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Mid-Atlantic Commercial Vegetable Guide

New Jersey Department of Agriculture

FSMA Produce Safety Rule

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FSMA Produce Safety Rule: Agricultural Water Systems Inspection is Different from the Agricultural Water Assessment

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This fact sheet provides information about the differences between an agricultural water systems inspection (§ 112.42) and the agricultural water assessment (§ 112.43) from the Food Safety Modernization Act (FSMA) Produce Safety Rule (PSR)[1]. Subpart E of the FSMA PSR can be grouped into requirements related to:

1. **Pre-harvest agricultural water** used for growing covered produce other than sprouts
2. **Harvest/Postharvest agricultural water** used during harvesting and packing covered produce other than sprouts

The PSA *Records Required by the FSMA Produce Safety Rule* fact sheet [2] provides templates to aid in recordkeeping.

Agricultural Water Systems Inspection and Agricultural Water Assessment Explained

The **agricultural water systems inspection** includes all agricultural water systems (i.e., pre-harvest agricultural water, harvest/postharvest agricultural water) at covered farms to the extent that they are under the farm's control. The agricultural water systems inspection requires consideration of potential influences from prior users of the water as well as adjacent and nearby land uses. The inspection must be done at least once per year, to identify conditions that may introduce hazards (e.g., human pathogens) to covered produce or food-contact surfaces through water.

Observations made during the inspection are used to guide the implementation of practices such as system repairs, maintenance, or other actions that reduce the identified risks. Findings of the inspection must be documented in the farm's record. The information in the agricultural water systems inspection (i.e., water source(s), conveyance(s), equipment) can be used in the agricultural water assessment, but the agricultural water systems inspection and the agricultural water assessment are different things requiring different records.

The **agricultural water assessment** requirement applies to pre-harvest agricultural water that is used to grow covered produce. The agricultural water assessment must be completed at least once per year, to identify conditions that may result in contamination of the water source or otherwise increase the likelihood of human pathogens being in the water. The agricultural water assessment requires consideration of how the water is used, crops being grown, environmental impacts, adjacent land uses, and other things that can influence the risk of fruits and vegetables being contaminated through water. Observations made during the assessment allow a farm to reduce risks by deciding what uses are appropriate for the water source, and any measures that might be needed to reduce produce safety risks. The findings of the assessment, and any corrective measures or mitigation measures applied as an outcome of the assessment, must be documented in the farm's record.

The table on the following page provides a moredetailed comparison of the two requirements.

Agricultural water system means a source of agricultural water, the water distribution system, any building or structure that is part of the water distribution system (such as a well house, pump station, or shed), and any equipment used for application of agricultural water to covered produce during growing, harvesting, packing, or holding activities [1].

Characteristic	Agricultural Water System Inspection	Agricultural Water Assessment
Regulatory requirement	Food Safety Modernization Act (FSMA) Produce Safety Rule (PSR) 21 Code of Federal Regulations (CFR) 112.42	§ 112.43
Compliance date	First compliance date: January 26, 2022 • Phased in by business size class	First compliance date: April 07, 2025 • Phased in by business size class
Scope of requirement	For all agricultural water systems on covered farms, to the extent under the farm's control. Applies to water used during growing (pre-harvest), harvest, and postharvest activities	Applies only to agricultural water used during growing activities (pre-harvest water) on covered farms
Frequency	§ 112.42: "*At the beginning of a growing season, as appropriate, but at least once annually …*"	§ 112.43: "*… at the beginning of the growing season, as appropriate, but at least once annually ...*"
Evaluation parameters	Abridged quote from § 112.42: "*... identify any conditions that are reasonably likely to introduce known or reasonably foreseeable hazards into or onto covered produce or food contact surfaces, including consideration of the following:* *(1) The nature of each agricultural water source (for example, whether it is ground water or surface water);* *(2) The extent of your control over each agricultural water source;* *(3) The degree of protection of each agricultural water source;* *(4) Use of adjacent and nearby land; and* *(5) The likelihood of introduction of known or reasonably foreseeable hazards to agricultural water by another user of agricultural water before the water reaches your covered farm.*"	Paraphrased from § 112.43(a): • Water system characteristics: include information collected as part of the agricultural water systems inspection • Agricultural water practices: include a description of how the water is applied and timing of application • Crop characteristics: examples include characteristics related to adhesion or internalization of hazards • Environmental conditions: examples include the frequency of heavy rain or extreme weather events that may impact the agricultural water system (such as by stirring sediments) or covered produce (such as damage to harvestable leaves) during growing activities, air temperatures, and sun exposure • Other factors: include water analysis results, if water is tested
Outcome	Paraphrased from § 112.42(a): Identify conditions that could increase the potential for introduction of pathogens into the water system	Paraphrased from § 112.43(c): • Determine whether either of the following is reasonably necessary based on findings of the assessment: (a) immediately discontinue use and take corrective measures because water is not safe, or not of adequate sanitary quality for its intended use, or (b) implement mitigation measures, within the timeframe defined for the condition, to reduce risk • Record the determination • Follow through with necessary and appropriate action
Documentation required	§ 112.50(b)(1): "*You must establish and keep the following records, as applicable: The findings of inspections of your agricultural water systems in accordance with the requirements of § 112.42(a)*"	Abridged quote from § 112.50(b)(2): "*Your written agricultural water assessments, including descriptions of factors evaluated and written determinations, in accordance with § 112.43*" Abridged quote from § 112.50(b)(7): "*Documentation of actions you take in accordance with § 112.45*" (e.g., discontinue use pending corrective measures, or implementation of mitigation measures)

Compliance Dates According to Agricultural Water Use

Business Size Class	Harvest and Postharvest Use [3]	Pre-Harvest Use [1]
All other businesses (> $500,000 annual produce sales*)	January 26, 2022	April 07, 2025
Small businesses ($250,000 to $500,000 annual produce sales)	January 26, 2023	April 06, 2026
Very small businesses (< $250,000 annual produce sales)	January 26, 2024	April 05, 2027

*Annual produce sales are calculated on a rolling three-year average basis and are not adjusted for inflation.

