Great Lakes Fruit, Vegetable & Farm Market EXPO
Michigan Greenhouse Growers EXPO
December 4-6, 2018
DeVos Place Convention Center, Grand Rapids, MI

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.

<table>
<thead>
<tr>
<th>Product</th>
<th>Active ingredient</th>
<th>FRAC1</th>
<th>Labeled GH</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actigard WG</td>
<td>acibenzolar-S-methyl</td>
<td>P01</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Actinovate WP</td>
<td><em>Streptomyces lydicus</em></td>
<td>--</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Agri-Mycin WP</td>
<td>streptomycin sulfate</td>
<td>25</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Kasumin SL</td>
<td>kasugamycin</td>
<td>24</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Kocide O DF</td>
<td>copper hydroxide</td>
<td>M01</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>LifeGard DF</td>
<td><em>Bacillus mycoides</em></td>
<td>P06</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Manzate DF, Manzate Flowable SC</td>
<td>mancozeb</td>
<td>M03</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Oxidate SL</td>
<td>hydrogen dioxide</td>
<td>--</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Regalia SL</td>
<td><em>Reynoutria sachalinensis</em></td>
<td>P05</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Stimplex SL</td>
<td>cytokinin</td>
<td>--</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CX 10250 DF</td>
<td>--</td>
<td>--</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

1Numbers 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 (≈1x10⁸ 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 inoculated with *X. vesicatoria* and treated in the greenhouse and field.

<table>
<thead>
<tr>
<th>Treatment (^1) and rate, vol/A for field, application schedule, applied at 7-day intervals</th>
<th>Foliar infection (%) (8/20)</th>
<th>Foliar necrosis (%)</th>
<th>Yield (lb)</th>
<th>Total Bacterial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Untreated control</td>
<td>5.5 a-c (^2)</td>
<td>43.8 a-c</td>
<td>91.3 ab</td>
<td>84.1</td>
</tr>
</tbody>
</table>
| 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 | 78.5 | 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 Field: Regalia SL 3 qt, apps A-B,D,F,H,J  
Actinovate WP 12 oz + Stimpex 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.  
\(^2\)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.
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

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

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EMAYNARD@PURDUE.EDU; LHOAGLAN@PURDUE.EDU

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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?

Some companies make dramatic claims about the potential benefits for plants

Benefits not always as dramatic on grower’s farms

Grown with the product
Grown without

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 biostimulants mad of/from?

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

Photos courtesy: S. Abdelrazek
https://downtoearthph.com/tag/fish-emulsion/
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 (i.e. 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
- 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

<table>
<thead>
<tr>
<th>Location</th>
<th>Organic Matter (lbs/acre)</th>
<th>Inorganic N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.37</td>
<td>18.6</td>
</tr>
<tr>
<td>B</td>
<td>3.49</td>
<td>28.7</td>
</tr>
</tbody>
</table>

Benefits varied by location

(Hoagland et al., 2008)

Benefits varied by year

(Hoagland et al., 2008)

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

**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 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**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Average yield</th>
<th>World record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>5.8</td>
<td>35.0 (USA 2016)</td>
</tr>
<tr>
<td>Soybean</td>
<td>2.9</td>
<td>11.5 (USA 2016)</td>
</tr>
<tr>
<td>Wheat</td>
<td>3.4</td>
<td>16.8 (New Zealand, 2017)</td>
</tr>
<tr>
<td>Rice</td>
<td>5.8</td>
<td>22.4 (India, 2012)</td>
</tr>
</tbody>
</table>

Yield in metric tonnes per hectare
Source: 4th/5th/6th/7th International Biostimulant Conference
Biostimulants

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

<table>
<thead>
<tr>
<th>Plant stresses</th>
<th>Cause reduction in yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td></td>
</tr>
<tr>
<td>Waterlogging</td>
<td></td>
</tr>
<tr>
<td>Drought</td>
<td></td>
</tr>
<tr>
<td>Salt</td>
<td></td>
</tr>
<tr>
<td>Heavy metals</td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td></td>
</tr>
<tr>
<td>Pathogens</td>
<td></td>
</tr>
<tr>
<td>Insect pests</td>
<td></td>
</tr>
</tbody>
</table>

Identifying the best products

**Look for specific modes of action (MoA)**
- Beware of products with no discernible 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 (i.e., surfactants, wetters, antifoaming agents)?
- Are they approved for use under organic certification guidelines?
- How should they be stored and what is the shelf life?
- How should they be applied?
- What is the optimal rate and frequency of application needed to achieve benefits?

Identifying the best products

**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 (i.e., 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!

[Links and resources provided]
Biodegradable Plastic Mulches are Effective and Sustainable

