61 Tomato / Pepper / Eggplant

Where: Grand Gallery Room A & B
MI re-certification credits: 2 (IB, COMM CORE, PRIV CORE)
OH re-certification credits: 0.5 (presentations as marked)
CCA Credits: NM (1) PM (0.5) SW (0.5)
Moderator: Ron Goldy, Michigan State University

9:00 AM **Cover Crops Do More Than Just Cover For Your Soil**
- Laura Van Eerd, University of Guelph

9:30 AM **Biodegradable Plastic Mulches Are Effective and Sustainable**
- Carol Miles, Washington State University

10:00 AM **Use the Right Tools to Battle Bacterial Blight (OH 2B, 0.5 hr)**
- Mary Hausbeck, Michigan State University

10:30 AM **Biostimulants: What Are They and Can They Help My Plants?**
- Lori Hoagland, Purdue University
- Liz Maynard, Purdue University

11:00 AM **Session Ends**

Use the Right Tools to Battle Bacterial Blight

Mary K. Hausbeck (517-355-4534)
Michigan State University, Department of Plant, Soil and Microbial Sciences

Michigan ranks 5th in the U.S. for tomato production and tomatoes are grown in the Great Lakes region for both the fresh market and processing industries. Bacterial spot, bacterial speck, and bacterial canker of tomato appear regularly in Michigan. Each disease can affect plant productivity, reduce yield, and/or cause fruit disorders. Disease management is similar for all three diseases. First, tomato transplants must be disease-free. This may be accomplished by using disease-free seed grown under a strict sanitation regime in the greenhouse. While field management strategies are also recommended, the most effective programs are those that begin in the greenhouse.

Symptoms of bacterial canker (caused by *Clavibacter michiganensis* subsp. *michiganensis*) on tomato depend on the age of the plant. Infected transplants show a light brown "blistering" on the petiole and browning of the midvein. Infected transplants can also appear healthy and not show any symptoms. On older infected tomatoes, sometimes the leaflets wilt on one half, while the other leaflets remain healthy. There can also be browning of the leaves, especially around the margins; this is commonly referred to as the "firing stage" of the disease. When the stem of an infected plant is cut open, a slight browning or discoloration of the internal tissue may be seen once the disease has really progressed. Infected fruits show a "birds-eye" spotting which begins as small, white dots. As the spots get larger, the centers die and turn dark, giving a "birds-eye" effect. Plants infected with bacterial canker do not always show these fruit lesions. While it may be difficult to diagnose bacterial canker based on any one symptom (except for birds-eye lesions on the fruit), when two or more of these symptoms appear in a plant, they are likely the result of bacterial canker infection. A university diagnostic clinic can assist in making the final diagnosis.

Bacterial spot (caused by *Xanthomonas* spp.) causes spots or blotches on the leaves and stems. The spots may have tan centers and are a maximum of ¼ inch in diameter. However, some years these spots/lesions may be very dark in color. Michigan growers can experience significant yield losses and devastating fruit spotting due to bacterial spot. In the field, the most diagnostic symptoms occur on fruit and include black spots or scabs that may be slightly raised and rough to the touch. This pathogen may be seedborne.

Bacterial speck (caused by *Pseudomonas syringae* pv. *tomato*) develops as small dark-brown spots occurring on the leaves and each spot may be surrounded by a yellow "halo." Although bacterial speck may not produce the panic that the other bacterial diseases do, speck can result in significant yield losses if the blossoms become infected. Typically, this disease occurs less frequently than either bacterial spot or canker.

Greenhouse Recommendations: Bacteria spread from plant to plant via water such as splash droplets from overhead watering. Since bacteria prefer warm, wet environments, transplants growing in a greenhouse offer a perfect home for bacterial diseases. The earlier that diseased transplants are identified and removed from the greenhouse, the better. Transplants are grown in tightly-packed transplant trays to maximize greenhouse space. Since bacteria move via splash droplets, not only should the obviously diseased transplants be removed from the greenhouse and disposed of in the dumpster, but the plug flats adjacent to the diseased plants should also be removed. Plants can be infected with low levels of bacteria and still appear healthy. Research in transplant greenhouses has shown that bacterial pathogens move several feet beyond those plants that are obviously diseased. Regular scouting, and quick and decisive action is an important management strategy. While it may be painful to remove seemingly healthy plants, the diseased transplants cannot be cured and it is unlikely these plants will be healthy and productive if planted in the field.