Exemptions and exclusions

Water that is not used as agricultural water is excluded from all requirements in Subpart E, including the agricultural water systems inspection and the agricultural water assessment.

Agricultural water systems inspection requirement

There are no exemptions from the agricultural water systems inspection requirement for any covered farms that use agricultural water.

Agricultural water assessment requirement

Three exemptions from the pre-harvest agricultural water assessment requirement are described in § 112.43(b):

1. Water that meets quality and testing requirements for postharvest water quality, with records from § 112.50(b)(5) and (if relevant) § 112.50(b)(12).
2. Water that meets requirements for water from a public water system or public water supply, with records from § 112.50(b)(6).
3. Water that is treated according to § 112.46, with records from § 112.50(b)(10) and § 112.50(b)(11).

Each of the three exemptions also requires that the quality of the water does not change prior to being used as agricultural water.

Supporting Guidance and Fact Sheets

The preamble to each FSMA published rule [1, 3] can help to understand the reasoning behind requirements. FDA also summarized the requirements that apply to various uses of agricultural water in § 112.40. In addition, FDA described Subpart E pre-harvest requirements in a series of fact sheets [4] and an *Agricultural Water Assessment Builder* tool [5] which provide insight into what compliance with the requirement may look like. PSA has created an agricultural water systems inspection and agricultural water assessment templates in the required records document [2].

PSA will continue updates and the creation of additional resources as FDA publishes new guidance and tools so check the website often or sign up to receive our newsletter.

References

1. U.S. Food and Drug Administration 2024. Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption Relating to Agricultural Water. Federal Register May 06, 2024 89(88): 37448-37519. Accessed October 2024.
2. K. Woods, D. Pahl, D. Stoeckel, B. Fick, G. Wall, and E.A. Bihn 2024. Water System Inspection Record Template and Agricultural Water Assessment Template. Page 2 in Records Required by the FSMA Produce Safety Rule. Fact Sheet. Produce Safety Alliance, Cornell University. Accessed October 2024.
3. U.S. Food and Drug Administration 2019. Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption; Extension of Compliance Dates for Subpart E. Federal Register March 18, 2019. 84(52) 9706-9714. Accessed October 2024.
4. U.S. Food and Drug Administration 2024. FSMA Final Rule on Pre-Harvest Agricultural Water. Web page. Accessed October 2024.
5. U.S. Food and Drug Administration 2024. Agricultural Water Assessment Builder. Online tool. Accessed October 2024.

Produce Safety ALLIANCE

Determining if You Need to Complete an Agricultural Water Assessment

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April 2025

In May 2024, revisions were made to the pre-harvest agricultural water requirements within Subpart E of the Food Safety Modernization Act (FSMA) Produce Safety Rule (PSR). Revised Subpart E moves from reliance on testing pre-harvest water for decision making to an **agricultural water assessment** of the whole water system. This fact sheet describes a process for determining which situations require a pre-harvest agricultural water assessment. Produce Safety Alliance provides a template for creating the agricultural water assessment record[1].

Farm Coverage Status and Water Uses

Farms are not required to comply with any Subpart E agricultural water requirements if they

1. Are not covered by the FSMA PSR;
2. Are eligible for exemptions in Subpart A of the FSMA PSR; or
3. Do not use agricultural water[2,3].

The definition of agricultural water is important because requirements of Subpart E only apply to agricultural water – uses where the water is intended to, or likely to, contact covered produce or food contact surfaces[4].

Exemptions from Agricultural Water Assessment

For farms that are subject to Subpart E, additional exemptions from just the Agricultural Water Assessment may apply. The water must have no detectable generic *E. coli*, and the quality of the water must be maintained from the source to the point of use. Three types of water sources meet these requirements. The regulatory language with full descriptions of exemption conditions can be found in the FSMA PSR under § 112.43(b).

- Untreated ground water that meets the testing and quality requirements for use as agricultural water during harvest and postharvest activities.
- Drinking water, such as water from a United States Safe Drinking Water Act-regulated public water supply.
- Treated water that meets the treatment requirements in the FSMA PSR § 112.46.

A helpful worksheet for describing pre-harvest agricultural water uses, and determining which uses require creation of an agricultural water assessment, can be found on the next page.

References:

1. Produce Safety Alliance 2025. *Records Required by the FSMA Produce Safety Rule*. Cornell University. Accessed April 2025.
2. FDA 2015. *Standards for Produce Safety: Coverage and Exemptions/Exclusions for 21 PART 112*. Federal Register November 27 2015, 80 (228): 74354-74568. Accessed April 2025.
3. Produce Safety Alliance 2017. *FSMA Produce Safety Rule Exemptions & Exclusions (PowerPoint)*. Cornell University. Accessed April 2025.
4. Produce Safety Alliance 2017. *"Is This Agricultural Water?" - Supplemental Activity (PowerPoint)*. Cornell University. Accessed April 2025.
5. U.S. Food and Drug Administration 2024. *Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption Relating to Agricultural Water*. Federal Register May 06, 2024 89(88): 37448-37519. Accessed April 2025.

