

MID-ATLANTIC

Fruit & Vegetable Convention

2026 Proceedings



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2027 Mid-Atlantic Fruit & Vegetable Convention





Pennsylvania Vegetable Growers Association Proceedings

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Cut Flowers

The Latest and Greatest New Cuts

John Dole

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Sources of Inspiration

- Association of Specialty Flower Growers (ASCFG) National Trials
- Breeders and suppliers
- Travels and growers

ASCFG Cut Flower Trials Highlights

- Zinnia 'Agave,' 'Aurora' and 'Ballerina' (Johnny's Selected Seeds)
- Celosia 'Sunday Bright Orange' (Ball/PanAmerican Seed)
- Celosia 'Shimmer' (Johnny's Selected Seeds)
- Craspedia 'SolarPop' (Benary)
- Delphinium 'Brezze Blue,' 'Brezze Light Blue' (American Takii)
- Dianthus 'Amazon Purple Magic' (Ball/PanAmerican Seed)
- Lisianthus 'Macherie Green,' 'Macherie White' (Ball Seed)
- Lisianthus 'Viviana Blue,' 'Viviana Pink' (Sakata/InFlora Express)
- Lisianthus 'Rosita 3 Bright Blue' (Sakata/InFlora Express)
- Ornamental cabbage 'Crane Early Red,' 'Crane Early White' (American Takii)
- Snapdragon Toulon series (Evanthia)
- Stock 'Trident White' (American Takii)
- Sunflower 'Vincent's Choice DMR,' 'Vincent's Fresh DMR' (Sakata)
- Sunflower 'ProCut Orange Splendor' (Nuflowes/Sunflower Selections)
- Sunflower 'Sunrich Gold Gen 2' (American Takii)
- *Centaurea moschata* 'The Bride' (Takii Europe/Sahin)



John Dole is a Professor in the Horticultural Science Department at NC State University. His research program focuses on the production and postharvest physiology of floriculture crops, in particular, working with cut flowers.

- *Centaurea* 'XL Yellow' (InFlora)
- *Centranthus* 'Roseus' (Ball Seed)
- Fresh/Dried Flowers
 - o *Ammobium grandiflorum* (Takii Europe/Sahin)
 - o *Rhodanthe* 'Goliath' (Ball Seed)
 - o Strawflower King Size Mix (InFlora/Express)

Flower Farms and Trials Highlights

- Agapanthus (many sources)
- Japanese anemone (many sources)
- *Cephalophora aromatica* 'Pineapples' (InFlora)
- *Eucalyptus polyamthemis* (Ball Seed)
- *Eucalyptus lunata* 'Moon Lagoon' (many sources)
- *Eucalyptus nicholii* 'Angus' (Southern Eucs)
- *Stachys byzantina*
- *Stachys officinalis* 'Summer Romance' (many sources)
- Succulents (many sources)
- Sunflower 'Sunfinity Yellow' and 'Sunfinity Double Yellow' (Syngenta)
- Sunflower 'Suncredible Saturn' and 'Suncredible Yellow' (Proven Winners)



Cut Flowers



Make Cut Flowers Last: The Postharvest Info You Need

Properly handled cut flowers last longer! And longer lasting cut flowers result in happy customers!

Many factors affect how long flowers will last, starting with preharvest factors, then harvesting, and finally postharvest handling. During these steps there are six main issues that must be considered at every step in the postharvest handling system: temperature, water, sanitation, carbohydrates, disease, and ethylene. Of these factors, temperature is generally the most critical, because it affects each of the other five factors. Nonetheless, all six can be limiting factors for various species and at various points in the marketing chain.

Preharvest. Optimizing the postharvest life of cut flowers begins with cultivar selection as they can vary greatly for each species. Other preharvest factors to consider include light levels, temperatures (especially night temperatures), nutrition, water status, and pests.

Harvest. Flower should be harvested at the best stage for the species, which can also vary with the market. For example, sunflowers for direct retail are harvested when the petals are at least perpendicular to the head (or fully open) as customers will be attracted to the petal color. However, sunflowers for wholesales will be harvested from when the petals are just beginning to lift off of the disc to perpendicular to the head as they will continue to open during marketing and there is less chance of damage during postharvest handling. Some flowers, such as gerbera, do not open up much or at all after harvest and should be harvested when they have just fully opened. Harvesting later will reduce vase life. Flowers that will be stored or shipped are cut at a younger stage than those being sold directly to the final consumer, especially those with large petals, such as glads and lilies, which might be damaged during transport.

Harvest Time. Flowers are typically harvested in the morning and placed in buckets of water or postharvest solutions. In the morning flowers will have their maximum water content and tissue temperatures are

low. Flowers harvested in the afternoon will have the highest carbohydrate levels and are best for those flowers that will be stored for a while. Some species are very wilt prone and need to be harvested in the morning regardless of storage. Other harvest factors to consider include harvest method, foliage removal and bunching in the field, and transport from the field or greenhouse to the cooler or processing area.

Temperature. Temperature is the most critical factor. The warmer the temperature, the faster the respiration rate, the faster bacteria grow, and the more stems bend if they are stored horizontally. For every 10°C increase in temperature, the respiration rate doubles and one day vase life is lost. Be sure to get field heat out ASAP.

Coolers should be set at 34 to 38°F. While close to 32°F is optimum for most species, 34-35°F or 34-38°F is more practical. A few crops, such as oriental lilies, zinnias, celosia, and tropicals are cold sensitive. Damage can be avoided by storing them in another location or cooling gradually, such as with lilies. The Take Home message for temperature: Short and cold as possible for species

Ethylene. Some species are sensitive to ethylene, which is a naturally occurring ripening hormone. Ethylene can cause leaf, flower, and bud abscission; bud abortion, epinasty, which is a distinctive curling, drooping of leaves or bracts, and most damaging, rapid flower senescence. Steps to prevent ethylene damage include lowering the temperature, applying anti-ethylene agents, such as Ethylbloc (MCP) or AVG (STS), and removing sources of ethylene. A common question - Can cut flowers and veggies/fruit be stored together? Generally, no, but possibly if duration is short and temperature is close to 32°F

Sanitation. Good sanitation is needed to ensuring that flowers have a long vase life. Microbial growth in the bucket or vase water will block the stems. The golden rule – would you drink out of your buckets? While black buckets are often used for displays, it is easier to know when white buckets are properly cleaned. A number of cut flowers are considered to be high polluting in that they tend to make the water



Cut Flowers



dirty by trapping debris on their stems and foliage or decompose fast. Such species include achillea, celosia, dahlia, gerbera, mums, sunflowers, and zinnias.

Air plugs. Air is drawn into stems when they are first cut and when they are held out of water for very long. These plugs are removed by recutting the stems. Eventually, however, the stems will start to deteriorate no matter how clean the water is or how often they are recut.

Water pH. For most species low water pH is best and tap water usually has too high of a pH. Flower foods have acidifiers that reduce the pH, even if your water has a very high pH.

Floral preservatives, flower foods. There are many products used during the postharvest handling of cut flowers. Most can be grouped into the following categories: hydrating, holding, vase, and species-specific products. They are available in a variety of formulations and sizes: powders, liquids, pills, buckets, jugs, packets, and tea bags. The majority of the products have the following components, **Acidifier**, **Biocide** and **Carbohydrate**, which can be remembered as “**ABC**.” Flower foods are designed to fix critical issues such as wilt-prone flowers, bacteria control, ethylene sensitivity, leaf yellowing, and other species-specific problems.

The number of options for flower foods can be overwhelming. One of the best strategies is to take a middle of the road approach and use a holding solution, which provides a low pH to boost water uptake, checks bacteria growth, provides at least some carbohydrates, and is active up to 5-6 days. Carbohydrates allow buds to open, develop, and maintain petal color, and, of course, extends vase life.

Overall recommendations for using flower foods.

High quality water (possibly with chlorine pills) should be used to hydrate flowers for at least four hours, and commercial hydration solutions should be used for species that need them. Commercial holding solutions (overnight or longer) should be used for most flowers, unless you see a problem, which is relatively unlikely.

Retail handling. Be aware that stored flowers may appear okay but die shortly after sale. Thus, it is important to manage inventory and not allow flowers to be stored for too long. Be sure to provide flower food packets to customers, prevent physical damage by using sleeves or packing loosely in the buckets, and keep flowers in water or floral solution.



Postharvest Handling Secrets of Dahlias, Peonies and Zinnias Revealed

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Dahlia

- Harvest when the flowers are 75% to fully open, but before the outer petals begin to decline.
 - If cut too late, petals will start to drop and vase life will be even shorter than it normally is.
 - If cut too early, dahlias typically fail to open, even in flower foods. Flowers that do eventually open are often of poor quality.
- Some cultivars appear to open effectively when cut as buds. The buds (defined as the breaking stage with one petal open and 50% color) required 3 to 5 days to fully open, and flowers lasted a total of 12 to 13 days when a holding solution was used.
- Get flowers quickly to the cooler to keep the already short vase life from declining any further.
- Harvest in the morning, and place stems immediately in hydrating solution. Some growers immediately put the cut stems in hot water, then allow the water to cool, before processing further.
- Cut dahlias last 3-5 days in water, 7-10 days if a holding solution is used.
- Pulsing stems overnight with 10-20 ppm GA + BA increase vase life by 1-4 days and improve flower quality.
- While dahlias were traditionally considered to be tolerant of ethylene, recent reports indicate the ethylene can cause petal abscission and wilting and anti-ethylene agents, such as 1-MCP and STS might prevent ethylene problems.



***John Dole** is a Professor in the Horticultural Science Department at NC State University. His research program focuses on the production and postharvest physiology of floriculture crops, in particular, working with cut flowers.*

- Flowers can be stored wet at 35-40F and about 80% humidity for less than a week, but storage should be avoided whenever possible.
- Floral foam had no effect on vase life of dahlias.

Peony

- Stage of harvest is important.
 - If harvested too tight, they may not open.
 - If harvested too open, they may continue to open during storage and transportation and be damaged, plus have a short vase life.
- Stems will likely need to harvest more than once per day, up to three times a day, especially in warm weather.
- Be sure to bring flowers to the cooler as soon as possible to prevent flower opening.
- As a general rule of thumb, flowers should be harvested when the first true color appears on top of the tight bud, but the specific stage varies with the cultivar.
 - Most were best harvested at the marshmallow stage, which is defined as “soft enough to give slightly when



Cut Flowers



squeezed between thumb and forefinger.

- o Double-flowered types should be further developed than single and semi-double types, and red cultivars should be more developed than whites.
- Flowers may last up to 9 days if harvested in the bud stage, but if already open, they last only 4 to 5 days.
- The use of carbohydrates either as a high concentration pulse solution or a holding solution generally increases vase life and increases flower size.
- For short term storage of less than 2 weeks, flowers can be stored in water at 32-36F at 75-80% humidity.
 - o Storage of up to 4 weeks should be done dry.
 - o Stems with lower leaves removed should be allowed to cool and all surfaces dry to prevent botrytis.
 - o Storage at sub-zero temperatures of 31F shows promise for long-term storage of 12 weeks, possibly longer.
 - o The foliage will be wilted at the end of the storage period, but don't worry, peonies rehydrate nicely.
 - o Long-term storage will reduce vase life, but flowers can still have a 3 to 5 day vase life. Flowers stored at 31F were more likely to open and less likely to be deformed than flowers stored at 33F.
- Most cultivars appear to be relatively insensitive to ethylene. STS often increases vase life, although not dramatically, and 1-MCP sometimes has positive effects, such as increasing vase life and decreasing petal drop.

Zinnias

- Harvest just before pollen is visible or as pollen begins to form, that is, when flowers are almost fully mature.
 - o If the stems are stiff and don't wiggle, they are mature enough to harvest.
 - o Immature flowers may not fully open and are more likely to be damaged during processing.
 - o Avoid harvesting old flowers as they will have a short vase life.
- Zinnias can be harvested any time of the day. Flowers harvested in the afternoon have higher carbohydrate content than those harvested earlier, which can be especially helpful for storing flowers.
- Flowers last 7-10 days when floral solutions are properly used.
 - o Zinnia vase life will change with the season, with the highest vase life double that of the shortest vase life.
- Most cultivars lasting longer when treated with a holding solution and some benefit from the use of both a hydration and holding solution.
 - o Zinnias appear to be a case where both too little and too much postharvest solutions reduces vase life.
 - o The best treatment appears to be hydration with a chlorine tablet solution followed by a holding solution.
- Zinnias are one of the "dirty" flowers, meaning that the stems tend to rapidly pollute the bucket water. Plus, zinnias appear to be especially prone to bacterial contamination. Use a chlorine solution for hydration. Make sure buckets are clean, cutters are clean, and fresh solutions are used when handling cut zinnias.



Cut Flowers



- “Zinnia meltdown” is the rapid (within 24 to 48 hours) deterioration of perfectly good-looking flowers after being cut. Stems turn brown and mushy. The problem is caused by *Fusarium commune*, which infects the plants in the field, but the symptoms do not typically appear until postharvest.
 - o The problem varies greatly from year to year with some years an almost complete loss, while not showing up at all in other years.
 - o The disease is favored by high humidity and high temperatures.
 - o Some cultivars appear far more susceptible than others.
 - o If meltdown starts to occur, it appears that maximizing postharvest procedures will help reduce the problem, including sanitizing buckets and using slow-release chlorine tablets or a commercial hydration solution followed by a holding solution.
 - o Long-term prevention strategies include rotating where zinnias are planted and growing succession plantings in various parts of the farm to minimize the likelihood of the entire crop being infected.
 - o Be sure to use strict sanitation practices, including sterilizing/cleaning clippers, when moving from one planting to the next to reduce the likelihood of spreading the disease.
- Zinnias do not handle storage well and should not be stored more than 3 to 5 days.
 - o Storage temperature is crucial and should be 40 to 45F.
 - o Cut zinnias can be held for a short time (1 to 2 days) at 33 to 35F, but longer storage at those temperatures can result in damage, which shows as brown spots on the petals.

FDA finalizes rules on Pre Harvest Water

Jeff Stoltzfus

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FDA has recently finalized the new FSMA regulations for pre-harvest water applied to the edible part of the crop. This will focus on irrigation, crop sprays, and frost protection water. When the original Food Safety Modernization Act (FSMA) regulation was finalized in 2016, surface irrigation water sources required 5 samples per year and an average of your last 20 samples. After much feedback from the produce industry, FDA realized that this may not be helpful or practical. In 2017 FDA decided to rethink the surface water requirements. In 2022, they came up with a different proposed strategy and released it for public comment. On May 2nd, 2024 they finalized the regulation that was proposed in 2022.

It is important to note that these changes apply to pre-harvest ag water which will contact the edible part of the crop. Water applied through drip irrigation under plastic to a crop growing above the ground is not considered ag water and is not regulated. Regulations for water used for post-harvest cooling, washing, equipment washing, and hand washing have not changed and have already gone into effect.

Instead of 5 water samples per year and a 20 sample water quality profile, FDA has moved toward a written water system risk assessment for each farm which will consider the unique situations on each farm. Water testing, although not required, may be helpful if you have a fairly controlled water source like a spring, pond, small stream, or cistern.

FSMA will ask farmers to perform a Water Quality Risk Assessment for their pre-harvest water which contacts the edible portion of the crop. This primarily refers to overhead irrigation but can also include drip irrigation of ground crops normally eaten raw like onions, garlic, radishes, turnips, and carrots. It can also refer to water used for things like spraying or frost control.

The major risks from water are a result of its source, the timing of application, the method of application

Jeff Stoltzfus

Jeff has been working with vegetable farmers on vegetable food safety issues for over 15 years. He leads Penn State's effort around FSMA, GAP, and food safety issues.

and the surface characteristics of the crop. Surface water sources are considered higher risk than ground-water. However, some surface water sources may be considered riskier than others. For example, water from a river will likely be a higher risk than water coming directly from a mountain stream or spring. Cisterns, ponds, and other impoundments are also considered surface water. In these cases, water tests may aid in assessing the risk of these water sources, but there is not an established number of tests that are required. Wells and municipal water sources are considered less risky than surface water.

Timing of irrigation is critical to the risk level of the water. Bacteria may die off over time from drying, sunlight, competition, and other environmental factors. Irrigation water that is applied weeks before harvest will be less risky than water applied the day before harvest. Water applied at planting before the edible part of the plant is formed would not be considered Ag Water.

The next area of risk to consider would be application method. The less likely the water will contact the edible portion of the crop, the lower the risk. Drip irrigation would be less risky than overhead irrigation.

Then consider the crop being grown. Does the vegetable or fruit have places where bacteria can hide and survive, like the net of a cantaloupe or the center of a head of lettuce or cabbage? Does it grow close the ground like leaf lettuce or strawberries or does the fruit grow up off of the ground like tree fruit or even peppers?

Adding these risks together will help determine if



General Vegetables



you comply with FSMA and what corrective actions you may need to take. A farmer may have a high risk water source like a river, but could pass a FSMA risk assessment if they have a low risk irrigation method or timing or a lower risk crop like watermelons which doesn't have many places for bacteria to hide.

Your water system risk assessment will not be a checklist or a list of yes or no answers. It will be a paragraph or two about where your water comes from, how it is applied as well as any risks to your water and how you may go about addressing those risks.

The timeline for grower to comply with this regulation is as follows.

Growers over \$500,000 in sales must comply by April 7, 2025

Growers over \$250,000 in sales must comply by April 6, 2026

Growers under \$250,000 in sales must comply by April 5, 2027

The following could be a **sample water system risk assessment**:

"We irrigate our produce from a spring fed pond. This pond has been tested in July and contains 50 e. coli and numerous Total Coliforms. Our pond does not interact with stream water or other surface waters. The bank around pond is higher than adjoining fields and pastures so manure applications to those areas will not have any significant risk to the water source. The area is fenced to ensure that cattle do not have access to the pond. The pond is visited by employees several times each week and wildlife and cattle are observed to make sure that animals are not getting into the water.

Our irrigation water is pumped through a sand filter to remove sediment and then through header lines to our fields where it distributed through drip irrigation to our FSMA covered crops of watermelons, tomatoes, and onions. Our onion crop is the only crop where the irrigation water will touch the edible part of the crop. We do not irrigate the onion crop for at least five days before harvest to allow the crop to dry out ahead of harvest. Once harvested the onions are placed in bins and dried for 5 days before harvest. This time between irrigation and packing will allow at least 99% of the bacteria to die.

The water we use for spraying our crops comes from a 150 foot drilled well. Water test results show less than 5 ml/l generic e.coli. By waiting two days after spraying to harvest crops, we can reduce e.coli levels by 90%. We consider this level to be safe for spraying.

Because of these factors we do not consider our pre harvest water system to be a significant risk to water quality."

For more information on this regulation go to <https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-pre-harvest-agricultural-water> or contact Jeff Stoltzfus at Penn State Extension 717-283-2597.

Investigating Plasma-Activated Water for Sustainable Microgreen Production

Sanchita Saha* and Francesco Di Gioia

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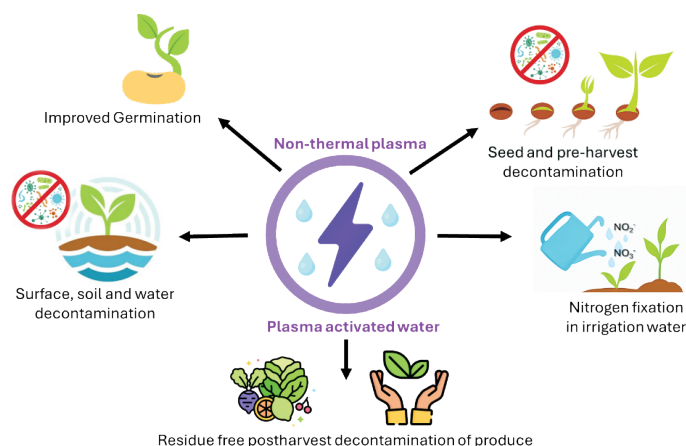
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Plasma is the ionized gas phase of matter and represents the most abundant state of matter in the universe, occurring naturally in the sun, stars, lightning, and auroras. Artificial plasma can be generated by energizing gases with high-voltage electricity, as in neon lamps, fluorescent bulbs, and plasma screens. Non-thermal plasma (NTP) is a partially ionized gas produced at atmospheric pressure and near-ambient temperature, making it suitable for biological and agricultural applications. In agriculture, NTP can be applied directly to seeds or plant tissues or indirectly using plasma-activated liquids.

Sanchita Saha is a Plant Biology graduate student at Penn State University, mentored by Dr. Francesco Di Gioia. Her research explores the use of plasma-activated water (PAW) as a sustainable tool to enhance plant growth and nutrient quality using microgreens as a model crop. With a strong interest in controlled environment agriculture and sustainable production systems, she aims to advance innovative technologies that reduce chemical inputs and promote environmentally friendly vegetable production practices.



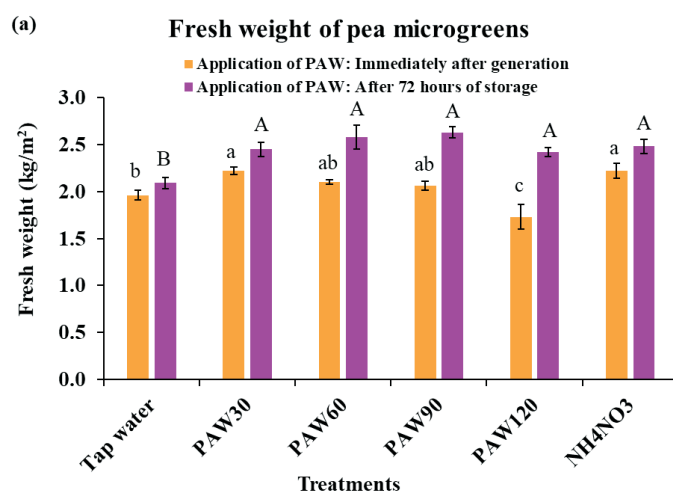
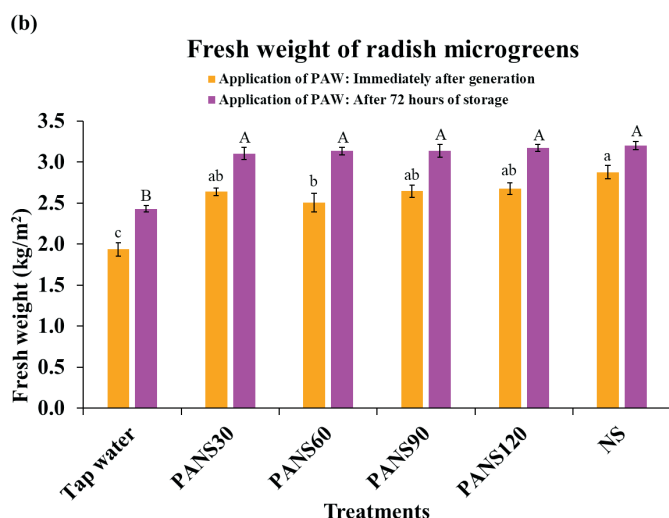
Among the indirect application methods, plasma-activated water (PAW) has gained significant interest. When water or other solutions are exposed to atmospheric plasma, reactive oxygen, and nitrogen species (RONS), including nitrate (NO_3^-), nitrite (NO_2^-), and hydrogen peroxide (H_2O_2), dissolve into the liquid. These species can influence germination, plant metabolism, nutrient uptake, and secondary metabolite production in plants, offering a sustainable alternative to synthetic fertilizers and sanitizers. However, the composition of PAW varies with processing conditions

such as plasma exposure time, storage duration, and the type of liquid being treated. Longer activation generally increases RONS content and electrical conductivity while reducing pH. Whereas storage causes short-lived ROS to decline and stable nitrogen species like nitrate to accumulate. Therefore, optimizing plasma parameters is essential to fully harness PAW's benefits for crop production.

Figure 1. Potential applications of plasma in agriculture.

To investigate the effect of plasma-activated water on plant growth and quality, we used microgreens as test crops. Microgreens are an emerging high-value crop category distinct from sprouts, baby leaves, and mature vegetables. Beyond their culinary appeal, microgreens are rich in vitamins, minerals, and health-promoting phytochemicals, including phenolics and carotenoids, that contribute to their antioxidant capacity. Their rapid growth cycle (7-21 days) and compatibility with controlled-environment agriculture make them ideal for vertical farms and urban production systems. As a result, the global microgreens mar-

ket is rapidly expanding. However, challenges persist, including the need to improve production efficiency, reduce reliance on fertilizers and sanitizers, and maintain high nutritional quality. PAW, a sustainable technology, has the potential to mitigate these risks and to enhance growth and food safety with minimal synthetic inputs. We hypothesized that storage of PAW will stabilize reactive nitrogen species (e.g., NO_3^-), leading to improved microgreen growth compared to freshly generated PAW and tap water. We also hypothesized that plasma activation of a nitrogen-free nutrient solution containing other essential macro- and micronutrients can generate enough reactive nitrogen species to support microgreen growth. But limited knowledge is available on how PAW properties translate into the agronomic performance and nutritional quality of microgreens. To address these knowledge gaps, a series of experiments was conducted at the Penn State University Greenhouse Facilities to evaluate how plasma processing time, application timing, and liquid type influence PAW chemistry and microgreen performance.



Pea microgreens were treated with PAW generated using a gliding-arc discharge system (Plasma Licensing Authority Inc., NY). Tap water (3 gallons per treatment) was activated for 30, 60, 90, or 120 minutes, producing PAW30, PAW60, PAW90, and PAW120. Untreated tap water and NH_4NO_3 solution (100 ppm N) served as controls. Each PAW batch was applied either immediately after generation or after 72 hours (h) of storage. For radish microgreens, the same plasma system and activation durations were used, but the treated liquid was a nitrogen-free half-strength Hoagland solution, resulting in a plasma-activated nutrient solution (PANS). Untreated tap water and complete nutrient solution (NS) served as controls in this case. This allowed us to test whether plasma-derived nitrogen species could substitute for synthetic N fertilizer.

Figure 2. Fresh yield of (a) pea microgreens treated with plasma-activated water (PAW) and (b) radish microgreens treated with plasma-activated nutrient solution (PANS), measured immediately after generation and after 72 h of storage (mean $\pm$ SE, $n = 3$). Lowercase letters indicate significant differences among treatments applied immediately after generation, while uppercase letters denote significant differences among treatments applied after 72 h of storage ($p < 0.05$).

Fresh weight of pea microgreens receiving immediately generated PAW exceeded that of tap water ($1.96 \pm 0.05 \text{ kg/m}^2$) except for the 120-minute treatment ($1.73 \pm 0.13 \text{ kg/m}^2$) (**Figure 2a**). After 72 h of storage, all PAW treatments improved fresh weight compared to tap water. Storage of PAW for 72 h significantly enhanced Ca and Mg contents in pea microgreens compared to both tap water and NH_4NO_3 controls.

Fresh yield of radish microgreens significantly increased for all the 72 h stored PANS-treated microgreens compared to tap water (**Figure 2b**). 72 h stored PANS application exhibited significantly enhanced K, Ca, Mn, Na content in radish microgreens compared to both tap water and NS control.

Collectively, these findings demonstrate that optimizing plasma processing time and application timing can enhance microgreen yield, increase nutritional quality, outperforming tap water, and even synthetic fertilizer in certain traits. Also, plasma activation fixed atmospheric nitrogen into plant-available forms in a nitrogen-free solution after 72 h of storage, enabling yields comparable to complete nutrient solution while enhancing several essential minerals. Although the present work focused on microgreens, the results point to broader opportunities to integrate PAW into sustainable vegetable production as a low-input, environmentally friendly alternative to conventional fertilizers and sanitizers.

Acknowledgements

This research was funded by the USDA-NIFA Specialty Crop Block Grants # C940001529 “Developing Plasma Agriculture Solutions to Improve Vegetable Yield and Quality” and by Penn State College of Agricultural Sciences through the Strategic Networks and Initiatives Program (SNIP) “Developing the Penn State Interdisciplinary Initiative on Plasma Agriculture”, with the support of Plasma Licensing Authority Inc. that provided us with the plasma generator.