Greenhouse sanitation is also important. Reusing plug trays from one year to the next is not advised because tomato pathogens including bacterial diseases could potentially survive and cause problems for new transplants. When removing diseased transplants, also dispose of the plug trays. If you are using tools, make sure they are sanitized after use. Greenhouse benches and floors can be sanitized by first washing the surface so there is no soil or plant tissue. After washing, the surfaces can be disinfected by using a 10% bleach mix or a commercial sanitizing product. Dousing the surface with the sanitizer is helpful so that there is an extended contact time to help kill any remaining pathogens.

Copper-based products and Agri-Mycin 50 (streptomycin) can be used on tomato transplants in the greenhouse to limit the bacterial pathogens. They should be applied to transplants very early beginning when the first true leaves have emerged and reapplied frequently. The time between sprays should be as short as that which is allowed by the product labels. In many instances, the bacterial pathogen has developed resistance to copper so mixing a copper product with Agri-Mycin 50 is preferred. While there are anecdotal reports that mixing mancozeb with copper is helpful, this concept has not been sufficiently proven. However, since mancozeb provides some protection against Botrytis gray mold and Alternaria leaf blight, it is okay to add it to the copper + Agri-Mycin 50 mix. Choose a copper product that has a relatively high level of metallic copper. Keep in mind that the copper products with a high percentage of this active ingredient will likely also require a longer reentry interval but this can be addressed by using personal protective equipment as described by the label.

Field Research and Recommendations: Copper resistance may be more common among isolates of *Xanthomonas* and *Pseudomonas* in Michigan than previously thought. Historically, growers applied copper preventively and continued throughout the season. Given the results of testing tomato bacterial leaf spot pathogen isolates for copper sensitivity and two field studies, it is time to reconsider control strategies. A contaminated field should be rotated out of tomatoes for at least three years. At one time it was believed that a rotation of at least five years was necessary; however, it is now known that the level of bacteria in a contaminated field drops dramatically after the first year of rotation. Any equipment used in the problem field should be washed and disinfected prior to entering a clean field. Equipment and workers should begin work in the cleanest field and finish with the contaminated field.

Copper sprays every five to seven days may help reduce the spread of bacterial canker. However, if the environment is favorable for bacterial canker (75 to 90°F with rain), coppers may be limited because the bacteria have a decided advantage in a wet environment.

Avoid working in a diseased field when it is wet to avoid spreading the disease. Bacteria may enter the plant through natural openings, or wounds created by wind, pesticide spraying or insects. A film of water on the leaf surface allows the bacteria to remain viable and move. If workers are moving within a wet field and creating new wounds on the plants, new infections are likely. If plants have been staked, all stakes should be soaked in a disinfectant such as bleach (10%) or GreenShield for a minimum of an hour and preferably overnight.

At MSU we continue to explore new products and strategies to improve bacterial control. No product or strategy is a “stand alone” solution (see the research study below). An approach that combines sanitation, dry greenhouse conditions, well-timed and helpful sprays, and diligent scouting can lessen disease losses in many situations.

Evaluation of bactericides applied in the greenhouse and in the field for control of bacterial spot of tomato.

A replicated, inoculated trial was initiated and treated in the greenhouse and planted and treated in the field to evaluate bactericides (Table 1) for control of bacterial spot of tomato.

Table 1. Products tested.

Product	Active ingredient	FRAC[1]	Labeled	
			GH	Field
Actigard WG	acibenzolar-S-methyl	P01	no	yes
Actinovate WP	*Streptomyces lydicus*	--	yes	yes
Agri-Mycin WP	streptomycin sulfate	25	yes	yes
Kasumin SL	kasugamycin	24	no	no
Kocide O DF	copper hydroxide	M01	yes	yes
LifeGard DF	*Bacillus mycoides*	P06	yes	yes
Manzate DF, Manzate Flowable SC	mancozeb	M03	yes	yes
Oxidate SL	hydrogen dioxide	--	yes	yes
Regalia SL	*Reynoutria sachalinensis*	P05	yes	yes
Stimplex SL	cytokinin	--	yes	yes
CX 10250 DF	--	--	no	no

[1]Numbers and letters are used to define the fungicide groups by their mode of action. M=multi-site inhibitors. P=host plant defense inducers. Visit www.frac.info for more information about FRAC codes.