Table 1: Pre-Harvest Agricultural Water, Exemption, and Assessment Determination

Describe the water uses at the farm in this table, cross out those that are not agricultural water or are exempt, and include the remaining uses in your agricultural water assessment

Number	Crop(s)	Water Use(s)	Does Water Contact the Harvestable Portion of the Crop?	Is This Agricultural Water?	Source Water	Is Water Exempt? Why?	Use Requires Agricultural Water Assessment?
1							
2							
3							
4							
5							

This worksheet can be used to understand and describe which water uses you list must be included in an agricultural water assessment.

- **Step 1**: List your crop(s), identify water sources, and make a list of all the ways you USE water on your farm while growing produce.
- **Step 2**: Determine if the uses of the water make it "agricultural water" as defined by the FSMA Produce Safety Rule because it contacts the harvestable portion of covered produce or food-contact surfaces. If your farm is not using "agricultural water", you do not need to complete an agricultural water assessment. For example, irrigation water applied to fruit trees using drip irrigation that is not intended to or reasonably likely to contact covered produce would not be considered "agricultural water".
- **Step 3**: Evaluate each use/source to see if an exemption applies. Please note that no exemptions apply for untreated surface water.
  - Untreated ground water: may be exempt if it meets requirements for postharvest water (including the 'no detect' criterion for generic *E. coli*, sampling frequency, test methodology, and recordkeeping requirements)
  - Water from a public water source: may be exempt if a certificate of compliance or test results can be obtained annually for the farm record
  - Treated water: may be exempt if it meets the treatment requirements of § 112.46 and associated recordkeeping requirements
- **Step 4**: Complete an agricultural water assessment for those agricultural water sources that require it. Document any exemptions.

IPM Fruit and Vegetable

INTEGRATED PEST AND POLLINATOR MANAGEMENT IN CUCURBITS

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Is building a *"bee-safe"* insecticide program an oxymoron? In pollinator-dependent crops, like most cucurbits, bees are essential to yield. Many chemical options used for pest management, however, can be harmful to pollinators and may reduce crop pollination. (This can even be true for some non-chemical pest management approaches as well.) Integrated Pest and Pollinator Management (IPPM) offers a balanced approach that protects yield and pollinators by limiting unnecessary inputs and improving timing. Below are key considerations when designing an IPPM program:

1) Scout your field and spray when needed. Use thresholds (Table 1) to determine when an insecticide application is justified. Preventative pyrethroid sprays are *not* always beneficial and can disrupt natural enemies that provide free biological control, increasing the risk of pest flare-ups.
2) Protect pollinators through timing. Many insecticides are safe to apply outside of pollinator foraging hours, but several neonicotinoids and pyrethroids are not safe to apply during bloom at all (see "Highly Toxic" column in Table 1). If these products are part of your program, position them before or after bloom to reduce harm to pollinators.
3) Avoid apply during foraging. If an insecticide application is needed during bloom, apply at dusk or when bees are inactive to limit exposure.
4) Rotate chemistries to prevent resistance. Check the IRAC code before each application and avoid repeated use of the same chemical class. Rotation extends the useful life of insecticides and maintains long-term control efficacy.

Pest	How to Scout and When to Spray	Insecticide Options	Insecticide class (IRAC)	Risks to beneficial insects
Cucumber beetles	Scout about **1 plant/acre.** There are **two generations per year**, so expect outbreaks early in the season and then later toward July-August. Make an insecticide application when beetles reach average of **<u>1 beetle/plant</u>** in all cucurbit crops, except watermelon where you can accept a higher threshold of *5 beetles/plant*.	Surround (Kaolin clay)	UNM	*Relatively Nontoxic*
		Assail	Neonicotinoids (4A)	*Moderately Toxic*
		Admire Pro, Belay	Neonicotinoids (4A)	*Highly Toxic*
		Bifenture, Perm-Up, Warrior II	Pyrethroids (3A)	*Highly Toxic*

Squash vine borer	Deploy a **pheromone trap** in June and **check weekly**. When you detect a moth in the trap, make an **insecticide application at base of plant** to target newly laid eggs/hatched larvae.	Assail	Neonicotinoid (4A)	*Moderately Toxic*
		Bifenture, Perm-Up, Warrior II	Pyrethroids (3A)	*Highly Toxic*
Aphids	Scout about **1 plant/acre.** Begin searching later in the field during prolonged hot/dry periods. Make an insecticide application when **15% of plants have aphids**.	Fulfill	Pymetrozine (9B)	*Relatively Nontoxic*
		Assail	Neonicotinoid (4A)	*Moderately Toxic*
		Harvanta	Anthrallic diamide (28)	*Toxic*
		Bifenture, Perm-Up, Warrior II	Pyrethroids (3A)	*Highly Toxic*
Mites	Scout about **1 plant/acre.** Outbreak likelihood increases during **hot and dry periods**. Prioritize scouting on field edges to identify early infestation; look for slight yellowing or webbing in the watermelon crown. Make an miticide application when **15% of plants have mites**.	Portal	Fenpyroximate (21A)	*Relatively Nontoxic*
		Zeal	Extoxazole (10B)	*Relatively Nontoxic*
		Oberon	Spiromesifen (23)	*Moderately Toxic*
		Agri-Mek	Abamectin (6)	*Highly Toxic*
Squash bug	Scout **1 plant/acre**. Make an insecticide application if you see an average of **1 egg mass/plant and/or 1 squash bug nymph/plant**.	Assail	Neonicotinoid (4A)	*Moderately Toxic*
		Harvanta	Anthrallic diamide (28)	*Toxic*
		Scorpion, Belay	Neonicotinoid (4A)	*Highly Toxic*
		Warrior II, Perm-up, Bifenture EC	Pyrethroids (3A)	*Highly Toxic*

Minimum toxicity to beneficial insects. Lowest bee toxicity values through contact or oral exposure.	**Toxic to beneficial insects, but reduced risk** compared to other products.	**Toxic to beneficial insects** including pollinators and other beneficial insects.	**High toxicity** across all insects including pollinators and other beneficial insects.

