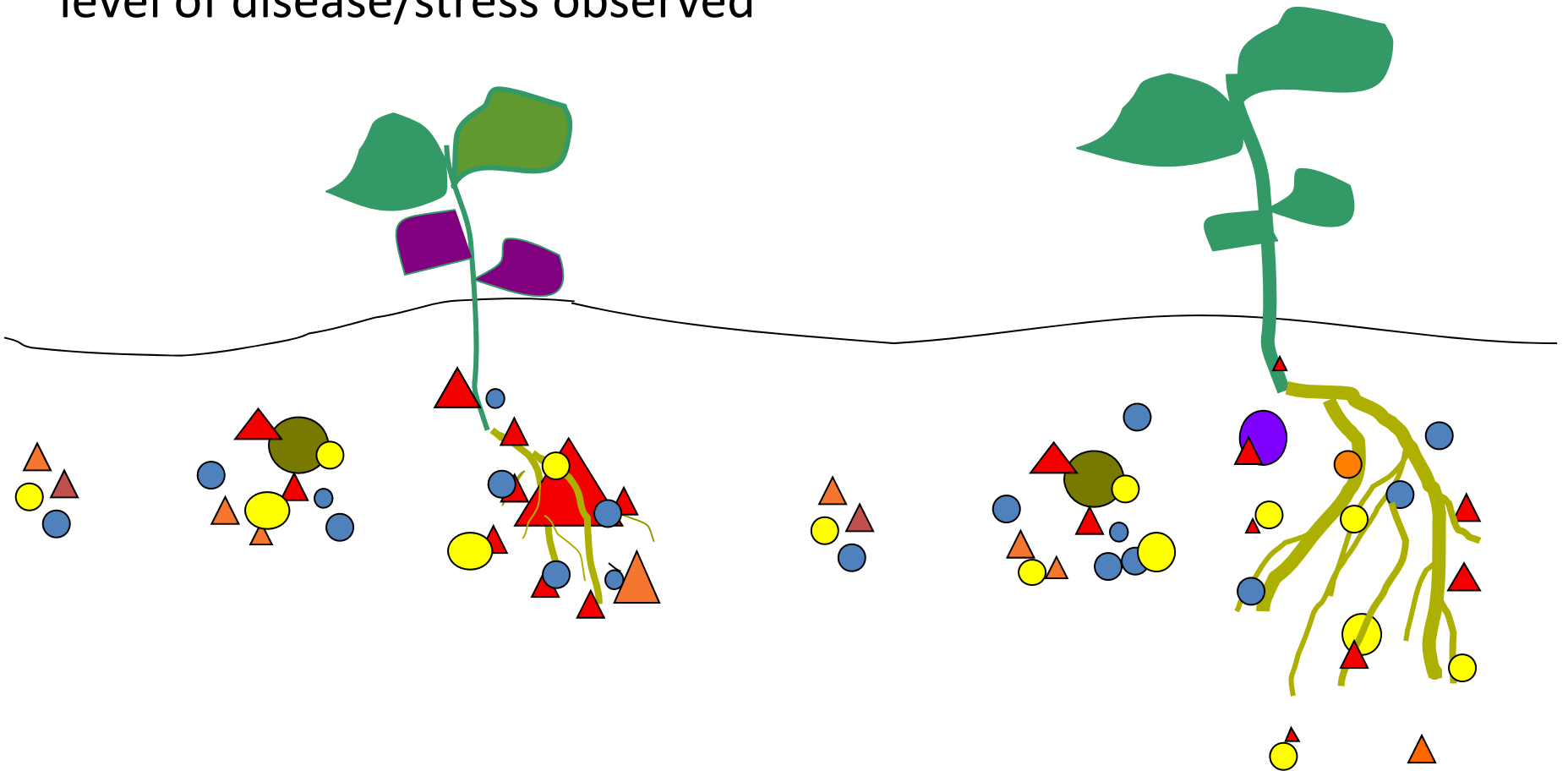
- Plant Incorporated Protectants (GMO-based)
  - Strengths
    - Whole plant protection
    - Potentially tissue specific and/or inducible
  - Limitations
    - **Not compliant with certified organic agriculture**
      - Mitigated by application to fiber, fuel, and conventional feed and food crops
    - Limited control over expression levels
      - Mitigated by selecting and propagating constitutive expressers that balance need for activity with yield drag
    - Rapid resistance development in the absence of refuges
      - Mitigated with refuges and mixed cultivar plantings
    - Reduction in beneficial fungal colonization
      - Mitigated by inoculation and/or supplemental inputs