Tomato 'Pony Express' seedlings were received in 128-cell plug flats and kept under greenhouse conditions until transplanting to the field. Treatments in the greenhouse were applied as a foliar spray with a hand-pump sprayer or as a drench to flats of seedlings on 8, 15 and 19 June. Tomatoes were transplanted into the field on 21 June at the Michigan State University Southwest Research and Extension Center located near Benton Harbor, MI, in a sandy soil previously planted to tomatoes. Transplants were planted 18 inches apart in raised beds covered with black polyethylene plastic spaced 5.5 feet apart. Treatments were arranged in a completely randomized block design, and four replicates were established for each treatment. A replicate consisted of a single 20-foot row plot with a 3-foot buffer between treatments within a row. The plants were staked and tied throughout the growing season. Plots were hand weeded when necessary. Treatments were applied in the field using a backpack sprayer with a three-nozzle boom and XR8003 flat fan nozzles operating at 50 psi and delivering 50 GPA. Treatments in the field were applied as a foliar spray on 29 June; 9, 16, 23, 30 July; 7, 14, 22, 29 August; 5, 12 September. Plants were inoculated on 16 August with *Xanthomonas vesicatoria* isolates sensitive to copper and streptomycin. Inoculum was prepared by placing a single colony of *X. vesicatoria* on nutrient broth yeast extract (NBY) agar, growing at 30°C for 24 hours, transferring into 25 ml of NBY broth, incubating overnight at 30°C on a rotary shaker at 100 rpm. After incubation, 5 ml of bacterial suspension was transferred to 500 ml of NBY broth and incubated under the same conditions. The bacterial suspension was centrifuged at 15,000 rpm for 5 min. The supernatant was discarded and the pellet was resuspended in sterile distilled water. The bacterial concentration was adjusted to an optical density of 0.3 at 600 nm ($\approx 1\text{x}10^8$ colony-forming units/ml) using a spectrophotometer. Tomatoes were inoculated with approximately 10 ml of bacterial suspension per plant using a hand sprayer. Foliar infection was visually rated on 20 August and 2 September, and foliar necrosis on 18 September on a 0 to 100% continuous scale. Fruits were harvested on 7 and 28 September, sorted for disease and weighed.

On the first rating date of 20 August, all treatments were similar to the untreated control with respect to foliar infection (Table 2). By 2 September, only treatment 2 had significantly lower foliar infection than the untreated, although it was similar to treatments 4 and 10. Treatment 10 had significantly less foliar necrosis than treatments 9 or 6, but no treatments were different from the untreated control. No differences were detected with respect to total yield. Treatments 3 and 9 produced fewer tomato fruits with bacterial symptoms than treatment 8, although none were different from the untreated control.

Table 2. Foliar infection and necrosis, and yield of tomatoes inoculuated with *X. vesicatoria* and treated in the greenhouse and field.

Treatment[1] and rate, *vol/A for field, application schedule*, applied at 7-day intervals	Foliar infection (%)		Foliar necrosis (%)	Yield (lb)	
	8/20	9/2		Total	Bacterial
1 Untreated control	5.5 a-c[2]	43.8 a-c	91.3 ab	84.1	6.4 a-c
2 GH: Manzate Flowable SC 2.4 qt + Kocide O WG 1.75 lb + Agri-Mycin WP 1 lb + Induce, spray, *8,15,19 Jun* Field: Manzate Flowable SC 2.4 qt + Kocide O WG 1.75 lb + Induce, *apps A-K*	3.8 c	26.3 d	83.8 ab	98.3	4.7 bc
3 GH: Actigard WG 0.25 oz, drench, *19 Jun* Field: Actigard WG 9.4 g + Induce, *apps A-B* Actigard WG 14 g + Induce, *70 gal/A*, *apps C-D* Actigard WG 21 g + Induce, *100 gal/A*, *apps E-K*	4.0 bc	43.8 a-c	83.8 ab	78.5	4.2 c
4 GH: Actigard WG 0.25 oz, drench, *15,19 Jun* Field: Actigard WG 9.4 g + Induce, *apps A-B* Actigard WG 14 g + Induce, *70 gal/A*, *apps C-D* Actigard WG 21 g + Induce, *100 gal/A*, *apps E-K*	5.8 a-c	40.0 b-d	88.8 ab	90.7	8.3 a-c
5 GH: Actigard WG 0.25 oz, spray, *15,19 Jun* Field: Actigard WG 9.4 g + Induce, *apps A-B* Actigard WG 14 g + Induce, *70 gal/A*, *apps C-D* Actigard WG 21 g + Induce, *100 gal/A*, *apps E-K*	5.8 a-c	42.5 a-c	85.0 ab	80.9	5.7 a-c
6 GH: Regalia SL 4 qt, spray, *8,15,19 Jun* Field: Regalia SL 3 qt, *apps A-K*	9.5 a-c	53.8 ab	95.0 a	74.3	5.1 a-c
7 GH: Kasumin SL 2 qt + Induce, spray, *8,15,19 Jun* Field: Kasumin SL 14 fl oz + Induce	11.8 a	51.3 a-c	81.3 ab	82.5	8.0 a-c
8 GH: Oxidate SL 1%, spray, *8,15,19 Jun* Field: Oxidate SL 8 fl oz, *apps A-K*	11.8 a	57.5 a	93.8 ab	89.6	9.4 a
9 [3]Field: Regalia SL 3 qt, *apps A-B,D,F,H,J* Actinovate WP 12 oz + Stimplex SL 3 qt, *apps C,E,G,I,K*	5.3 a-c	50.0 a-c	95.0 a	74.9	4.7 bc
10 Field: Manzate DF 2 lb + Kocide O WG 1.5 lb, *apps A-K*	9.0 a-c	37.5 cd	78.8 b	95.5	9.1 ab
11 GH: CX 10250 DG 2 oz + Kocide O DF 1.75 lb + Manzate F 2.4 qt, spray, *15,19 Jun* Field: CX 10250 DG 2 oz/100 gal + Manzate DF 2 lb + Kocide O WG 1.5 lb *-alt-* Manzate DF 2 lb + Kocide O WG 1.5 lb	10.5 a-c	46.3 a-c	88.8 ab	84.1	6.5 a-c
12 GH: LifeGard DG 4.5 oz + Kocide O DF 1.75 lb + Manzate F 2.4 qt, foliar, *15,19 Jun* Field: LifeGard DG 4.5 oz/100 gal + Manzate DF 2 lb + Kocide O WG 1.5 lb *-alt-* Manzate DF 2 lb + Kocide O WG 1.5 lb	10.8 ab	46.3 a-c	88.8 ab	88.2	8.4 a-c