Optimizing Iron Biofortification in Pea and Radish Microgreens

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Proceedings Summary:

In humans, dietary iron (Fe) deficiency is one of the leading micronutrient deficiencies affecting approximately 10 million people in the U.S., and over 2 billion people worldwide (Klaus et al., 2014). Fe deficiency can lead to numerous health complications, like Fe deficiency anemia. Pregnant women and young children are disproportionately affected by Fe deficiency due to having relatively high physiological needs, and depending on the severity, consequences of deficiency can include maternal and neonatal deaths during pregnancy (Di Gioia et al., 2019; Klaus et al., 2014). Production and consumption of Fe-rich foods can greatly help in improving dietary Fe intake. Agronomic biofortification is an approach that has been widely used to directly improve the content and bioavailability of micronutrients like Fe in plant-based foods. Compared to other biofortification strategies such as breeding or transgenic approaches, this method utilizes agronomic techniques like fertilization to enhance nutritional quality in a much quicker and straightforward manner (Teklu et al., 2023) also known as hidden hunger, affect more than a quarter of the global population. Agronomic biofortification helps to increase the concentration of a target mineral in food crops and improve human mineral dietary intake. It is a means of providing nutrient-dense foods to a larger population, especially among rural resource-poor settings, providing that they have access to mineral fertilizers. However, the feasibility of agronomic biofortification in combating hidden hunger depends on several factors in addition to fertilizer access, including crop type, genotype, climate, soils, and soil mineral interactions. Consideration of its effectiveness in increasing human mineral intake

Rishi Ravichandran is a fourth-year PhD candidate in the Plant Biology graduate program at Penn State University. His research interest lies in crop improvement, specifically improving nutritional quality, also known as biofortification. His thesis involves researching alternative agronomic techniques for the simultaneous biofortification of iron and zinc in microgreens.

to the daily requirements and the improvement of human health and the cost-effectiveness of the program is also important. In this paper, we review the available literature regarding the potential effectiveness and challenges of agronomic biofortification to improve crop micronutrient concentrations and reduce hidden hunger.”,”container-title”:”Agronomy”,”DOI”:”10.3390/agronomy13082173”,”ISSN”:”2073-4395”,”issue”:”8”,”language”:”en”,”license”:”http://creativecommons.org/licenses/by/3.0/”,”note”:”number: 8\npublisher: Multidisciplinary Digital Publishing Institute”,”page”:”2173”,”source”:”www.mdpi.com”,”title”:”Effectiveness of Agronomic Biofortification Strategy in Fighting against Hidden Hunger”,”volume”:”13”,”author”:[{“family”:”Teklu”,”given”:”Demeke”},{“family”:”Gashu”,”given”:”Dawd”},{“family”:”Joy”,”given”:”Edward J. M.”},{“family”:”Amede”,”given”:”Tilahun”},{“family”:”Broadley”,”given”:”Martin R.”}],”issued”:[{“date-parts”:[[“2023”,8]]}],”schema”:”https://github.com/citation-style-language/schema/raw/master/csl-citation.json”} . Vegetable crops are good sources of vitamins and minerals, and among vegetables, microgreens are a particularly noteworthy nutritional source. Microgreens are described as young, tender seedlings that have a short growth cycle, are suitable to grow indoors and for diverse crop species, and

most notably, are extremely nutrient-dense with low amounts of anti-nutritional compounds like phytic acid (Di Gioia et al., 2019; Kyriacou et al., 2016). These attributes make microgreens an ideal and convenient target crop for agronomic biofortification.

With Fe fertilization, depending on the source of the fertilizer used and external conditions, the mobility and uptake of Fe might be problematic. Even with sufficient levels present in the environment, in oxidizing and alkaline conditions, Fe is converted from a more bioavailable ferrous form (Fe^{2+}) to a less bioavailable ferric form (Fe^{3+}), and consequently Fe uptake in the plant is limited. Conventional Fe fertilizer salts like ferrous sulfate (FeSO_4) have been widely used in agriculture as well as in research. However, various studies have reported the use of alternative fertilizer sources that improved the effectiveness of Fe enrichment such as chelated forms of Fe (Fe-EDTA, Fe-EDDHA) as well as different forms of Fe salts (Ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$) (Buturi et al., 2021; Lata-Tenesaca et al., 2023; Teklu et al., 2023)2023; Teklu et al., 2023. The use of Fe nanofertilizers has also shown promise in effectively promoting Fe delivery and uptake of Fe, while simultaneously minimizing detrimental effects on the soil environment (Garza-Alonso et al., 2023; Tombuloglu et al., 2020). There is limited information in the literature testing and comparing the effectiveness of multiple Fe fertilizers together in enhancing Fe concentration, particularly in microgreens. To this purpose, a study was conducted at Penn State Greenhouse facilities to investigate and assess, in a soilless system, the optimal Fe fertilizer sources and application rates that can be provided via fertigation to maximize Fe concentration in radish and pea microgreens.

Pea and radish microgreens were grown in a soilless system on sprouting nursery trays that comprised of a bottom reservoir (4-cm deep) and an upper seed incubation tray (20-cm wide $\times$ 28-cm long) consisting of perforations for root penetration. After seeds were sown and complete germination occurred, microgreens were grown in sunlight with supplementary light provided for 16 h, and the fertigation treatments commenced until harvest. Radish and pea microgreens were fertigated using a half-strength modified

standard Hoagland nutrient solution that contained five selected Fe fertilizer sources— ferric sulfate ($\text{Fe}_2(\text{SO}_4)_3$), ferrous sulfate (FeSO_4), iron-EDTA (Fe-EDTA), iron-EDDHA (Fe-EDDHA), and iron oxide-nanoparticles (Fe_3O_4 , denoted as Fe-NP), prepared at three predefined application rates (15, 30, 45 mg/L). An additional untreated control was included, containing the standard nutrient solution with 0 mg/L Fe. Prior to fertigation, the Fe treatments were pH adjusted to 5.8-6.0 using 0.1 M potassium hydroxide (KOH) solution. Once a day, defined volumes of the treatments were manually added to each growing tray's reservoir, as needed. After 7-10 days, pea and radish microgreens were harvested, and the fresh and dry biomass were measured. Mineral analysis included measuring the iron and zinc concentration (mg/kg dry weight) in the plants.

In pea and radish microgreens, the impact on fresh yield and dry biomass varies depending on the source and rate. Fertigation of pea microgreens with Fe-EDDHA at 30 mg/L resulted in an 18% and 13% increase in fresh and dry biomass, respectively. Fe-EDTA, Fe-NP, and ferrous sulfate treatments applied at 15 mg/L slightly increased the fresh and dry biomass of pea microgreens; however, at the highest rate of 45 mg/L, these treatments, along with ferric sulfate, decreased the fresh and dry biomass by 16-19% compared to the untreated control. Conversely, in radish microgreens, ferric sulfate application at 30 mg/L resulted in the highest fresh and dry biomass, increasing by 14% and 8%, respectively. Meanwhile, Fe-EDTA, Fe-EDDHA, and ferrous sulfate all resulted in lower fresh yield at higher rates. There was no detrimental effect of the different sources on the dry biomass of radish microgreens. Despite these differences, overall, both the fresh yield and the dry biomass did not differ from the untreated control in either species.

The treatments' effects on Fe and Zn concentrations exhibited similar trends in both pea and radish microgreens. Pea microgreens fertigated with Fe-EDTA at 45 mg/L resulted in the highest Fe enrichment, with Fe concentration increasing by 210% compared to the untreated control. This was followed by Fe-EDDHA, which showed an increase in Fe levels up to 92%. On

the other hand, Fe-NP was the least effective source in increasing Fe concentration. Like Fe, zinc (Zn) is an essential micronutrient involved in numerous important processes in plants and humans. However, Zn has been reported to have an antagonistic relationship with Fe during plant uptake, where biofortifying Fe has resulted in reduced uptake of Zn, and vice versa. In this study, there were no significant detrimental effects from the Fe source or rate on Zn concentration. In fact, Fe-EDTA application resulted in a 5-20% increase in Zn levels, compared to the untreated control, in pea microgreens. In radish microgreens, like in pea, Fe-EDTA followed by Fe-EDDHA were the most effective sources at enriching Fe, resulting in Fe levels increasing by 350% and 180%, respectively, when applied at 45 mg/L. Meanwhile, for Zn concentration, higher rates of Fe-EDTA resulted in a slight increase in Zn concentration, while ferric and ferrous sulfate reduced Zn accumulation, compared to the untreated control.

In summary, this study showcased a comparative analysis of alternative Fe fertilizers, revealing Fe-EDTA as the most efficient source for Fe enrichment in pea and radish microgreens, with minimal yield loss. In pea microgreens, fertigation of Fe-EDTA resulted in Fe levels that could contribute up to 14-23% of Fe's recommended dietary allowance (RDA), as calculated for an adult male, and 6-10% of the RDA for an adult female. In radish microgreens, the contribution to Fe's RDA as a result of Fe-EDTA treatment was up to 9-19% for an adult male, and 4-9% for an adult female. As per the FDA regulatory guidelines, pea and radish microgreens enriched with Fe-EDTA could be considered "good" dietary sources of Fe. Ultimately, agronomic biofortification can help in optimizing the production of Fe-enriched microgreens, which may serve as functional foods to help combat Fe deficiency at individual household and larger community scales.

Acknowledgements

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Lighting Solutions and Strategies for Leafy Greens in Controlled Environment Agriculture

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The Mid-Atlantic U.S. region is home to a significant portion of the U.S. population and represents one of the largest fresh produce markets in the country. Recent shifts in agricultural policies have prioritized domestic production of fruits and vegetables, making it increasingly important to explore ways to produce more food locally and reduce reliance on food imports. Controlled environment agriculture (CEA) addresses this need by enabling year-round, climate-independent production of fresh produce. CEA systems are particularly well-suited for high-value crops like microgreens and leafy greens, which have short production cycles and can enhance regional food security while meeting consumer demand for fresh, locally grown produce.

As the adoption of CEA systems is rapidly expanding, artificial lighting is emerging as a critical component of these systems. Light (radiation) has a direct influence on plant growth, nutritional quality, and operational profitability. Producers can choose three primary approaches: greenhouse production with natural solar radiation (free but seasonally variable), greenhouse production with supplemental lighting (allowing control during low-light periods), or indoor vertical farming with sole-source artificial lighting (independent of seasonal variations but requiring substantial capital investments and operational energy costs). Regardless of the production system selected, understanding how light affects crop performance is essential for optimizing production and managing operational expenses.

Light (radiation) is characterized by three key components: intensity (the amount of light available), photoperiod (the hours of light per day), and spectrum (the wavelengths or colors of light). Light intensity can be measured instantaneously as PPFD (Photosynthetic Photon Flux Density, $\mu\text{mol}/\text{m}^2/\text{s}$) or cumulatively as DLI (Daily Light Integral, $\text{mol}/\text{m}^2/\text{d}$). Plants absorb light through pigments for photosynthesis and have many photoreceptors to sense the quality

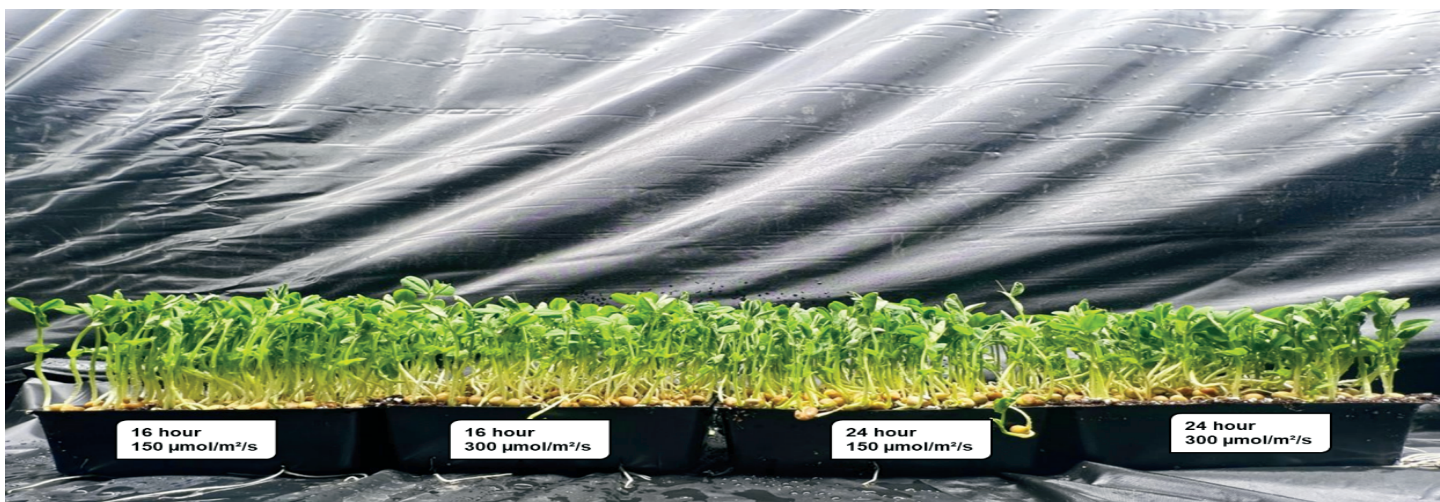
Aline Novaski-Seffrin is a third-year Ph.D. student whose research focuses on controlled environment agriculture, resource-use efficiency, and the nutritional quality of leafy greens. She investigates how light influences plant growth to improve both the efficiency and quality of vegetable production systems.

of radiation, modulating physiological processes that determine plant morphology, growth, and nutritional content.

Given the importance of radiation in all its components and the cost of artificial lighting, the objective of this research was to evaluate the effects of light intensity, photoperiod, and spectrum on the yield and quality of microgreens, and to assess the energy consumption associated with different lighting strategies.

Response to Light Intensity and Photoperiod

To understand how microgreens respond to continuous lighting and varying DLI, we conducted a study at the Penn State Greenhouse Facilities. Three microgreen species were selected: 'Dwarf Grey Sugar' peas (*Pisum sativum* L.) (Figure 1), 'Black Oil' sunflower (*Helianthus annuus* L.), and 'Daikon' radish (*Raphanus raphanistrum* subsp. *sativus*). Seeds (Johnny's Selected Seeds, Winslow, ME) were sown in a peat-perlite mix at densities of 1 seed/ cm^2 (pea and sunflower) and 2 seeds/ cm^2 (radish). A split-plot design was employed with two PPFD levels (150 and 300 $\mu\text{mol}/\text{m}^2/\text{s}$) and two photoperiods (16 and 24 hours), resulting in four DLI treatments: 8.64, 12.96, 17.28, and 25.92 $\text{mol}/\text{m}^2/\text{d}$, achieved using broad-spectrum VYPR LED lights (Fluence, Austin, TX). The greenhouse was divided into four isolated compartments, each dedicated to a light treatment, with four replications conducted across two cycles. Microgreens were harvested 6-7 days after sowing (Figure 1), with measurements



including fresh and dry weight, and photosynthetic pigment analysis.

The fresh yield was higher at the 24-hour photoperiod compared to 16 hours and at 150 $\mu\text{mol}/\text{m}^2/\text{s}$ compared to 300 $\mu\text{mol}/\text{m}^2/\text{s}$ across all species. Dry matter content, an important indicator of shelf life and nutritional density, increased with both higher photoperiod (24 hours) and higher light intensity (300 $\mu\text{mol}/\text{m}^2/\text{s}$) in pea and sunflower microgreens, but not in radish. Total chlorophyll and carotenoid content increased with higher light intensity and longer photoperiod. Energy consumption monitored using plug power meters, increased from 10 kWh to 30 kWh by increasing DLI from 8.64 to 25.92 $\text{mol}/\text{m}^2/\text{d}$ (achieved by increasing intensity to 300 $\mu\text{mol}/\text{m}^2/\text{s}$ and extending the photoperiod to 24 hours), registering a 200% increase in electricity costs.

Figure 1. Pea microgreens grown under different light intensities and photoperiods.

Response to Light Spectrum

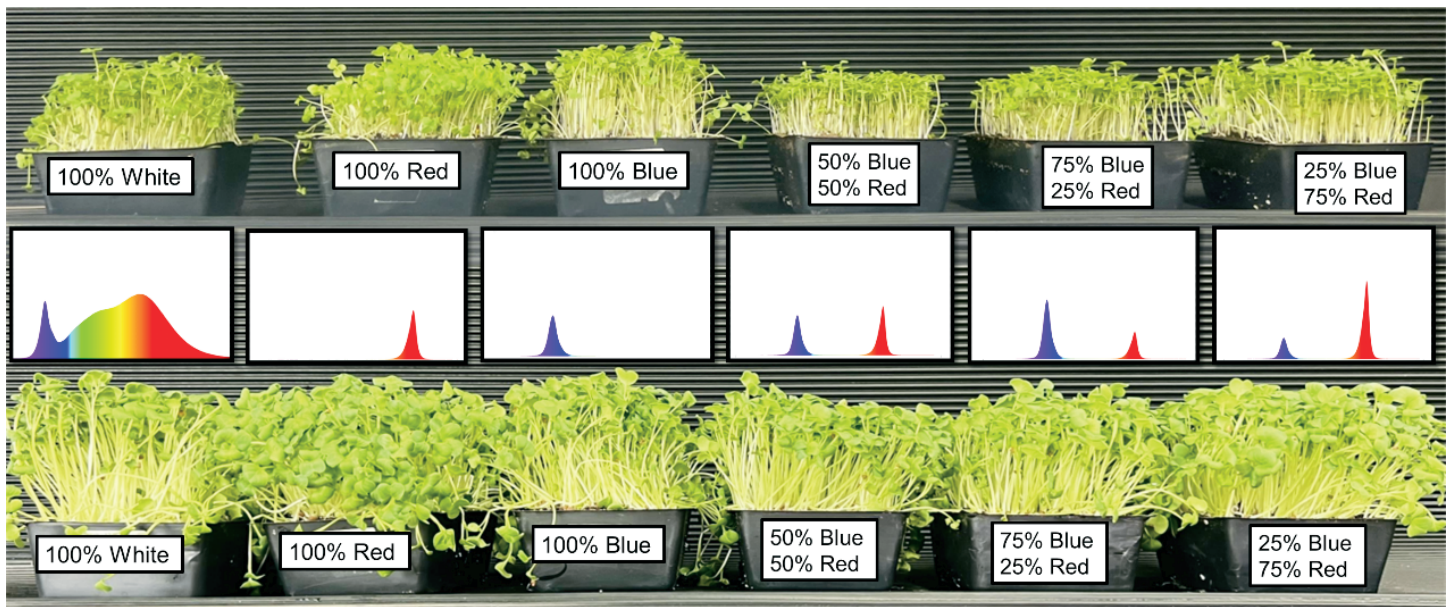
To understand how microgreens respond to different proportions of red and blue light, a study was conducted in a Penn State walk-in growth chamber using radish (*Raphanus raphanistrum* subsp. *sativus*) and broccoli (*Brassica oleracea* var. *italica*) microgreens grown under Phytofy RL LED lights (OSRAM). Six

spectral treatments were tested: 100% blue, 100% red, 100% white, and three blue/red combinations (75%/25%, 50%/50%, and 25%/75%), all maintaining 14-hour photoperiod and a DLI of 10.08 $\text{mol}/\text{m}^2/\text{d}$. Radish seeds were sown at 2 seed/ cm^2 and broccoli seeds at 3 seeds/ cm^2 in a peat-perlite mix and grown at a constant temperature of 72°F. Microgreens were harvested 6-7 days after sowing, with measurements including fresh and dry biomass, shoot height, and mineral content (Figure 2).

The fresh yield was not affected by spectral composition in either species. Dry yield was lowest under 100% blue light, while all other treatments did not differ from each other. Shoot height was greatest under 100% blue, 100% red, and 100% white light, while the blue/red combinations produced the shortest plants. Iron content was highest under the 75% blue/25% red and 25% blue/75% red treatments in broccoli microgreens only. The results demonstrate that the LED light spectra can be strategically used to manipulate both morphology and nutritional profiles, although in the case of microgreens, it may have a limited impact on crop yield, due to the short crop cycle.

Figure 2. Broccoli (top) and radish (bottom) microgreens grown under different proportions of red and blue light.

Greenhouse Vegetables



Conclusions

Light intensity, photoperiod, and spectrum affect microgreen yield and quality in a species-specific way. Higher radiation intensities induced higher dry matter and photosynthetic pigments content, and reduced shoot height. Extended photoperiods produced higher yields, dry matter content, and pigments. Additionally, higher light intensities and photoperiods resulted in proportional increases in energy consumption. The radiation spectrum influenced shoot height, dry biomass, and iron content, with blue/red combinations producing shorter shoots, 100% blue light producing lower dry biomass, and the 75% blue/25% red and 25% blue/75% red treatments increasing iron content in broccoli microgreens. Understanding these relationships is essential for developing economically viable CEA systems that support regional food production goals.

Acknowledgements

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Keep Herbs Off the Menu for Blights and Rots

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Downy Mildew on Basil: This disease caused by *Peronospora belbahrii* is very destructive on basil. Early symptoms include sections of the leaves appearing yellowish. When the leaves are turned over, the dark mildew can be seen on the undersides. However, sometimes the leaves can appear entirely green and healthy, but when the leaves are turned over the spores are evident. While basil plants with yellow or brown areas of the leaves should be investigated for evidence of the dark mildew, growers should inspect as many plants as possible including those that appear healthy. The dark spores (mildew) that develop on the undersides of the leaves are a key symptom. The spores form in the dark during the evening and early morning hours. Frequent scouting is a critical element of basil downy mildew control programs. A small outbreak of one or two infected plants can go undetected, yet this can enable the pathogen to spread and increase rapidly. Infected plants should be identified early and disposed of immediately to limit the infection of other plants in the greenhouse or field.

Cultural growing conditions can be adjusted to minimize basil downy mildew and include keeping the foliage dry and the relative humidity low. Limiting the duration of time that the plants are wet is important to reduce the threat that downy mildew poses. Adjusting the watering so that the plants are not oversaturated helps to decrease the relative humidity around the plant zone. While the optimum temperature for downy mildew is around 65°F, it can produce spores at higher temperatures if the weather is wet. If the humidity is high and the plants are wet for an ex-

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tended time, basil downy mildew can develop under a range of temperatures.

The MSU Plant Pathology Vegetable and Ornamental lab has been working to develop downy mildew of basil control strategies for several years, including developing the information needed to secure specialty fungicide labels through the USDA IR-4 Program. Today, there are several fungicide products have now become registered nationally. In the southern region of Florida, downy mildew on basil is endemic (naturally occurring) and can overwinter due to the lack of a killing frost. In the northern states, basil downy mildew does not overwinter outside, and the pathogen must be introduced each year. Contaminated seed with the downy mildew pathogen is the most likely means by which disease gets started, especially early in the greenhouse or the field during the growing season. For many crops, seed treatments can include hot water. However, this method for downy mildew on basil seed has proven to be troublesome. When basil seed is treated with hot water there is a gelatinous exudate that oozes out of the seed resulting in issues with handling and sowing. There are efforts to use steam as a seed treatment which could be helpful.

Growers have choices for fungicide management of basil downy mildew based on the growing environ-

Table 1. Downy mildew foliar severity (%) of basil cultivars in a replicated field study.

Cultivar	Downy Mildew Foliar Severity (%)*					
	07 Aug	11 Aug	13 Aug	19 Aug	27 Aug	03 Sep
Genovese Compact Improved	7.0 b**	7.0 b	11.5 b	23.8 b	87.5 c	100.0 c
Piedmont AAS	14.5 c	23.3 c	33.8 c	50.0 c	71.3 b	86.8 b
Prospera Compact	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.5 a
MIA Prospera Active	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	3.0 a
Monteverde Genovese	0.0 a	0.0 a	0.0 a	1.8 a	3.8 a	3.8 a
Monteverde Compact	0.0 a	0.8 a	0.0 a	0.0 a	0.0 a	0.0 a
Rutgers DMR Obsession	0.0 a	1.0 a	0.5 a	0.0 a	1.3 a	2.5 a
Monteverde Late Flowering	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.8 a
<i>P-value</i>	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

*Based on visual estimation of percentage of foliage with downy mildew symptoms

**Values with a letter in common are not statistically different (LSD t-test; $P=0.05$).

ment (greenhouse or field) and intended use (seedlings for field production or for sale to consumers). Rotating fungicides based on the mode of action is important. Growers concerned about seed contamination should apply a fungicide very early in the production cycle. Subdue Maxx can be used early at seeding because of its soil activity (see the fungicide label for specifics). Other fungicides that can be considered, depending on the specific production system, include Ranman, Micora, Segovis, and phosphorous acid fungicides. For organic basil production, OM-RI-certified coppers and other products can be used for downy mildew.

Resistant basil varieties are the best defense against the aggressive downy mildew. Each year, MSU conducts a replicated field trial to test commercially available and experimental basil cultivars for resistance to downy mildew. The basil cultivars were planted in a completely randomized block design with four replications. Single treatment plots were 20 ft long with 13 plants per plot and a 5 ft buffer between plots within a row. The cultivars Genovese Compact Improved and Piedmont AAS were susceptible with most of the foliage infected by the end of the growing season. All other cultivars had little to no disease.

Powdery Mildew: Powdery mildew is a common

pathogen of mint and occurs on other herbs including dill. Powdery mildew symptoms include leaf yellowing and browning causing heavily infected leaves to drop. The white growth (called colonies) develop on the leaves, stems, and petioles giving a powdery appearance to the infected plant parts. The pathogens that cause powdery mildew are favored by high relative humidity and moderate temperatures. Some powdery mildew pathogens may survive on certain weeds in the greenhouse or plants growing outside of the greenhouse in the field.

There are some growing strategies that can help to limit powdery mildew and include keeping the relative humidity low and removing diseased plants.

Botrytis Gray Mold: The high relative humidity and lack of air circulation often found beneath the plant canopy are especially ideal for the pathogen *Botrytis cinerea*, commonly called gray mold. This pathogen can infect any type of herb and is considered the second most important plant pathogen in the world. Common disease symptoms include leaf spots, blight, and stem cankers with the fuzzy gray mold being the primary way to identify the *Botrytis* culprit. *Botrytis* spores move by air and are carried to healthy plants where new infections begin. Infection requires water, which is needed for spore germination. Penetration of

the plant by *Botrytis* can be direct or indirect through natural openings or wounds. Small leaf spot symptoms may quickly combine into large, blighted areas under high relative humidity and wet conditions. *Botrytis* usually becomes established and produces spores on older leaves near the moist soil surface and under the plant canopy. Dead tissue in the plant pot or on the greenhouse bench or floor can support gray mold and spore production.

There are times in the north when growers face a perfect storm for a *Botrytis* outbreak. Elements of the storm include overcast, chilly, wet weather, and maturing crops with dense foliage.

Preventing and controlling gray mold relies on a multi-pronged approach including cultural. Sanitation includes reducing the spore load by removing dead and dying plants, and leaves from greenhouse production areas. Improving air flow to reduce relative humidity is also important. Relative humidity can also be reduced by slightly increasing the temperature via heating. Limit watering whenever possible and water at a time of day when the foliage can dry quickly.

Pythium Root Rot: A common and persistent disease is crown and root rot caused by the water mold *Pythium*. This pathogen can “nibble” the feeding roots of plants, resulting in stunted growth. *Pythium* also causes severe symptoms, such as crown rot, that can result in plant death. Saturated, overwatered growing media favors the *Pythium* pathogen. *Pythium* can persist in the greenhouse and ‘hibernate’ on dirty plant containers, benches, hoses, and greenhouse walkways, ready to become activated by the right crop and weather conditions. Almost any greenhouse crop can be infected by *Pythium*. Sanitation is especially important in limiting root rot. Minimizing stress on the crop by promoting good growth makes the plant less vulnerable to attack by a root rot. Use a pressure washer with soap and water when cleaning walkways, benches, etc. Follow with a disinfectant to remove any remaining *Pythium*. If *Pythium* crown and root rot is a recurring problem, growing cultivars that are less susceptible to the pathogen may be an option. Scouting is an important first step in controlling *Pythium*

root rot. If *Pythium* has a significant head start, the root system of some plants will be too rotted, and the fungicides will not be able to rescue them.

Fungicides: Overall, few fungicides are registered for use on herbs although the USDA IR-4 Project is working to add new control tools. Check product labels as the approved use varies based on whether herbs are being grown in the field, produced and harvested in the greenhouse, or grown as potted herbs for retail sale to consumers. Products are assigned FRAC codes by the Fungicide Resistance Action Committee which are based on the mode of action of the active ingredients. Check product labels and rotate among FRAC codes when applying fungicides.

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High Tunnel Sweet Pepper Production Strategies and Variety Selection

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Introduction

Sweet colored peppers represent a highly lucrative opportunity for small and medium-sized farms in Indiana. According to the 2022 Census of Agriculture, Indiana farmers dedicated an average of 0.7 acres (U.S. 2.9 acres) to bell peppers and 0.9 acres (U.S. 1.9 acres) to other pepper varieties. High tunnel production has become increasingly popular as it extends the growing season by 2-4 weeks in spring and allows harvest to continue until the first hard freeze in autumn, while simultaneously protecting crops from severe weather and reducing foliar disease incidence. Despite the advantages of high tunnel production, comprehensive variety performance data specific to Indiana conditions has been limited. To address this knowledge gap, we initiated a systematic evaluation program at the Purdue Student Farm in West Lafayette, Indiana. Since 2018, we have evaluated 40 open field pepper varieties across 6 growing seasons (2019-2024), with each variety assessed in two distinct production cycles to ensure reliable performance data.

Materials and Methods

All trials were conducted on Mahalasville silty clay loam soil with organic matter ranging from 5.5% to 9.6%, pH between 7.2 and 7.8, and variable nutrient levels across years. Nitrogen management evolved from 60-65 lb/A in early years to 140-170 lb/A in later seasons, using combinations of Sustane® 8-2-4, urea, and Nature's Source® 10-4-3. Phosphorus and potassium applications were adjusted based on annual soil test results. Trials were conducted in a 30' x 96' Nifty Hoops high tunnel with automated louvered gable vents and manual roll-up sidewalls.



Dr. Petrus Langenhoven is a Clinical Assistant Professor at Purdue University, specializing in production horticulture. He leads an integrated research and Extension program supporting Indiana's

specialty crop industry, including vegetables and peppermint for essential oil. His work focuses on sustainable technologies that enhance input efficiency and farm productivity. Dr. Langenhoven directs the Purdue Student Farm, edits the Vegetable Crops Hotline, and co-edits the Midwest Vegetable Trial Reports. His research in open-field and high-tunnel vegetable production informs his teaching and outreach, offering practical, science-based solutions to industry challenges and advancing small and medium-scale agriculture.

The randomized complete block design included six replications, with each variety assigned to plots containing five plants per 7.5-foot row. Plant spacing of 1.5 feet in-row and 4 feet between rows resulted in 7,260 plants per acre. Peppers were seeded in mid-April and transplanted in mid-May each year.