# Consider a General Ecological Model

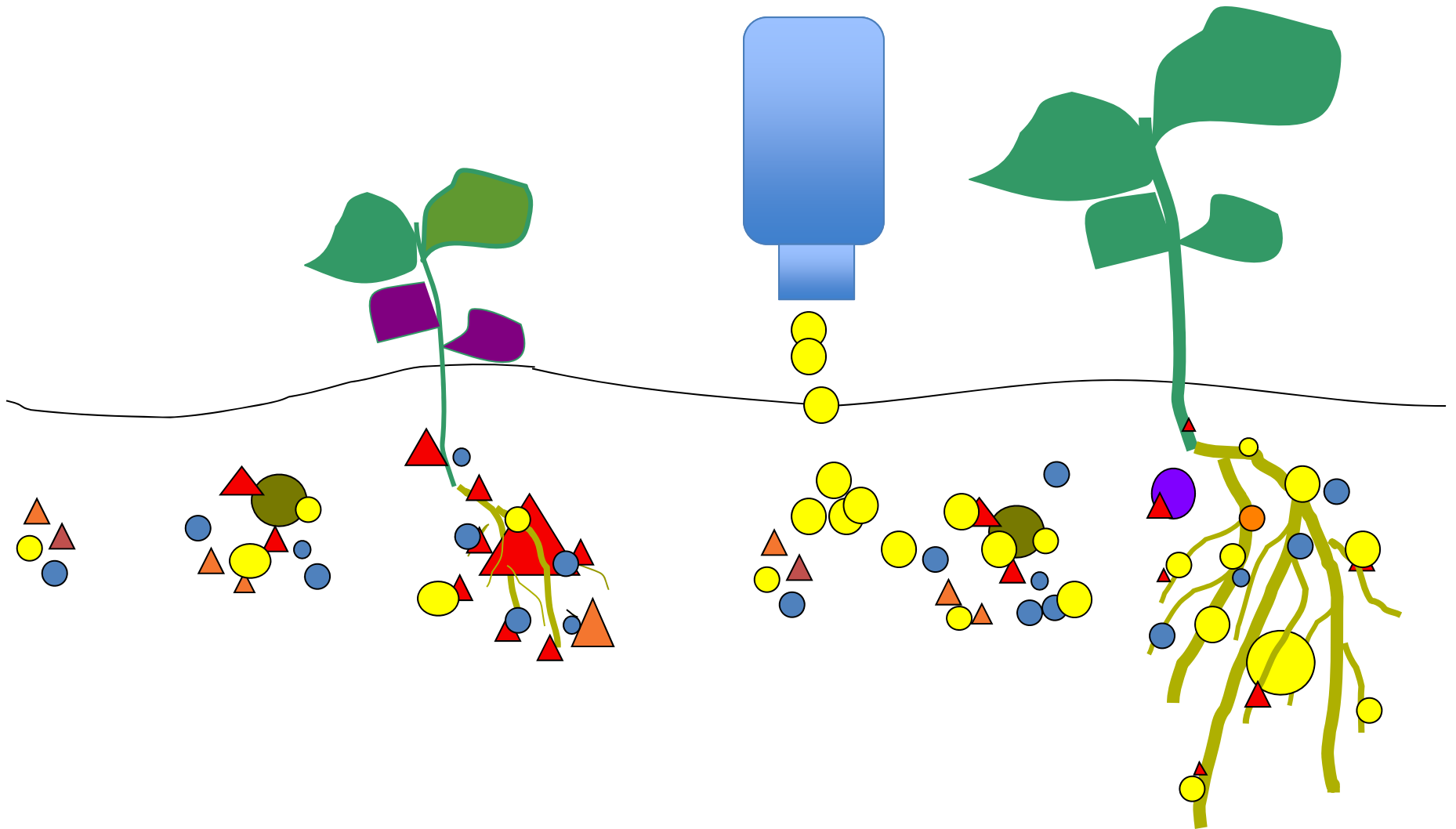
Microbial communities develop around each plant