[1]GH: treatments were per 100 gal, applied as a foliar spray or via drench to seedling flats in the greenhouse. Field: treatments were per A (unless rate otherwise specified), applied as a foliar spray to plants in the field. *-alt-* =alternate. Field treatments applied at 50 gal/A, unless otherwise specified. Induce SL added at 0.25% v/v.
[2]Column means with a letter in common or with no letter are not significantly different (t Test LSD; P=0.05).
[3]BioTam 2.0 drench applied at transplant and every 4-6 weeks after on 19 Jun, 16 Jul, 7 Aug.

This research was supported by Project GREEEN GR18-049.

Biostimulants: what are they and can they help my plants?

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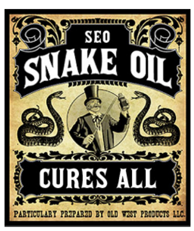
Explosion of new biostimulant products in the marketplace in recent years

Continued growth expected

Total market value of agricultural biologicals estimated at $5.1B in 2015 and expected to reach $10B by 2020

Some companies make dramatic claims about the potential benefits for plants



Outline of today's presentation

- What are biostimulants?
- How are they expected to promote crop growth?
- Are there unbiased, scientific evidence to support the benefits of these products?
- How can I determine whether they are worth it in my cropping systems?

What are biostimulants?

Definition in the United States

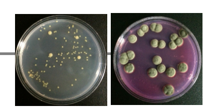
"Products derived from natural or biological sources.."

Definition in the European Union

"A material that, when applied to a plant, seed, soil or growing media - in conjunction with established fertilization plans, ***enhances the plant's nutrient use efficiency***, or provides other direct or indirect benefits to ***plant development or stress response***."

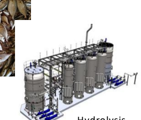
Does not contain nutrients

What are they mad of/from?



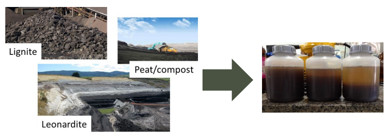
Photos courtesy: S. Abdelrazek

- Microorganisms (*bacteria, fungi, viruses*) isolated from soil and plants for their beneficial activities, or developed in the lab
- Microbial products (metabolites)
- Compounds derived from plants
- Byproducts from other industries
- Reformulated plant compounds and byproducts



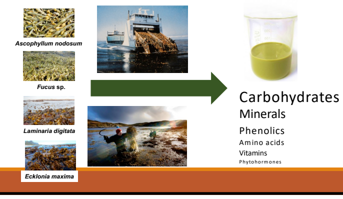
Humic substances

- A mixture of complex organic compounds having yellow to black color formed by transformations (humification) of organic residues of plants and animals by soil microorganisms



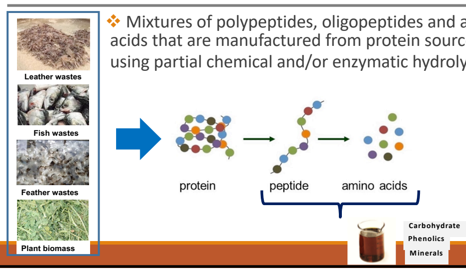
Seaweed extracts

- A mixture of organic/inorganic compounds from seaweed biomass using different manufacturing systems such as alkaline or acid hydrolysis or cellular disruption under pressure or fermentation