LOWEST RISK TO POLLINATORS ⟷ **HIGHEST RISK TO POLLINATORS**

Remember: *The label is the law.* Always confirm product restrictions, bloom-period guidance, and re-entry and pre-harvest intervals. This list was created December 2025 and may be out of date as labeling and registration changes. Make sure you double check with your local educators and state to assure proper application practices.

► WHAT DOES AN IPPM PROGRAM LOOK LIKE THAT COMBINES FUNGICIDE AND INSECTICIDE?

Three pesticide programs were tested in Ohio across 3 years (plots >1 acre):

Reduced-risk program

- Fungicides + insecticides applied only when thresholds were met
- Priority on low-arthropod-toxicity products

Higher-risk program

- Calendar-based, prophylactic sprays
- Little consideration of pollinator/beneficial toxicity

Untreated control

- No insecticides or fungicides

Objective: Evaluate impacts on pests, pollination, and pumpkin yield.

► RESULTS: WHAT HAPPENED IN THE FIELD (figure 1)?

✓ **Pests:** Reduced-risk IPM worked as well as (or better than) high-risk programs. Cucumber beetles, aphids, and squash bugs were lowest or equivalent in reduced-risk plots compared to high-risk plots, while untreated plots had the highest pest pressure.

✓ **Pollination**: High-risk programs had lower bee visitation. Wild bee activity was lowest in high-risk plots and highest in reduced-risk and untreated plots. Fungicide + insecticide combinations likely contributed to reduced visitation.

✓ **Yield:** Reduced-risk = High-risk (despite 40% fewer sprays). Pumpkin yields in reduced-risk plots were statistically comparable to high-risk programs, despite >40% fewer pesticide applications.

► SO WHAT?

These findings show that:

- Fungicide and insecticide are important in cucurbit production. Yields were low in untreated control fields.
- Reduced-risk approaches may protect pollinators, which, in turn, may support yield stability.
    - Threshold-based spraying should lower input costs and minimize negative pesticidal interactions.

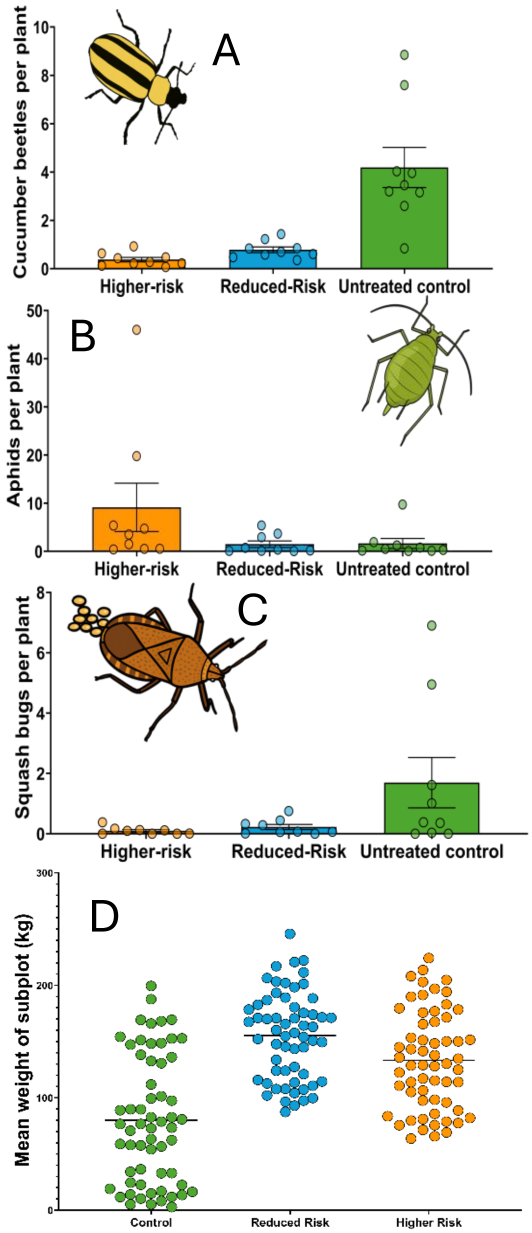

Figure 1. *Comparing pest pressure (a-c), pollinator activity (d), and pumpkin yield (e) across three pesticide management programs in Ohio.* Reduced-risk IPM, high-risk conventional spraying, and untreated control plots were monitored for key cucurbit pests (striped cucumber beetle (a), aphids (b), and squash bug (c) and pumpkin yield (d). Pest densities varied among programs, with untreated plots generally showing the highest pressure Despite using over 40% fewer insecticide and fungicide applications, reduced-risk IPM programs produced pumpkin yields comparable to higher-risk programs. These results demonstrate that reduced-risk, threshold-based approaches can effectively manage pests and maintain yields while reducing pesticide inputs.

Farm Labor and Regulations

Resources to Support Farmers in Providing Well Managed and Safe Employee Housing

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In New York, farm-provided employee housing has evolved from a basic necessity into a strategic advantage. Over the past decade, farms have recognized that quality housing is essential for attracting and retaining skilled workers. Employees now evaluate job opportunities based on housing standards, and consumers and policymakers expect farms to meet high benchmarks. This growing pressure created an opportunity for the Cornell Agricultural Workforce Development program to step in, developing research-based resources and education to help farm businesses not only meet expectations but set new standards for workforce well-being.