A mix of pathogens ▲ and beneficials ● determine plant health

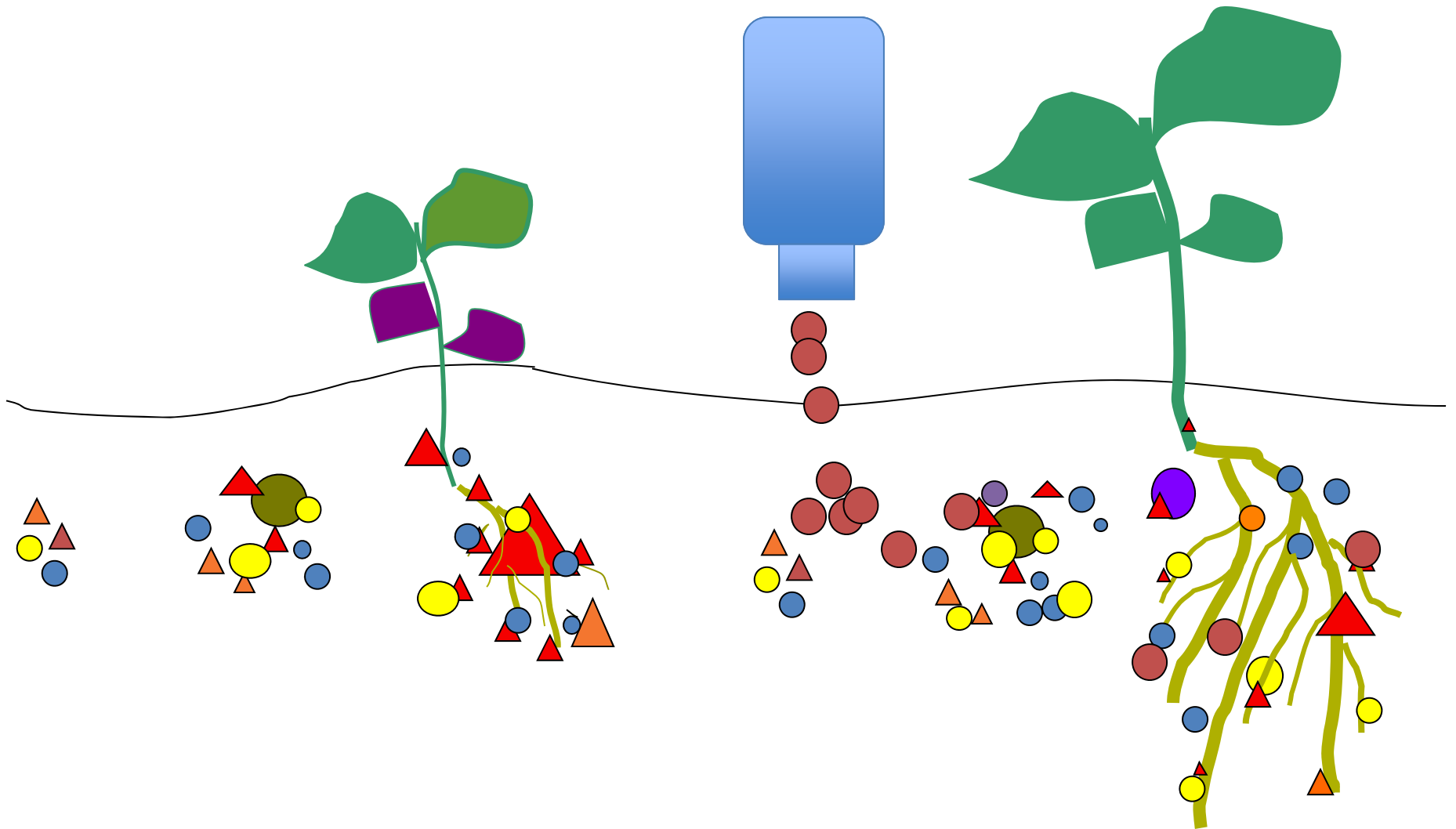
Host, environment, and pathogen/pests interact to determine the level of disease/stress observed