Protein hydrolysates

- Mixtures of polypeptides, oligopeptides and amino acids that are manufactured from protein sources using partial chemical and/or enzymatic hydrolysis



Can be distinguished from other types of "agricultural biologicals" based on market potential

Bio-stimulants

- Microorganisms (bacteria, fungi)
- Seaweed extracts
- Humic and amino acids and other complex organics

Application:

- Yield enhancers
- Improve nutrient uptake
- Increase tolerance to and recovery from abiotic stress

Bio-fertilizers

- Microorganisms (bacteria, fungi)
- Organic fertilizers
- Compost tea
- Soil improvers

Application:

- Generally specifically meant to enhance nutrient status

Bio-pesticides

- Microorganisms (bacteria, fungi, viruses)
- Plant extracts (botanicals)
- Plant growth regulators
- Semiochemicals (pheromones)

Application:

- Disease, insect and pathogen control
- Tightly regulated by the USDA

Potential mechanisms responsible for promoting plant growth/mitigating plant stress responses

- Stimulate root growth
- Enhance nutrient availability and assimilation within plants
- Enhance photosynthesis
- Activate secondary metabolism
- Detoxify plant stress compounds (ie. reactive oxygen species)

Research

The challenge:

Matt Kleinhenz (OSU)

Ideal pipeline for product development

Product development → Internal testing → On-farm tests & recommendations

Actual pipeline

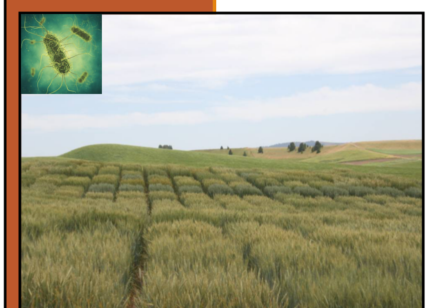
Product development → Internal testing → On-farm tests & recommendations

Testing under controlled conditions

University specialists are scrambling to:

- Provide unbiased, scientific assessments of the efficacy of these products
- Identify when and where they could provide the greatest benefits
- Provide guidance on how to use these products

http://u.osu.edu/vegprolab/research-areas/vegebiostimsferts/



Azospirillum brasilience inoculant in dryland wheat

- "free-living" nitrogen-fixing microbe
- 20 historic and modern wheat varieties
- Field (2 locations) and greenhouse trials
- Treated & untreated controls
- Replicated and randomized trials

2006-2009

Results

- Initial results at field site A in year one were impressive -> (*10-20% yield and protein gains*)
- Yield and protein benefits varied by location

Location	Average Rainfall inches	Organic Matter (%)	Inorganic N (lbs/ac)
A	9.8	2.37	18.6
B	20.4	3.49	28.7

<- greater benefits

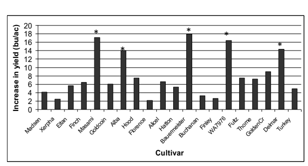
- Benefits varied by year

(Hoagland et al., 2008)

Inoculated Uninoculated

Results

- Benefits varied by wheat variety

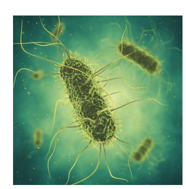


- In some cases, the inoculant had severe negative effects, but not likely to occur in the field (Hoagland et al., 2008)

Inoculated Uninoculated

Conclusions

- This microbial inoculant does have potential to increase yield and protein in dryland wheat production systems
- Benefits were likely more likely related in the potential of this microbe to stimulate root growth and help plants withstand water stress than provide significant nitrogen
- Opportunity to enhance plant growth under stressful conditions, but not likely to provide significant benefits when plants are not under stress
- More research needed to identify most responsive cultivars to optimize the benefits of these inoculants

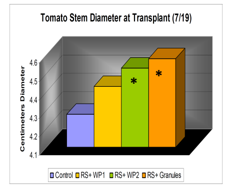


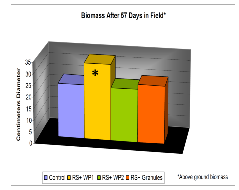
Managing transplant stress in tomatoes

- *Trichoderma species* -> two product formulations and untreated control
- Two tomato varieties
- Field trial
- Replicated and randomized trials

2011

Increased tomato transplant size in the greenhouse | Increased transplant survival and RS+WP1 increased biomass