The initiative began with the hands-on Farm-Provided Employee Housing Evaluation, a voluntary, confidential, and non-regulatory “housing wellness visit” that provides managers with actionable feedback. These evaluations revealed gaps in management practices and compliance, leading to the development of the Farm-Provided Employee Housing Guide, a comprehensive resource covering everything from orientation to regulatory requirements. As farms engaged with these tools, one question kept surfacing: “How much does providing housing cost—or how much should it cost?” To answer that, Cornell Agricultural Workforce Development recently partnered with Cornell ProDairy to create the Agricultural Employee Housing Expense Calculator, the first tool of its kind. This calculator allows farms to identify true housing costs, benchmark against industry standards, and incorporate housing into strategic planning.

Today, farm-provided employee housing in New York is more than a line item—it’s a competitive advantage and a cornerstone of workforce development. By addressing housing quality and cost transparency, CAWD has strengthened relationships with farms and expanded its role as a trusted resource for labor management. With continued support from industry partners and state agencies, CAWD will keep refining tools and helping farms turn housing into an investment in people and in the future of agriculture.

Technologies for Field Crop Production

INTRODUCTION TO AGRICULTURAL DRONES – USES FOR PEST MANAGEMENT AND SEEDING, EQUIPMENT, AND LEGALITIES

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Drones, or unmanned aircraft systems (UAS) as they are termed in the industry are a new and exciting opportunity for farmers, service providers and academics to integrate into their operations and will be an invaluable tool in advancing precision agriculture efforts. This presentation aims to introduce key concepts, capabilities, limitations and new opportunities that UAS systems can provide to the agriculture community. This will cover drones with special multispectral sensors, processing data collected from UAS platforms and importantly spray drones and the regulatory process and restrictions behind them.

Drones have been mapping critical infrastructure, buildings, and agriculture fields for many years now. This is done through a process termed photogrammetry. Photogrammetry is the process of taking images with considerable overlap between them, usually 70-80% overlap between images and stitching these images together to make a measurable 2D map termed an orthomosaic or a 3D model. The first topic of discussion will be mapping damage with standard UAS systems.

Mapping drones are simple and only require an FAA Part 107 certificate to operate. Mapping drones are not anything crazy, it is likely that when you hear “drone” you are thinking of a mapping capable drone. Mapping drones can fly over a 50-acre field in 10 or so minutes and then being able to generate an accurate, measurable model/ map with another 30 minutes of processing time (if that). From this map, there are integrated tools in most of the commercially available post processing software that can measure or quantify the damage present within a field, so long as it is visible to the naked eye, think severe lodging or something like bear damage. Reference figures 1-1 and 1-2 to see an example of this output.

Figure 1-1 (processed map but no measurement)

Figure 1-2 (map with damage measurements)

The next topic is more complex and deals with using specialized sensors on a UAS platform called a multispectral sensor. This multispectral sensor looks in different bands of light on the electromagnetic spectrum. These bands will typically be the Red, Green and Blue bands but will also capture Near Infrared (NIR) and a more specialized band called Red-Edge. What the sensor does is measure the amount of reflectance that the sensor captures within each band; NIR and Red-Edge have a very high reflectance when there is a lot of chlorophyll within the crop, that is why we care so much about these specialized bands of light. With this data we can quantify crop health, specifically chlorophyll content of the plant. This can be beneficial for nutrient recommendations, it can identify areas within the field of pest pressure or nutrient deficiency, as well as help to calculate yield estimations. There are many more capabilities as well, but I will just discuss some of the most common applications of the technology.

From these multispectral images, we can run our images through something called a vegetation index. What this does is quantify our images and indexes each pixel on a scale from -1 to 1, with a value of 1 being the healthiest plant possible and a value of -1 being not living at all, like a road. The most common vegetation indices that you may have heard of are “normalized difference vegetation index” (NDVI) and “normalized difference red edge” (NDRE). These will generate a map like you will see in figure 1-3. When looking at this map, just think “green is good, yellow is okay and red is bad”. There’s much more analysis you would want to do than this, but you will get the gist of it with that understanding.

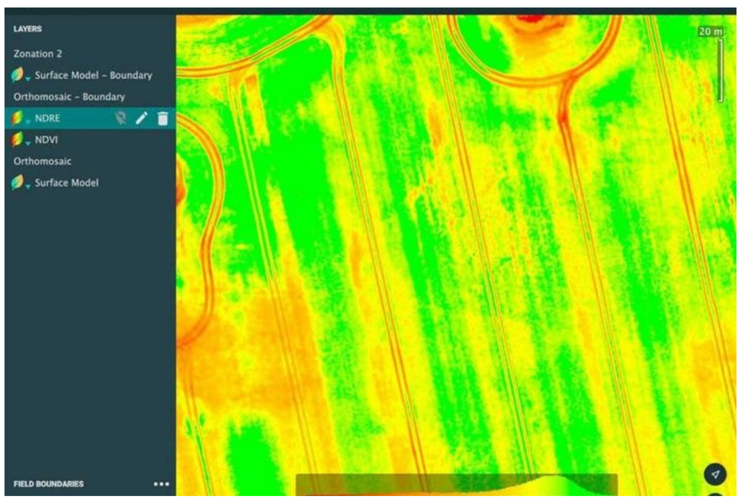

Figure 1-3 (Vegetation Index Map)

Now we will finally talk about spray drones and everything that comes along with them, the good and the bad. Spray drones cannot be operated with just your FAA Part 107 certificate; they fall outside of the regulations within Part 107. Because of this you must go through the FAA exemptions or waiver process, which is very complex and confusing. With this, you also get overregulation as the FAA does not have a formal set of regulations to go by.