Walkways were covered with black woven polypropylene ground cover, overlaid with 3-footwide white polypropylene between rows to enhance light penetration. Irrigation systems transitioned from emitter-based to drip tape (Rivulis T-tape 5/8" with 12" emitter spacing) in 2021, with two lines per row positioned diagonally for uniform moisture distribution. Initial stake-and-weave systems were upgraded to HD trellis supports (8" wide, 37" high) in 2021. Vigorous tapered varieties received enhanced



support using tomato trellis twine and clips, with four stems per plant trellised to six feet. No pruning was conducted during any growing season. Pest pressure remained consistently low throughout all years, requiring no foliar pesticides. Weekly harvests continued from 87 to 168 days after transplanting, depending on variety and year. Marketable and unmarketable fruits were recorded, and fruit size was measured using electronic calipers. Fruits were classified by shape using length-to-diameter ratios: ≤ 0.95 (very blocky), 1.00 (blocky), and ≥ 1.05 (elongated). Data were analyzed using ANOVA with Tukey-Kramer separation at $P \leq 0.05$.

Variety Performance

Flavorburst (yellow bell) emerged as the most consistent bell pepper performer across all evaluation years, producing 15.0-19.4 marketable fruits per plant, with individual weights of 6.4- 7.4 oz, and yields of 43,825-64,003 lb/acre. Most significantly, Flavorburst demonstrated exceptional blossom end rot (BER) resistance, producing minimal to no BER-affected fruit in most years. The variety's compact plant architecture, early maturity, elongated fruit shape, and continuous production throughout the season make it the industry standard for high tunnel production. **Midas** (yellow bell) proved to be a high-yielding variety with particularly large fruit (8.7-10.3 oz), producing 14.6-17.8 fruits per plant and yields of 67,469-70,248 lb/acre. The variety's elongated fruit shape and very uniform appearance make it attractive for premium markets, though it showed moderate BER susceptibility in some years. **Sweet Sunrise** (yellow bell, 2022-2024) emerged as a strong alternative to Flavorburst, producing 17.5-22.9 fruits per plant, each weighing 6.3-6.4 oz, with yields of 50,679-65,090 lb/acre. Performance improved notably from 2022 to 2024, with a 30.5% increase in fruit number attributed to more moderate summer temperatures, which reduced flower abortion.

PS 09941819 (red bell with X5R® disease resistance, 2022-2024) demonstrated consistent performance across three years, producing 12.5-13.4 fruits per plant weighing 10.5-11.4 oz, with yields of 63,990-

64,638 lb/acre. The X5R® gene provided protection against bacterial spot. **Regulator** (red bell, 2022-2024) produced 12.6-13.3 fruits per plant weighing 9.2-9.6 oz, yielding 54,256-55,456 lb/acre. This variety consistently produced distinctive four-lobed fruits with a nearly blocky shape, offering market differentiation. Goliath Gold Rush suffered from severe pepper stip disorder and moderate to high BER, resulting in the lowest yields (33,209- 49,232 lb/acre) and is not recommended. Turnpike, despite producing very large fruits (11.1-11.5 oz), was affected by excessive cork-like striations, with cull rates of 20.8-23.0%, limiting its commercial viability. **Cornito Arancia** (orange) and **Cornito Giallo** (yellow, 2023-2024) represent the most reliable tapered options. Cornito Arancia produced the highest fruit counts (38.9-47.2 per plant) with exceptional BER resistance (0.0-0.2 affected fruits per plant) and yields of 46,182-48,612 lb/acre. Cornito Giallo produced 42.0-42.5 fruits per plant with equally outstanding BER resistance (0.1-0.5 affected fruits) and yields of 51,105-56,921 lb/acre. Both varieties feature small individual fruits (2.3-2.9 oz) but make up for it with prolific production, excellent flavor, vibrant color, and minimal quality issues. **Peppigrande** (red tapered, 2023-2024) emerged as the highest-yielding tapered variety, producing 41.9-46.5 fruits per plant weighing 3.1-3.9 oz each, with yields of 64,810-73,404 lb/acre. The variety produces 6.7-7.0-inch fruits, many of which contain no seeds, and begins harvest approximately three weeks later than other varieties (100- 104 days after transplanting) but continues vigorous production for 8-10 weeks. While percent culls were elevated (23.4-27.3%), most were undersized rather than physiologically damaged.

Carmen (red tapered) served as the industry standard, producing 29.2-43.7 fruits per plant weighing 3.8-4.7 oz each, with yields of 53,163-75,379 lb/acre. Fruit length averaged 6.3-7.6 inches with excellent flavor and firm texture. The variety showed moderate BER susceptibility (1.5-2.6 affected fruits per plant) but maintained strong overall performance and market recognition. **Escamillo** (yellow tapered), Carmen's yellow counterpart, demonstrated similar characteristics with 27.2-36.6 fruits per plant



High Tunnel



weighing 4.8-5.2 oz each and yields of 64,100-78,855 lb/acre. Like Carmen, it showed moderate BER susceptibility (1.1-3.6 affected fruits per plant). **Oranos** (orange tapered, 2021-2022) produced 43.4-44.3 fruits per plant—among the highest of all varieties—with exceptional flavor and minimal BER susceptibility (0.2-0.5 affected fruits per plant). While individual fruits were small (2.4-2.5 oz) and relatively short (5.1- 5.5 inches), yielding 48,086-49,530 lb/acre, the variety's bright orange color, outstanding taste, and consistent weekly production made it valuable for specialty markets. Marcato and Giubileo showed extreme BER susceptibility, with 2.9-7.0 affected fruits per plant representing over 85% of unmarketable fruit and are not recommended. Yellow Crest demonstrated unacceptable year-to-year variability, with BER incidence increasing six-fold from 2021 to 2022.

BER emerged as the primary physiological disorder, with bell peppers showing lower susceptibility (1.9-63% of unmarketable fruit) than tapered varieties (6.4-92.2%). Environmental conditions significantly influenced BER incidence—the 2022 season's extreme temperatures and high nitrogen rates (170 lb/A) exacerbated BER in several varieties, while more moderate conditions in 2023-2024 with refined fertility management (140-170 lb/A) substantially reduced BER across most varieties.

Conclusions

Based on six years of evaluation, clear recommendations emerge for Indiana high tunnel pepper production. For bell peppers, **Flavorburst** stands as the most reliable performer with excellent BER resistance and consistent yields exceeding 43,000 lb/acre. **Sweet Sunrise** provides a strong alternative

with higher fruit numbers, while **PS 09941819** offers reliable large-fruited production with disease resistance. **Regulator** provides market differentiation through its unique four-lobed fruit shape. For tapered peppers, **Cornito Arancia** and **Cornito Giallo** represent the most reliable options with outstanding BER resistance and prolific production. **Peppigrande** produces the highest yields among tapered varieties with unique seedless fruits. **Carmen** and **Escamillo** remain industry standards with good market recognition, while **Oranos** excels for specialty markets, emphasizing exceptional flavor.

Optimal production management includes nitrogen application of 140-170 lb/A per season, split between preplant and multiple fertigation events. HD trellis supports work well for most varieties, though vigorous tapered types benefit from enhanced support using tomato trellis twine with four stems per plant, trellised to six feet. High tunnel production allows harvest from mid- July through late October—approximately 14 weeks of consistent production. Growers should select three to five varieties matched to their target markets, prioritizing BER resistance and production reliability. Direct-market operations benefit from variety diversity offering multiple colors and shapes, while wholesale operations should prioritize consistent varieties with excellent BER resistance. With proper variety selection and management, growers can achieve consistent yields exceeding 50,000 lb/acre for most recommended varieties. More information is available at <https://docs.lib.purdue.edu/mwvtr>

High Tunnel Disease Management Programs

Steve Bogash, PSU Extension and ProFarm Group (retired)

Along with providing ideal conditions to grow high quality produce, high tunnels are excellent breeding grounds for diseases, insects, and mites. Common practices such as continuous cropping of tomatoes often create conditions that accelerate pest challenges. There has been a steady increase in the number and type of soil-related problems in tomato high tunnels along with the usual aphids, mites, whiteflies, tomato pinworms, Septoria leaf spot, Leaf mold, Early Blight, and occasional bacterial disease(s). Creating a proactive pest management program can slow down the impact of diseases and potentially prevent them from becoming serious economic issues.

Inspect transplants carefully: Do this before bringing the plants into your tunnel(s). Using a hand lens check the tops for any insects, mites, lesions, dark spots, fungi, etc. Pull a couple of plants from multiple trays and inspect the roots for aphids, dark areas, and rots. Ideally, you've got a good place to set the plants in a greenhouse where you can place sticky cards in the canopy for 2-3 days before planting. Reject infested plants and shop for replacements. Also, reject overgrown transplants that have been held too long. Ideal plants are compact with root systems just filling tray cells enough to hold the plug together.

Apply biological inoculants before transplanting: Drench potting media thoroughly with a biological inoculant. Two that have been proven effective over many years are Actinovate® AG, and RootShield® Plus, but there are many others. Read the labels carefully and follow the directions for the highest efficacy. Most inoculants are alive but in some kind of storage and shipping slumber, but all have a limited shelf life and generally prefer cool to cold storage conditions between applications.

When continuously cropping soil or media: Both the soil in your tunnel and any media that gets used to fill containers are highly valuable commodities. Careful plant inspections and the use of inoculants are strongly encouraged but all too often, insufficient especially



Steve Bogash retired as a Horticulture Educator and Researcher, PSU Cooperative Extension in June 2016. Then retired again from ProFarm Group formerly known as Marrone Bio Innovations as their NE / Mid-Atlantic Product Development and Territory Business Manager in 2024. Steve now consults for ProFarm Group, growers, and other bio-focused or plant nutrient focused companies. Steve is also burnishing his woodworking skills in retirement as he learns to build small boats and smell like sawdust much more often.

when continuously cropping tomatoes. The application of Majestene® for the suppression of nematodes as a soil drench can save a crop if applied before the plants are badly damaged. Test your soil for nematodes prior to planting. Proactively treat if populations are high.

If your soil or media become a source for disease inoculum: consider drenching with a PAA product such as JetAg®5 or TerraClean. Follow all label directions including the reapplication of biological inoculants within 4 to 24 hours following the PAA drench. Repeating this treatment once the plants are installed once a month may be necessary if managing fusarium, rhizoctonia, verticillium and bacterial spot and speck. Plant stimulants such as Regalia injected a few days after these treatments can improve overall plant health and performance.

Lesion and Root knot nematodes often paired with *Fusarium* are the latest problem to infest tomato high tunnels. This problem was first recognized in high tunnels in the Midwest, but now seems to be spreading to tunnels in the NE and Mid-Atlantic. Symptoms vary from barely noticeable variations in plant health to



severe stunting where populations of both nematodes have reached high levels. Growers first get a notion that something is amiss when individual plants or clusters of plants show signs of stunting. When plants are dug up masses of galls are plainly visible along with numerous lesions on the roots. High tunnel tomato growers should now include a nematode assay in their annual soil evaluation.

The use of soluble fertilizers in tunnels will typically result in salt levels / EC's increasing over time as unused nutrients build up. As part of an annual soil evaluation include a soluble salt assay along with macro and micronutrient levels, nematode assay, and organic matter levels. High salt levels will weaken plants and symptoms will often mimic diseases.

Disease management begins at seed planting and never ends: Growers often ask, 'when should they begin foliar disease prevention'? Foliar fungicide applications begin at the emergence of the first true leaf, then should continue until the last fruit is harvested and the irrigation turned off. Ask your transplant producer about their disease prevention program. Timber Rot / Sclerotinia / White Mold prevention begins in the transplant stage. Botrytis mgt is a must in early season transplant production. Weekly applications of Stargus from first true leaf can reduce both Timber Rot and *botrytis*. If high humidity persists during transplant production, reduce the incidence of *botrytis* with frequent applications of a PAA product at a preventative rate.

Immediately after transplanting begin foliar applications of a fungal / bacterial preventive tank mix. Regalia + copper + mancozeb provides high levels of prevention of most common tomato, pepper, and cucumber diseases. Remove the mancozeb from the mix once the crop is 5 days from the first harvest due to the 5 day PHI. Add Early blight, Septoria, and Late blight management products as needed during the season based on local crop reports and scouting. Cucumbers will require the addition of Powdery mildew products once fruit set begins. Downy mildew can do a lot of damage to a high tunnel cucumber crop so pay careful attention to regional IPM reports and apply the first DM product before spotting any in your tunnel.

When some PA area growers first noticed stunting on their high tunnel tomatoes in late-May and June of 2018, we applied Majestene® nematicide at 1 gallon per acre through drip irrigation followed by Regalia at 1 gallon per acre also through the drip and got a positive response with renewed plant growth and no further stunting. This was repeated once every 4 weeks until the end of the season. Ideally, this treatment would begin at transplanting.

Using Grafted Tomatoes to Combat Root-Knot Nematodes in High Tunnel Production

Wenjing Guan

Purdue University

Tomato grafting was introduced to Indiana high tunnel growers about a decade ago, and some farms adopted the practice for its benefits in improving yield and managing soilborne diseases. However, three to four years ago, we started to notice root-knot nematode (RKN) galling on the roots of grafted tomato plants. This failure to control RKN was documented at three independent farms in southern Indiana. The affected plants were grafted onto rootstocks ‘Maxifort,’ ‘DR0141TX,’ and ‘Multifort’.

The root-knot nematode (RKN) was identified as southern root-knot nematode (*Meloidogyne incognita*) in all the three cases. Resistance breakdown was initially suspected to be caused by high soil temperatures, as *Mi-1*-mediated resistance in tomato becomes compromised at soil temperatures of 28°C or higher. However, subsequent testing showed that nematode populations isolated from grafted plants successfully reproduced on tomato cultivars carrying the *Mi-1* resistance gene under controlled conditions at 24 °C. These results confirm the emergence of virulent *M. incognita* strains. Part of the findings has been published by Kunwar et al. (2024).

Meanwhile, our team has been surveying RKN in high tunnel production systems across Indiana. Three species—*Meloidogyne incognita*, *M. hapla*, and *M. arenaria*—were found causing galling on tomato and carrot roots under high tunnel conditions. However, to date, only isolates obtained from grafted tomato plants were confirmed as virulent *M. incognita* strains.

These observations raise critical questions: can grafting remain an effective strategy for managing RKN, and if so, which rootstocks are most suitable? To address these questions, we evaluated 13 commercial



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tomato rootstocks—‘Maxifort,’ ‘Arnold,’ ‘Estamino,’ ‘DR0141TX,’ ‘Multifort,’ ‘Shin Cheong Gang,’ ‘Synergy,’ ‘Balance,’ ‘Fortius,’ ‘Ficus,’ ‘Booster,’ ‘Fortamino,’ and ‘RST-04-105-T’—in greenhouse trials infested with both virulent and avirulent *M. incognita* populations, using a susceptible tomato cultivar Rutgers as control. We then grafted tomato cultivar ‘BHN589’ onto each of the 13 rootstocks and assessed their performance in high tunnels under conditions with and without RKN pressure, compared to non-grafted ‘BHN589’.

This presentation will share results from these experiments. We will also discuss strategies to prevent the emergence of virulent *M. incognita* strains, with the goal of sustaining the effectiveness of grafted tomatoes for RKN management in high tunnel production.

High Tunnel Soil Solarization: Principles and Best Practices

Rachel Rudolph, PhD

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High tunnels are passively heated and cooled structures that can be helpful structures for season extension and improved specialty crop quality. However, due to the intensive and repeated crop production in high tunnels, soilborne diseases, pests, and weeds can become problematic and cause yield loss and issues with crop and soil quality.

Soil solarization is a potential method for remediation of soil-related issues. It uses passive solar heating of wet soil under transparent plastic tarping to achieve high soil temperatures. Temperatures reached can be detrimental to soilborne pathogens, pests, and weeds . Target temperature is 104°F (40°C) or higher. Efficacy depends on: target organism, temperatures reached, duration of solarization.

Factors that affect soil temperature:

Air temperature and solar radiation

- Cooler or cloudy days will lead to lower soil temperatures

Soil preparation

- Smooth, level surface
- No clods or debris

Soil moisture

- 70% field capacity to the target depth—almost muddy

Soil texture

- Less heat transfer with sandy soil
- More water retention with clay soil

Tarp characteristics



Rachel Rudolph is Associate Professor and Extension Vegetable Specialist at the University of Kentucky. Much of her Extension and applied research deal with high tunnel systems, abiotic disorders, crop nutrition, and soil fertility. She is interested in evaluating chemical alternatives to manage common issues in both field and high tunnel systems, such as grafting with resistant rootstock and soil solarization. Her aim is to have these alternative approaches be applicable and useful to a variety of different growers and production systems.

- Thin > thick
- Clear > black

Duration of soil solarization depends on:

Season/time of year

- Middle of summer ideal

Target organism

- Difficulty of managing the organism
- Life cycle

Grower objectives and needs

- Frequency of solarization
- Market
- Economics

How to implement soil solarization



High Tunnel



Materials: The “what” of soil solarization—what materials do you need?

- *Irrigation*
- Plastic tarp(s)
 - o Size—depends on area of coverage
 - o Thickness—6 mil poly or thinner
 - o Should be relatively new
- Sod staples
- Mallets
- Hoes
- Plastic repair tape (in case there are holes)

To see implementation in action, see YouTube video *How to Solarize Soil*: <https://www.youtube.com/watch?v=LB2G3E0OPsU>

Another video that may be helpful or of interest is the *Benefits of Soil Solarization*: <https://www.youtube.com/watch?v=DH4IY-8IdNk>

Timing: The “when” of soil solarization

The hottest time of the year is ideal, but may not work with each grower’s crop production schedule

- June through August

If solarizing in cooler months, duration will need to be longer

- 2 weeks vs. 4 weeks

Implementation: The “how” of soil solarization

1. Till or disc soil to remove clods and break up debris
 - Smooth soil surface for better heat transfer
2. Irrigate soil (to 70% field capacity)
 - Better heat transfer
 - Weakens pathogens
3. Make a small trench slightly larger than the area you want to solarize
4. Place plastic tarp down
5. Secure with sod staples
6. Bury edges of tarp
 - No air seeping through
 - Trap heat to get soil temperatures as high as possible

Managing Soilborne Pests and Pathogens and Improving Soil Health with Anaerobic Soil Disinfestation

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High tunnels are increasingly popular for the opportunity they offer to extend the growing season and protect horticultural crops, creating microenvironmental conditions that promote plant growth and allow the achievement of high yield and quality standards. Nevertheless, the extension of the growing season and the necessity to invest in high-value crops that can guarantee a quick return on investment, leave limited space to crop rotations and the management of soil health. The adoption of intensive cultivation practices, often combined with monoculture, over time, leads to a deterioration of soil health and the consequent emergence of a series of soilborne pest and pathogen issues (Table 1).

Table 1. Emerging soilborne pathogen issues commonly affecting tomato and other vegetable crops in soil-based high tunnel production systems within the U.S. Mid-Atlantic region.

Francesco Di Gioia “ Associate Professor of Vegetable Crop Science in the Department of Plant Science at The Pennsylvania State University

Although crop rotations and the use of cover crops that are not susceptible to these soilborne pathogens may prevent, limit, and delay their emergence, once these issues occur, it is important to implement adequate control strategies capable of suppressing the causal agent and regenerating the soil health to prevent their proliferation and diffusion within the soil.

While in the past, we relied heavily on the use of methyl bromide and other chemical fumigants to control soilborne pests and pathogens affecting specialty crops, the application of fumigants in high tunnels is neither practical nor desirable, considering the growing consumers’ preference for more sustainable production systems and pesticide-free produce. Un-

Common soilborne pathogens	Causal agent
Fungal pathogens	
Fusarium wilt	<i>Fusarium oxysporum</i> f. sp. <i>lycopersici</i>
Fusarium crown and root rot	<i>Fusarium oxysporum</i> f. sp. <i>radicis-lycopersici</i>
Timber rot or “White mold”	<i>Sclerotinia sclerotiorum</i>
Southern blight	<i>Sclerotium rolfsii</i> , <i>Athelia rolfsii</i>
Verticillium wilt	<i>Verticillium dahliae</i>
Corky root rot	<i>Pyrenochaeta lycopersici</i>
Colletotrichum	<i>Colletotrichum coccodes</i>
Plant-parasitic nematodes	
Dagger nematodes	<i>Xiphinema</i> spp.
Root-knot nematodes	<i>Meloidogyne incognita</i> , <i>M. hapla</i> , <i>M. javanica</i>

der this scenario, it is important to identify and adopt more sustainable, chemical-free management practices that allow the effective suppression of soilborne pests and pathogens, while preserving soil health and the quality of the produce.

Among the non-chemical alternatives considered suitable for high tunnel production systems, Anaerobic Soil Disinfestation (ASD) is emerging as a pre-planting broad-spectrum biological solution capable of suppressing fungal and bacterial soilborne pathogens, plant-parasitic nematodes, as well as weeds. ASD is applied in three steps: 1) Incorporating in the soil easily labile organic amendments; 2) Sealing the treated soil with an impermeable film; 3) Irrigating the soil to field capacity.

Amending the soil with organic amendments such as wheat middling or molasses, characterized by an easily degradable carbon fraction, activates microbes already present in the soil and stimulates their rapid growth, leading to the rapid consumption of oxygen in the soil, thus turning the soil into an anaerobic environment within 24-48 hours. The impermeable film and the soil saturation with water facilitate and contribute to maintaining anaerobic conditions for one or two weeks. Under anaerobic conditions, the organic amendments are subject to a fermentation process, in which easily labile sugars are converted into organic acids (i.e., lactic acid, acetic acid, propionic acid) and volatile organic compounds (VOCs), which can suppress soilborne fungal and bacterial pathogens, root-knot nematodes, and weeds. After the anaerobic phase, the soil gradually returns to aerobic conditions, and after 3 to 4 weeks, a new crop can be established.

Being a microbial-driven biological solution, ASD is more effective at relatively higher soil temperatures and requires a minimum soil temperature of 60°F. Given this minimum temperature requirement, ASD should be applied in the spring before a late planting, over the summer if the crop is established at the end of the summer, or in the early fall at the end of an early crop. Depending on the target issue and crop, ASD may be applied to the entire soil area through a flat-bed broadcast application or through a banded application, by treating only the raised-bed area (Figure 1).

A critical aspect for the successful application of ASD is the selection of the organic amendment (carbon source) and of the relative application rate. Our research demonstrated that it is possible to use several locally available organic amendments as a carbon (C) source for ASD, and it is even possible to use cover crops as a source of C, although they are less labile than other organic residues. The most reliable C source identified so far is wheat middlings, a residue of the wheat milling process, typically used as a feed for animals. Wheat middlings are a stable byproduct that can be stored for a relatively long time; being finely ground are relatively easy to apply evenly on the soil surface, and have a well-balanced C:N ratio (typically around 18:1), which allows the microbes to feed rapidly on it and release adequate amounts of nitrogen right after the ASD treatment.

The application rate of the wheat middling or of any alternative C source is determined considering their total content of C and nitrogen (N). A standard application rate for the effective application of ASD is 5,353 lb/acre of total C, which in the case of wheat middlings corresponds to about 12,900 lb/acre of wheat middlings (see calculations in Figure 1). Applying wheat middlings at this rate will provide the equivalent of about 290 lb/acre of total N, which will be released gradually post-ASD and should be accounted for by reducing the amount of N fertilizer applied. Compared to other solutions, like chemical fumigation or soil steaming, ASD allows the suppression of several soilborne pests and pathogens, while also providing nutrients and preserving organic matter, thus contributing to promoting microbial growth and overall soil health.

Our on-farm research suggests that ASD is effective in suppressing a range of fungal pathogens, plant-parasitic nematodes, and weeds, and when applied to high-value specialty crops typically grown in high tunnels, it is an economically viable solution.

High Tunnel



Case #1 (US units) – Broadcast Application

High tunnel 30 ft × 200 ft m (6000 sq ft), **Broadcast application**, Wheat middlings at the standard application rate: **6,000 kg/ha** ($6,000 \times 0.892179$ = **5353.1 lbs/A**) of total Carbon (C).

1st step:

Analysis of the wheat middlings composition: **41.50% Total C, 2.26% Total N**

2nd step:

Calculate the application rate of wheat middlings:

5353.1 lbs/A / 0.415 = 12,899 lbs/A of wheat middlings

3rd step:

Calculate the application rate of wheat middlings for the area of the high tunnel:

12,899 lbs/A / 43,560 sq ft/A × 600 sq ft = 1,777 lbs of wheat middlings



Case #2 (US units) – Band application

High tunnel 30 ft × 200 ft m (6000 sq ft), **raised bed application (beds 3 ft wide, 6 ft apart)**, Wheat middlings at the standard application rate: **6,000 kg/ha** ($6,000 \times 0.892179$ = **5353.1 lbs/A**) of total Carbon (C).

1st step:

Analysis of the wheat middlings composition: **41.50% Total C, 2.26% Total N**

2nd step:

Calculate the application rate of wheat midds:

5353.1 lbs/A / 0.415 = 12,899 lbs/A of wheat middlings

3rd step:

Calculate the wheat middlings application rate per Linear Bed Foot (LBF):

43,560 sq ft/A / 6 ft = 7,260 ft/acre
12,899 lbs/A / 7,260 ft/Acre × 0.5 = 0.88 lbs/LBF

4th step:

Calculate the LBF in the high tunnel and the wheat middlings application rate:

6,000 sq ft / 6 ft = 1,000 ft (LBF)
0.88 lbs/LBF × 1,000 LBF = 888 lbs of wheat middlings

Figure 1. Examples of flat-bed broadcast and raised-bed banded Anaerobic Soil Disinfestation (ASD) application in high tunnel on commercial farms in Pennsylvania and relative calculations using wheat middlings as a labile carbon source.

Acknowledgements

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Preparing for Immigration Enforcement / Course Summary

Andy Mahon and Caleb P. Setlock | Barley

We will discuss important updates and challenges in immigration enforcement & compliance in the agricultural industry, as well as predicted changes for 2026 and beyond. We will cover I-9 audits, worksite enforcement actions, H-2A audits, and proactive responses for you to consider. We will also address how these changes in immigration policy may impact your workforce. Our goal is to help you navigate a rapidly changing immigration landscape.

Updates, challenges, and predictions

- o Distinguishing types of immigration enforcement actions
- o Increasing frequency of federal immigration enforcement
- o Increasing frequency of local law enforcement involvement through 287(g) agreements

Proactive responses

- o Creating a team. Employers should have a dedicated team within their organization that is responsible for responding to immigration enforcement actions. The team should be familiar with the various issues that these actions present and should be able to work with counsel to identify a particular action when it occurs.
- o Preparing a written response plan. With the assistance of counsel, employers should have a plan in writing that outlines an appropriate response when confronted with each type of enforcement action. The response plan should identify employees of the organization who are most likely to make initial contact with immigration authorities and provide those employees with precise guidance on several points.
- o Practicing. Once a response plan is in place, employers should ensure that the plan is disseminated throughout the organization and that employees with responsibilities understand



Andy Mahon is an attorney in Barley Snyder's Immigration and Employment practice groups with over a decade of experience. He concentrates his practice on immigration law, representing businesses and families seeking

immigration benefits as well as defending individuals placed in removal proceedings. Andy manages a complex caseload of immigration matters for the firm, counseling a diverse range of businesses across industries including healthcare, dental, engineering, architecture, construction, manufacturing, technology, nonprofit, higher education, and agriculture.

Caleb Setlock is an attorney concentrating his practice on employment law, labor law, and litigation. He regularly represents employers in litigation and advises them on best-practice methods. Caleb represents employers in audits and investigations brought by governmental agencies. He has successfully defended companies in actions brought by the EEOC, PHRC, HUD, USDA, Pennsylvania DOL, U.S. DOL, Pennsylvania DHS, PLRB and OSHA.

their roles and how to perform them. A response plan is only as good as the organization's ability to implement it correctly.

- o Staying Updated. As enforcement priorities and practices change, it is important to work with counsel to adjust your response plans accordingly.

Workforce impact

- o Termination of humanitarian programs, including Temporary Protected Status and Humanitarian Parole
- o Immigration sponsorship challenges: fee increases, continuous vetting, social media review, and delays in visa determinations
- o Removal proceedings and immigration detention



Labor/Farm Management

Strategies for Recruiting Talent

Cher Harpster

Penn State Extension Educator

Leadership and Community Vitality Team

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This 30-minute workshop provides business owners and managers with practical, modern strategies for attracting and hiring high-quality talent. Participants will explore today's competitive talent landscape, learn how to strengthen their employer brand, and discover effective sourcing channels. The session also covers creating clear, compelling job descriptions, and delivering an exceptional candidate experience. Extension Educator, Cher Harpster, is part of the team delivering programs and services through AgWorks, a unique, grant-funded partnership with PA Department of Labor and Industry. Penn State Extension is offering free resources to help agribusinesses with issues and

concerns related to human resources, ag law, health and safety, business operations and accessing the workforce system, including the PA CareerLink (www.pacareerlink.pa.gov). This program offers a series of workshops and seminars as well as one-on-one assistance in any of these areas. The program can also help connect businesses with professional human resource consultants. For more information on the AgWorks program, visit: <https://extension.psu.edu/agworks>

4th Generation Perspective: Navigating Family Transition in Farm

Denise Bosworth | Rohrbach's Farm Market

Our Family's Story

In 2025, Rohrbach's Farm celebrated their 70th anniversary. At the end of 2014, the Farm Market and agritourism abruptly transitioned to Denise Bosworth, 4th Generation Owner. Her brother had already been farming the family land for some time before that. Eleven years after that abrupt transition, Denise has gained a lot of insight into what worked well and what did not.

As 4th Generation Owner, she will speak to all generations facing a farm transition in a candid and informative way. She will share personal stories of working alongside her 3rd generation family to honor their history, while respectfully adapting to the changing environment of agriculture.