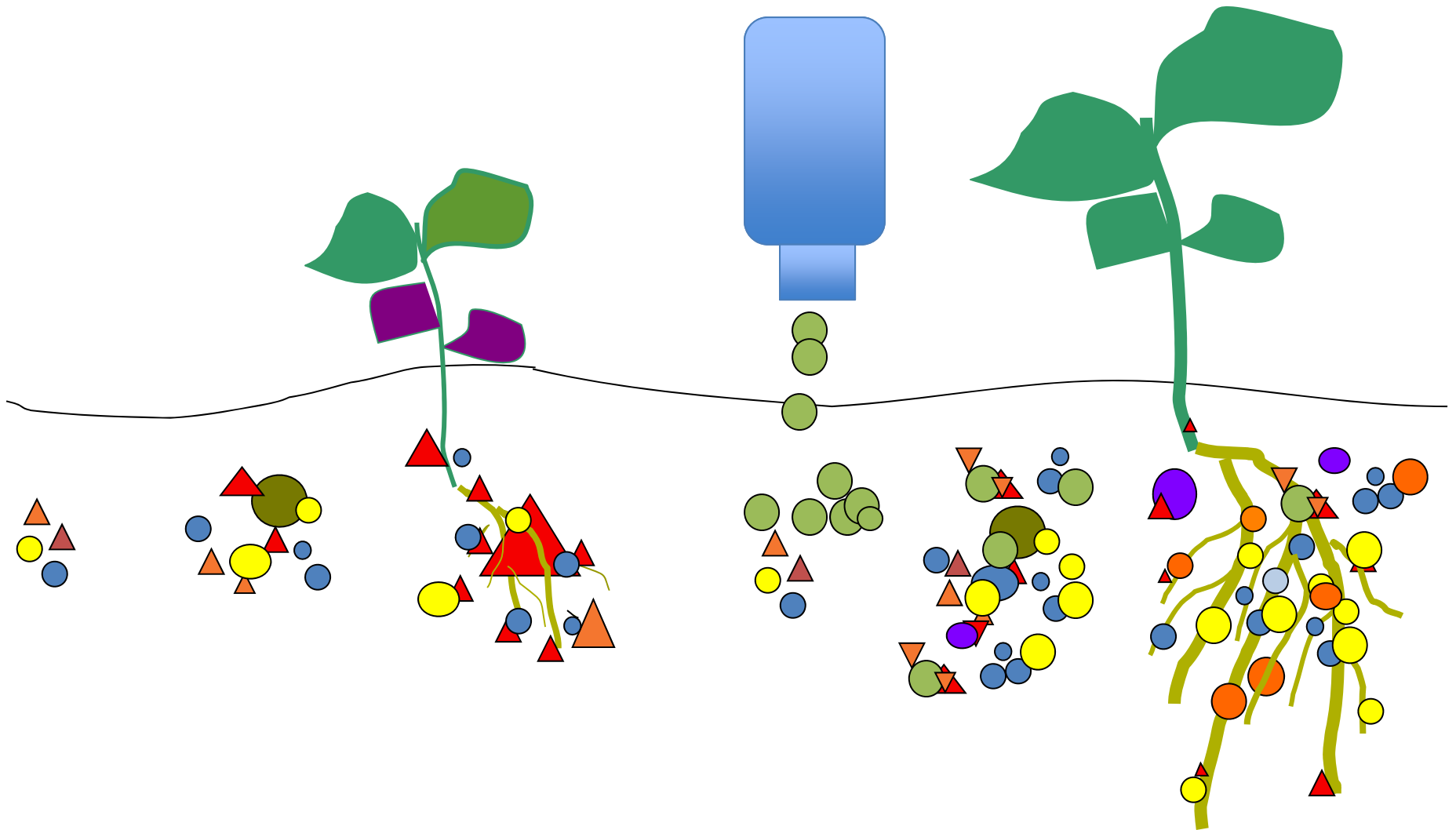
**Products** may include **beneficial microorganisms** ● that promote plant growth and health through a variety of mechanisms