* indicates significant difference from the control

RS+ WP1 = treated with RootShield Plus WP at 4 oz/100 gallon rate
RS+ WP2 = treated with RootShield Plus WP at 6 oz/100 gallon rate
RS+ Granules = treated with RootShield Plus Granules at 1.5 lb/cu yd

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Conclusions from these and other studies with this organism

- Inoculating plants with this microbe can improve early seedling growth under controlled conditions
- Transplant stress with the appropriate formulation of this product can be reduced
- Whether these benefits will translate into marketable yield and greater profits for growers likely depends on the degree of stress plants are subject to

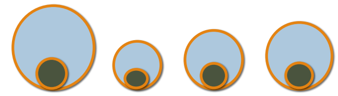
Determining whether these products can help your plants

Where do these products have a role?

- As part of an integrated management system that supplements, but does not replace other inputs
  - *Ex. Mycorrhizal inoculants could help aid in phosphorous acquisition if it is unavailable form in soil, but will not supply P if it is not already present*
- By closing the yield gap caused by plant stress

Closing the yield gap: an opportunity for biostimulants

Unrealized yield is due to stress



	Corn	Soybean	Wheat	Rice
Average yield	5.8	2.9	3.4	5.8
World record	35.0 (USA 2016)	11.5 (USA 2016)	16.8 (New Zealand, 2017)	22.4 (India, 2012)

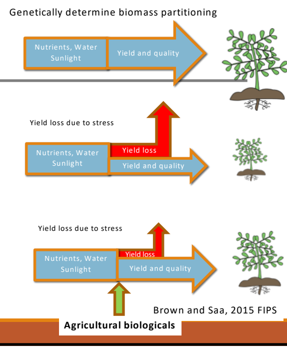
Yield in metric tonnes per hectare
Source: FAS/USDA/3rd International Biostimulant Conference

Biostimulants

- Opportunity to reduce yield loss caused by stress, but unlikely to increase yield beyond what is genetically predetermined

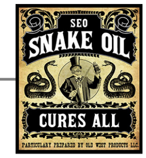
Plant stresses

- Cold
- Waterlogging
- Drought
- Salt
- Heavy metals
- Heat
- Pathogens
- Insect pests



Brown and Saa, 2015 FIPS

Identifying the best products



Look for specific modes of action (MoA)

- Beware of products with no discernable MoA other than "increases plant growth" (*the more details the better*)

Look for reliable, independent research trials

- Trials conducted by companies selling the products or farmers who have received products free of charge are fine as indicators of how to use the products, but do not hold much rigor
- Trials conducted by an organization or institute you know to be of high integrity and with no declared financial interests

Identifying the best products

Look for specific recommendations

- Are they tank mix compatible with co-applied agrochemicals or other biologicals?
- Do they contain specific adjuvants to maximize action (ie. surfactants, wetters, antifoaming agents)?
- Are they approved for use under organic certification guidelines?
- How should they be stored and what is there shelf life?
- How should they be applied?
- What is the optimal rate and frequency of application needed to achieve benefits?

Conducting your own on-farm trials

- ***University Extension Specialists cannot keep up so we need your help in evaluating these products!***
- Identify specific objective for using these products (ie. water stress)
- Include untreated plots as a control
- Budget time to collect measurements and analyze data
- Quantify how much you gained in yield vs. cost of the product
- ***Share your results!***

OSU – "Bugs in a Jug" Webpage
https://u.osu.edu/vegprolab/research-areas/vegebiostimsferts/

http://www.sare.org/Learning-Center/Bulletins/How-to-Conduct-Research-on-Your-Farm-or-Ranch http://biodegradablemulch.org

Biodegradable Plastic Mulches are Effective and Sustainable

Carol Miles

Department of Horticulture, Washington State University
Northwestern Research and Extension Center,
Mount Vernon, WA

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PE mulch use in agriculture

- Weed management
- Conserves moisture
- Warms soil in spring
- Hastens time to harvest
- Increases yield
- Reduces erosion
- Increases crop quality
- More efficient use of water and fertilizer
- Reduces soil compaction
- Efficient double or triple cropping

Biodegradable plastic mulch

Has the potential to be a sustainable technology if it:

- Provides benefits equal to PE mulch
- Reduces labor costs for removal and disposal
- Completely biodegrades
- Causes no harm to soil ecology or the environment