Key Dynamics in a Transition:

1. Inheriting Employees

Change is hard for most people, especially when they feel like they have not had an active role in that change, or in the decisions leading to the change. Existing employees may have been faithful to the previous generation, but now there is a new owner who they may not feel a connection or a commitment towards. The same is true in reverse, the new generation of hires may not feel a commitment to the "inherited" employees. This creates delicate and complicated situations. Navigating employee retention and turnover will thrive best when expectations are clearly communicated.

2. Inheriting Culture

The culture of a company is the shared set of values, beliefs, attitudes, and practices that define an organization. It shapes how work gets done. It also determines the general



After college, **Denise (Rohrbach) Bosworth**, moved to Philadelphia to work in Human Resources. She met her husband Dan and eventually they moved back to the farm with their three small children to start a roadside BBQ business. The BBQ is now a restaurant in the farm market. In 2015, Denise took over the farm market and the orchards from her parents. She farms alongside of her brother Mark. Her dad and aunt are also involved. Denise has a passion for agriculture education. She has written two children's books and began a nonprofit, *Seeds of the Future*, to fund educational events.

expectation of interactions of people within the organization. Culture will look different from generation to generation. Intentionally identifying which parts of the culture are frustrating is the easiest starting point. Making these changes must come from a positive approach and not a critical mindset.

3. Inheriting Policies

Policies, whether they are well documented and implemented or not, are a foundational aspect of any successful business. If they are not documented, that is the first thing that needs to be addressed. After that, clear training, and accountability for adhering to those policies is key! Accountability happens on a day-to-day basis, as well as a yearly basis. Adaptability of policies is equally essential. A transition time creates the perfect time to implement new policies, as well as stricter policies if needed.

Key Take Aways (what should these look like/ what should they not look like):

1. Honor the History

The history of the farm provides a strong foundation to build upon. While we honor the past and celebrate the contributions of previous generations, we also recognize that change may be necessary. Adapting farming practices, responding to evolving consumer demands, and keeping pace with advances in best practices drive the need for change. Although we learn from our mistakes, it is important to distinguish that the need to change usually stems not from errors but from opportunities to improve and grow. By balancing respect for our history with thoughtful adaptation for progress and profitability, we can ensure a strong and successful transition into the future.

2. Respect the Knowledge

Generational farmers come with years of experience, which is an invaluable resource. The previous generation has an abundance of knowledge that must be validated and is wise to adapt into current practices. Equally, some of those practices are not going to serve the farm well. Assessing from both sides is essential and we will talk specifically about that in a bit.

3. Listen to Learn

In traditional farming, the mindset has typically been “just get the work done!” This is what farm families know to do well. Training, documenting or even explaining the “why” has not been a well-established practice in generational farming. But taking the time to ask questions and then listen to explanations will foster strong transitional relationships.

4. Communicate to Grow

Strong communication skills are not often at the top of the list for generational farm

families. Traditionally, farm families work side by side, making sure the work gets done, pushing through long days, and long seasons. Finding ways to deal with broken equipment, financial challenges and perseverance are the driving forces that help them make it to the end of a season. But genuine communication is essential to transitional times. Good communication saves time and money, avoids confusion, and prevents double-work. Putting a few key guidelines in place will build essential communication skills to assist all generations in a transitional time.

Practices for Robust and Healthy Crop Production

Melvin Fisher

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Presentation Summary

We live in a day and age where many farmers are experiencing less and less success with the chemical approach in crop production. Increasingly, we hear from growers whose crop yields are plateauing, or they have to apply more and more fertilizers to get the same result, and it bothers them. Something seems to be missing. They think there should be a better way, something more regenerative.

At the same time, consumer demand for regeneratively grown crops is on the rise. They want to get away from all the chemicals. They are willing to pay more for regeneratively grown food. And a large number of them want to know their farmer. This trend is especially prevalent in the younger generation, although there are certainly many of the “more-mature” generation that are stepping up to the plate as well.

In this session, Melvin will be describing why he believes that many growers are seeing these yield and quality challenges, and what to do about it.

Are chemicals all bad? Should growers stop using them right away? His answer is that sometimes the chemicals might be needed and that he is certainly appreciative of what they can sometimes do to save a crop. However, they do get overused and the key point is that they often get used at the “wrong” time. He will describe why and how that works; when to use and when not to use chemicals.

He will also be describing how regenerative agriculture really works and how to get the soil in a position that it can thrive and produce high quality fruits and vegetables with much less chemicals, and with much less dependance upon synthetic fertilizers.

***Melvin Fisher** is a consultant with Keystone Bio-Ag. He is passionate about helping farmers regenerate their soil and grow better crops with reduced dependance on synthetic inputs. Drawing from personal farming experience, as well as 10 years of consulting experience, Melvin likes to challenge farmers to become more intentional in their practices – creating better outcomes.*

The principles for growing healthy crops are simple in theory, but how do growers actually put it into practice? In this session, Melvin will describe how to build a strong foundation for healthy crops, starting from the soil up. The topic will include some specifics about cover crops, soil balancing, thoughtful tillage practices, and the proper use of nutrients and microbial inoculants to enhance crop vitality and increase resistance to diseases and insects.

Practices for Robust and Healthy Crop Production

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Organic Potatoes Integrated with Cattle

Nolan L. Masser | Red Hill Farms Inc.

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Over the past 5 years we have grown from 2 acres of organic potatoes and summer grazing a few feeders to 75 acres of organic potatoes and selling 50 fat animals both on the hoof and by the cut

So what have we learned?

Marketing anything is the biggest key to success. We are aiming to sell a premium product to a customer who is concerned about healthy food. We've found it more profitable to change our practices to what the customer wants, rather than try to push out the same commodity the same way we always grew it in the past.

Potatoes:

We started with 2 small customers and a few leads. Since then, we have concentrated on a few key relationships that allow us to know where 75 percent of our crop is going before it is planted.

Organic potatoes are in the process of being commoditized and we try to not compete with organic potatoes grown outside of the North Eastern US. Instead, we try to identify customers who value locally or regionally grown potatoes grown to higher than organic standards (in addition to the organic stamp). Rotationally grazing cattle is a sound management plan and also fits well into the picture we are painting for our customers.

Cattle:

Red Hill Harvest is the direct marketing arm we formed to sell beef directly to customers. The best advice we got at the start was that direct marketing takes longer and is harder to start than you ever thought but can take you further than you ever dreamed. We are still in the first phase, but interest is strong and we continue to build every day. We sell chicken, turkey, pork, eggs, and honey in addition to beef and potatoes. Customers can order online for ups delivery or pickup at our farmstand.

Nolan, John, and Nathan Masser

The Masser family has been farming near Pitman, Pennsylvania since the Revolutionary War. Their passion is to provide clean, healthy food in order to make people's lives better.

We also wholesale some beef and sell live animals to other grass finished producers and customers. It builds one customer and one contact at a time.

How do we produce both?

Potato production is generally destructive to soil organic matter, but the tillage is a great reset for establishing new pastures. We're not aware of a faster, more cost effective way to build soil than grazing ruminants on mixed perennial pasture- so the two complement each other. Land is plowed the fall before a potato crop to encourage the breakdown of the sod mat. After the potatoes are harvested, a pasture mix is planted with a small grain nurse crop. Depending on the weather, the nurse crop may or may not be harvested before moving on to grazing. Grazing will take place every 30 to 90 days for the next 2 to 3 years. Some forages may be harvested for hay depending on the year and the timing, but we try to graze on standing pastures for as much of the year as possible.

Challenges

Surprisingly, most of the production challenges for potatoes and beef both have to do with implementing a natural system in a chemical world.

Most modern potato varieties thrive in a high synthetic nitrogen, chemically dependent system. Organic requires a variety that thrives well on its own without much intervention. It needs to grow quickly and aggressively to out compete weeds and pests. We are happy with the Fenway variety of reds, but are still searching for the perfect gold.



In the cattle world we struggle to find animals that thrive in a grass only environment. Even among the British breeds (Angus and Hereford for example) which are smaller and more efficient, years of breeding have selected for larger frame animals that grow quickly on grains. We try to buy feeders from farms that select for grass but they are often far away and never cheap. The solution, though not easy, is to identify the animals that thrive for us and breed them ourselves.

Where are we going from here?

Conversion to certified organic is a three year process and we are incrementally converting more acres. We are struggling to build fences and grow the retail beef business at the pace necessary to keep up with the land available for grazing- but the animals are key to the potato production.

As our soil health improves, we hope to see both enterprises become easier to manage and more profitable.

Evaluation of new insecticides for control of Colorado Potato Beetle and Wireworm in Potatoes

Kemper L. Sutton

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Colorado potato beetle

Potato growers in the mid-Atlantic U.S. are all too familiar with the Colorado potato beetle (CPB) and its voracious larvae that can rapidly defoliate plants resulting in significant yield loss. Beetles overwinter in the soil usually where potatoes were grown the previous year. They emerge in the spring and immediately walk to potato plants, where they mate and deposit their bright yellow egg masses. Seed-treatment applications of neonicotinoid insecticides such as Admire Pro (or other imidacloprid 2F products), Platinum, Belay, Scorpion, Venom, or Brigadier have been widely used by potato growers as a cornerstone of their insect pest management programs. These insecticides have a relatively low mammalian toxicity and work well as a systemic insecticide that is taken up by the roots and moved to above-ground plant tissue to kill certain insects such as CPB, potato leafhoppers, flea beetles, and aphids. Unfortunately, wide-scale use of neonicotinoids globally has brought about various levels of concern and regulatory action, which has caused some growers to seek alternative insecticide to the neonicotinoids. In addition, insecticide resistance to neonicotinoids has appeared in some populations of CPB from the northeastern, mid-Atlantic, and Midwestern U.S. Managing neonicotinoid resistance in CPB through integrated pest management practices and rotation of insecticide active ingredients is key to sustaining the long-term efficacy of these compounds for potato producers.

Kemper Sutton is an Assistant Professor in the Department of Entomology at Virginia Tech, located at the Eastern Shore Agricultural Research and Extension Center in Painter, VA. Dr. Sutton began his appointment with Virginia Tech in December 2024. His research program investigates the integrated pest management of vegetables, specialty crops, and select row crops. Dr. Sutton, raised in Windsor, NC, achieved his associates of applied science (A.A.S.) from North Carolina State University in 2014, his B.S. in environmental science from Chowan University in 2017, and his PhD in entomology from Virginia Tech in 2022. Prior to his current appointment at Virginia Tech, Sutton worked as a postdoctoral associate with the University of Georgia in Tifton, Ga where he worked with the integrated pest management of peanut pests.



Tom Kuhar is a Professor in the Department of Entomology at Virginia Tech. He has been a regular speaker at the MAFVC since the mid-2000s. Dr. Kuhar's research focuses on the integrated pest management of insect pests of potato and vegetable crops. He has trained over 30 graduate students and has published over 130 peer-reviewed papers and 6 book chapters on insect pest management in agricultural crops. A native of Baltimore, MD, he received his B.S. degree in biology from Towson, University, Towson, MD in 1992 and his Master's (1996) and Ph.D. (2000) degrees in entomology from Virginia Tech. He formerly worked as a postdoctoral research associate at Cornell University, Ithaca, NY researching alternative methods for managing vegetable pests.

Potatoes

Treatment	Rate fl oz / acre	Mean no. Colorado potato beetle larvae / 10 stems		% defoliation May 27	Yield of Grade A tubers (lb/40 ft)
		small larvae 21 May (7 DAT)	large larvae 21 May (7 DAT)		
Untreated check		13.6 a	8.0 a	46.9 a	7.46 b
Torac EC (tolfenpyrad)	14	2.5 b	0.3 b	5.2 b	15.50 a
Torac EC (tolfenpyrad)	21	5.0 b	0.5 b	5.6 b	14.07 a
Tolfenpyrad SC	14	3.8 b	0.05 b	4.8 b	11.63 ab
Tolfenpyrad SC	21	2.3 b	0.0 b	4.8 b	11.77 ab
Coragen eVo	2.5	3.5 b	0.05 b	5.0 b	13.78 a
P-value from Anova		0.012	<0.0001	<0.0001	0.0024

All data were analyzed using analysis of variance procedures. Means were separated using Fisher's LSD at the 0.05 level of significance. Means followed by the same letter within a column are not significantly different ($P>0.05$).

In Virginia, we are continuously evaluating new insecticides for potential use in potatoes and other crops.

In 2025, in Painter, VA, we evaluated the efficacy of tolfenpyrad insecticide Torac EC and a new SC formulation of the same insecticide along with Coragen eVo (new formulation of the diamide insecticide chlorantraniliprole). All insecticides effectively controlled CPB eliminating defoliation and significantly improving yield (Table 1). Tolfenpyrad offers a different mode of action to rotate away from diamides, spinosyns, or neonicotinoids for resistance management.

Table 1. Summary of efficacy of foliar insecticides applied twice (May 7 and 14) for the control of Colorado potato beetle larvae in potatoes; ESAREC, Painter, VA 2025

Also in 2025, we evaluated a novel foliar insecticide Zivalgo™ with the active ingredient Plinazolin (isocycloseram); this new insecticide will be available in 2026. Treatments included: Zivalgo™ + DyneAmic (0.25% v"v); the diamides Coragen 20SC and Vantacor + DyneAmic (0.25% v"v); and the spinosyn insecticide Blackhawk 36WG. All insecticide treatments provided excellent control of CPB larvae and basically eliminated any defoliation, which reached as high as 80% in the untreated control (Table 2). All tested insecticides in this trial are highly recommended for control of CPB.

Potatoes

Treatment	Rate / Acre	Mean no. Colorado potato beetles / 10 stems					% defoliation 3 Jun	
			19 May small larvae	19 May large larvae	23 May small larvae	23 May large larvae	1 Jun large larvae	
Untreated check			122.5 a	8.0	77.3 a	171.8 a	13.3 a	80.0 a
Zivalgo™ + DyneAmic	2.74 fl oz		n/a	n/a	0.0 b	0.0 b	0.0 b	2.8 b
Coragen 20SC	5 fl oz		n/a	n/a	0.0 b	0.0 b	0.3 b	3.3 b
Vantacor + DyneAmic	1.66 fl oz		0.0 b	0.0	0.0 b	0.0 b	0.3 b	3.3 b
Blackhawk	3 oz		28.5 b	0.3	1.0 b	0.3 b	8.5 ab	9.3 b
P-value from Anova			0.0001	ns	0.0001	0.0015	0.0268	0.0001

Table 2. Efficacy of foliar insecticides including Zivalgo™ for the control of Colorado potato beetles in potatoes; ESAREC, Painter, VA. Insecticides were applied 18 & 26 May.

Wireworms

Wireworms are the subterranean larval stage of click beetles, and in the Mid-Atlantic U.S., the cornfield wireworm, *Melanotus communis*, is a major species attacking potatoes. Wireworms cause damage by feeding on the surface and tunneling into tubers, which reduces marketable quality and creates entry points for plant pathogens that can potentially rot the tuber. In addition to wireworms, white grubs, the larval stage of scarab beetles such as Japanese beetle, also feed on tubers making them unmarketable. Since the early 2000s, we have evaluated insecticides for these pests and the ones that have provided the best reduction in wireworm damage to potatoes include the older organophosphates Mocap or Thimet, Regent (fipronil), and the pyrethroid Capture LFR (bifenthrin). It should also be noted that the neonicotinoids applied at-planting for other pests like potato beetles also will reduce wireworm damage.

It has been many years since we've seen a new insecticide for wireworms. We conducted the same insecticide trial in two locations in Virginia in 2025 to evaluate at-planting insecticides in potatoes. Nurizma (broflanilide) is a new Group 30 soil insecticide registered on potatoes. In our 2025 trials Nurizma provided similar control as the standard Regent, but when Sniper (bifenthrin) was added as a tank mix, Nurizma + Sniper outperformed Regent + Sniper, and provided the best overall reduction in wireworm damage even compared with Mocap (Table 3). Plinazolin® (active ingredient = isocycloseram), which was evaluated in the aforementioned CPB foliar insecticide trials also shows promise as a new wireworm insecticide in the future; however, it is not currently registered for soil use in potatoes.

Potatoes

Treatment	Rate / acre	% tubers damaged by wireworm		Average % control
		Painter, VA	Abingdon	
Untreated check		17.0 a	26.5	
Nurizma	1.3 fl. oz	10.0 ab	12.5	48.3
Nurizma + Sniper	1.3 fl. oz + 12.0 fl. oz	7.0 b	6.0	70.1
Regent	3.2 fl. oz	7.0 b	17.0	44.8
Regent + Sniper	3.2 fl. oz + 12.0 fl. oz	6.0 b	11.5	60.0
Mocap EC	4.4 oz/1000 ft	4.0 b	13.0	60.9
Plinazolin SC400	3.8 fl. oz	4.0 b	17.5	50.6
<i>P</i> -value from Anova		0.0001	0.0758	

Table 3. Summary of efficacy of soil applied insecticides for the control of wireworms in potatoes in Painter, VA and Abingdon, VA 2025.

Rinotec™ Technology (MBI-306) is another new insecticide that contains insecticidal metabolites derived from a soil bacterium. We tested this biopesticide applied at-planting in potato trials in two locations in Virginia in 2025. MBI-306 definitely demonstrated activity on wireworm reducing damage to tubers by about 50%, which was comparable to the

standard, Regent (Table 4). An at-planting application followed by a second application at hilling (cultivation) appeared to provide better efficacy than the at-planting treatment alone.

Table 4. Summary of efficacy of the biologically derived insecticide MBI-306 for the control of wireworms in potatoes in Painter, VA and Abingdon, VA 2025.

Treatment	Rate / acre	% tubers damaged by wireworm		Average % control
		Painter, VA	Abingdon	
Untreated check		15.0	26.5	
MBI -306- at-planting + MBI-306-at hilling	20 fl. oz + 20 fl. oz	5.0	14.0	54.2
MBI-306- at-planting + Capture LFT- at hilling	20 fl. oz. + 32 fl. oz	15.0	9.0	42.2
MBI-306- at-planting	20 fl. oz	11.0	12.0	44.6
Regent - at-planting	3.20 fl. oz	7.0	17.0	42.2
<i>P</i> -value from Anova		0.0676	0.0758	

Fungicide Resistance and Late Blight

Leah Fronk | Penn State Extension

Understanding Fungicide Resistance

Fungicide resistance is a genetic shift within a pathogen population that allows individuals to survive applications that previously provided control. Two conditions drive resistance: (1) a genetic trait enabling survival and (2) selection pressure from repeated use of the same pesticide or mode of action (MOA). Initially, resistant individuals occur at very low quantities, but repeated applications eliminate susceptible organisms, allowing resistant strains to dominate.

Resistance develops faster with single-site fungicides because they target a single, specific process in the fungus, making it easier for mutations to survive. Multi-site fungicides, which affect multiple pathways, are less prone to resistance. The speed of resistance development depends on pest biology, pesticide characteristics, and management practices. Resistance develops quicker when selection pressure is high. For example, when the same mode of action is applied repeatedly or when fungicides are used at doses too low to kill the pathogen – this is considered high selection pressure.

Consequences of resistance include reduced efficacy over time, leading to control failures. Models show that initial control of 90% can drop to 30% after several generations of selection pressure. Once resistance becomes widespread, options for control are limited. Since developing new fungicides is costly and slow, often requiring over a decade and millions of dollars, it is imperative growers reduce selection pressure whenever possible to preserve the effectiveness of existing fungicides.

Late Blight as an Example

Late blight of potato (*Phytophthora infestans*) is a good example of the challenges of fungicide resistance. This pathogen thrives in cool, wet conditions and spreads rapidly, causing devastating crop losses. Resistant strains have emerged due to repeated use of specific fungicides. For example,

Leah Fronk is a commercial horticulture Extension Educator based in Juniata County. She holds a bachelor's degree in Horticulture from Temple University, and MS in Horticulture from Penn State. Her programming focuses on organic and conventional pest management for vegetable and small fruit crops, as well as assisting growers with issues related to pesticide certification and the Food Safety Modernization Act (FSMA).

US-8 is associated with resistance to phenylamide fungicides such as mefenoxam, while US-24 shows reduced sensitivity to certain chemistries. US-23, although generally sensitive to mefenoxam, is highly aggressive and widespread.

Monitoring by USABlight (<https://usablight.org>) shows that *Phytophthora infestans* populations in U.S. potatoes have dramatically shifted over time. Key genotypes detected in recent years include:

- **US-23:** Currently the dominant lineage in most potato-growing regions since 2013. This aggressive, mefenoxam-sensitive strain attacks both potato and tomato.
- **US-25:** Found predominantly on tomato, and less common than US-23, identified in some regions (e.g., New York, 2023). Notably, it displays resistance to both Ridomil (mefenoxam) and oxathiapiprolin (Orondis)—marking the first documented resistance to oxathiapiprolin in *P. infestans*.
- **US-22:** Once widespread on tomatoes (circa 2009), it has been largely displaced by US-23.
- **US-8 and US-11:** These historic lineages persist mainly on the West Coast and are known for their resistance to phenylamide fungicides like mefenoxam

These examples underscore the importance of proactive resistance management. Proper fungicide selection is critical: rotate fungicides by FRAC code, avoid consecutive applications of the same MOA, and use labeled rates at the correct timing to prevent sub-lethal dosing. Tank mixes and integration of protectant and systemic fungicides can help maintain efficacy.

Growers have access to valuable forecasting tools to stay ahead of late blight outbreaks. The website <https://usablight.org> provides real-time outbreak maps and reports, helping growers track disease movement and risk levels across regions. In Pennsylvania and other states, Extension supports growers by posting late blight updates at produce auction kiosks statewide and sending weekly email reports. These updates include disease occurrence and, when available, the specific strain detected and fungicide guidance.

Best Practices for Fungicide Safety

Accurate disease identification and regular scouting are essential. Misdiagnosis or delayed detection can lead to ineffective treatments and accelerate resistance development. Integrated disease management combines fungicide rotation, cultural practices such as field sanitation and resistant varieties, and forecasting tools to optimize application timing.

Resistance management must start early—before failures occur—because the genetic shift happens long before symptoms of resistance appear in the field. By combining crop scouting, resistance monitoring, and informed fungicide choices, growers can protect yields and preserve fungicide effectiveness for the future.

Can I Use AI for Crop Recommendations?

Leah Fronk and Jim Ladlee | Penn State Extension

Artificial intelligence (AI) tools, including large language models (LLMs) such as ChatGPT, are increasingly being explored in agricultural contexts. These tools can summarize information, suggest management options, and assist with communication. However, questions remain about their reliability and appropriate use in providing crop recommendations.

LLMs excel at processing and organizing large volumes of text, drafting outreach materials, and offering accessible explanations of technical topics. They are valuable for brainstorming and improving efficiency in communication. However, these tools are not designed to ensure factual accuracy. They generate responses based on patterns in text rather than verified data. As a result, AI outputs can include outdated, incomplete, or fabricated information. Importantly, LLM AI systems do not possess ethical consideration, a moral compass, local context, or professional judgment. The models are often optimized for many factors that may appear useful or helpful to the user; however, in actuality, the LLM models may not be constructing a correct or complete answer based on the prompt.

Users should evaluate LLM AI-generated content for accuracy, completeness, and local relevance, verifying information with trusted Extension or research sources. The quality of AI output is strongly influenced by the prompt: specific, detailed prompts produce more useful and accurate results. For example, “Summarize Penn State nitrogen recommendations for field cucumbers” will yield better results than “How much fertilizer do cucumbers need?”

We tested eight LLM platforms (ChatGPT free, ChatGPT premium, Copilot free, Copilot paid, Gemini free, Grok3 free, Grok3 paid, and Perplexity) by asking them ten practical questions about cucumber production, and then rated the answers using a four-point rating system: 1 = Poor (<70% correct), 2 = Okay (70–85% correct), 3 = Good (85–95% correct), and 4 = Excellent (95–100% correct). A current Extension Educator’s responses served as the control for comparison. While several platforms delivered accurate information, the quality varied widely, with

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many responses lacking clarity, prioritization, and locally adapted applicability necessary for on-farm decision-making.

Among the eight LLM platforms tested, Gemini Free emerged as the top performer. Grok3 Paid and Grok3 Free followed as strong contenders. ChatGPT Premium outperformed its free counterpart. Copilot Paid scored slightly higher than Copilot Free, but both lagged behind Grok and Gemini in overall quality. Perplexity landed in the mid-range, comparable to Copilot Paid. These results underscore that while AI platforms can provide valuable information, but reliability varies greatly. This case study was limited to a single topic and a single educator review, and the prompts were not optimally designed, which influences the responses. The findings and limitations of this study highlight that further research is needed, and current results should be used only as general information rather than definitive guidance in choosing an LLM platform.

AI tools with strong data-driven foundations, such as disease forecasting models, pest identification apps, and predictive irrigation or yield systems, show promise for specialty crop production. In contrast, chat-based AI platforms should be used cautiously and never as a substitute for human expertise, particularly for pesticide rates, worker safety, or financial decisions. Critical thinking, discernment, and verification remain essential when interpreting AI-generated information. Used wisely, AI can complement Extension and research-based



decision-making; used carelessly, it can mislead and erode trust. The goal is to stay curious but cautious, exploring what LLMs and Generative AI can offer your business while keeping in mind their limits and making sure every recommendation is backed by solid, science-based sources.



Don't Let Mildew Make You Miserable

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The first foliar sign of powdery mildew is a white powdery growth that frequently begins on the underside of the leaves. Only powdery mildew has a white, talcum-like appearance on leaf surfaces (top or bottom) and stems. By the time that the white colonies of the fungus are noticed on the topside of the leaves, the fungus may already be well-established making control more difficult. If only protectant fungicides (ex. chlorothalonil, mancozeb, copper, sulfur) have been used, the first indication of powdery mildew may be limited to the underside of leaves and escape early detection.

Powdery mildew is most effectively addressed before the disease first appears or just after it has been found through scouting. Scouting is a critical component of powdery mildew management resulting in appropriately timed fungicide sprays while reducing unnecessary applications that are costly and may increase the risk of resistance. Resistance of powdery mildew to certain fungicides has been an ongoing concern for growers and may be contributing to control difficulties.

Now is the time to consider the effectiveness of your current control strategies and plan for next season. Whenever possible, choose a cultivar that has some level genetic resistance to powdery mildew. This approach along with scouting and the application of either fungicides or biologically based plant protection products can lead to success against powdery mildew. Two different field studies were conducted last year at Michigan State University to guide control recommendations.

Powdery Mildew Control Using Fungicides: To determine which fungicides perform best when the vine crop is susceptible to powdery mildew, we used the pumpkin 'Cherokee Bush' (see Table 1). While we used only one fungicide type applied multiple

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times for each research plot, this approach is not recommended for growers. We conducted the trial in this way to determine which product provided a good level of control even when the cultivar is vulnerable to disease. Once the effective products are identified in the research plots, they can be placed into an overall program that alternates among the active ingredients based on the FRAC code (see below in the table). Also, each fungicide label specifies the maximum number of applications that can be made for each product per season. Alternating among the FRAC codes of the fungicides and limiting the number of applications for each specific product is important so that the powdery mildew fungus does not become resistant. Overall, the fungi responsible for powdery mildew on vine crops and other specialty crops are well known to develop resistance to highly effective fungicides over time.

Among the fungicides that we tested in 2025, Switch 62.5 WG, Vivando SC, Prolivo 300 SC, and Gatten provided a level of powdery mildew control that was better than the untreated control at the end of the season. Among the effective fungicides in our trial, Vivando SC was more effective than Switch 62.5 WG and Gatten. The AUDPC (Area Under the Disease Progress Curve) indicates the amount of disease over the season whereas the higher the number the greater the level of disease.

Table 1. Foliar disease caused by powdery mildew on the susceptible pumpkin 'Cherokee Bush' when treated with fungicides.

Pumpkins

Fungicide and rate/A, (FRAC) Active ingredient, application order, applied at 7-day intervals	Leaves with Powdery Mildew (%)						AUDPC	Necrotic Leaves (%)		
	14 Aug	18 Aug	25 Aug	28 Aug	4 Sep			15 Sep	17 Sep	
Untreated	23.0 a ²	82.0 a	100.0 a	100.0 a	100.0 a		3045.3 a	88.3 a	88.5 a	
Pristine DF 18.5 oz (7/11) Boscalid + Piraclostrobin, apps A-E	20.0 b	51.3 a	99.5 a	100.0 a	100.0 a		2908.4 a	93.3 a	96.5 a	
Switch 62.5 WG 14.5 oz (12/9) Cyprodinil + Fludioxinil, apps A-E	8.5 c	25.8 b	58.8 b	50.0 b	52.5 b		1860.3 b	62.5 b	52.5 b	
Torino SC 3.4 fl oz (U06) Cyflufenamid, apps A-E	15.0 b	50.0 a	99.5 a	98.8 a	100.0 a		2867.1 a	89.5 a	92.0 a	
Vivando SC 15.4 fl oz (U08) Metrafenone, apps A-E	8.3 c	19.5 c	36.3 c	27.5 c	33.8 c		1342.0 c	31.3 c	20.0 c	
Prolivo 300 SC 5.0 fl oz (50) Pyriofenone, apps A-E	8.3 c	22.5 c	36.3 c	30.0 c	41.3 bc		1574.9 bc	46.3 bc	33.8 bc	
Gatten 8.0 fl oz (U13) Flutianil, apps A-E	9.5 c	20.0 c	45.0 c	31.3 c	52.5 b		1715.9 b	60.0 b	55.5 b	

²Column means with a letter in common are not significantly different.

Powdery Mildew Control Using Biologically Based Products:

In this trial, we used an acorn squash cultivar that is not considered as susceptible to powdery mildew as other cultivars (See Table 2). This was done so that the biologically based products would not be overwhelmed by disease as quickly than if we had used a cultivar that is especially sensitive to powdery mildew.