**Products** may include essential mineral nutrients, amino acids, or phytohormones ● that support root growth and development



**Products** may include **mixtures of compounds** ● that stimulate **soil biology**; enhancing nutrient cycling, altering WHC, and/or suppressing pathogens and pests to promote plant health



# Biopesticide Applications

## Inoculative Approaches

- Seed, soil, and compost treatments
  - Applications pre bagging (1 to 18 month)
  - Applications closer to planting (<1 month)
- In hopper/at planting treatments
  - In the hopper (flowable powder, liquid)
  - Transplant dips (liquids/powders)



# Biopesticide Applications

## Inundative Approaches

- In furrow/potting mix incorporation
  - Flexible rate at planting/ potting (on site)
  - Controlled rate pre-bagging (6 – 24 month)
- Post planting drenches/fertigation
  - Blending with fertility and/or pesticides (liquids)
  - Controlled frequency and rates (alternate, weekly)

# Strengths and Limitations By Application

- Seed, soil, and compost treatments
  - Strengths
    - Convenient for diverse end users
    - Can use all Types of active ingredients
  - Limitations
    - Stability during distribution and storage
      - Mitigated by use of high inoculum rates and formulation adjustments
    - Limited volume of application to seeds
      - Mitigated by seed coatings and pelleting

# Strengths and Limitations By Application

- In hopper/at planting treatments
  - Strengths
    - Allows for “last minute” addition to protect against unexpected stresses
    - Supports more controlled delivery of “less durable” actives
  - Limitations
    - Requires additional handling and thoughtful timing by grower
      - Mitigated by automating on-site treatment and clear label instructions

# Strengths and Limitations By Application

- In furrow/potting mix incorporation
  - Strengths
    - Inundative applications possible in a spatially-defined root zone
    - Compatible with all Types of active ingredients
  - Limitations
    - Heterogeneity of soils and potting mixes limits control provided by live microbials
      - Mitigated by high inoculation rates, selecting for good rhizosphere colonists, and physiological priming

# Strengths and Limitations By Application

- Post-planting drenching and chemifertigation
  - Strengths
    - Exquisite control of timing and rate
    - May be compatible with all Types of active ingredients
  - Limitations
    - Limited to irrigated and/or hydroponic production
      - Mitigated by carefully identifying customers with root disease and pest problems
    - Needs to be compatible with water and fertilizers used
      - Mitigated by alternating applications and proper flushing/cleaning