Biodegradable mulch plots 2015-2019

Mulch treatments 2015-2018

Treatment	Manufacturer	Thickness (mil)	Bio-based %
Bare ground			
BioAgri	BioBag Americas, Inc., Dunedin, FL	0.7	20-25%
Exp. PLA/PHA	Experimental Film	1.0	86%
Naturecycle	Custom Bioplastics, Burlington, WA	1.0	≥ 20%
Organix (black)	Organix Solutions, Maple Grove, MN	0.7	10%
Organix-Clr (clear)	Organix Solutions, Maple Grove, MN	0.5/0.6	10%
Polyethylene	Filmtech, Allentown, PA	1.0	< 1%
WeedGuardPlus	Sunshine Paper Co., Aurora, CO	10	100%

Organix-Clr 2017 & 2018 only

Pumpkin 2015 & 2016

Sites:
1. Mount Vernon, WA
2. Knoxville, TN

- 5 rows per plot, 30 ft long row
- 'Cinnamon Girl' pie pumpkin

Source: Ghimire et al. 2018. HortScience 53:288-294.

Sweet corn & bell pepper

2017 & 2018

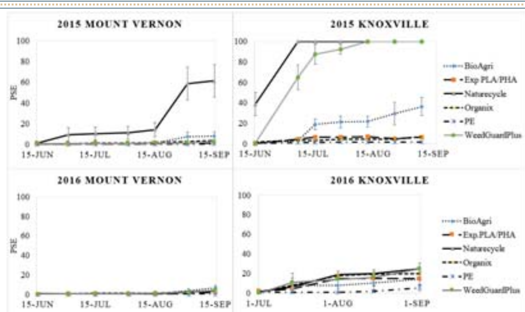
Mount Vernon, WA
- 'Xtra-Tender 2171' sweet corn

Knoxville, TN
- 'Aristotle' green bell pepper

Percent soil exposure (PSE)

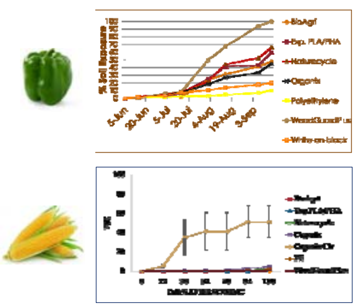
5% 40%

Percent soil exposure (PSE)



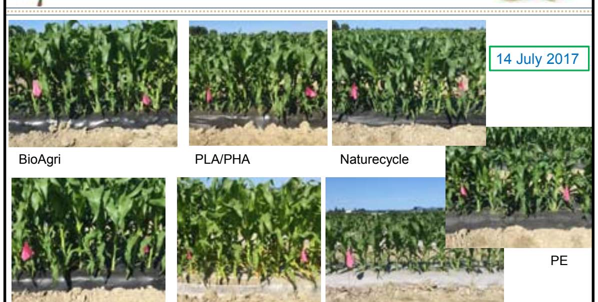
Source: Ghimire et al. 2018.

Percent soil exposure (PSE)

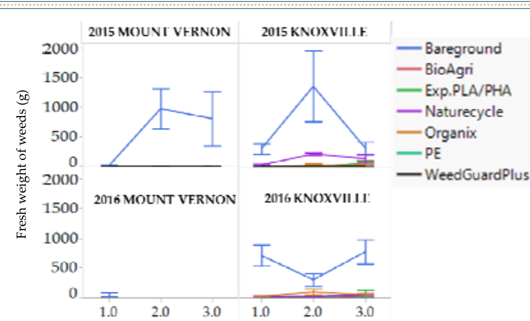


Source: Wszelaki and Moore. 2018.

Mulch deterioration

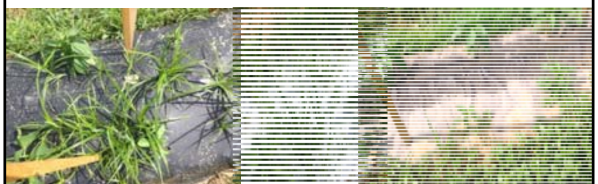


Weed control



Weed Control

- WeedGuardPlus excellent for controlling weeds, especially nutsedge, during critical period



Crop yield

	Pumpkin[1]	
	Mount Vernon	Knoxville
PE	**22.8 a**	**20.4**
Exp.PLA/PHA	21.0 ab	16.3
BioAgri	20.9 ab	18.8
Naturecycle	19.9 ab	17.3
Organix-Blk	18.4 bc	19.9
Organix-Wht/Blk	-[3]	-
Organix-Clr	-	-
WeedGuardPlus	15.3 c	16.2
Bare ground	8.7 d	15.3
P-value	*< 0.0001*	*0.27*

[1] Data combined for 2015 and 2016

[2] 2017 only

[3] Mulch product not included

Mulch performance

	Yield		Weed Control
Crop	**vs. Bareground**	**vs. PE**	**vs. PE**
Broccoli	+[1]		
Cucumber	+	=	=
Eggplant	+	=	-
Pepper	=	=	-
Lettuce		-=[2]	
Melon	+	+=	≅
Strawberry		-=+	-
Sweet Corn	+	-=	-
Sweet Potato	+	+=	+
Tomato	+	=	≅
Zucchini		=	

[1] + BDM performed better, = BDM performed equivalent to, - BDM did not perform as well, and empty cell not measured.