As the disease progressed, research plots treated with Serenade Opti WP or Badge X2 WP had less powdery mildew than the untreated control. At the very end of the trial, these products had slowed powdery mildew significantly compared to the untreated control so that the percentage of necrotic leaves was less than the untreated control and the other treatments that

we included for comparison. The AUDPC (Area Under the Disease Progress Curve) indicates the amount of disease over the season whereas the higher the number the greater the level of disease. When using biologically based plant protection products, growing a vine crop cultivar with powdery mildew resistance or tolerance could be helpful.

Table 2. Foliar disease caused by powdery mildew on the tolerant acorn squash ‘Tiptop’ when treated with biorational plant protection products.

Treatment and rate/A, application order, applied at 7-day intervals	Leaves with Powdery Mildew (%)							Necrotic Leaves (%)		
	28 Aug	4 Sep	8 Sep	10 Sep	15 Sep	17 Sep	AUDPC	15 Sep	17 Sep	
Untreated	71.3 a ²	86.3 a	92.5 ab	100.0 a	95.0 a	95.0 a	2374.3 a	85.0 a ^v	88.8 a	
LifeGard WG 128 g/100-gal, Bacillus mycoides, apps A-E	67.5 a	83.8 a	93.8 ab	98.8 a	93.8 a	97.5 a	2319.9 a	78.8 a	90.0 a	
Ecoswing LC 32 fl oz, + Silwet L-77 6 fl oz/100-gal, Extract of Swinglea glutinosa, apps A-E	71.3 a	88.8 a	96.3 a	98.8 a	100.0 a	99.3 a	2445.5 a	88.8 a	94.3 a	
Badge X2 WP 2.5 lb, Copper Oxychloride+ Copper Hydroxide, apps A-E	51.3 ab	62.5 b	68.8 c	88.8 a	68.8 b	82.5 b	1687.1 bc	46.3 bc	52.5 b	
Serenade Opti WP 20 oz, QST 713 strain of Bacillus subtilis + Induce 0.125% V/V, apps A-E	33.8 b	57.5 b	62.5 c	75.0 b	72.5 b	92.5 ab	1514.8 c	36.3 c	41.0 b	

²Column means with a letter in common are not significantly different.

Aronia Production: Research and Education of a Model Crop

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Nationally, the age range of farmers is between 55 and 65 (NASS Data). One of the greatest challenges for transitioning farms to younger owners is land accessibility. Three-quarters of new farmers in the 2017 survey were not inheriting land since they do not come from traditional family farms. Land prices have doubled throughout the country over the past 10 years making land increasingly difficult for new farmers to find and afford. Alternatively, young urban farmers are finding spaces inside urban areas, either reclaimed land or on rooftops. Farmers need to make the most profit off of smaller land parcels. This is where high-value, specialty crops have a place in U.S. agriculture.

University of Maryland Extension has developed an alternative crop program to assist farmers, both experienced and new, to find new high-value, alternative specialty crops and understand fundamentals of plant production to increase farm efficiency, productivity, and profitability on smaller areas of land. A few of these plants, being grown at University of Maryland's Wye Research and Education Center (WyeREC) in Queenstown MD, are featured in this program talk along with ideas on their cultural management.

The fruit-crop *Sorbaronia x mitchurinii* (*Aronia mitchurinii*) is an intergeneric hybrid of *Sorbus aucuparia* and *Aronia malanocarpa*, the Eastern U.S. native plant, black chokeberry. This crop has been extensively cultivated in Eastern Europe for over 50 years. For the past 20 years, the fruit has been cultivated primarily in Mid-Western states like Iowa, Nebraska, and Wisconsin. The fruit has a very high concentration phytochemicals which include polyphenols, flavonoids, and anthocyanins, which are touted to be potent antioxidants. This gives *Aronia* a marketable trait as a specialty crop. Some of these antioxidants give the fruit an astringent flavor, described by some as like dry, red wine. The fruit are dark purple pomes, about the size of a blueberry, and have a relatively thick skin like an apple. Plants flower in late April to mid-May depending on local climate. Flowers are apomictic which means they can self-pollinate with the help of



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pollinators like native bees, which have been observed at WyeREC. The fruit develops over the summer and is harvested between mid-August and early September. At harvest, the fruit can have a soluble sugar (brix) content between 15 and 18. The plants can yield up to and over 15 lb of fruit within 4 years, with some of the plants yielding over 30 pounds. The crop is very hardy and very resistant to the typical pests and diseases that plague pome and drupe crops in the rose family. However, the plant is not without problems. Japanese beetle predation is the most critical and some IPM strategy is necessary to minimize leaf canopy damage. Another major introduced pest is Japanese Maple Scale. A very active IPM program is required to control this test in both organic and non-organic production. The crop is also susceptible to apple scab (*Fusicladium*) a prevalent disease for *Aronia* on the Eastern Shore of Maryland.

In partnership with polymer and phytochemist, Dr. Victoria Volkis at the University of Maryland, Eastern Shore (UMES), research has focused on how nitrogen nutrition and irrigation affects yield and fruit quality including content of phytochemicals like anthocyanins, flavonoids, and polyphenols; all considered powerful antioxidants. At UMES, an education program capturing student's interest in high-tech agriculture using



aronia as a model research crop, has provided numerous opportunities for continued funding into specialty crop agriculture. We've expanded our palette of interesting specialty crops including ground cherry (*Physalis grisea*), tulsi (*Ocimum tenuiflorum*), and ginger (*Zingiber officinale*), and have incorporated precision agriculture research studies testing wireless sensor networks for autonomous plant-driven irrigation.

Challenges and Wins in Matted Row Strawberries

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Overview of the Matted-Row System

Matted row production is a perennial system where runner plants form a dense mat over the ground, and straw is used to overwinter the planting and mulch the walkways. Dormant crowns are planted in early spring and harvested the following year. After harvest, a renovation process helps to maintain productivity, which involves weed elimination, mowing, thinning, and fertilizing. Common cultivars suited to this system in PA include varieties such as Earliglow, Jewel, Flavorfest, and Galletta. According to a Penn State trial established in 2014 and harvested in 2015-16, yields range from 7,000-18,000 lbs/acre.

One of the main advantages of matted row production is its lower initial cost, as it does not require plastic mulch or raised beds, and plant cost is also lower. This system promotes sustainability by reducing plastic use and waste. Fields can remain productive for three to five years with proper management, making it appealing for growers who prefer a longer production cycle or growers with u-pick markets. Additionally, matted row systems are well-suited for colder regions and diversified farms of Pennsylvania and the Mid-Atlantic.

Despite its benefits, matted row production presents several challenges. Weed pressure is a major concern because there is no plastic mulch to suppress weeds, requiring more labor and herbicide use for weed management tasks. A summer of care is required to establish the plants. Soilborne diseases and overwintering pests can also be problematic, given the perennial nature of the system. Renovation after harvest is labor-intensive since it requires several steps. Furthermore, yields in matted row systems tend to be lower and less predictable compared to plasticulture and fruit size is smaller which can impact profitability for some growers.

How Plasticulture Differs from Matted Row

In contrast to matted-row production, plasticulture is an annual system that uses raised beds, plastic mulch, high-density plantings, and drip irrigation. It generally offers higher yields and better weed control, but at a

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higher initial cost and with more concentrated labor demands during planting and plastic removal. Plastic disposal, specialized equipment, and frost protection are other considerations for this system. Plasticulture is often preferred for growers targeting early markets, and those who have a longer growing season such as southeast Pennsylvania and the Atlantic shore regions. Since fruit bloom and fruiting occur earlier, access to overhead irrigation and/or row cover application for frost protection is critical.

General Guidelines for Matted-Row Strawberries

Plant bare-root strawberry plants in the spring as soon as the plants are delivered and soil is workable with no chance for freeze. Aim for a soil pH of 6.0–6.5. Test your soil in the fall prior to planting and add needed nutrients like phosphorus or calcium; sandy soils may need boron.

Space crowns 18–24 inches apart in rows 3–4 feet apart. Spread the roots out, and plant so the crown is level with the soil surface, not too deep or too shallow. After planting, water thoroughly to settle the soil. Apply nitrogen fertilizer approximately 3–4 weeks later. Allow runners to establish a 12–18-inch-wide row with 2-foot walkways between. During the first year, remove all flowers to promote strong root development. Maintain weed control through shallow cultivation or, if needed, apply herbicide according to label directions during the establishment year. For help in selecting herbicide, refer to the Strawberry chapter of the Mid-Atlantic Commercial Vegetable Production Recommendations Guide.



In early December, I have a lot of straw to protect plants over winter. Use a soil thermometer—when soil at 4 inches is 40°F or colder, it's time to mulch. Plants should look flat, and some varieties may turn reddish. Apply 4–6 inches of straw in cold areas, less in warmer regions. In spring, when soil warms above 40°F, pull mulch back from the plants, but leave it between rows and next to plants to keep fruit clean.

To retain vigor and maintain berry size in subsequent years, renovation is required immediately after harvest is completed. This process includes eliminating weeds, mowing off the strawberry plants (without damaging crowns), and narrowing the width of the rows to 6-12 inches. When narrowing the rows with a cultivator or similar equipment, cover the crowns lightly with $\frac{1}{2}$ to 1 inch of soil to encourage new root growth. Apply a balanced fertilizer, or just nitrogen if other nutrients are already adequate. Keep irrigating and continue weed control after renovation to help plants recover and set up for next year's crop. Maintain a row width of 12 to 18 inches by heading off runners from escaping into row middles. This requires moving runners back into the row with equipment, and possibly chopping some them off after a plant density of 4 to 6 plants per linear foot of row is reached. Do not neglect a strawberry planting after harvest and renovation - this will decrease runner production and the number of flower buds initiated, reducing yields the next season.

Matted row strawberry production offers a viable alternative to plasticulture, particularly for diversified farms seeking lower costs and sustainable practices. However, growers must be prepared to address challenges such as weed control and renovation labor. Ultimately, the choice between matted row and plasticulture should be based on farm goals, available labor, and market demands.

What's Bugging My Berries? Strawberry Pest Review

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Strawberries play host to many insects, only some of which are pests. Managing insect pests efficiently and effectively requires an understanding of pest biology and behavior, so that controls can be used to their best advantage. Preventing pest infestations is a major part of any pest management program. Removing alternate pest hosts, including weeds in and around the planting is critical for preventing insect and disease problems. Proper row spacing and narrow row widths allow good air movement through the plants to reduce disease infection. Finally, encourage natural enemies of pests, such as predatory mites, lacewings, and lady beetles, by using pesticides only when necessary, and avoiding broad-spectrum compounds that are very toxic to natural enemies.

An (IPM) program uses regular monitoring or “scouting” of insect populations and/or damage in a field to determine if and when control is necessary. A relatively small sample of plants or insects in a field can provide good estimates of the total number of insects or the amount of damage present. In order to have an accurate sample, a scout should stop at ten or more locations in a field following an “X” or “Z” pattern and examine a certain number of plants at each stop, looking for the presence of pests or the damage they cause. Once a pest or damage is found, the amount is compared to an action threshold to determine if control measures are necessary. An action threshold is the level at which the cost of the pest damage will soon exceed the cost of controlling it. If only a few pests are present, control may not be justified by the cost. Using an action threshold is a more efficient way of controlling pests than methods such as calendar sprays (e.g., every 5 to 7 days), or plant growth stage (pre-bloom, petal fall, etc.), because these do not take into account whether or not a pest is actually present.

Strawberry bud weevil or “clipper”: Expect these insects to become active soon as temperatures rise and flower buds emerge. The clipper is a small weevil, which girdles strawberry flower buds, causing them to dry up and fall off the flower stalk. Scout for damage

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by counting the number of clipped buds in two feet of row length at five different locations in a field. If the average number of clipped buds per two-foot sample exceeds 1.2, or if live clippers are found, control measures are recommended. Damage is usually first noticed at the edges of the field. Border sprays may be effective in keeping this insect from becoming a problem in larger fields. Fields with a history of clipper problems will typically exceed threshold nearly every year. Insecticide options for clipper include Lorsban®, Brigade®, Sevin® and PyGanic®.

Tarnished plant bugs: Adults can be seen when strawberry flowers open and will lay eggs into flower and leaf stems. Once the eggs start to hatch, nymphs (immature stage) can be found feeding in the flowers. The nymphs are small, active, yellow-green insects. It is important to scout for them regularly, as they can appear very quickly in warm weather. Tarnished plant bugs feed on the open strawberry flowers, causing the berries to have seedy ends. To scout for the nymphs shake 30 flower clusters (six clusters in five different locations) over a plate. If four or more of the clusters out of the 30 sampled have any nymphs, control measures should be taken. Insecticide options for tarnished plant bug include Malathion, Brigade®,



Danitol®, and PyGanic®.

Cyclamen mites: Plants showing weak growth and yellow, pinkish, or blackened, crinkled leaves may be infested with cyclamen mite. Cyclamen mites are very small, smaller than spider mites, and reside in the crown of the strawberry plant feeding on the developing leaves and flower buds. They are very hard to see, even with magnification. Infested plants have shrunk, distorted leaves and flower stalks, and produce few, if any, marketable fruit. Miticides such as Portal® can be effective but must be applied in lots of water to be sure that the material is carried down into the crowns where these mites reside.

Two-spotted spider mites: Growers with plants under rowcovers should be on the alert for these as soon as growth starts in the spring. This is often where we first find mite problems. Spider mites will reproduce rapidly when warm weather arrives, so it is important to scout for them often. Spider mites feed on the undersides of strawberry leaves, rasping the plant tissue and sucking the sap. Infested leaves will develop yellow flecking and a bronzed appearance. The plants become weakened and stunted. Fields that have had excessive nitrogen fertilizer and/or rowcovers tend to be most susceptible to mite injury. To scout for mites, collect 60 leaves from various locations in the field, and examine the undersides for the presence of mites. Mites are very small - you may need a hand lens to see them. Chemical control options for two-spotted spider mites include Acramite, Savey®, Zeal®, Vendex®, Oberon®, Brigade®, Danitol® and JMS Stylet oil ® (oils will cause plant injury if used in combination with captan or within 14 days of an application of sulfur).

Potato Leafhopper:

The potato leafhopper does not over winter in the northeastern United States but migrates into the region from southern states to feed on strawberry plants and many other host plants late in the spring. The adult leafhopper is bright green with whitish wings, bullet-shaped and about 1/8 inch long. The nymphs are smaller and lighter green. They cannot fly and are easily identified by their habit of crawling sideways when disturbed. Leafhoppers suck plant juices from the veins along the undersides of leaves causing new growth to be stunted and yellow. Leaves on affected plants have yellow streaking visible on the upper side, especially along the leaf margins. The

symptoms can easily be mistaken for herbicide injury. Brush the leaf canopy with your hands and watch for adult leafhoppers flying off the plants. Examine the undersides of leaves to find the nymphs. Leafhoppers can usually be managed with several broad-spectrum insecticides, but it is important to apply controls before the injury is widespread, as it can reduce growth and lower of next season's yield

Root weevils: Symptoms of strawberry root weevil and/or black vine weevil larvae are often noticed among plants in the spring. Infested plants appear weak and stunted, usually in circular patches in a field. Digging under the plants reveals small (1/4 -1/2") crescent-shaped, legless grubs. Grubs begin to pupate when the plants are in bloom, but this may occur earlier under warm conditions. A soil drench of Platinum® (thiamethoxam) insecticide during the spring and/or fall when the grubs are active can provide control. However, Platinum® has a 50-day pre-harvest interval, so it must be applied early in the spring. Platinum® may also be used as a pre-plant or planting treatment for root weevils. A spring application of nematodes may also provide control of the grubs (optimal timing is about mid-May). Two species of nematodes appear to offer the best control of root weevil grubs. *Heterorhabditis bacteriophora* (Hb) appears to be the best candidate for control of root weevils when the soil temperature is above 60 degrees ('J-3 Max Hb' from The Green Spot; 'GrubStake HB' from Integrated Biocontrol Systems; 'Larvanem' from Koppert Biologicals).

Nematodes are living organisms and can be killed if they are misapplied. Order nematodes ahead of time and be ready to apply them through a sprayer or irrigation soon after they arrive, refrigerating if delay is necessary. Do not apply nematodes using a sprayer with a piston pump. Use clean equipment, removing all screens finer than 50-mesh. Apply early in the morning or evening in a high volume of water to already moist soil, pre-irrigating if needed. Apply another ¼ inch of irrigation after application to wash them onto and into the soil. 250 million nematodes (if banded in the row) to 500 million per acre, at a cost of about \$100 to \$200 acre depending on volume and source. Ironically, nematodes probably work best in the worst weevil-infested fields. High populations of weevil larvae allow explosive growth in nematode populations, while low populations of larvae may not permit efficient nematode reproduction. Strawberry



Small Fruit



plants can recover their vigor remarkably well if crown feeding has not occurred and diseases haven't taken over the roots.

Once the adult weevils become active in July bifenthrin (Brigade®) will provide some control if used at the highest labeled rates. The best timing for this spray is at night during the peak feeding activity of adults, before they start laying eggs, or about the time harvest ends.

White Grubs: Weak spring growth may be the result of white grubs feeding on the roots of newer plantings. These grubs are the larvae of beetles, most likely Asiatic Garden Beetle, European Chafer, or Japanese Beetle. They differ from the larvae of black vine weevil and strawberry root weevil in that they have legs and a swollen anterior (rear end), and they tend to be larger. The grubs can be found by pulling up weak plants and sifting through the soil that surrounds the roots. Controlling white grubs once they have become established in a field can be difficult. These tend to be more of a problem in new fields that have been planted following a grass rotation crop, because the adults prefer to lay their eggs in sod. Admire® and Platinum® insecticides are labeled for control of white grubs. They should be applied within two hours of irrigation or rainfall to be sure the product gets into the root zone. Nematode applications in the spring and/or fall may also be effective (see above)

Strawberry Sap Beetle: Sap beetles are small (2-3mm) and dark brown. They chew small holes in ripe strawberries and may introduce fruit rot organisms as they feed. Although the damage may be obvious, sap beetles can be difficult to find because of their habit of dropping to the ground when disturbed. Sanitation is an important part of managing sap beetles. They are highly attracted to fermenting and decaying fruit, so keeping strawberry fields free of over-ripe fruit through frequent harvests can help prevent them from becoming a problem. There is some evidence suggesting that early renovation of strawberry beds after harvest may reduce sap beetle populations the following year. Trapping beetles using baskets of over-ripe fruit (strawberries or pineapple chunks) placed between the edges of the field and wooded areas may also reduce infestations. Insecticide sprays including Brigade®, Danitol® and Assail® may be applied to control sap beetles, but because this occurs during the harvest period, the potential benefits must

be weighed against the likely customer resistance to spraying.

Spotted Wing Drosophila (*Drosophila suzukii*): This pest may be a concern for late ripening strawberries and will definitely impact day neutral strawberries. This small fly lays its eggs on fruit as it ripens, resulting in fruit infested with small white larvae at harvest. Infested fruit quickly rots and has no shelf life. Drosophila can complete a generation in less than two weeks, with each female laying hundreds of eggs. Thus, millions of flies can be present soon after the introduction of just a few into a field. They can be very difficult to control, and frequently repeated insecticide sprays (2 to 3 times per week) have been needed to prevent infestations once the insect is established in a field. Spotted winged drosophila can successfully overwinter here but may not build up to damaging levels until most June bearing strawberries are harvested. However, day-neutral strawberries will need to be protected.

Evaluation of Strawberry Cultivars for Plasticulture Production

Timothy Elkner and Leah Fronk | Penn State Extension

Kathleen Demchak | Penn State University

New strawberry varieties are continually being bred and released, many of which have not been formally evaluated in the Mid-Atlantic region. Some strawberry breeding programs are now putting an emphasis on improving resistance to diseases including *Neopestalotiopsis* (NeoP), an emerging disease. NeoP is impacting the strawberry industry world-wide, including growers in PA and the nurseries that grow the plant material they use. We decided to conduct a trial to evaluate these new varieties for disease resistance, yields and fruit quality.

Materials and Methods

A strawberry trial with 19 varieties from various breeding programs was established at the Southeast Research and Extension Center (SEAREC), Lancaster County, PA during the summer and fall of 2025 (Table 1). The experimental design was a randomized complete block with 16 plants per plot and six replications for a total of 96 plants per variety.

Three of the varieties, Cordial, 'Rutgers D'Light,' and 'Rutgers Scarlet' were available only as dormant plants and were established in 15-cell trays on June 6 and grown outdoors on landscape fabric until being planted in the field on August 5. 'Ember' and a new advanced selection from Rutgers, referred to here as RAS1, were available only as runner tips. Tips were obtained and stuck in 50-cell trays on July 23 to produce plug plants. Fourteen varieties were available as plug plants from nurseries. 'Keepsake' was available as dormant plants and plug plants, so both were included for a comparison of plant type and source. All plugs were planted in the field on August 20-21, except for 'Yambu' which was planted on September 16.

Runners were counted and removed from dormant plants on August 21 and from all plants Oct. 23-Nov.

3 and totaled. Data were also collected on disease severity and plant survival on Oct. 29. Diseases were rated visually in 3 categories: 1) NeoP-like lesions (which could have included some *Gnomonia* leaf blotch), 2) other traditional foliar diseases which included *Phomopsis* leaf blight and common leaf spot, and 3) powdery mildew. A scale of 1 (none to extremely low) to 5 (severe) was used.

We did not want to impact evaluation of disease susceptibilities by suppressing disease symptoms, so no fungicides were applied to the field. Sprays were applied to the 4 varieties of dormant plants started in pots early (captan on June 30 and July 7, and Pristine on July 14) targeting *Gnomonia* leaf blotch and common leaf spot. These diseases were noticed to the greatest extent on 'Rutgers Scarlet' and 'Rutgers D'Light.' This was during a time when over 13 inches of rain fell.

Winter survival, as well as yields and fruit quality, will be evaluated in the spring.

Results and Discussion

Runner production varied significantly among plant type (plugs vs. dormant plants) and variety (Figure 1).

Dormant plants had more time to grow and produce more runners. All varieties planted as dormant plants produced a high number of runners, ranging from 8.6 runners per plant for 'Rutgers D'Light' to 11.5 for 'Rutgers Scarlet.'

Among varieties planted as plugs, 'Chandler,' 'Galietta,' 'Victor,' 'Ember' and 'Fronteras' produced the most runners. 'Flavorfest,' 'Keepsake,' 'Surflin,' and 'Monarch' produced low numbers of runners despite plants being healthy and receiving low disease ratings (Table 2). 'Ruby June,' 'Rocco,' 'GF Belle (08x22),' and 'Liz' produced low numbers of runners, but also re-



ceived higher disease ratings, so it is unclear whether low runner production was due to variety (genetics) or lower vigor due to disease. ‘Yambu’ and 025 produced no runners – ‘Yambu’ perhaps because of late planting, while 025 acted like a day-neutral, producing numerous flowers and fruit. For 025, this could be problematic for nurseries from the propagation standpoint and for growers, the question is whether it will still have enough vigor left to fruit the next year.

It is notable that ‘Keepsake,’ when started early as a dormant plant, produced numerous runners but had among the lowest numbers when planted as a plug. This indicates that it could be suitable in both matted-row and plasticulture production.

‘GF Belle’ (formerly known as 122 x 08) had the highest (worst) rating for NeOP, with ‘Chandler,’ ‘Ruby June,’ and ‘Rocco’ receiving only slightly lower ratings. Plug plants receiving the lowest (best) ratings for NeOP leaf spots were ‘Galletta,’ ‘Flavorfest,’ ‘Keepsake,’ ‘Surflin,’ and ‘Monarch.’ Intermediate varieties were ‘Liz,’ ‘Ember,’ ‘Fronteras,’ ‘RAS1,’ ‘Victor,’ ‘025,’ and ‘Yambu.’ All varieties received as dormant plants received low ratings for NeOP-like lesions, which could have indicated resistance or been a reflection of propagation methods, as these plants were not subjected to rooting under mist. Considering traditional leaf spotting diseases, ‘Rutgers Scarlet’ received a moderate disease rating, but leaf spot ratings on other varieties were not high enough to be a cause for concern.

Among plug plants ‘Galletta,’ known for powdery mildew susceptibility, and ‘Flavorfest’ received high powdery mildew ratings, but ‘Ember’ was rated higher than either one, indicating it also has considerable powdery mildew susceptibility. All varieties grown from dormant plants had a greater incidence of powdery mildew, likely due to their exposure to more favorable conditions for powdery mildew development (i.e., warmer temperatures) during the summer.

Conclusions

Several varieties demonstrated strong establishment and acceptable disease resistance, while others exhibited concerning levels of disease symptoms or poor

vigor, often because of what appeared to be considerable susceptibility to NeOP.

If you plant dormant plants early in the season rather than plug plants later, yields may be increased but be prepared to cut runners. It remains to be seen in yield data collected next year whether potential yield differences justify the extra labor required for runner removal. On the other hand, low runner production as seen with some varieties will be advantageous for growers since it reduces the labor required for runner removal, if these plants also have other desirable plant characteristics.

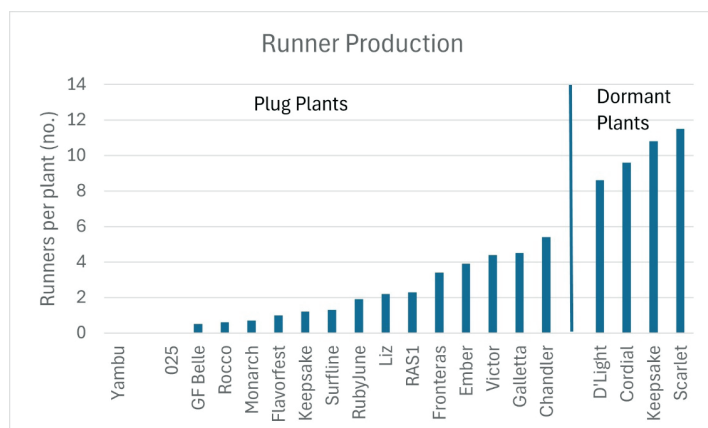
At this point, our thoughts regarding varieties are as follows:

- Have serious reservations: ‘Ruby June’ and ‘GF Belle’ (122x08) due to poor establishment and high disease ratings.
- May be challenging to grow: ‘Chandler,’ ‘Fronteras,’ ‘Liz,’ ‘Surflin,’ ‘Victor,’ ‘Ember,’ and ‘Rocco.’ A robust fungicide program will be needed to suppress disease susceptibilities. These varieties also showed inconsistent performance between plots.
- Shows promise but showed variation across the field: ‘Monarch’ had few disease symptoms but lacked uniformity in establishment.
- Looking good so far: ‘Rutgers Scarlet,’ ‘Rutgers D’Light,’ ‘Cordial,’ and ‘Keepsake,’ all as dormant plants, and ‘Flavorfest,’ ‘Galletta,’ ‘Keepsake,’ and ‘RAS1’ as plugs. These varieties exhibited strong establishment and manageable disease levels.
- Too early to tell: ‘Yambu’
- Potential concern: 025’. The tendency to produce fruit rather than vegetation during establishment and no runners. This may be a problem for growers and propagators.

Acknowledgements: Thanks to PVGA for funding this trial, Indiana Berry, and Plant Company for donating dormant plants, Crown Plants for donating runner tips of Ember, and Rutgers for donating runner tips of RAS1. Thanks also to John Rost for assistance with trial establishment and maintenance.

Small Fruit

Figure 1. Runner production by variety and plant type*.



*Total of runners counted and removed on Aug. 21 for dormant plants only and Oct. 23-Nov. 3 for all plants.

Table 1. Strawberry varieties established at SEAREC in fall of 2025, including breeding programs, nurseries that grew the plants, and additional comments.

Variety	Breeding program	Nursery	Comments/Purported Traits of Interest
Plug plants			
Chandler	Univ. of California	Maplewood	Main season standard, susceptible to anthracnose and NeoP
Ruby June	Lassen Canyon Nursery, CA	Maplewood	Large flavorful fruit, but susceptible to anthracnose and NeoP
Galletta	NC State	Maplewood	Early season, widely grown, some resistance to NeoP
Flavorfest	USDA-Beltsville	Maplewood	Midseason, productive, resistant to anthracnose fruit rot, some resistance to NeoP
Fronteras	Univ. of California	Maplewood	Moderate resistance to verticillium wilt and Phytophthora crown rot, but susceptible to anthracnose crown rot
Keepsake	USDA-Beltsville	Maplewood	Midseason, very good flavor, long shelf-life
Surflin	Univ. of California	Walker Bros	Early season, large firm fruit, long shelf-life
Victor	Univ. of California	Walker Bros	Mid-late season, potential for NeoP resistance, very firm
Monarch	Univ. of California	Walker Bros	Early season, long shelf-life.
SB_14_028-025 (aka 025)	Strawberry Sciences, LLC, CA	Walker Bros	Early season, large attractive fruit, small plants, high yield
Yambu	Fresh Forward, The Netherlands	Kube-Pak	Large orange-red fruit, long shelf-life, resistant to botrytis
Rocco	NC State	Fresh-Pik	Early season alternative to Sweet Charlie, said to have NeoP resistance, susceptible to anthracnose fruit and crown rots
Liz	NC State	Fresh-Pik	Midseason, consistent high yields in NC, firm, susceptible to anthracnose fruit and crown rots
GF Belle (122x08)	Good Farms, CA	Fresh-Pik	Large sweet fruit, high percentage marketable. Small plants.
Ember	University of Florida (UF/IFAS)	Crown Plants for tips	Early, holds up in rain, improved resistance to NeoP over other FL varieties
RAS1	Rutgers University, NJ	Rutgers for tips	Mid-season, good flavor, nice shape
Dormant Plants			
Keepsake	USDA-Beltsville	Indiana Berry	Mid-season, good flavor, long shelf-life
Cordial	USDA-Beltsville	Indiana Berry	Late season, large firm fruit, high yields, long shelf-life
Rutgers Scarlet	Rutgers University	Indiana Berry	Mid-late season, good flavor and attractive color, disease resistant
Rutgers D'Light	Rutgers University	Indiana Berry	Mid-season, excellent flavor, unique berry shape



Small Fruit



Table 2. Disease ratings averaged over replications. 1=none-extremely low, 5=severe.