# Outline

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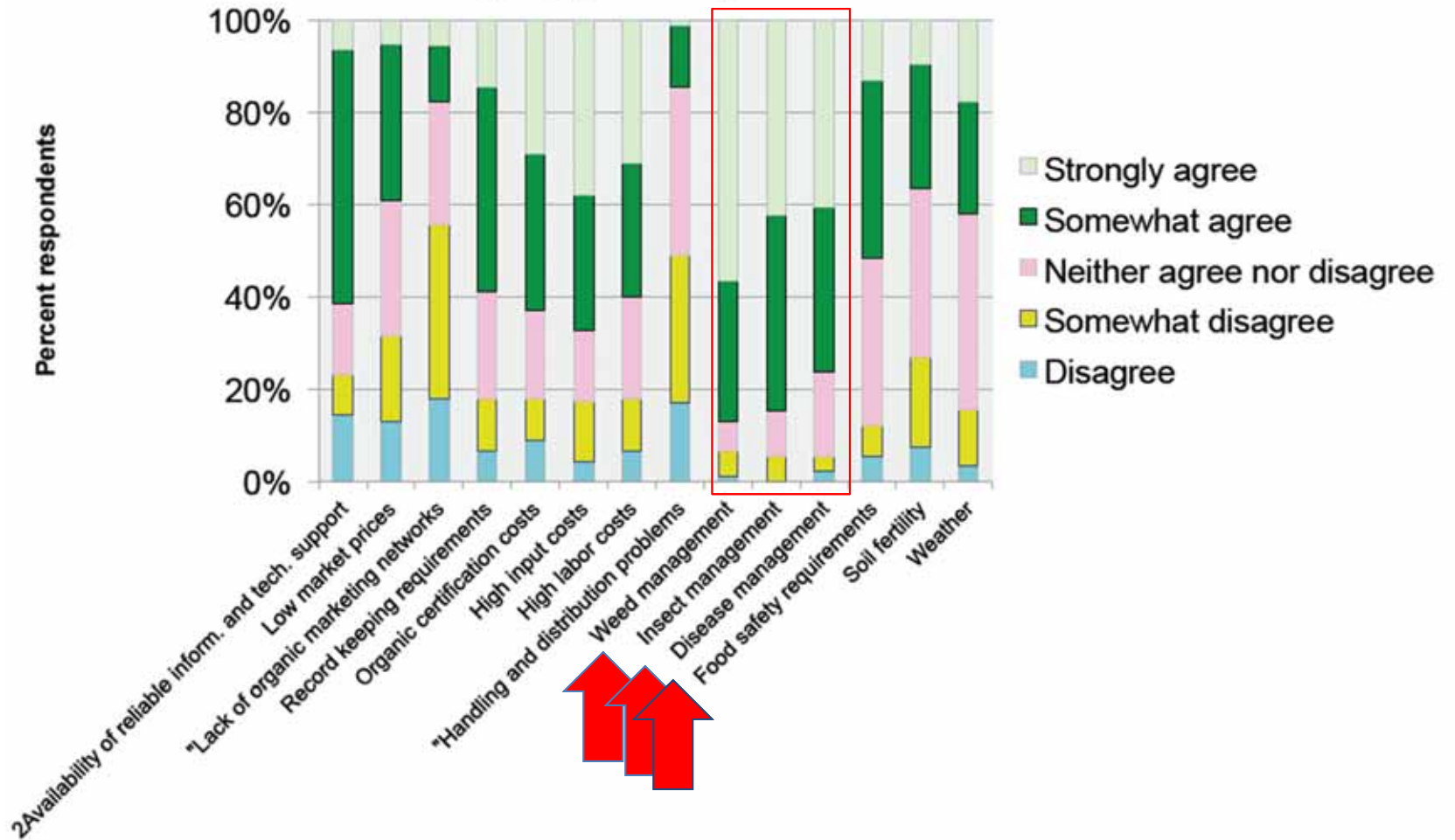
# First step to finding the best bets...

## 2011 Organic Vegetable Grower Survey

- **Topics covered:** cover crops, disease management, microbial inoculant and **biopesticide use**
  - 40 Multiple choice and 10 open-ended questions
  - 93 respondents (29% response rate) from throughout North Central and Northeastern Region
  - 71% vegetable farmers, with ~45% listing tomato as top crop in acreage and/or value
  - 57% listed tomato as the crop with biggest disease problems

# Challenges to Crop Health and Productivity

Fig. 2. To what extent do you agree or disagree that the following factors are challenges or obstacles you face in managing your organic farm?





# Bioproduct Use

by Organic Vegetable Growers

- Nearly half of organic growers use microbial biofertilizers and/or biopesticides
  - 43% used inoculants and 49% used biopesticides
    - Inoculants used primarily for legume crops, but also applied to other crops
    - Biopesticides used mainly for foliar diseases and pests
    - 51% thought cost justified use
    - 74% waited until after symptom appearance to make application

# Second step to finding the best bets...

## 2014 Class Review of Published Reports Plant Management Network

- **Topics covered:** Evaluation of **efficacy of 8 well studied biopesticides** in University trials reported over the past 14 years
  - Data obtained from Plant Management Network's Plant Disease Management Reports and Biological & Cultural Tests
  - Over 200 independently published reports examined
  - 286 product assessments completed
  - 18 to 84 reports per biopesticide product
  - Comparisons made to control treatments in each trial
  - Evaluations typically conducted on conventionally managed land