This is accentuated when you go over 55lbs, which any spray drone worth its weight will be well in excess of 55lbs. This is because part 107 regulates drones up to 55lbs in takeoff weight, so when you are under this threshold with a spray drone you can still use a lot of the established regulations under Part 107. When over 55 lbs, you operate under Part 91, which is the same set of regulations that manned pilots operate under. You then ask for exemptions for certain regulations within Part 91. This is where the excessive red tape comes into play.

This means that you now need to become a bit of an aviation expert to legally operate a spray drone. This includes logging flights, keeping records, certifying maintenance, requesting for certain notices that go out to other pilots for when you plan to fly, reporting flights and other information monthly and more! The process of getting the exemption can be confusing, as you just submit documents to the FAA and then wait 90 days to either hear that it was approved or denied. They usually do not tell you why you were denied, just that you were denied. It is often said that the FAA says “go get me a rock” and you bring them one just for them to tell you “no not that one, get me a different one”.

Even with all this red tape, spray drones provide undeniable capabilities to farmers that did not exist even 10 years ago. The precision that these spray drones can achieve thanks to high accuracy GPS enables precise spot spraying applications for in-season applications, as well as capabilities for entire field variable rate missions when other traditional methods would not be possible. Think about wet fields, minimizing compaction, application into standing crops and anything else you can imagine.

Traditional crop dusters are not nearly as accurate from a positioning and application rate standpoint. They may overspray/ underspray parts of your field due to pilot error and other factors, but spray drones have a preprogrammed flight path and will hit that location exactly and will spray/ spread the exact rate you set. Because of this, there are many situations where a spray drone would be a better tool for the job when compared to a crop duster. Of course, the standard commercially available spray drones do not currently have the same volume capabilities as a crop duster but do their job extremely well.

We can utilize our multispectral imagery captured by drone or satellite to create variable rate or spot spraying operations for our spray drones to complete. This workflow is where the possibilities become nearly endless for just how effective these systems can be when paired together. Stop by this presentation to get more details on real world applications and some of the work that we are actively doing at Warren in conjunction with the Rutgers Agricultural Research Extension to test these systems and their capabilities.

ECONOMICS OF DRONE ADOPTION

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Drone adoption has grown consistently since 2010, with the most rapid expansion occurring in the Southwest. As of 2025, Federal Aviation Administration (FAA) registration data[1] indicate that Texas leads the nation with more than 600 registered agricultural drones, followed by California with over 500 units, while New Jersey has approximately 50, reflecting both regional cropping patterns and technology diffusion.

This study focuses exclusively on applicator drones, where costs and benefits are more directly tied to operational efficiency and field-level outcomes. While scouting drones also hold promise, evaluating their economic value is complicated by the highly variable costs of data processing and analysis, which depend heavily on farm management capacity and service arrangements.

Existing economic evidence, largely from China, suggests benefits from drone spraying, including increases in farm revenue of $176-$198 per acre (Quan et al., 2023), decreases in pesticide expenditures by $66 per acre (Li et al., 2025), for large-scale rice producers. Recent reviews further emphasize the potential of aerial spraying applications, especially in orchard systems, despite ongoing technical and regulatory challenges (Calderone et al., 2025). Although drone technology holds considerable potential, the question of whether owning an applicator drone represents a financially viable decision for producers remains a critical issue.

This study evaluates drone investment decisions from a farm management perspective, with the objective of identifying the economic and operational conditions under which drone adoption can enhance farm profitability. The primary analysis compares the relative costs and benefits of on-farm drone application with those of custom-hired spraying services. Both fixed investment costs and ongoing operating costs of drone use, including labor time and fuel required for battery charging, are incorporated into the analysis.

Drone specifications determine the time and fuel required for application operations. Higher coverage rates and longer flight (hovering) times reduce total application time, while lower generator fuel consumption rates decrease operating fuel costs. Larger battery capacities and faster charging times further improve operational efficiency by reducing the number of batteries required to sustain continuous field application. Additional assumptions regarding operational conditions and drone specifications are summarized in Table 1.

Figure 1 presents the net present value (NPV) of the investment over time. Under the assumed lifespan, batteries are replaced in year 5 and the drone is replaced in year 10. Greater application intensity increases cost savings relative to custom hiring. Under the baseline parameter assumptions, total annual applications must exceed 20 for the investment to achieve a positive NPV and pay off before year 6.

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[1] Under Federal Aviation Administration (FAA) rules, all drones weighing 0.55 lb (250 g) or more at takeoff must be registered prior to operation. In addition, any drone used for commercial purposes, including agricultural pesticide or fertilizer application, must be registered regardless of weight under 14 CFR Part 107.

Table 1: Parameter assumption

Operational conditions		Drone investment		
		Item	Price ($)	Lifespan (year)
Field size	30 ac	Drone	11,000	10
# of Application per year	20	Battery (x4)	12,000	5
Wage	$20 /hr	Generator	7,500	10
Fuel costs	$3.5 /gal	Maintenance	500	1
Interest rate	7%	License	600	-
Custom application rate	$16 /ac	**Drone spec**		
		Cover rate		15 ac/hr
		Hovering time		9 min
		Battery power		52.22 v 15500 mAh
		Generator – Fuel consumption rate		600 ml/kWh