Variety	Plant type	NeoP-like lesions	Other leaf spots	Powdery Mildew
GF Belle (122x08)	plug	3.50	1.33	1.00
Chandler	plug	2.83	1.50	1.33
Ruby June	plug	2.83	1.50	1.17
Rocco	plug	2.83	1.33	1.67
Liz	plug	2.50	1.83	1.50
Ember	plug	2.17	1.83	3.00
Fronteras	plug	2.00	2.00	1.33
RAS1	plug	2.00	1.33	1.67
Victor	plug	1.83	1.83	1.33
025	plug	1.67	1.33	1.50
Yambu	plug	1.67	1.67	1.17
Monarch	plug	1.50	2.00	1.00
Surflin	plug	1.33	2.00	1.50
Galletta	plug	1.00	2.17	2.50
Flavorfest	plug	1.00	1.33	2.67
Keepsake	plug	1.00	2.00	1.50
Keepsake	dormant	1.50	2.00	2.83
Rutgers D'Light	dormant	1.17	2.33	3.33
Rutgers Scarlet	dormant	1.00	3.17	3.50
Cordial	dormant	1.50	1.17	3.50

Emerging Challenges in Blueberry Pest Management: The Case of *Prionus* Beetles in North Carolina

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Prionus spp. longhorn beetles have recently emerged as a serious and previously under-recognized threat to North Carolina’s blueberry industry. While *Prionus imbricornis* is widespread across the eastern United States, extensive infestations in commercial blueberries have only recently been confirmed. Detailed field observations, grower reports, and statewide monitoring data now document extensive plant losses, with thousands of mature bushes dying in affected fields due to chronic root and crown feeding by concealed larvae. Prior to this work, blueberries were not recognized as an economically significant host in the southeastern region, delaying awareness and limiting available management tools. Growers in Bladen, Pender, and Sampson counties have each reported rapid bush decline, stand losses during mechanical harvest, and characteristic symptoms, including sparse foliage, chlorosis, border-edge mortality, and plants that are easily uprooted by hand.

Prionus beetle larvae have a multiyear, cryptic life cycle, making infestations extremely difficult to detect early. Adults are nocturnal and short-lived, males are highly attracted to pheromone-baited traps, and females are believed not to fly, placing egg-laying activity near the base of blueberry bushes. Females can deposit up to 200 eggs in clusters around the crown, and the larvae feed internally for three to five years before pupating in the soil. Larval feeding destroys vascular integrity, hollows the crown, and weakens entire bushes.

To address this emerging pest, a season-long monitoring program was established across six commercial blueberry farms in 2025, including three farms with confirmed larval infestations. Two pheromone-baited black panel traps were deployed per farm and serviced weekly by county agents from March through September 2025. This effort produced the first state-level dataset characterizing adult *Prionus* activity in blueberries. Adult emergence first occurred the week of April 1 and reached peak flight in May, with overall captures tapering off through June and ceasing by late August. A total of 5,260 adult males were



Lorena Lopez’s program focuses on management of insect and mite pests infesting small fruits and tobacco. Lorena is an outstanding entomologist with research and extension experience gained throughout her career at the University of Florida, Virginia Tech, and NCSU. She has committed to enhancing insect and mite management through implementation of standard and new pesticides, promoting registration of products in highbush blueberries for control of chili thrips and southern red mites, monitoring predatory mites in FL blueberries, and implementing biocontrol in strawberries in VA and NC. Her extension program meets the needs of growers through comprehensive educational activities and research.

collected across all six farms in 2025. The three farms with confirmed larval feeding consistently recorded far higher trap captures, indicating stronger local populations and greater infestation risk (Fig. 1).

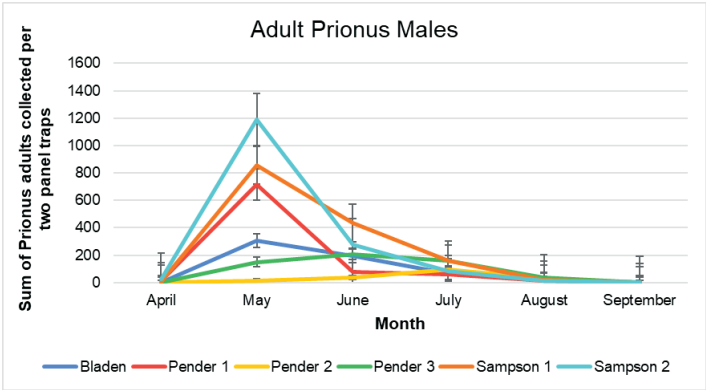


Figure 1. Sum of adult *Prionus* beetle males collected overtime per two lured panel traps per location during the 25-month monitoring program in 2025.

In parallel, uprooted bushes were dissected monthly from February to October 2025 at the three farms with confirmed larval feeding. A total of 127 larvae

Location	Larvae Count	Average Body Length (in.)	Max Body Length (in.)	Min Body Length (in.)	Average Body Width (in.)	Average Weight (mg)	Max Weight (mg)	Min Weight (mg)
Sampson 1	37	1.51	2.54	0.37	0.36	1725.03	5616.10	20.60
Pender 1	66	1.16	2.26	0.09	0.30	868.83	3274.70	12.00
Sampson 2	24	1.31	3.38	0.12	0.31	1431.13	8917.20	3.70
Total	127	1.28	3.38	0.09	0.32	1210.79	8917.20	3.70

were collected and examined. Table 1 documents larval size distributions, body lengths, widths, and weights by farm. We confirmed the presence of both *P. imbricornis* and *P. pocularis* through molecular identification using larval DNA. Notably, early-instar larvae were found in July and August, strongly suggesting that eggs laid during the May adult peak hatch mid-summer. These findings establish a baseline understanding of life-stage timing, developmental patterns, and the vulnerability window for future chemical control, as larger larvae are not susceptible to known insecticides.

Table 1. Number of larvae collected from blueberry stump collections per location. A total of 9 blueberry stumps were collected per month in three commercial farms (3 per farm per month) with actively feeding *Prionus* larvae in blueberry plants. Body measurements of the collected larvae are shown.

The 2025 monitoring and diagnostic work demonstrates that *Prionus* infestations are more widespread in NC blueberries than previously recognized. More than 800 adult males were captured in a single 11-week trapping period in 2024 at one Sampson County farm during a preliminary monitoring program, and hundreds of dead plants were removed the same season due to internal larval feeding. Both years’ data confirm *P. imbricornis* as the primary species attacking blueberries in the state.

With no registered insecticides capable of controlling larvae inside plant tissue, and with no economic thresholds currently developed, removal of old fields heavily infested remains the only available tool. Early detection is vital to developing practical tools for blueberry growers. The Small Fruits and Tobacco IPM Lab at NCSU has therefore prioritized the development of diagnostic tools, including exploring laser vibrometry for larval detection, and the expansion of trap-based monitoring. Additional research includes scanning uprooted bushes to determine larval feeding distribu-

tion, and an IR-4–funded project evaluating potential chemical control tools. Key Extension outputs from this effort include multiple fact sheets, downloadable monitoring guidelines (in press), YouTube videos, and updates distributed through the NCSU Blueberry Portal. These materials provide growers with clear symptom descriptions, trap deployment instructions, and scouting recommendations.

Overall, the integration of field monitoring, larval diagnostics, and statewide outreach has yielded the first evidence-based framework for understanding *Prionus* infestations in North Carolina blueberries. This work contributes to the understanding of the biology, extent, and severity of the problem in blueberries and establishes a foundation for designing future management strategies once effective controls become available. The combination of emerging scientific knowledge and grower-centered educational materials strengthens the industry’s capacity to detect infestations earlier, prioritize high-risk fields, and prepare for new tools to mitigate this increasingly significant pest threat.



What's New In Spotted-Wing Drosophila Research?

Dr. Beth Ferguson and Dr. Cesar Rodriguez-Saona

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Fig. 1. Female spotted-wing drosophila

Since its rapid global spread in the early 2010s, spotted-wing drosophila (SWD), *Drosophila suzukii* (Fig. 1), has remained a top research priority for small fruit production systems because of its ability to oviposit in ripening fruit. Over the last decade, re-

searchers have made important advances in integrated pest management (IPM) for SWD. This proceedings synthesizes those developments and provides current research gaps and priorities.

Monitoring: trapping and salt-floatation testing

Monitoring is essential for detecting SWD activity, guiding control decisions, and evaluating management effectiveness. Because SWD can infest fruit as soon as ripening begins, early and accurate detection is critical.

1. Adult trapping. Most monitoring programs rely on baited traps using cup-style designs, commercial lures paired with red sticky cards, or proprietary traps (e.g., Scentry, Trécé). These tools help detect first activity and track population trends across the season.

2. Salt-floatation test. This simple and widely used method detects larvae inside fruit. Samples of ripening fruit are lightly crushed, submerged in a saltwater solution, and examined for larvae that float to the surface.

Implications. In many production systems, the first detection of adults signals the need to initiate control, especially as fruit enter the susceptible stage. Effective monitoring supports IPM by improving timing, reducing unnecessary insecticide use, and increasing

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the reliability of control programs.

Behavioral control: repellents, oviposition deterrents, and push-pull strategies

Push-pull and spatial-repellent tactics have progressed from conceptual models to field-scale trials. Several naturally occurring compounds show promise as spatial repellents or oviposition deterrents capable of reducing fruit injury. Notably, methyl benzoate, a plant volatile and FDA-approved food additive, has been shown in field studies to function as a spatial repellent and oviposition deterrent in blueberry systems. As part of push-pull schemes, these compounds have produced measurable reductions in fruit infestation.

Implications. Behavioral control tools are now at a stage where field deployment, dispenser longevity, non-target effects (pollinators, natural enemies), and cost-benefit analyses are the primary next research needs.

Biological control: parasitoid establishment, rearing, and releases

Substantial progress has been made toward classical biological control of SWD:

- Mass-rearing improvements have increased production efficiency for key larval parasitoids such as *Ganaspis kimorum* and *Leptopilina japonica*.



- Field establishment of adventive *L. japonica* populations is now documented in the Mid-Atlantic and multiple other regions, with evidence of persistence across seasons.

- New research is evaluating overwintering ecology, compatibility among released and wild parasitoid populations, and interactions with insecticides commonly used in SWD programs.

Implications. Biological control is emerging as an operational component of SWD IPM in several U.S. regions. Priority research needs include long-term monitoring of population impacts, refinement of release timing and placement, and integration with behavioral and chemical control tools.

Chemical control: new insecticide trials and considerations

Chemical control remains a key component of SWD management, especially during periods of high pressure and ripening fruit. However, SWD's ability to develop resistance underscores the need for careful stewardship.

- Resistance management. Continued selection pressure highlights the need for rotation among IRAC modes of action and the integration of non-chemical tactics.

- Newer or reduced-risk chemistries offer opportunities to minimize impacts on beneficial insects and delay resistance development.

- Attract-and-kill strategies (e.g., baits paired with insecticides such as Combi-protec or BioMagnet Ruby) show promise for reducing the reliance on repeated cover sprays, particularly when paired with parasitoid releases or repellents.

Implications. While insecticides remain indispensable, long-term sustainability will depend on rotation, diversification of tactics, and integration into broader IPM strategies.

Cultural control: sanitation, harvest management, canopy modification, and exclusion

Cultural practices aim to reduce habitat suitability and remove breeding sites, thereby lowering population pressure.

1. Sanitation. Removing cull fruit, unharvested berries, or other waste reduces larval development sites. Effective approaches include frequent removal of overripe fruit, burial or solarization of waste, and regular cleaning of bins and packing areas.

2. Frequent and complete harvesting. Harvesting every 1–2 days limits the availability of soft, ripening fruit that females prefer for oviposition.

3. Canopy management. Pruning to improve airflow and light penetration reduces shaded, humid microclimates that favor SWD survival and promotes faster fruit drying.

4. Irrigation management. Overhead irrigation can raise humidity and maintain fruit softness. Adjusting irrigation practices can reduce SWD activity.

5. Exclusion netting. Fine-mesh netting (≤ 0.98 mm) installed prior to ripening can significantly reduce infestation. Successful use depends on preventing adults from being trapped inside and maintaining good sanitation.

Implications. No single cultural tactic provides stand-alone control, but together they can reduce population pressure and enhance the performance of chemical, behavioral, and biological strategies.

Research gaps and priorities

Behavior-based tactics: field-scale dispenser design, longevity, release rates, costs, and non-target effects require multi-site validation.

Biological control impact: multi-year monitoring is needed to quantify establishment, overwintering success, and suppression of SWD populations.



Compatibility studies: how parasitoids, repellents, and selective insecticides interact under commercial production conditions is still poorly understood.

Socioeconomic and regulatory analyses: adoption of novel behavioral, attract-and-kill, and potential genetic strategies requires understanding economic feasibility and regulatory considerations.

Closing remarks

The SWD research community has advanced several promising technologies from laboratory discovery to field evaluation. Attract-and-kill and push–pull tools are emerging as viable operational strategies, and parasitoid rearing and release programs show strong signs of establishment. The next challenge is commercial-scale integration, demonstrating economic feasibility, minimizing non-target impacts, and leveraging combinations of tactics to achieve durable suppression. Collaborative, regionally coordinated research, and extension efforts will be essential to translating these innovations into effective, sustainable IPM for SWD.

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Integrated Pest Management in Blueberries, Back to the Basics

Carrie Mansue | Rutgers University

Monitoring and Scouting

Effective blueberry IPM begins with consistent monitoring using 10-bush sampling units across the field to assess bud injury, fruit damage, terminal infestation, and pest populations. Strategic trap placement throughout the growing area helps track pest emergence and population levels throughout the season.

Seasonal Pest Management

The pre-pollination period focuses primarily on blossom weevil management. Scout by beating canes (approximately one-fifth of each bush) across 15 bushes, repeating 15 times, then divide the total weevil count by 3 to determine the number per bush. The treatment threshold is 5 weevils per bush, with recommended products including Asana XL, Avaunt, Brigade WSB, Hero, Imidan, and Mustang Max.

During bloom, insecticide options become limited due to honeybee presence. Only Confirm 2F, Intrepid 2F, and Bt products can be used during this critical pollination window. These products target caterpillar pests like gypsy moth larvae and leafrollers.

The post-pollination period presents the most complex pest management challenges. Cranberry fruitworm produces a single generation each season, with adults typically emerging May 10-14 and peak pheromone trap catches occurring in late May. Insecticides should be applied 5-7 days after peak trap catches, usually around May 30-June 5. Scout for the presence of frass, silk, and small holes in fruit to assess infestation levels.

Plum curculio has no specific treatment threshold and is typically addressed in the first post-bloom insecticide spray after bee removal. Scout using beating trays between bushes or examine berries directly for the characteristic egg-laying scars. Recommended products include Imidan and Avaunt, while pyrethroids should be reserved for later spotted wing



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drosophila sprays.

Blueberry aphids serve as vectors for blueberry scorch virus, making their management particularly important. Scout by examining 5 lower shoots on 10 plants for a total of 50 shoots. While the traditional treatment threshold is 10% infested shoots, current recommendations suggest spraying when any aphids are found due to increased scorch disease observations in recent years. Control options include Assail, Movento, and Sivanto.

Oriental beetle management targets the grub stage rather than adults. Monitor trap catches using standardized cup measurements, where one cup equals approximately 2,025 beetles. Soil applications should be made in early June, with products like Admire Pro applied 7 days before harvest providing 100 days of control throughout the blueberry season. The goal is to target grubs before they reach the third instar stage. Mating disruption tabs offer an alternative management approach.

Blueberry maggot and spotted wing drosophila require particularly intensive monitoring and management. Deploy traps around Memorial Day week to monitor for both pests. For spotted wing drosophila, begin a 7-day spray program once the first male is caught in traps and berries show any blue coloration. Multiple insecticide options are available including Asana, Brigade, Danitol, Diazinon, Entrust, Exirel, Hero, Lannate, Malathion, and Mustang Maxx, with Diazinon reserved for later in the season.



Sharpnosed leafhopper management involves trap placement beginning Memorial Day week, with treatment delayed until the second population peak in September. Diazinon is the preferred treatment as it simultaneously controls second-generation scale crawlers that emerge at the same time, allowing one spray to manage both pests. Alternative products include Actara, Assail, and Lannate.

Disease Management

Anthrachnose management requires careful timing based on bud stage development. The Rutgers Philip E. Marucci Center website provides degree-day calculations that help predict optimal fungicide application timing. The standard bloom program consists of four applications initiated during early bloom with 7-day intervals.

During wet or cold bloom periods, Botrytis becomes a significant concern requiring specific management. Switch at 11-14 ounces or Pristine at 18.5-23 ounces effectively control this disease under challenging weather conditions. Leaf drop, which typically manifests as early foliage drop symptoms in August, can be managed by applying Quadris Top at 12-14 fluid ounces or Quash at 2.5 ounces toward the end of the bloom period.

Successful blueberry IPM requires maintaining consistent scouting schedules throughout the season, using pheromone traps and beating trays for accurate pest monitoring, timing insecticide applications based on trap catches and pest life cycles, carefully considering bee safety during the bloom period, integrating disease forecasting models with field observations, and preserving beneficial insects when possible while managing pests at economic thresholds.

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Biological Soil Disinfestation Method to Improve Soil Health in Tomatoes

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Background

In vegetable production systems, soil health is tied to the suppression of soilborne pests and pathogens, improved nutrient cycling, and crop productivity. Anaerobic soil disinfestation (ASD) is a biological pre-plant soil disinfestation strategy that uses organic amendments and temporary anaerobic conditions to suppress soilborne pathogens, plant-parasitic nematodes, and weeds, while improving soil health. This makes ASD attractive for organic and sustainable vegetable production systems where soilborne diseases can be a major constraint, and the use of fumigants and chemicals is neither desirable nor permitted.

ASD is implemented in three basic steps that growers typically follow in the field. First, easily degradable carbon sources (e.g., overwintering cover crop residues, wheat middlings) are incorporated into the topsoil. This is followed by covering the soil with a totally impermeable film for about 3 weeks to restrict gas exchanges and promote temporary oxygen-limiting conditions. Lastly, the soil is irrigated to field capacity to provide adequate soil moisture necessary for promoting soil microbial activity and reducing conditions.

Rather than sterilizing the soil, ASD temporarily alters soil oxygen availability and provides labile carbon to promote the growth of soil beneficial microorganisms while suppressing soilborne pathogens. As these microbes break down the added organic amendments under low-oxygen conditions, their fermentative

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activities accumulate organic acids and volatile organic compounds in the soil that are suppressive to soilborne pathogens. At the same time, ASD lowers soil pH and promotes the formation of reduced metal ions, like Fe²⁺, Mn²⁺, and Al²⁺. Together, the change in soil microbial communities and chemistry generated during the ASD process create a stressful environment for many soilborne pathogens.

Important indicators of soil health in ASD include soil chemical properties (e.g., pH, electrical conductivity (EC), redox potential, nitrogen nutrient availability), and biological properties (e.g., microbial diversity, community composition). Together, the improvement of these soil chemical and biological properties in ASD



contributes to enhanced tomato crop productivity in organic production systems (Ono-Raphel et al., 2025). We conducted an ASD field study in 2024 to investigate the effect of ASD treatments on these soil health indicators during and post-ASD in an organic tomato production system.

Field experiment and methods

The study was conducted on organic-certified land at the Penn State Russell E. Larson Agricultural Research Center in Rock Springs, PA (Hagerstown silt loam, Typic Hapludalf; pH ~5.6, 2% organic matter). The field experiment started on this land in the Fall of 2021 with the establishment of a tomato–soybean rotation that included overwintering cover crops and ASD treatments applied prior to the tomato crop production phase. The ASD field experiment was first implemented on May 11, 2022, using cover crops and wheat middlings (WM) as organic amendments. In this study, we installed a second ASD field experiment on the same field on May 21, 2024. ASD treatments were applied with overwintering cover crops including crimson clover (*Trifolium incarnatum* L.; CC), triticale ($\times$ *Triticosecale* Wittmack; Tr), and their mixture (Tr+CC), combined or not with WM. Together, the treatments consisted of CC, Tr, and Tr+CC, CC+WM, Tr+WM, Tr+CC+WM, plus fallow controls receiving only irrigation (F+W) or irrigation with WM (F+WM) (**Table 1**). The experiment followed a split-plot randomized design with 25 $\times$ 10 ft subplots and four replicates per treatment. Fresh cover crop biomass was flail-mowed and incorporated using moldboard plowing, disk plowing, and rototilling, followed by raised-bed formation. Wheat middlings were applied at the equivalent of 5,350 lb/acre and incorporated to a depth of 8 inches. All plots were irrigated to field capacity and covered with gas-impermeable plastic tarp for 21 days. On day 21, a single row of tomato plants was transplanted in each treated bed. Soil samples were collected at 0, 3, 7, 14, 21, 49, 77, and 134 days after treatment (DAT). Soil chemical analyses were performed on each soil sample. Total genomic DNA was extracted from each soil sample, and amplicon sequencing of bacterial 16S rRNA gene and fungal ITS region was performed on an Illumina NextSeq platform. We analyzed the effect of the different ASD treatments

and sampling time (hereafter Timepoint) on the soil chemical properties (redox potential, pH, electrical conductivity, ammonium ($\text{NH}_4\text{-N}$), and nitrate ($\text{NO}_3\text{-N}$)). We also examined the effect of ASD treatments and timepoint on the soil biological properties (bacterial and fungal diversity (i.e., Shannon index) and community composition). This enabled us to understand the shifts of the bacterial and fungal communities in the soil during ASD and tomato crop production. Further, we identified the specific groups of microbes that responded most noticeably to each ASD treatment over time.

Effect of ASD on soil chemical properties

Within the first week of ASD treatments, soil redox potential dropped from oxidized conditions (around +200 mV) to strongly reducing conditions reaching –250 mV (**Figure 1**). After 21 DAT, the recovery pattern was different across treatments. ASD treatments, including F+WM, CC, and CC+WM had the fastest increases (reaching above the +200 mV threshold before 49 DAT), whereas Tr and Tr+CC+WM had a steadier increase over time. Soil pH displayed contrasting patterns over time. Soil pH was affected by timepoint and cover crop treatment, whereas WM and its interaction with cover crops did not affect pH (**Table 2**). At 3 DAT, all treatments behaved similarly, in which pH dropped slightly from pre-treatment values (6.6 to 7.11 at 0 DAT vs. 6.25 to 6.69 at 3 DAT). By 21 DAT, ASD treatments amended with CC, Tr, and the Tr+CC mixture maintained higher pH (6.51 to 6.58) than the fallow plot (F+W) (6.32), indicating that cover crops helped buffer soil pH after ASD was completed at 21 DAT. During the tomato cropping period (49–134 DAT), soil pH declined slowly in all treatments. By 134 DAT, soil pH dropped to values around 5.0 to 5.13, regardless of cover crop or WM amendment. Soil EC was found to be affected by cover crops, WM, and timepoint (**Table 2**). For most treatments, soil EC increased from 0.1 dS m^{-1} at 0 DAT to 0.3 dS m^{-1} at 3–14 DAT and remained constant throughout the ASD treatment. After 21 DAT, treatments like CC+WM and Tr+WM showed the largest increase in EC and reached 0.6 dS m^{-1} by 134 DAT. Soil $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ were affected by cover crop, WM, and timepoint (**Table 2**). At 3–7 DAT, plots that received WM

(CC+WM, F+WM, Tr+WM, and Tr+CC+WM) showed a significant increase in $\text{NH}_4\text{-N}$ compared with cover crop only and fallow plots. By 14-49 DAT, CC+WM and F+WM showed a higher increase in soil $\text{NO}_3\text{-N}$ compared to other treatments, while $\text{NH}_4\text{-N}$ generally reduced across treatments. By 134 DAT, soil $\text{NO}_3\text{-N}$ levels decreased but remained moderate, relative to pre-ASD across all treatments.

Effect of ASD on soil microbial diversity and community composition

Bacterial diversity was affected by the addition of WM and timepoint ($P < 0.01$), but not the choice of cover crop ($P = 0.51$). At 3 DAT, bacterial diversity dropped across treatments. By 14 to 21 DAT (i.e., end of ASD treatment), bacterial diversity recovered to same or higher levels than before ASD treatment across all treatments. Fungal diversity remained stable or declined through the ASD experiment across all treatments and did not rebound as bacterial diversity did. These results indicate that the amendments used in our ASD treatments increased bacterial diversity, while having neutral to slightly negative effects on fungal diversity. Statistical test (PERMANOVA) showed that timepoint was the biggest contributor to changes in soil bacterial and fungal communities during the ASD field experiment, explaining about 11% of the variation in bacteria and 14% in fungi ($P < 0.001$). Cover crop, wheat middlings, and soil pH each explained a similar percentage of variation in bacterial communities (3% each; $P < 0.001$). Soil EC had a smaller effect on the dynamic changes in bacterial communities (1%; $P < 0.001$). For fungi, cover crop and WM contributed to their community dynamics ($P < 0.001$). Soil pH also contributed to fungal community dynamics (2%; $P < 0.001$), whereas EC had a smaller effect (1%, $P < 0.001$). These results indicate that soil pH was a stronger driver than EC for differences in microbial community structure within ASD treatments. During ASD, specific bacterial taxa (e.g., *Bacillus*, *Clostridium*, *Paenibacillus*, and *Pseudomonas*) were found to be enriched and persisted through tomato crop production. These beneficial taxa are known for organic matter decomposition, suppression of soilborne pathogens, and nutrient cycling in soils. Beneficial fungal taxa (e.g., *Aspergillus*,

Cladorrhinum, *Mortierella*, and *Trichoderma*) were also enriched in ASD and remained through tomato cropping.

Conclusion

Biological soil disinfestation method e.g., ASD implemented with overwintering cover crops and wheat middlings predictably alters soil chemical and biological properties in ways that are consistent with improving soil health in organic tomato systems. ASD treatments with cover crops and WM generated strong reducing conditions within the first 14 days. ASD treatments that included WM produced early availability of $\text{NH}_4\text{-N}$ and subsequently increased $\text{NO}_3\text{-N}$ levels during tomato crop production. ASD treatments caused an initial decline in bacterial diversity followed by a recovery and improvement, while fungal diversity was generally stable or reduced. Changes in bacterial and fungal community composition were observed at different timepoints during the experiment. Soil pH was a significant driver of microbial community dynamics, indicating that pH is a key soil health indicator in ASD systems. Importantly, ASD consistently enriched beneficial bacterial and fungal taxa. These beneficial groups persisted into the tomato cropping phase. Together, our findings show that ASD applied with cover crops (especially CC) and WM is an effective biological pre-plant disinfestation method that improves soil health and nitrogen nutrient availability in organic tomato production.

Acknowledgments

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Reference

Ono-Raphel, J.G., Custer, G.F., Arrington, K., Morrison, B., Kaye, J., Roskopf, E., Dini-Andreote, F. and Di Gioia, F., 2025. Effects of carbon sources on soil bacterial community dynamics during anaerobic soil disinfestation in an organic tomato production system. *Agriculture, Ecosystems & Environment*, 381, p.109448.

Tables

Table 1. Description of cover crop and wheat middlings inputs (biomass and application rates) for each experimental treatment. The table also reports total C and N inputs and the resulting C:N ratios of the treatments.

Treatment	Cover crop dry biomass (lb/ acre)	Wheat middlings application rate (lb/ acre)	Total C (lb/acre)	Total N (lb/acre)	C:N ratio
Fallow control (F+W)	NA	NA	NA	NA	NA
Crimson clover (CC)	4298	NA	1767	112	15.7
Triticale (Tr)	6508	NA	2717	72	37.6
Triticale + Crimson clover (Tr+CC)	6367	NA	2629	106	24.8
Fallow + Wheat middlings (F+WM)	NA	13383	5554	302	18.4
Crimson clover + Wheat middlings (CC+WM)	4298	13383	7320	415	17.6
Triticale + Wheat middlings (Tr+WM)	6508	13383	8271	375	22.1
Tr + CC + Wheat middlings (Tr+C-C+WM)	6367	13383	8183	409	20.0

*NA = Not Applicable

Table 2. Significance of the effects of cover crop, wheat middlings, their interaction, and sampling timepoint on soil chemical properties. *P*-values derived from the ANOVA presented in bold indicate a significant effect at $\alpha = 0.05$.