# Plant Management Network

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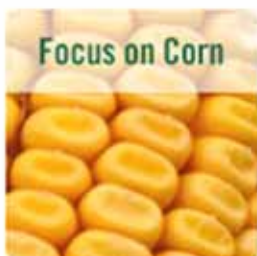
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Education Center



Efficacy Trials



Efficacy Trials



Proceedings



Image Database

# Summary of 286 Reports

Data	Product	# of Reports	Crops	Volumes
SD	Votivo	33	corn soy cotton	4 to 8
RM	SoilGard	39	17 different	2 to 8, 16 to 21, 55 to 61
MB	PlantShield	30	18 different	1 to 3, 17 to 21, 57 to 61
MI	Actinovate	42	tomato, strawberr	1 to 8
NS	Sonata	18	tomato	1 to 7, 18 to 21, 58 to 60
FE	Serenade	51	tomato	1 to 7, 16-19, 57 to 61
DG	Serenade	33	strawberry	1 to 8, 50, 55 to 61
RK	Contans	32	Lettuce +	1 to 8, 16 to 17, 21, 58 to 61
JL	Milstop	30	15 different	1 to 8, 59 to 61

The data sets for most widely advertised biopesticides  
are indicative not comprehensive  
(i.e. data does not cover all labeled crops or diseases)

# Summary of 286 Reports

<b>Product</b>	<b>% Positive</b>	<b>Sig % Pos.</b>	<b>% Negative</b>	<b>Sig % Neg.</b>
Votivo	48	15	52	0
SoilGard	62	36	38	8
PlantShield	60	17	40	3
Actinovate	83,96	28,35	17,4	0,0
Sonata	61	6	39	6
Serenade	94	33	6	0
Serenade	67	21	33	6
Contans	78	38	22	0
Milstop	80	47	20	3

Most reports show biopesticides to have positive efficacy relative to the controls but less than half are statistically significant results

# Variation by Crop

Product	Crop	# of Reports	% Positive	Sig % Pos.	% Negative	Sig % Neg.
Votivo	Corn	7	57	0	43	0
	Cotton	18	39	11	61	0
	Soy	8	63	37	37	0
Actinovate	Strawberry	23	96	35	4	0
	Tomato	18	83	28	17	0
Serenade	Strawberry	33	67	21	33	6
	Tomato	51	94	33	6	0

Biopesticides can be more effective on some crops than others

# Product Comparisons

Product	Crop	# of Reports	% Positive	Sig % Pos.	% Negative	Sig % Neg.
Actinovate	Strawberry	23	96	35	4	0
Serenade	Strawberry	33	67	21	33	6
Actinovate	Tomato	18	83	28	17	0
Serenade	Tomato	51	94	33	6	0
Sontata	Tomato	18	61	6	39	7

Only a few products have been evaluated frequently enough to make statistically robust comparisons and retain the caveats of “on station” trials which define the data set

# Third step to finding the best bets...

## OFFER/OEFFA Survey of Bioproduct Inputs

- **Topics covered:** Adoption and **use patterns of bioproducts** by organic growers in the region from 2009 to 2014
  - >100 OSPs representing Ohio vegetable growers examined
  - >165 inputs noted to date (**3 microbial biopesticides, 22 biochemical biopesticides, 8 microbial inoculants**)
  - Changes in use rates will be evaluated using 47 paired comparisons of past two OSPs
  - Variation in use rates will be evaluated comparing newly certified farms versus more established farms
  - Geographic variation in use rate will be assessed across different eco-regions



# Data Collected

- Input name & brand
- Ingredients
- Input type
- Input function
- Application method (seed treatment, soil amendment, etc.)
- Source (on-farm, neighboring farm, distributor, etc.)