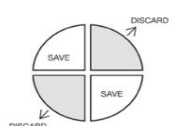
[2] Reports provide variable results.

Source: Cowan and Miles. 2018.

Mulch incorporation

Collecting mulch from soil

- Collect soil sample 3 ft^2 and 6 inch depth
- Quartering method, repeated 3 times per sample, ~5 gal. per sample
- Extract mulch fragments by wet sieving soil sample (2.4 mm screen)



QUARTERING A SAMPLE
(TOP VIEW)

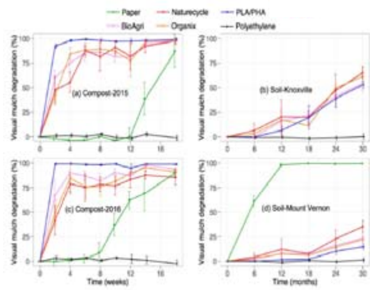
Source: Ghimire and Miles. 2018.

Measuring mulch fragments

- **Graph paper**
  conversion factor: x 1.189

- **Image J software**
  conversion factor: x 0.868

Biodegradation in soil and compost



Source: Flury et al. 2018.

USDA National Organic Program Rule

Biodegradable biobased mulch film was added to list of allowed substances on October 2014, but it **MUST**:

1. Be biobased (*ASTM D6866*)
2. Be produced without the use of non-biobased synthetic polymers; minor additives (colorants, processing aids) not required to be biobased
3. Be produced without organisms or feedstock derived from excluded methods (i.e., synthetic, GMO)
4. Meet compostability specifications (ASTM D6400, ASTM D6868, EN 13432, EN 14995, or ISO 17088)
5. Reach ≥ 90% degradation in soil within 2 years (*ISO 17556* or *ASTM D5988)*

Biodegradable mulch ingredients

Ingredient[1]	Feedstock	Synthesis	ERBD in soil[2]
Cellulose	Biobased	Biological	High
PBAT	Hydrocarbon	Chemical	Low moderate
PBS	Hydrocarbon	Chemical	Low moderate
PBSA	Hydrocarbon	Chemical	Low moderate
PCL	Hydrocarbon	Chemical	Moderate
PHA	Biobased	Biological	Moderate high
PLA	Biobased	Biological & Chemical	Low
Sucrose	Biobased	Biological	High
TPS/Starch	Biobased	Biological	High

[1] Abbreviations: PBAT polybutylene adipate terephthalate; PBS polybutylene succinate; PBSA PBS-co-adipic acid; PCL polycaprolactone; PHA polyhydroxyalkanoate; PLA polylactic acid; TPS thermoplastic starch

[2] **Source:** Brodhagen et al. 2015. Biodegradable plastic agricultural mulches and key features of microbial degradation. Appl Microbiol Biotechnol (2015) 99:1039–1056.

Use of GMO in biodegradable mulch

- Genetically modified organisms (GMOs) are commonly used in the manufacture of biodegradable mulch:
  - Feedstocks, such as starch: corn, sugar beet
  - Fermentation of feedstocks: bacteria, yeast
  - Minor additives
- Difficult to determine GMO status of end product:
  - Source of feedstocks not disclosed
  - DNA may be degraded after fermentation and processing, thus not measurable

Oxo-degradable plastic

- **Made with conventional plastic:** high density polyethylene (HDPE), low density PE (LDPE), polypropylene (PP), polystyrene (PS), polyethyleneterephtalate (PET), polyvinylchloride (PVC)
- Includes additives that promote oxidation of the material, triggered by UV light, heat, and oxygen
- Product becomes brittle and fragments
- Independent third party standard ASTM & ISO test data show small percent or no film fragments utilized by soil microorganisms

3 years after mulch application, Everett, WA
Photo by Andy Bary

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Oxo-degradable plastic

- FTC concludes company making false and unsubstantiated claims about oxo-products
- Designed to degrade very slowly: < 2% in 2 years
- Does not undergo biodegradation
- Not suitable for composting or anaerobic digestion
- Recommend prohibition of sales into markets where plastics are recycled:
  - Reduces quality of plastics recyclate
  - Cannot be identified and separated

For more information

www.biodegradablemulch.org

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