Effect	Soil pH	Soil EC	Soil NH ₄ -N	Soil NO ₃ -N
Cover crop	0.001	0.056	0.001	0.001
Wheat middlings	0.998	0.001	0.001	0.010
Timepoint	0.001	0.001	0.001	0.001
Cover crop × Wheat middlings	0.347	0.979	0.155	0.933

Figure

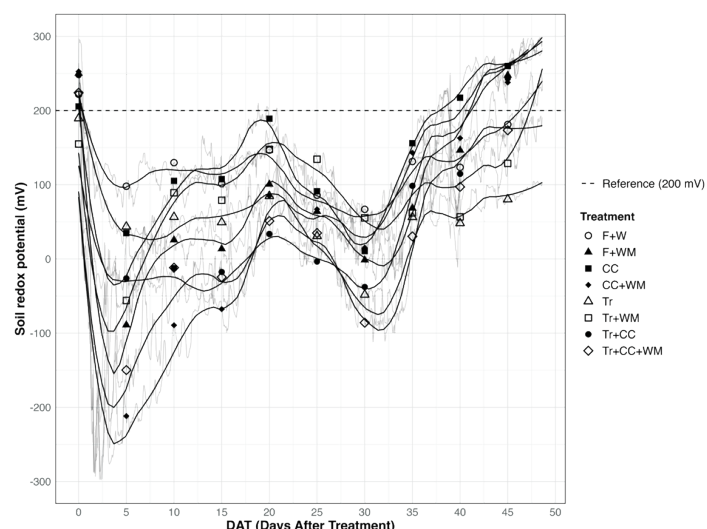


Figure 1. Changes in soil redox potential across treatments during the ASD period. F+W = fallow control; F+WM = fallow with wheat middlings; CC = crimson clover; CC+WM = crimson clover with wheat middlings; Tr = triticale; Tr+WM = triticale with wheat middlings; Tr+CC = triticale and crimson clover; Tr+CC+WM = triticale, crimson clover, and wheat middlings.



The Garden of Eden Approach to Soil Health and Crop Nutrition

Carbon in the Spotlight: The Real Story Behind Humic Acids

Dr John Murphy | AgXplore

Humic acids continue to draw interest as growers look for tools that support soil function and nutrient efficiency. This session will provide a research-based overview of how humic acid structure contributes to soil aggregation, nutrient availability, and water movement. Their diverse functional groups create sites for ion exchange and nutrient interactions, helping retain key elements in the rooting zone while making them more available to the crop. These properties position humic acids at the intersection of soil chemistry, soil physics, and overall crop productivity.

A second focus will be biological activity and root development. Studies show that humic substances can influence microbial processes by supplying carbon, affecting enzyme activity, and supporting nutrient pathways. Research also indicates that humic acids may affect early root architecture and often increase lateral root formation, fine-root growth, and total root surface area. These changes improve the crop's ability to explore soil volume, access nutrients, and maintain function under stress. Because humic sources differ widely in parent material, extraction method, molecular weight distribution, and aromatic structure, the presentation will highlight how these factors contribute to differences in field performance.

The session will conclude with practical guidance to help maximize utilization by giving a framework for evaluating humic acid products, determining where they best fit within fertility programs, and recognizing situations where they provide the most consistent value. The goal is to separate marketing claims from well-established agronomic effects so humic acids can be used with confidence and precision across production systems.



Soil Health: The Garden of Eden Approach

H Grant Troop, CPAg/CCA

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Soil Health is often evaluated in terms of soil organic matter and bio-diversity with a goal of reducing crop production inputs. Without careful attention to what is happening to the soil, we can end up with soil that is dense and infertile. We have seen reports of vegetable research plot soils becoming more dense after years of cover crop use. Not what we would expect. Instead of moving toward sustainable or regenerative farming, we head in the subsistence farming direction. In this presentation, we will look at soil physiochemistry as a great place to start the journey toward sustainable or regenerative farming. A properly taken soil sample analyzed by a reputable soil test lab will yield a treasure trove of information for us to begin the process of building or maintaining healthy highly productive soil. Due to the complexity of interpreting soil test information, you may wish to involve an agronomist trained in soil physiochemistry for your soil and water management decision making. Let's look at the plant nutrient data from a soil test report. **Calcium** (Ca) and **magnesium** (Mg) are the cations we associate with soil pH. Their soil levels not only help determine soil pH but also strongly influence soil structure, water infiltration, percolation, and water capillary action. Both are important secondary plant nutrients. In the Eden Approach to Soil Health, how we arrive at a desired pH is much more important than just having a "correct" pH. We can "correct" the pH with sodium (Na) for example, but we won't grow much of a crop on high sodium soil. Correct soil Ca and Mg levels will promote optimized soil pore space to best house soil organisms and roots. Perfect soil is 50% pore space 50% solids. **Nitrogen** (N) is a primary plant nutrient known as the "great escape artist." A study of the nitrogen cycle shows us how and where N leaves a field and indicates management touch points to limit loss in each particular soil. N application timing, rate, placement, source material, and management aid technology can be used in concert to maximize

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nitrogen use efficiency. **Phosphorus** is part of the main plant energy transfer molecule adenosine triphosphate (ATP). Highly productive soils supply crops with an excellent supply of this primary nutrient. Plant roots, especially row crop roots, are limited in the ability to grow to all the plant available soil phosphorus. Phosphorus rich soils and phosphorus in-soil banding are key components for high yield high quality crops. The major challenge is getting and maintaining enough soil phosphorus in a plant available form to meet crop demand. **Potassium** (K) is a primary plant nutrient that is key to plant water management. Soils rich in potassium yield crops that are drought resistant and highly productive. To a lesser extent, potassium effects the soil characteristics discussed under Ca and Mg. **Sulfur** (S) is a key secondary nutrient that is becoming more limited in the soil due to reduced atmospheric deposition, crop removal and sulfate leaching below the root zone. Test, monitor and supplement the soil as needed. Crops require almost as much sulfur as they require phosphorus. **Boron** (B) is a key plant micronutrient required all growing season, especially during the reproductive phase. Once native soil borate levels are depleted, that soil will never again be able to supply



Soil Health



sufficient boron for high yield without regular boron supplementation. Most cropland in the Mid-Atlantic and Northeast is now boron depleted by years of crop removal and leaching. Boron supplementation is positive for higher yield. **Copper** (Cu) is one of the three key plant health micronutrients. Copper is stable in the soil. Correct plant copper levels helps limit plant brittleness and green snap in corn. Too much soil Cu can cause toxic conditions to plants and plant consumers. Over use of copper based fungicides and copper sulfate are problematic, creating excessive soil copper that requires many many years to reduce. **Iron** (Fe) is an important micronutrient. A fairly wide range of Fe soil test levels are fine in high yield crop production. We find Fe to be quite important in a plant's transition phase from seed sourced nutrition and energy from germination through V2 to root sourced nutrition and sunlight sourced energy as a seedling. **Manganese** (Mn) is the second of the plant health micronutrients. Important in rapid plant establishment and the crop maturation processes. We are seeing more soil tests indicating the need for additional Mn. **Molybdenum** (Mo) is a micronutrient with involvement in the nitrogen cycle in plants and rhizobial symbiosis in legumes. Mo significantly increases the N output of rhizobia nodules on legume roots and increases the efficiency of a plant's conversion of nitrate N to ammonium N. A true trace element, extreme caution should be used not to over apply Mo in field application. **Zinc** (Zn) is the third plant health micronutrient. Aids the efficient use of other plant nutrients. Many soil tests are indicating relatively low levels of soil zinc. Like P, Cu, Fe and Mn, Zn should be placed in the soil rather than on the soil surface if you want the nutrient to be available for this year's crop, since Zn moves in the soil quite slowly. Soil nutrients interact with each other in unique ways. Antagonism occurs when high levels of one nutrient makes it harder for plants to absorb another nutrient by inhibiting uptake. Synergism

occurs when an increase in one nutrient boost the demand for another nutrient. Listed here are the nutrients followed by the nutrients they interact with. **Nitrogen** (N) interacts with B, Ca, Cu, K, Mg and Mo. **Phosphorus** (P) interacts with Ca, Cu, Fe, K, Mg and Zn. **Potassium** (K) interacts with B, Ca, Cu, Fe, Mg, Mn, N and P. **Calcium** interacts with B, Fe, K, Mg, Mn, N, P and Zn. **Magnesium** interacts with Ca, Fe, K, N and P. Sulfate **sulfur** interacts with N and as an anion/cation balancer. **Boron** interacts with Ca, K and N. **Copper** interacts with Fe, K, Mn, Mo, N and P. **Iron** interacts with Ca, Cu, K, Mg, Mn, P and Zn. **Manganese** interacts with Ca, Cu, Fe and K. **Molybdenum** interacts with Cu and N. **Zinc** interacts with Ca, Fe and P. Understanding how these interactions work and developing a nutrient management plan based on how nutrients effect each other is essential to high yield crop production. We can not grow high yield high quality crops on a starvation or out of balance diet. Manage nutrient shortages and excesses in the soil (The Eden Approach). This approach will set up soil physiochemistry to drive high yield of high quality crops from soil that is healthy, soil that allows you to grow crops in a regenerative and sustainable way.



Soil Biology: The Hidden Helpers in Crop Nutrient Uptake

Lisa Blazure

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Soil microbiology plays a critical role in regulating the availability, transformation, and acquisition of nutrients that support crop productivity. But management decisions on the farm greatly influence the composition, diversity, and function of the soil microbes. This presentation explores the key microbial processes that drive nutrient cycling in agricultural soils and their direct influence on plant nutrition.

Bacteria are the most abundant type of microbe in the soil and tend to have larger populations in a tilled system than no-till. They can rapidly respond to changing soil conditions and can double their populations in 15-20 minutes. They are very efficient at incorporating nitrogen from fertilizers into their bodies and this protects it from leaching down below the root zone. Some bacteria have the ability to convert nitrogen from the air into plant-available nitrate-N. The most common of these are *Rhizobia* that grow inside legume root nodules, but there are also free-living nitrogen-fixing bacteria in healthy, diverse soil systems. Some plants also host these free-living nitrogen-fixing bacteria in leaf hairs.

There are two beneficial types of **fungus** in agricultural fields. The first are called saprophytes, which break down old crop residues and manure to cycle nutrients and minerals back into plant-available forms. The other major group is mycorrhizal fungi, which form a beneficial partnership with the crops and grow inside the root system. This spider web-like fungal system growing out from the plant roots, greatly expands the root zone and leads to more water and nutrient uptake. Mycorrhizal fungi are very efficient at supplying phosphorus and micronutrients, as well as organic nitrogen sources such as amino-nitrogen.

Similar to above-ground food webs, there are predators in the soil which feed on bacteria and fungi. **Protozoa** are single-cell organisms which move through the soil on thin films of water and graze on

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bacteria. In the process, they consume more nitrogen than their bodies need and then excrete this extra nitrogen in the ammonium form that can be taken up by crop roots. **Nematodes** also eat bacteria and fungi, as well as feeding on pest nematode species. Plant roots can also be “predators” of soil bacteria. Recently discovered and named the rhizophagy cycle, the growing roots tip has the ability to absorb bacteria, strip off the cell walls to get nitrogen and micronutrients, and then expel the bacteria back into the soil through the root hairs.

Understanding the role of soil biology in plant nutrition, disease suppression, and soil health is the new frontier in agriculture. There are over a thousand products for sale that claim to enhance soil biology. They can be grouped into three general categories: biostimulants (which enhance native microbial activity), probiotics (which contain “living” species), or prebiotics (metabolites or biochemical products of microbes but don’t contain living organisms.) A 2024 meta-analysis of 94 different mycorrhizal inoculants found that most products were ineffective, with less than 10% of them colonizing the plant roots. The best course of action is to enhance the native microbe species on your farm by following the soil health principals and building good soil structure.

WPS – What you Need to Know

Penn State Worker Protection Standard Specialist – Joni Davis
Email: WPSprogram@psu.edu **Phone:** (814)863-8656



PennState

Worker Protection Standard Program

Worker Protection Standard: Are you in compliance?

- Do you grow or maintain a production agricultural crop?
- Do you apply pesticides to those crops?
- Do those pesticides have an agricultural use requirement statement on them?
 - If you answered "YES" to all three questions, you have WPS responsibilities.
 - If you are a family only operation you are exempt from much of the following information but why wouldn't you want to provide the same protections for you family. At the very least you must follow all label requirements, because "The Label is the Law!"
 - If you have employees outside your immediate family, you must provide all of the following information/protections to them.

This checklist serves as a brief overview of basic WPS requirements. For a detailed explanation of the requirements and assistance with compliance, schedule a farm visit with the Worker Protection Standard Specialist 814-863-8656.

Central Posting Location

	Central posting location is located in a spot accessible to all WPS employees while they are on site and includes: application information including: pesticide name and formulation, EPA registration number, active ingredients, location and description of treated area, start date and time of application and Restricted Entry Interval (REI).
	Pesticide application information and Safety Data Sheets (SDS) must be displayed within 24 hours of application and before employees enter the treated area.
	Display SDS sheets of applied pesticide products for 30 days after the REI has expired. SDS sheets must be kept for 2 years after product was last used.
	Pesticide Safety Information – May be in poster format or in other format as long as the following required topics are included: 1) local medical facility name, address and phone number 2) contact information for your regional PA Department of Agriculture office 3) address of the business
	In addition to the central location, the poster information must also be at permanent decontamination sites and other decontamination sites that serve more than 10 employees.

Pesticide Safety Training

	Training must be done on Day 1 for agricultural operations where it has been less than 30 days after the last REI has expired.
	Training must be done annually for both workers and handlers.
	Trainers in Pennsylvania must have a current Pennsylvania Pesticide Certification to train employees.
	Trainers must be present at the training to answer questions even if an approved video is being used.
	If an employee requests a copy of the signoff sheet, the employer must provide one.
	EPA approved training materials (2015 revision) must be used.
	Training must be in a language that the trainees can understand.

Applicator Notification

	Oral <u>and</u> posted warnings are given in accordance with the label requirements. Restricted Entry Intervals for REI's greater than 48 hours in outside applications will require a "Do Not Enter" posting. Enclosed spaces with a REI greater than 4 hours will require a "Do Not Enter" posting. Check pesticide labels for any posting requirements with lessor REIs. Employees MUST be told either verbally, posting or both.
	Agricultural employers must provide application information to a Handler employer in advance so that custom applicators know what areas are unsafe to be in.

Joni Davis is the Worker Protection Standard Specialist in the Pennsylvania Office of Rural Health at Penn State University. Her primary role is to assist growers with understanding and compliance with the EPA's Worker Protection Standard regulation. She works with growers across all commodities throughout the state, providing resources and materials to gain compliance.

Decontamination Supplies

	Workers must have access to at least 1 gallon of wash water (per worker), soap and single use towels within a quarter mile of the crop area that they are working in.
	Handlers must have at least 3 gallons of wash water, soap and single use towels; at the mix and load site, where they take off their personal protective equipment (PPE), and within a quarter of a mile of the application area. They must also have a change of clothes or coveralls in case their clothes are saturated.
	In the event of an exposure, natural waters can be used in emergency situations but this does NOT take away the responsibility of having decontamination supplies within a quarter mile. There must be an eyewash system at the mix and load site capable of delivering .4 gallons per minute of water for 15 minutes or 6 gallons of water capable of gently rinsing for 15 minutes. The same decontamination supply requirements are also required for EARLY ENTRY workers.
	For Handlers using pesticides requiring eye protection, they must have at least 1 pint of immediately available eye wash water on their person or application equipment.

Personal Protective Equipment (PPE)

	There is NO family exemption for wearing the label required personal protective equipment or for abiding with the label required REI.
	All Handlers, working with pesticides requiring respirators, must have an annual Fit Test. There is NO family exemption.
	A Respirator Fit Test involves a medical evaluation by a licensed medical professional (may be done on online). A medical evaluation does not necessarily require a medical physical but does involve a series of OSHA based questions. Once the medical evaluation is successful the actual Fit Test can be completed. The Fit Test, can be performed by a contractor, occupational safety and health department or on the farm by family members or employer using a fit test kit. The final step is training; on how to properly use the respirator.
	If Handlers are not using pesticides that require respirators, a Fit Test is not required. If the Handler uses a loose-fitting Powered Air Purifying Respirator (PAPR) , the Handler does not need to take the actual Fit Test but the medical evaluation and respirator training is still required.

Monitoring Handlers

	Handlers and Early Entry Workers must be at least 18 years old except for family members.
	Handlers working with 'skull and crossbones' pesticides must be checked once every two hours by sight or sound. Constant voice or visual contact must be maintained with Handlers applying fumigants indoors.

Application Exclusion Zone

	Maintain a 100-foot Application Exclusion Zone (AEZ) for high drift applications such as air blast or aerial applications, fogging or fumigation and a 25-foot AEZ for lower drift applications such as boom spraying or backpack spraying more than 12 inches above the ground. This applies both on and off your property.
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Family Exemption

	The Immediate Family Exemption includes the following members: children, step children, foster children, parents, step parents, foster parents, spouses, brothers, sisters, first cousins, nephews, nieces, uncles, aunts, grandparents, grandchildren and in-laws.
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Updated October 2025

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Pesticide Educational Resources Collaborative (PERC)- www.pesticideresources.org



Grower Panel – Insights and Experiences from Sweet Corn Growers

Neil Palmer | Palmer's Farm

My name is Neil Palmer. I manage Palmer's Farm which is a small, diversified produce farm in Western PA. We grow 15 acres of sweet corn on our own land which we hand harvest and sell by the dozen at our on-farm market.

In the past we leased several tracks of land in our area and grew about 25 acres of sweet corn. However, circumstances in recent years have led to us relinquishing rented ground and focusing solely on the use of our own land.

We are growing sweet corn in the same ground nearly every year, which is not ideal, and creates challenges. My goal is to simultaneously achieve high yields of sweet corn while building soil health in a meaningful way, in spite of the limitations.

I primarily want to share how we have been implementing the following principles of regenerative agriculture to attain the goal of building soil health.

Maintain living roots: We are seeding cover crops shortly after harvesting sweet corn, allowing them to grow into the next spring as long as possible by terminating them either shortly before planting sweet corn, or shortly after planting.

Increase diversity: We are seeding a mix of cover crop species which includes cereal rye (grass), hairy vetch (legume), and tillage radish (brassica). This isn't a huge amount of diversity, but I think of it as an upgrade over rye only. I've been experimenting with other cover crops but these three have been a big success and nice fit.

Keep soil covered: In the spring we are terminating the cover crops (the tillage radish winter kills) when they are at least 2 feet high but more typically 3 to 5 ft. tall and in reproduction stages. They are rolled down which creates a thick, carbon-rich mat that lasts at least until the next cover crop establishes in the fall and gets thick.

Minimize soil disturbance: The only tillage that takes place is a low intensity method of strip-till prior to planting sweet corn. It involves removing residue from a 6 inch wide strip and lightly tilling to a depth

***Neil Palmer** is the Manager and Owner of Palmer's Farm in Western PA, a fourth generation produce farm*

of no more than 1 inch. This is accomplished with row cleaners and coulters and a chain or rolling bucket. This strip-till results in a low level of disturbance and helps create a drier and warmer seedbed which results in successful stand establishment of sweet corn.

Integrate livestock: We graze over 50 head of cattle and 100 head of sheep on the cover crops in both the spring and fall. We also graze corn stalks in the summer after harvesting. Grazing helps to maximize the potential of the cover crops and manage the growth, recycles carbon and nutrients, and feeds soil biology.

The improvements I've seen in the way our soils are functioning is truly stunning. Soil tilth has greatly improved, the CEC has nearly doubled in the last several years, and I'm counting 40 earth worms per square foot.

We've been able to drastically decrease fertilizer applications, yet we're planting a population of about 28,000 seeds per acre (7.5 inch spacing) and picking large, beautiful ears of corn with yields of 1500 to 1750 dozen per acre. Overhead irrigation and diligent pest management help secure top yields.

While I do wish we had more land and could rest our fields from sweet corn production, I'm very pleased and grateful that our soils are greatly improving without having to sacrifice yields. It is easier for me to manage production since downsizing. Even the acres we are planting are easier to manage because of less field operations. Also, our large tractors and plows are no longer being used and I'm saving money on fuel and fertilizer, so I consider our approach to be more cost-effective and simpler, as well as more ecologically sound. Thank You.



Sweet Corn

Seed Supplier Panel

From Field to Fork: How New Hybrids are Redefining Sweetcorn Quality and Shelf Life

Jay Ruwet | Harris Seeds

The sweetcorn market has evolved dramatically: from early SU types such as Butter and Sugar and Silver Queen, through SE-type lines like Lucious, Ambrosia, and Kandy Korn, to today's dominant SY (Synergistics) and Sh2 hybrids. Leading SY hybrids include Essence, Allure, Primus, Temptress, and Evolution, while top Sh2 cultivars include Signature, Kate, the Nirvana series, 7143, Superb, and Kickoff. Throughout this progression, two attributes have consistently driven consumer adoption: eating quality and hold ability from field to shelf. Although yield, disease resistance, and robust plant health remain essential, future market growth hinges on varieties that offer superior eating experiences and extended shelf life without sacrificing agronomic performance.

This presentation examines:

How breeding priorities have shifted to align superior eating quality with shelf stability.

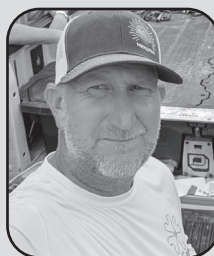
The major germplasm sources — Chief Genetics, Crookham, Seneca Vegetable Research, Harris Moran, IFSI, Seminis, Syngenta, and others — and how they are enabling new hybrids and novel traits.

Case studies of current leading varieties and what their performance suggests for future category development.

Emerging opportunities to redefine sweetcorn with pericarp improvements and enhanced post-harvest behavior, and the practical implications for growers, supply chains, and retailers as the industry moves toward better eating quality, greater shelf stability, and new consumer-facing categories.

Company highlights and breeding program notes

Chief Genetics: A newer program founded by two veteran breeders, Chief Genetics has assembled diverse germplasm from global sourcing to create high-eating-quality hybrids with tender pericarps and clean-textured bites. Its first commercial seed



***Jay Ruwet** has been a dedicated sweet corn grower on his family's farm his entire life, cultivating diverse varieties and working on improving production challenges. He has been in the seed industry for over 20 years, traveling extensively throughout the U.S. conducting variety trials across a wide range of diverse regions. Collaborating with growers, I specialize in selecting hybrids that match their unique operations, boosting yields, quality, and market edge. Passionate about innovation bridging my farm experience with industry insights to drive operational progress for growers.*

production is slated for 2026 with introductions such as 704BC, M1, and M3. Growers familiar with Mirai 315 should take a look M1 and M3; Chief Genetics' future releases are expected to deliver improved pericarp texture, plant health, in-field and shelf holdability, and elevated eating quality.

Crookham: One of the longest-running U.S. sweetcorn programs, Crookham continues to push eating-quality boundaries. Elysian, a 78-day bicolor Sh2, has gained traction for its tender eating quality and is positioned in Crookham's "Nirvana" high-eating-quality class. Dash, an early 68-day bicolor Sh2, shows strong cold-soil vigor, good eating quality, excellent tip fill under stress, and promising hold ability. From breeding to product development and sales, Crookham's cohesive team is producing noteworthy hybrids worth watching.

Harris Moran: Harris Moran made a market impact with its earlier "model series" (Kate, Nicole, Natalie, Elle), which elevated eating-quality standards and became market mainstays. A recently added breeder has further advanced the program, expanding



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the pipeline across maturities — from early 68-day types to main-season 80-day varieties — with continued improvements in eating quality and plant performance.

Seneca Vegetable Research: An established program responsible for notable SY varieties such as Progression, Evolution, Essence, and Cup-A-Joe. Their new 78-day bicolor Sh2, Cosmic, has demonstrated strong hold under high NCLB pressure during mid-to-late season trials.

IFSI: Played a key role introducing Sh2 varieties into local roadside markets with foundational lines like 274A, 277A, 2170, and 278A. Contemporary IFSI releases — Bolt, Superb, Signature, and Kickoff — continue to perform well and support local-market adoption.

Syngenta: The Attribute trait package has been transformative for growers protecting crops from above-ground lepidoptera pests (European corn borer, Western bean cutworm, armyworm, and

especially corn earworm). Hybrids such as Matriarch (Sh2), Patriarch (Sh2), and Revision (SY) help maintain quality during high pest pressure and can reduce unwanted spray applications.

Seminis: Varieties such as 7143, Obsession, 1336, and 1580 are widely used by shipper-market growers for their versatility under challenging climates, consistent marketable yields, and substantial eating quality.

Conclusion Breeding is converging on the twin goals of exceptional eating experience and durable hold ability. Advances coming from established and emerging programs — through pericarp texture improvements, pest-protection trait packages, and optimized germplasm combinations — will shape new sweetcorn categories and unlock downstream value for growers, distributors, and retailers. Practical adoption, however, will depend on delivering these consumer benefits while preserving the agronomic traits growers require.

Don't Let Diseases Ruin Your Beautiful Tomatoes

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Bacterial Disease: have the potential to cause plant stunting, wilting, browning of the leaf margin, and fruit spotting. Two important bacterial diseases include bacterial spot and bacterial canker.

Bacterial canker is an important disease of tomatoes. Bacterial canker symptoms can occur on greenhouse transplants include white to tan blisters on the petiole, necrosis of the leaflet, and plant wilting. On established plants in the field, necrosis of the leaf edge, referred to as “firing”, occurs along with unilateral wilting, necrosis, and death of the leaflet with the entire leaf eventually dying. Browning of the vascular tissue of infected stems is common. Cmm infections of fruit result in small (< 0.3 cm in diameter) necrotic “birds-eye” spotting with a white halo and generally do not affect quality of tomatoes grown for processing. Fruit produced on plants stunted because of bacterial canker infection are typically reduced in size and quantity resulting in significant economic loss.

Bacterial spot 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. 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.

Bacterial Control in the Field: Applications of copper products may reduce foliar blight and/or fruit spotting. Growing recommendations include fall plow down of infected plants. A contaminated field should be rotated out of tomatoes for at least three years. Any equipment used in a diseased field should be power washed prior to entering a clean

Mary Hausbeck is a University Distinguished Professor and Extension Specialist at Michigan State University. Her crop responsibilities include vegetables and greenhouse ornamentals.

field. Equipment and workers should begin work in the cleanest field and finish with the diseased field. 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. Copper sprays at the minimum-labeled application interval may be helpful in reducing bacterial spread. However, if the environment is favorable for bacterial pathogens (75° to 90° F with rain) coppers may be limited because the bacteria have a decided advantage in a wet environment.

Bacterial Control in the Greenhouse: 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 pathogens. The earlier that diseased transplants are identified and removed from the greenhouse, the better. Transplants may be 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 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 streptomycin is preferred. 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.

Fungal Foliar Blight and Fruit Rots:

Anthracnose is caused by the fungus *Colletotrichum coccodes* and causes the rotting of ripe fruit which reduces yield and fruit quality. Disease symptoms do not appear on the foliage. Early symptoms include slightly depressed, water-soaked circular spots that increase in size (up to 1/2"), become further sunken and may contain a pattern of concentric rings. As the fungus spreads within the fruit, a semi-soft decay occurs. Lesion development is most rapid at 80°F and

disease development is greatest during wet, rainy weather. To control the disease, a 2- or 3-year crop rotation is suggested. Also, avoidance of sandy soil sites to minimize injury from blowing sand particles will reduce anthracnose.

Early Blight is caused by a fungus (*Alternaria* spp.) infects foliage and ripening fruit. Infection can occur at the point of attachment to the stem and through growth cracks and wounds on the fruit. The early blight fungus causes dark brown, leathery sunken spots with concentric rings. When young fruit become infected, they may drop off prematurely. Infection is greatest in warm weather (75-85°F). Extended dews, humid and wet weather, and frequent rainfall contribute to severe disease. To control the disease, a 3- or 4-year rotation will reduce the levels of the fungus in the soil. After each growing season, it's important to plow down plant debris to speed up the breakdown of the crop debris so that the early blight pathogen cannot survive for an extended time.

Late blight is a disease that most commonly affects potatoes but can affect tomatoes. When the weather is favorable, late blight can be a very serious disease. This disease does not occur frequently. Late blight symptoms include blighting on all aboveground parts of the tomato plant. Spots and blighting of the leaves often appear dark and oily with production of spores occurring on the undersides of the leaves resulting in a purplish appearance especially when conditions are wet and humid. Blackened lesions on the stems also occur and are unique to late blight disease. Late blight affects green and ripened tomato fruit. The blighting on fruit appears as dark, greasy areas that enlarge rapidly encompassing the entire fruit. During wet and humid conditions, white threads (mycelium) can be seen on the fruit. Between cropping seasons, the fungus survives on volunteer and abandoned potato and tomato plants in fields, cull piles, and homeowner gardens. Cool nights and warm days are ideal for late blight development. The spores can be carried from diseased plants to nearby healthy plants via wind. Control measures include eliminating all potato cull piles in the vicinity of tomato plantings and destroying volunteer potato plants that grow from overwintered tubers. Tomato varieties can vary in their susceptibility to late blight. The fungicides used to limit *Alternaria* leaf blight, *Septoria* leaf blight, generally provide a good level of control from late blight. However, when late blight on potatoes has



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been reported in the state, fungicides that control late blight are recommended for tomatoes.

TOMCAST Disease Forecaster: Recommendations to control early blight and anthracnose fruit rot on tomatoes include a 3-to-5-year crop rotation, disease free transplants, planting in a well-drained site with good air flow, and plant protection products. Plant protection products are often initiated when the plant canopy develops and becomes dense and then are applied every 7 to 10 days. Biologically based plant protection products should be applied frequently at 7-day intervals. With high spray costs, concerns about grower safety, environmental concerns, and pesticide residues, there are many advantages in applying fungicides only when weather conditions are favorable for disease development.

Growers intuitively know that during periods of dry weather, the days between fungicide sprays can be stretched without loss of yield or fruit quality. TOMCAST is a tool that helps growers decide when to apply fungicides for control of early blight on tomatoes. Although TOMCAST is designed specifically to help time the application of fungicides for the control of early blight, it is also helpful in timing sprays for the control of anthracnose and Septoria leaf spot. According to TOMCAST, the need for a fungicide application is determined by the duration of continuous leaf wetness and the average temperature during the leaf wetness period. The temperature and duration of leaf wetness can be measured by a simple piece of field equipment that has electronic sensors and the capacity to store the recorded information (Spectrum Technologies, Inc. is an example of a resource).