# Project Status

- IRB Approval ✓
- Data Collection ✓
  - 47 farms with 2 OSP years
  - 38 farms with 1 OSP year
  - Total of 132 OSPs
- Data Entry
  - Will complete in February
- Data Analysis
  - Will complete by the end of the semester

C. PEST MANAGEMENT PLAN

What are your problem pests?

rodents  gophers  birds  insects (list)

Other animals (list) DEER / GROUND HOGS

No pest problems

Do you work with a pest control advisor?  Yes  No

If yes, please provide name and contact information:

What strategies do you use to control pest damage to crops?

None  crop rotation  selection of plant species/varieties  timing of planting  companion planting

development of habitat for natural enemies  frog ponds  bat houses  bird houses  hand picking

monitoring  trap crops  physical barriers  physical removal  traps  lures  IPM

insect repellents  animal repellents  release of predators/parasites of pest species  use of approved

use of restricted products  limited use of prohibited products  Other (specify) PLANT ENOUGH TO FEED THEM

Do you keep a record of how often you utilize these pest control methods (i.e. dates when you scout or apply in a field or crop)?  Yes  No

# Preliminary Results

12 farms x 2 OSPs

- Microbial bioproducts (rhizobia, mycorrhizae, etc)
  - 50% farms used at least once
  - 17% used more than one product
- Microbial biopesticides
  - 25% farms used at least once
  - 8% used more than one product
  - Used most by farms with diverse input usage

# Preliminary Results

12 farms x 2 OSPs

- **Biochemical Biopesticides**
  - 92% used at least once
  - 92% used more than one product
  - Commercial products used much more frequently than “home brews”
- **Consistency of use**
  - Most farms reported using same inputs on both OSPs
  - More inputs per farm reported in most recent cycle

# Outline

- Biopesticides
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- **Guidance for Organic Growers**
  - **Current advice and future activities**

# Guidance to Organic Growers

Regarding Adoption Biopesticide Inputs

- Know the NOP rules
- Know your soil and crop history
- Know your growing conditions
- Know your limits
- Know your options



# Guidance to Organic Growers

- 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: provide *multiple* benefits to soil and plants; but make sure source provides reliable quality
  - **Application of allowed materials**
    - **Look from OMRI certification or check with your certifier**

# Guidance to Organic Growers

- 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 (an ounce is worth a pound of cure!)
  - Mechanical and physical methods
  - **Application of allowed materials**
    - **Look from OMRI certification or check with your certifier**



# Guidance to Organic Growers

- Know your soil and crop history
  - 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 disease/pest problems and management as well as marketable yields in one's organic system plan (crop, input, management, and harvest history)
  - Identify trouble spots to test and manage separately

# Guidance to Organic Growers

- Know your limits
  - Determine if the application of biopesticides “fits” your operation and management style
  - Evaluate costs and likely benefits of an input in terms of marketable yield improvements



# Guidance to Organic Growers

- Know your options
  - Identify the types of products that fit your operation's needs
  - Look for data supporting efficacy
  - Evaluate your return on investment to ensure profitable use



# Link to Related Information

- [Biopesticide controls of plant diseases](http://ohioline.osu.edu/sag-fact/pdf/0018.pdf) ohioline.osu.edu/sag-fact/pdf/0018.pdf
- [Inoculants and Soil Amendments](http://ohioline.osu.edu/sag-fact/pdf/0017.pdf) ohioline.osu.edu/sag-fact/pdf/0017.pdf
- [EPA's What are biopesticides?](http://www.epa.gov/oppbppd1/biopesticides/whatarebiopesticides.htm)  
http://www.epa.gov/oppbppd1/biopesticides/whatarebiopesticides.htm
- [Biopesticide Industry Alliance](http://www.biopesticideindustryalliance.org) http://www.biopesticideindustryalliance.org
- [Industry report Biopesticides Primed for Growth](http://www.meistermedia.com/biopesticidesreport/)  
http://www.meistermedia.com/biopesticidesreport/
- [IR-4 Searchable Database of Biopesticides](http://www.ir4.rutgers.edu/Biopesticides/LabelDatabase/index.cfm)  
http://www.ir4.rutgers.edu/Biopesticides/LabelDatabase/index.cfm