Carol Miles

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

This material is based upon work that is supported by the National Institute of Food and Agriculture, under award number 2014-51181-22382. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

http://biodegradablemulch.org

Biodegradable Plastic Mulches are Effective and Sustainable

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

Mulch treatments 2015-2018

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Manufacturer</th>
<th>Thickness (mil)</th>
<th>Bio-based %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare ground</td>
<td></td>
<td>0.7</td>
<td>0-25%</td>
</tr>
<tr>
<td>BioAgri</td>
<td>BioBag Americas, Inc., Dunedin, FL</td>
<td>0.7</td>
<td>20-25%</td>
</tr>
<tr>
<td>Exp. PLA/PHA</td>
<td>Experimental Film</td>
<td>1.0</td>
<td>86%</td>
</tr>
<tr>
<td>Naturecycle</td>
<td>Custom Bioplastics, Burlington, WA</td>
<td>1.0</td>
<td>20%</td>
</tr>
<tr>
<td>Organix (black)</td>
<td>Organix Solutions, Maple Grove, MN</td>
<td>0.7</td>
<td>10%</td>
</tr>
<tr>
<td>Organix-Clr (clear)</td>
<td>Organix Solutions, Maple Grove, MN</td>
<td>0.3/0.6</td>
<td>10%</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>Filtech, Allentown, PA</td>
<td>1.0</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>WeedGuardPlus</td>
<td>Sunshine Paper Co., Aurora, CO</td>
<td>10</td>
<td>100%</td>
</tr>
</tbody>
</table>

Pumpkin 2015 & 2016

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

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

Sweet corn & bell pepper

2017 & 2018
Mount Vernon, WA
• ‘Xtra-Tender 2171’ sweet corn
Knoxville, TN
• ‘Aristotle’ green bell pepper

Percent soil exposure (PSE)

Source: Ghimire et al. 2018.

Percent soil exposure (PSE)


Mulch deterioration

14 July 2017

BioAgri, PLA/PHA, Naturecycle
Organic-Blk, Organic-Cr, WGP

Weed control

2015 MOUNT VERNON 2015 KNOXVILLE

Source: 2015 MOUNT VERNON 2015 KNOXVILLE
Weed Control

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

Crop yield

<table>
<thead>
<tr>
<th></th>
<th>Pumpkin</th>
<th>Mount Vernon</th>
<th>Knoxville</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>22.8 a</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>Exp. PLA/PHA</td>
<td>21.0 ab</td>
<td>16.3</td>
<td></td>
</tr>
<tr>
<td>Ridge</td>
<td>20.0 ab</td>
<td>18.8</td>
<td></td>
</tr>
<tr>
<td>Naturecycle</td>
<td>19.9 ab</td>
<td>17.3</td>
<td></td>
</tr>
<tr>
<td>Organic-Bk</td>
<td>18.4 bc</td>
<td>19.9</td>
<td></td>
</tr>
<tr>
<td>Organic-Wh/Bk</td>
<td>- -</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Organic-Cd</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>WeedGuardPlus</td>
<td>15.3 c</td>
<td>16.2</td>
<td></td>
</tr>
<tr>
<td>Bare ground</td>
<td>8.7 d</td>
<td>15.3</td>
<td></td>
</tr>
<tr>
<td>Profit</td>
<td>4.66</td>
<td>2.37</td>
<td></td>
</tr>
</tbody>
</table>

* Data combined for 2015 and 2016

Mulch performance

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield vs. Bareground vs. PE vs. PE</th>
<th>Weed Control vs. PE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Cucumber</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Eggplant</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Pepper</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Artichoke</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Melon</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Strawberry</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Sweet Potato</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Tomato</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Mushrooms</td>
<td>=</td>
<td>=</td>
</tr>
</tbody>
</table>

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

Source: Cowan and Miles. 2018.

Collecting mulch from soil

- Collect soil sample 3 ft² 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)

Source: Ghimire and Miles. 2018.

Measuring mulch fragments

- Image J software conversion factor: x 0.868
- Graph paper conversion factor: x 1.189
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 D6868)
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 D3988)

Biodegradable mulch ingredients

<table>
<thead>
<tr>
<th>Ingredient 1</th>
<th>Feedstock</th>
<th>Synthesis</th>
<th>ERBD in soil 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>Biobased</td>
<td>Biological</td>
<td>High</td>
</tr>
<tr>
<td>PBAT</td>
<td>Hydrocarbon</td>
<td>Chemical</td>
<td>Low moderate</td>
</tr>
<tr>
<td>PBS</td>
<td>Hydrocarbon</td>
<td>Chemical</td>
<td>Low moderate</td>
</tr>
<tr>
<td>PBSA</td>
<td>Hydrocarbon</td>
<td>Chemical</td>
<td>Low moderate</td>
</tr>
<tr>
<td>PCL</td>
<td>Hydrocarbon</td>
<td>Chemical</td>
<td>Moderate</td>
</tr>
<tr>
<td>PHA</td>
<td>Biobased</td>
<td>Biological</td>
<td>Moderate high</td>
</tr>
<tr>
<td>PLA</td>
<td>Biobased</td>
<td>Biological &amp; Chemical</td>
<td>Low</td>
</tr>
<tr>
<td>Sucrose</td>
<td>Biobased</td>
<td>Biological</td>
<td>High</td>
</tr>
<tr>
<td>TPS/Starch</td>
<td>Biobased</td>
<td>Biological</td>
<td>High</td>
</tr>
</tbody>
</table>

1 Abbreviations: HDPE, high density polyethylene; LDPE, low density PE; PP, polypropylene; PS, polystyrene; PET, polyethylene terephthalate; PVC, polyvinylchloride
2 Biobased: synthesized from renewable sources; Biodegradable: materials that can be degraded by soil organisms

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), polyethylene terephthalate (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

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 recycle
  - Cannot be identified and separated

3 years after mulch application. Everett, WA. Photo by Andy Flury.
For more information
www.biodegradablemulch.org

Acknowledgements

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