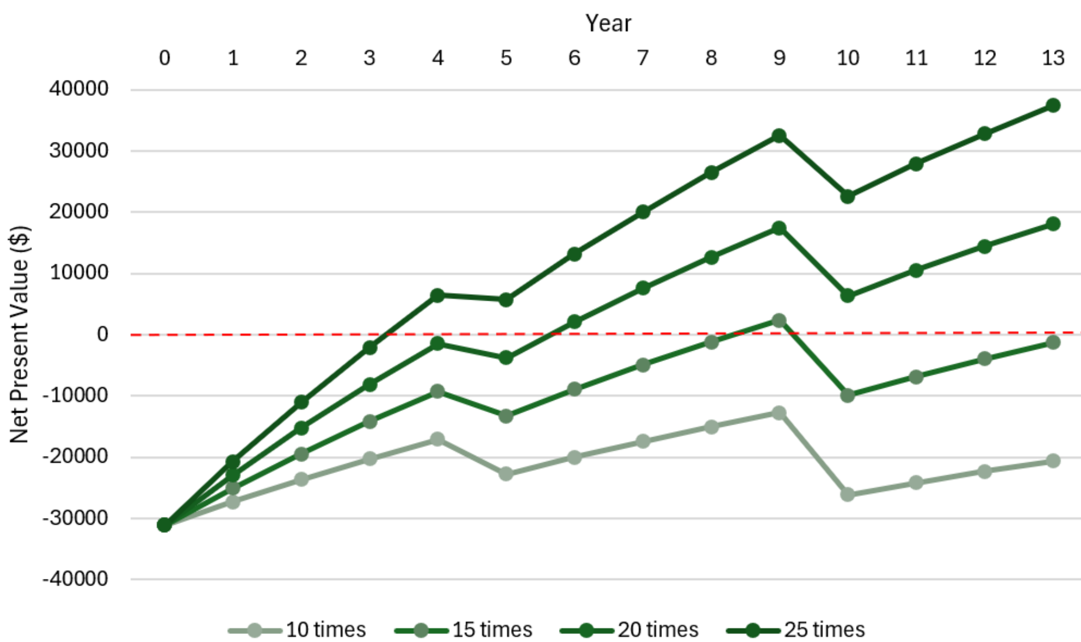

Figure 1: NPV over time for 30ac field, across number of applications

Drone investment becomes more economically favorable as field size increases (Figure 2). Assuming 30 applications per year, a minimum of 30 acres is required to reach the break-even point before year 6, while a 35-acre operation achieves break-even before year 4.

Drone application can affect farm revenue through multiple channels. Timely applications may increase crop yield or improve quality, while more targeted spraying can reduce input costs. However, technical inefficiencies may lead to ineffective applications that reduce revenue. The sensitivity analysis below examines how changes in revenue per acre and field size influence investment outcomes, assuming 20 applications per year. The baseline scenario assumes a 30 acre field with no revenue change, for which the investment breaks even in year 6. When revenue increases by more than $40 per acre, positive NPV can be achieved on fields as small as 25 acres. In contrast, on a 35 acre field, even a revenue loss of $40 per acre yields NPV outcomes similar to the baseline case, indicating break-even at approximately year 6.

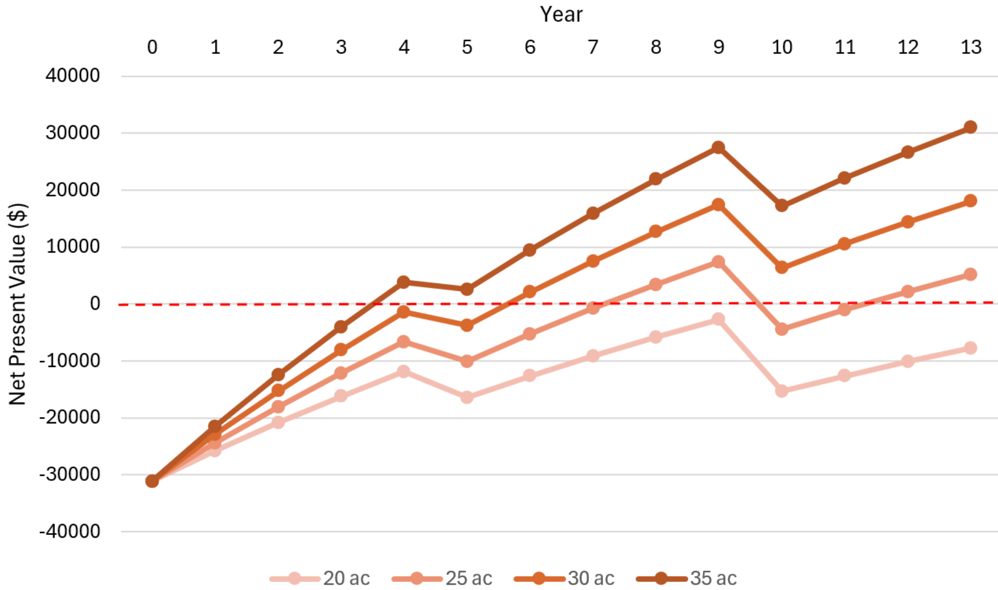

Figure 2: NPV over time for 30 applications per year, across field size

Table 2: Sensitivity analysis of revenue changes and field size, assuming 20 applications per year.

		Change in revenue				
		-$40/ac	-$20/ac	0	$20/ac	$40/ac
Field size	15 ac	($14,863.02)	($12,755.95)	($10,648.87)	($8,541.80)	($6,434.73)
	20 ac	($5,428.16)	($2,618.72)	$190.71	$3,000.14	$5,809.57
	25 ac	$4,006.71	$7,518.50	$11,030.29	$14,542.08	$18,053.87
	30 ac	$13,441.58	$17,655.73	$21,869.88	$26,084.03	$30,298.17
	35 ac	$22,876.45	$27,792.95	$32,709.46	$37,625.97	$42,542.47

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Tree Fruit Crop Production

PAWPAWS 101, ORCHARD PLANNING AND ESTABLISHMENT

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Pawpaws are a high-value specialty fruit crop, native to the Eastern United States. The oblong fruit weighs from a few ounces to over a pound. It has green skin and the inner yellow flesh is the only part that should be consumed. Fruits contain approximately ten large black seeds. Mature trees can reach 15 to 25 feet and grow in a pyramidal shape. A significant limitation hindering the commercial production and shipping of pawpaws is their limited shelf life. Fruit lasts for only two to three days at room temperature and one to two weeks in the refrigerator before becoming overripe and unmarketable. However, the shorter shelf life also offers a marketing opportunity for small growers who sell at farmstands and farmers markets to offer a unique product. Pawpaws are picked ripe or nearly ripe when the fruit is slightly soft (similar to a ripe avocado or peach) and will not ripen if picked too early.