Early blight is considered a threat if tomato leaves are wet and if the temperature is greater than 55°F. The longer the leaves are wet at warm temperatures, the more likely disease will develop. Likewise, the warmer the temperatures, the more likely disease will develop. The specific combination of these two variables are assigned Disease Severity Values (DSVs). For example, if the leaves are wet for 10 hours and the average temperature for that 10 hours is 60°F, TOMCAST would assign a DSV of 1 (weather for that day was not favorable for disease). If the leaves are wet for 18 hours at an average temperature of 80°F, the DSV for that wetting period would be 3 (weather for that day was favorable for disease). The DSVs are added up for each day, and when the total reaches a specific number (a total of 15 DSVs is recommended), a spray is suggested.

Building a Tomato Nutrition Program from the Bottom UP

Steve Bogash, PSU Extension and ProFarm Group (retired)

Achieving the greatest yields of the highest quality tomatoes (and peppers) demands that growers plan their nutrition program long before the first plants are getting transplanted. Growers must avoid existing soil disease challenges, water and soil pH issues (mostly pH that is too high), rebuilding or building a nutrition injection system that is accurate and reliable, application of manures, composts and other 'green' amendments, application of granular and related bulk dry nutrients including gypsum, then once planted, planning and managing the injection of nutrients to maintain healthy, high yielding plants, and, the application of foliar nutrients to fine tune production, plant health and fruit quality. We'll take these on one-by-one to build an effective nutrient management program.

Water resources, pH, and alkalinity

Tomatoes and peppers have the best nutrient uptake at a soil solution pH of 6.2-6.5. This will maximize potassium uptake as well as create a situation where it is possible to keep the other nutrients in the high end of the 'sufficient' zone. Regular testing of your irrigation source for pH and alkalinity will provide you with information to adjust your pH through the addition of acids. *Note: low pH is seldom a problem, but where the irrigation solution pH is below 5.8, the use of alkaline fertilizers is indicated. The injection of alkaline materials specifically for pH adjustments such as calcium carbonate and potassium bicarbonate is only recommended where the pH is below 5.5.* Sulfuric acid is the most common input used to reduce pH and alkalinity. Organic growers have had good success with citric acid for pH reduction. Nine ounces of powdered citric acid per 100 gallons of irrigation water will reduce the pH of most water by about 1 full point on the pH scale. Conventional growers can use the AlkCalc alkalinity calculator (http://extension.unh.edu/Agric/AGGHFL/alk_calc.cfm) to get extremely close to a proper dose for all commonly



Steve Bogash retired as a Horticulture Educator and Researcher, PSU Cooperative Extension in June 2016. Then retired again from ProFarm Group formerly known as Mar-rone Bio Innovations as their NE / Mid-Atlantic Product Development and Territory Business Manager in 2024. Steve now consults for ProFarm Group, growers, and other bio-focused or plant nutrient focused companies. Steve is also burnishing his woodworking skills in retirement as he learns to build small boats and smell like sawdust much more often.

used acids. The use of a properly calibrated pH meter is highly recommended to test the irrigation stream regularly as the online calculator and citric acid recommendation are simply tools to get close to the target pH. Water pH often changes during the growing season based on rainfall and source. Limestone aquifers can experience an increase in pH and alkalinity in a dry season as the underground storage volume decreases, thus increasing the concentration of bicarbonates. Surface waters will change with every rain event as rainwater combines with runoff.

Note on the pH scale: Even small incremental changes in pH mean a lot for soil solution chemistry. This is because the scale is logarithmic. The difference between a pH of 6 and 7 is ten-fold. Going from a pH of 6 to 8 is 10 x 10 or 100-fold. Most tomato growers that have adopted acid injections find that their crop quality improves dramatically as their potassium utilization improves.

Note on pH meters and litmus paper: Litmus paper is nearly useless for accurate water testing as it will age rapidly once the package is opened and is only designed to get within ½ of a pH point. The author

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regularly finds litmus paper tests to be off by 1-2 points. Purchase a high-quality digital pH meter that self-temperature adjusts, read the directions carefully, change the batteries at least annually and use fresh pH 4 and 7 calibration solutions. Replace calibration solutions at least annually. If you notice crystallization around the lid of the solutions, it's time to replace them. Your test results are only as good as the solutions that you use to calibrate your meter. pH meter sensors are generally good for 2-3 years if cleaned and stored properly between uses. If your meter will not hold a calibration, then it is likely time to replace the entire unit or the sensor with replaceable sensor assemblies.

Granular and dry product applications

An acre of tomatoes can use a lot of nutrients, approximately 70-150 lb. of N, 100-200 lb. of P, and 200-300 lb. of K plus Ca, Mg, S, and assorted micronutrients. Beginning with a soil test, broadcast about 50% of what is needed prior to bed construction and planting. This will ensure that the soil has a solid bank of nutrients and make injecting the remainder of the nutrients easier. Also, dry, granular products are generally cheaper than soluble nutrients.

Unless you grow on lower pH soils, consider using gypsum as your primary granular Ca source as it is inexpensive, effective, and does not mess with soil pH like limestone.

Tomatoes are a high dollar return product making the investment in crop stimulants like kelp meal well worthwhile. Kelp can be challenging to apply, so work with your nutrient suppliers on a version that applies easily and evenly. Liquid kelp applied through boom sprayers at low pressure with extremely coarse nozzles is often easier than trying to get dry kelp spread thru a 'spinner' or drop spreader. *Note:* I've often used burnt kelp meal in high tunnels and have often simply hand-spread it while using the mostly clogged 'cyclone' sprayer as a bucket on wheels.

Application of injected nutrients

The potassium / nitrogen (K/N) ratio deserves careful consideration. Tomato plants require substantial nitrogen to rapidly grow a strong plant. Nitrogen demands change during the plants' lifespan. Prior to flowering, dry matter tissue levels of 5-6% N are recommended. At flowering and during subsequent fruit fill, the nutrient ratio between K and N becomes critical. Experiments in Southwest Michigan indicate that a 2K to 1N feedstock ratio is necessary to produce quality fruit during fruit filling. This ratio will tend to enhance fruit firmness as well as reduce yellow shoulder. Potassium plays a key role in water relations and epidermis (skin) elasticity. Sites that are very poor in fertility may benefit from a 3K to 1N ratio fertilizer. While tissue N levels of up to 6% are advisable as plants are growing out from a transplant, those levels need to be brought down to 3.5-4.5% once fruit set and maturation gets underway or suffer the likelihood of soft fruit and yellow shoulder.

The Michigan research also indicated that a single foliar application of boron at .25 lb./A reduced shoulder checking. In some, but not all cases, foliar calcium applied both with and without boron was also beneficial. Growers need to be cautious in applying micronutrients such as boron as excessive amounts can result in fruit defects and phytotoxic damage to skin and leaves.

Once tomato plants are fruiting (about 4 weeks after transplanting) look for the following tissue nutrient levels (by dry matter):

Nitrogen	N	3.5-4%
Phosphorus	P	.8-1%
Potassium	K	3+%
Calcium	Ca	2.5-3%
Magnesium	Mg	.6-1%
Sulfur	S	.3-1.2%
Manganese	Mn	40-500ppm
Zinc	Zn	20-50ppm
Boron	B	25-75ppm
CopperCu		5-20ppm



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A good program to begin injecting nutrients is to base your initial applications on general plant population requirements. An acre of tomatoes needs approximately .5 lb. of N per day. From this starting point, you can adjust your program as necessary based on soil and tissue analysis. A tomato acre has 4,840 plants (plants 18" apart with rows on 6' centers). Start with a balanced fertilizer such as 20-20-20 (1-1-1 ratio) or 20-10-20 until the first flowers appear (about 4 weeks post-transplant), Switch to a high K, low N fertilizer at this point such as 9-15-30 (1-1.5 to 3-4 N/K ratio) and adjust other nutrients based on tissue results. There is good research to support moving to a high potassium program two weeks prior to flowering as this is when the higher consumption begins. This may explain why growers that begin to increase potassium at visible flowering or shortly after find it so difficult to restore plant tissue levels. They tend to 'chase' potassium levels due to the late start increasing added potassium.

Calcium is a little special as it does not move from older plant leaves as Magnesium, Mg does, so plants need it regularly in the irrigation stream for reduced cracking, firmness and preventing blossom end rot. Tissue testing will reveal whether you need to adjust this nutrient. It is not uncommon to have to regularly tweak levels of Mg and Ca. Note that testing for tissue Ca and Mg is always measuring past uptake. However, measuring these levels is useful in adjusting your regular feeding program.

Foliarly Applied Nutrients

Keeping up with rapidly ripening fruit demands when a single tomato plant may be ripening 8-15 lb of fruit at a time require careful attention. High yielding tomato varieties often benefit from the application of very small amounts of Ca, Mg, B, and K to foliage. Research has demonstrated a synergy between the application of potassium to the roots coupled with a foliar application of potassium. Regular applications of Ca, Mg and K help in maintaining sufficient levels of these nutrients during highest demand. Carefully follow the label directions and double check your math as there is always the potential to burn leaves

and fruit through wrongly applied foliar materials. Avoiding applications during the hottest part of the day once temperatures reach 85F will greatly reduce the potential for these phytotoxic reactions from spray materials. Products that are blended specifically for foliar application have adjuvants that increase the uptake of nutrients through leaf tissue. Nutrients can only move from the surface of the leaf to plant tissue when still in solution. Dried nutrients will only sit on the surface and either wash off or accumulate and potentially burn plant tissue. Apply only enough solution to wet leaves but keep runoff to a minimum as runoff will increase the potential for edge and tip burn. Early morning and late evening applications will stay wet longer so work better for nutrient uptake.

If applying foliar nutrients, be sure to request that your tissue analysis lab washes your sample leaves before processing. They will use distilled, deionized water for this purpose.

Important Additional Notes:

-Tissue phosphorus (P) levels drop precipitously shortly after fruit set. Start tissue testing about 4 weeks after planting, then continue every 2 weeks until last fruit set. In trials at the Penn State SE Research Farm, tunnel tomatoes consistently went through a deep P drop in plant tissue that was solved by adding a high soluble P to the mix (12-48-8 in our case, but there are other similar materials) for several weeks. After 2-3 weeks of this high P regimen the nutrition program was able to go back to regular maintenance fertilizers such as 9-15-30 or 8-16-42 as P levels stabilized after the first heavy fruit set.

-The use of soil inoculants that include *Trichoderma harzianum*, other *Trichoderma*'s, *Streptomyces lydicus*, and other specific soil microbes can significantly improve P and other nutrient uptake while assisting in disease management.

-When to switch from a balanced nutrient blend to a high K soluble? Earlier wisdom was that we switched at the onset of blossoms. One of the reasons catching up is always so difficult is that we **started several weeks late**. High potassium usage begins several



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weeks before visible flowering. This earlier potassium need just underscores the need for a consistent tissue testing program. Four weeks post-transplant seems the 'sweet spot' to begin tissue testing followed by switching from a balanced nutrient blend to a higher K version at the same time.

-Boron everywhere: more soluble fertilizers contain boron as it is often identified as being deficient. Carefully consider which fertilizers you choose, to avoid a boron toxicity. Boron is only needed at 25-75 ppm by dry matter. Higher levels are toxic to plants.

-Magnesium formulation matters a great deal. While Epsom Salts / Magnesium Sulfate / $MgSO_4$ is an excellent source of Mg when building soil fertility, it is generally too slowly available to provide necessary Mg when dealing with an in-season deficiency. Look for chelates, oxides, citrates and perhaps nitrates applied both foliarly (at very low concentrations) and fertigated when correcting a deficiency. When consulting with your nutrient suppliers, ask about molecule size and trials that demonstrate movement into plant tissue. In general, smaller-sized molecules will more readily cross the epidermis in foliar applications and be more plant available. This includes EDTA chelates and amino acid chelates.

-Your transplant water formula matters a great deal. This is your opportunity to stimulate root growth, apply living inoculants, and generally get your plants off to a rapid start. Regalia® at 1 qt / 100 gallons of solution applied at transplant has been proven to increase root mass even under harsh conditions. Regalia mixes well with most starter nutrients in the transplant tank. Apply living root inoculants as a drench several days or up to one week prior to transplanting to allow the microorganisms to thoroughly inoculate plant roots before exposure to soil organisms. This can include *T. harzianum*, *B. subtilis*, *B. amyloliquefaciens*, and *Streptomyces lydicus* as well as other related organisms and blends of these products.

-It's often tough to get Calcium uptake early in the season. This is due to the combination of cloudy rainy weather and shorter days coupled with low sun angle (low light levels). This is one of the reasons why we often see so much blossom end rot / BER on early set fruit. Foliar application of small molecule Ca products including chelates can offset some of these problems. The use of pro-transpiration products such as Haven® have been proven in field and university trials to improve fruit quality by increasing transpiration, thus the movement of nutrients from the soil solution into plant tissue. Begin applying Haven at 77 oz / 100 gallons foliarly every 2 weeks beginning at 4 weeks after transplanting. Haven will also reduce sunscald, so use it consistently during the growing season. Glycine betaine products such as Lalstim OSMO® have a similar mode of action to Haven.

Getting the Most from Your Vine Crops: From Seedling to Harvest

Brent Clever | Miller Plant Farm

Watermelon Production on a Family Farm

My name is Brent Clever, and I have worked at Miller Plant Farm in York, PA for 22 years and was asked to do this presentation on my favorite crop to work with in my growing career. We start watermelon transplants for growers and our own field production. As technology and expenses have grown we have had to incorporate numerous changes to the process of getting seedless watermelon transplants to our fellow farmers in as low of costs as possible while still providing and producing quality healthy transplants. One way we have done this is through "Co-Planting." The incorporation of co-planting in the process has allowed us to not only simplify things on our end of production, but it has saved our customers headaches and costs as well as labor. Another way we help our customers is with our willingness to trial new varieties and have close ties with our seed reps to stay current of new varieties for our growers. We enjoy taking the time to help our growers to pick the right varieties for their farm and their specific avenues to sell the watermelons. My go to variety is "Talca." In the presentation I will explain why this has become my favorite variety as well as a few other ones for specific grower needs. In picking the right variety for your needs, being aware of "Hollow Heart," has been a factor in my recommendations to customers. We not



Brent Clever has been with Miller Plant Farm since 2003 and makes most of the decisions concerning all phases of vine crop production. He is married to wife Casey and has a daughter Maddie and a son Brayden.

only help our customers pick good varieties for their applications, but we enjoy helping new and existing customers with laying out their fields using multiple plantings to extend the growing season as well as help with calculations. I will also be going over briefly some growing information in field production, touching on the importance of herbicide control as well as the importance of pollinators on the farm.

Tackling the Challenges of a Wet Year

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The *Phytophthora capsici* pathogen can rot the crown and fruit of hard squash, pumpkins, and other related vine crops such as summer squash and zucchini and is a limiting problem for many growers. The crowns, petioles, and fruits of hard squash are all susceptible to infection. Symptoms of crown rot include watersoaked and brown tissue of the plant and/or fruit followed by a rot that becomes soft. In some cases, a water-soaked blight may be seen on the leaves during times of high rain and humidity. Infected fruit typically show patches of white spores that look like powdered sugar; these areas expand as the rot develops. Healthy-appearing fruit can be harvested but develop a rotted area days later during shipment or on grocers’ shelves.

Major crop losses can happen despite following recommended rotation and other control strategies. Since survival spores (oospores) of *Phytophthora* are long-lasting (10 years or more) in soil, fields infested with this pathogen are sometimes taken out of vegetable production because many important crops are susceptible (See Table 1). An important advance in the battle against this pathogen was made when research showed how easily *Phytophthora* can spread by irrigating with surface water contaminated with the pathogen. While it was known that *Phytophthora* is favored by rain and spreads readily in the field via water, it was not widely recognized that the pathogen could be in the creeks, ponds, ditches, and culverts used to irrigate squash, pumpkins, and other susceptible vegetables. Recognizing that *Phytophthora* may be introduced to new fields via irrigation water and cause squash and pumpkins to rot in fields without a history of *Phytophthora* or vegetable production has prompted many growers to establish wells.

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Table 1. Vegetables that can be infected by *Phytophthora capsici*.

Cucumber	Pumpkin	Zucchini	Tomato
Gourd	Summer squash	Eggplant	Lima bean
Honeydew	Winter squash	Bell pepper	Snap bean
Muskmelon	Watermelon	Hot pepper	Wax bean

Known as a water mold, *Phytophthora* may form many sporangia (spores) on the surface of infected fruit (See Figure 1). If these sporangia encounter water, each will develop into 20 to 40 swimming zoospores. These zoospores may swim through water-saturated soil or may be carried in flowing water, including irrigation water. Swimming zoospores use electrical and chemical signals to locate a susceptible plant. Zoospores in water can survive and cause infection for days, even after they have stopped swimming. *Phytophthora* is not likely to be found in surface water when the water temperature is greater than 77°F or less than 57°F. Since vegetable producers usually irrigate during the warm summer months, the temperature of irrigation water is unlikely to limit infection. If high numbers of zoospores are present in the water, infection of susceptible crops like squash and pumpkins is more likely, even when the water is cooler. Older zoospores still caused infection of pickling cucumber fruits in MSU studies. The amount of infection observed depended on the number of zoospores in the water; more fruit became infected at higher zoospore numbers. Zoospores were able to infect fruit even after being in water for 5 days. Well water or water from well-fed ponds should be used

to irrigate squash and pumpkins and all vegetables susceptible to *Phytophthora*.

Management Strategies

- Plant into well-drained, tiled fields
- Use raised beds and drip irrigation
- Avoid using surface water for irrigation
- Irrigate sparingly from a well
- Rotate crops
- Scout fields regularly for *Phytophthora*
- Remove any diseased plants and adjacent healthy-appearing plants
- Apply fungicides preventively and at short intervals when needed
- Remove fruits from field as quickly as possible and store in a warm, dry place
- Powerwash equipment after it has been in infested fields
- Do not dump diseased culls in production fields

While treatment options for disinfecting surface water sources are not currently available, MSU research found that algaecides work well in the laboratory setting to kill zoospores in water. These products are often used to clear algal growth from filter intakes and irrigation lines. Managing water in the field is important to managing *Phytophthora*, and drip irrigation is recommended to reduce splashing of infested soil onto the fruit, petioles, and crown. If overhead irrigation must be used, reduced watering during fruiting is recommended to limit infection.

If you do not have *Phytophthora capsici* in your fields, do everything you can to prevent it from being introduced and established. If there is a history of *Phytophthora* in a particular field, take preventive measures. Do not plant winter squash or pumpkins in that field. Soils should be well-drained. Leave the low-lying areas of the field unplanted as that is often where disease can begin. Plant winter squash and pumpkin into raised beds, allowing excess water to drain away from the plant and fruit. If *Phytophthora* crown rot develops, remove the diseased plants, including the adjacent healthy-looking plants, as they are likely already infected and will show symptoms soon. Work fields without a history of *Phytophthora* first and finish with problem fields. Clean all equipment used in an infested field to prevent spread to other fields. Discard infected and rotting fruit culls in an area where crops are not grown.

Hard squash types that become more resistant to rot as the fruits mature (21 days following pollination) including ‘Butternut Ultra’, ‘Buckskin’, ‘New England Cheddar’, ‘Dickinson’, spaghetti squash, and acorn squash. Some cultivars that remain susceptible as the

fruit mature include ‘Hubba Hubba’ Hubbard squash, ‘Autumn Cup,’ ‘Sweet Mama,’ ‘Thunder,’ ‘Delica,’ ‘Sunshine,’ ‘Space Station,’ and ‘Golden Delicious.’ Fungicides can offer help but must be applied preventively, frequently, and add cost. Protecting the young fruit from *Phytophthora* is critical and good coverage is mandatory. Many cultivars produce large, dense canopies and proper application equipment is usually required to penetrate the canopy. To protect fruits, it is recommended to apply heavy foliar sprays with drop nozzles at the time of initial fruit formation and reapply every 7 days, depending on the weather conditions and the squash cultivars. Rotate fungicides using those representing different modes of action to prevent *Phytophthora* from developing resistance. On some farms, *Phytophthora* has become resistant to fungicide containing mefenoxam or metalaxyl as their primary active ingredient.

Preferred Phytophthora Fungicides for WINTER SQUASH			
Product	A.I.	FRAC*	Comment
Elumin	ethaboxam	22	Rotate between applications. Apply as a soil or foliar spray or via drip.
Orondis Gold 200	oxathiaprolin	49	Apply at-plant in-furrow or via drip (after plant emergence if direct-seeded).
Orondis Ultra	oxathiaprolin/mandipropamid	49/40	Rotate to a fungicide with a different FRAC after 2 sequential applications. Use either soil or foliar applications of oxathiaprolin products, but not both for disease control.
Presidio 4SC	fluopicolide	43	Use in a fungicide tank mix. Apply via drip or as a foliar spray.
Revus 2.08SC	mandipropamid	40	Include surfactant.
**Apron XL	mefenoxam	4	Seed treatment. Wait 6 weeks after transplant to apply mefenoxam products.
**Ridomil Gold	mefenoxam	4	Apply as a preplant-incorporated, at-plant soil spray or via drip.
Phytophthora ‘B’ Team for WINTER SQUASH			
Forum 4.18SC	dimethomorph	40	Use in a fungicide tank mix.
Gavel 75DF	mancozeb/zoxamide	M03/22	Relatively long PHI.
Ranman 400SC	cyazofamid	21	See label about surfactant.
Zampro 4.4SC	ametoctradin/dimethomorph	45/40	Apply via drip or as a foliar spray.
*The FRAC code is an alphanumeric code assigned by the Fungicide Resistance Action Committee and is based on the mode of action of the active ingredient.			
**While mefenoxam is not labeled for <i>Phytophthora</i> , it is labeled for control of <i>Pythium</i> . Fungicide resistance has been detected in <i>Phytophthora</i> where mefenoxam has been used frequently.			

High Tunnel Cucumbers: Two Crops and a Full Season of Cucumbers

Steve Bogash, Penn State Extension and ProFarm Group. (retired)

Producing and marketing high tunnel cucumbers both before and after the typical field production season has distinct advantages that can greatly augment the sustainability of a vegetable business. High tunnels provide the ideal environment to produce high quality, trellised, cucumber harvests both well in-advance of and as field-grown of cucumbers are dwindling in early fall. The window to turn a high tunnel around and replant with fresh cucumber plants for a second crop is a bit narrow, but manageable.

If you grew a spring cucumber crop in your tunnel, then harvests and quality are likely dwindling by the end of June and there is substantial good quality field production coming into markets pulling prices downward. What a great time to clean that old crop out and prep for a fresh crop that begins harvests in late August to early September. While there is some variation by variety, most *parthenocarpic* cucumbers will start producing fruit at about 45 days after the first true leaf emerges and can produce economically interesting fruit for another 45-60 days. If you replant via direct seeding to soil or into potting media by mid-July, you will begin harvesting from fresh, young vines by early to mid-September. It's important to get new plants started as early in this window as possible so they put on enough growth to 'coast' into the shorter days of September and October. Unless you provide artificial lighting the reduction in production and increased cull rate is significant by early October.

Definition: *parthenocarpic*: fruit set that does not require pollination or fertilization of the ovule to set fruit. When seeds are present, they are sterile. Commonly grown tunnel varieties include Corinto and Lisboa. In cucumbers, *parthenocarpic* varieties should be protected from pollinators or fruit quality can suffer. The most common symptom when *parthenocarpic* varieties are pollinated is misshapen / curved fruit. Plain window screening used on the roll up sides, doors and vents not only prevents pollinators, but also provides control of cucumber beetles (but not thrips, aphids, or mites).

Cucumber Pest Management: Pest management



Steve Bogash retired as a Horticulture Educator and Researcher, PSU Cooperative Extension in June 2016. Then retired again from ProFarm Group formerly known as Marone Bio Innovations as their NE / Mid-Atlantic Product Development and Territory Business Manager in 2024. Steve now consults for ProFarm Group, growers, and other bio-focused or plant nutrient focused companies. Steve is also burnishing his woodworking skills in retirement as he learns to build small boats and smell like sawdust much more often.

of cucumbers begins with aphid control as Green Peach Aphids are active during the entire spring crop growing cycle from Mid-March thru the end of June / July. The fall growing cycle requires management of aphids, thrips, spider mites, cucumber beetles, and whiteflies from transplanting or emergence. This crop is emerging into what is often a very high-pressure environment. Proactive management of likely insects, mites, and diseases is highly recommended!

-Powdery mildew (PM): Summer is PM season. As humidity increases and plants age, the likelihood of PM increases rapidly. Plants that are fruiting are much more susceptible to PM than young, vegetative plants prior to fruiting. A proactive preventative fungicide program is necessary due to PM. PM looks like talcum powder and first appears as pencil eraser-sized spots that spread rapidly. Begin management of PM at emergence in your late-season crop!

-Downy mildew (DM): DM is interesting as this disease does not overwinter in our area but does come in annually on storms from the south. Pay careful attention to the DM IPM PIPE program and begin management when DM is nearby. In cucumbers, yellow spots visible on the top of the leaf are usually the first signs that this disease has

arrived. Rapid and timely treatment with a DM pest management material at the first signs of infection is necessary to avoid premature defoliation of your plants. These infected areas will continue to senesce even with treatment. Proactive treatment when nearby DM sentinel sites or scouting indicates disease presence can prevent infection.

-Gray Mold / *Botrytis cinerea*: Early Spring conditions and cooling weather into late September increases gray mold potential. High humidity and cool, rainy conditions are ideal for *Botrytis* to infect new tissue rapidly. Flowers and young fruit are especially prone to infection. The best way to avoid *Botrytis* is through improving airflow and ventilation, but if it's rainy, then ventilation accomplishes very little. 'Peroxide/ PAA' products like JetAg 5® and Oxidate® applied at maintenance rates during periods of high infection can help to reduce inoculum. At these low concentrations it is safe and labeled to allow for daily applications during multiple day rain events. Weekly applications of botryticides such as Stargus® coupled with frequent applications of PAA's can keep botrytis losses low.

-Soil disease management: Fall cropping typically means going into soil or potting media that's coming out of another crop, so the opportunity for soil disease inoculum is high. One method to reduce inoculum is to drench your soil with a 'Peroxide / PAA' product like JetAg® 5 or TerraClean® following the label instructions. The PAA drench will significantly reduce disease inoculum, then follow up after at least 4 hours, but not more than 24 hours with a re-inoculation with Actinovate® AG, RootShield® Plus, or your favorite beneficial brew prior to replanting. Potting media is a significant investment so take the time to treat it between crops. It's not difficult to reuse good media for 4 crops before replacing.

-Spider Mites: High tunnel crops get spider mites and summer tunnels are ideal for them. This is a simple fact of growing in a tunnel and cucumbers are no different than any other tunnel crop. The dry leaf conditions coupled with a well-irrigated and fertilized crop are ideal conditions for spider mites. Scout regularly, apply miticides as necessary (M-Pede®, Oberon®, Portal®, Grandevo®, Bronte®, and Venerate®). *See the insect / mite management tables in the 'Cheat Sheet,' Steve Bogash, for a solid program to manage mites and other small pests.*

-Aphids and Western Flower Thrips: Both are common tunnel residents and are typically rapid colonizers to a new summer tunnel crop. Begin a proactive pest management program from emergence.

-Striped cucumber beetles (CB): Cucumbers are very susceptible to Bacterial wilt vectored by cucumber beetles. There is some varietal difference in tolerance to bacterial wilt, but not enough to use as a management tool. The striped cucumber beetle has always been our dominant type, but it is not unusual to find spotted cucumber beetles by late summer. Plants die rapidly once fed on by infected cucumber beetles. This is especially so for younger plants, so control is necessary from plant emergence though the end of harvest. There are a number of choices of insecticides in controlling CB populations. Rotate MOA using the IRAC code often and include an aphid management program if using broad spectrum insecticides. The screening noted in the *definition of parthenocarpic* section is worthy of consideration as it is inexpensive, quick, and easy to install, and highly effective.

Marketing: Traditional markets will likely prefer varieties like Corinto and Lisboa due to their appearance. Excelsior is the one pickling type that has performed well in tunnels and sells well at markets as it is *super crispy*, but price may be an issue due to modest plant yields for this variety

Comments:

- 1) In order to reduce input costs, reuse potting media from the spring production run in the fall. Strip the old plants and roots from the pots, then top off with fresh media and direct seed. Unless soil-borne diseases are present, there is no reason that a high-coir / composted bark potting media could not last 2+ years (4 crop cycles). A wetting agent will likely be necessary after the pots dry out completely between cropping cycles in order to get them to evenly wet again. Always use a soil inoculant such as Actinovate AG, or RootShield Plus in order to reduce the opportunities for pathogens to take hold.
- 2) Direct seeding results in very compact

plants that are tougher in the seedling stage vs. transplanted plants. Even using the larger spacing from 32 or 50 cell trays produces some stretching prior to transplanting. Direct seeding makes it easier to install the first trellis clip as the young vines are stronger vs. transplants. Cooler conditions in the spring favor transplants, but the fall crop can be direct seeded.

- 3) Plant spacing: Practices vary a little by region: most PA growers use 2 plants per foot, NY growers tend to grow 1 plant per foot, and MN growers often use 3 plants per foot but always use a 'V' trellis with plants alternating direction on the 'V'.

As you get through September and into October, *Botrytis* related problems increase and production of #1 fruit will rapidly decrease. Keep an eye on your ROI costs to determine when to shut things down and clean house in preparation for the next spring run.

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