As with any fruit orchard, growers should plan carefully before establishing a pawpaw orchard. Pawpaws grow best on well-drained soils and will benefit from supplemental irrigation during dry periods. Consider access to a water source and the use of drip irrigation when planning your orchard (Figure 1). Tree spacing should be approximately 10 ft within rows and 15 ft to 20 ft between rows for a final plant density of 200 to 300 trees per acre. Growers may want to consider the use of landscape fabrics or mulches to control weeds in orchards, particularly when trees are young and weed pressure is highest. Standard plastic mulch layers can be used to lay landscape fabrics in raised beds, which can be beneficial for drainage (Figure 1). Several herbicides, including glyphosate and carfentrazone-ethyl, are labeled for weed control in pawpaw. Ensure the formulation used lists ‘Pawpaw’ on the label and be very cautious to avoid getting herbicide on leaves and stems of the pawpaw trees.

Pawpaw trees are sold as seedlings or grafted trees. Grafted trees (of named cultivars) are recommended for commercial plantings as fruit quality and yield are consistently higher compared to seedling trees. Recommended cultivars include those from the Peterson Breeding Program (including ‘Susquehanna,’ ‘Shenandoah,’ and ‘Wabash’), the Kentucky State University Breeding Program (including ‘Benson’), and ‘Sunflower.’ It is recommended to incorporate several named cultivars in new pawpaw plantings, as trees are generally self-incompatible and require cross-pollination from genetically different cultivars. Genetically different trees should be integrated into rows/blocks rather than being planted in adjacent blocks. Growers should source trees or scion wood from trusted nurseries or suppliers. Trees can be purchased pre-grafted, or growers can start out by planting seedling trees and graft scion wood directly onto trees in the field. Whip and tongue grafting can be used when scion and rootstock are the same size, while bark inlay grafting should be used when the rootstock is significantly larger than the scion.

Protection of young pawpaw trees with shading via tree tubes or other structures is critical to establishment (Figure 1). Naturally, pawpaws grow as understory trees and experience shady conditions during initial years of growth. In commercial settings, pawpaw trees do well in full sun from their second year in the field onward, but benefit substantially from shading their first season, particularly when trees are small at planting. In 2023, multiple protection methods were trialed: coated cardboard tree tubes, plastic tree tubes, cages with woven mesh bags, and a control group without protection. Cardboard and plastic tree tubes offered comparable levels of protection to young trees, but cardboard tubes began to break down toward the end of the growing season and are not reusable. Plastic tubes are reusable but are also more expensive and can take longer to set up in orchards. In this preliminary trial, plants without shading or those protected by cages with mesh bags had low survivability and these methods would not be recommended for establishment. In April 2024, an orchard (n = 805 trees) in central New Jersey was established using cardboard tree tubes. By May 2025, 92.4% (n = 744) of the trees utilizing this protection method were still alive.

Figure 1: Photo demonstrating use of landscape fabric, cardboard tree tubes, and drip irrigation in a young pawpaw orchard. Trees are completely shaded by the cardboard tree tubes during their first growing season. Note that the spacing of plants within rows and between rows is closer in this research orchard than recommended in a commercial orchard.

Beach Plums: An Old/New Niche Crop for NJ – Pest Considerations and Cultural Practices

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Beach Plums (*Prunus maritima*) have been grown for decades as a niche crop from the coast of Virginia up to New Brunswick, Canada. They are touted for their tolerance to salt, drought stress and land disturbance. Beach plums have historically been used in a variety of value-added products including jellies and jams and more recently as an ingredient in hard cider. These products are popular in Jersey shore tourist destinations such as Cape May, where a few small growers are growing and marketing this crop.

Horticultural Considerations
Beach plums are bushy spreading trees that grow to a height of approximately 10 feet tall. They grow naturally in thickets in sandy soils, thus it is important that they are planted in a well drained site with irrigation. Soils should be tested prior to planting and the pH should be adjusted to 6-6.5, phosphorous and potassium should also be adjusted based on soil test results.. Just prior to planting, 50 lb/A of nitrogen should be applied, and again applied every year thereafter.

It is recommended that beachplums be planted at a spacing of 5' between plants and 12' between rows to encourage their hedge growth habit. Beach plums should be pruned each year in the early spring just before bud break. The primary purpose of pruning is to remove dead and diseased wood, and to open the tree canopy to ensure light penetration and fruiting bud formation.

Beach plums produce small white flowers which bloom in late April in central New Jersey. Pollination of beach plums is still not fully understood, as cropping can vary substantially from year to year. However, they are believed to require cross pollination.

Disease Considerations
Brown Rot
Beach plums are susceptible to brown rot, which is one of the most common fungal diseases of stone fruit. Fungal spores infect moist plant tissue (fruits, shoots or flowers) and may grow to eventually girdle the shoots, and branches. Spores overwinter in cankers on the tree or in mummified fruit. This disease can be managed by pruning out cankers, and removing diseased fruit. It can also be managed by applying fungicide sprays at bloom, full bloom and petal fall.

Black Knot
As with European and Japanese plums, one of the most major disease challenges to beach plums is black knot. This disease causes small brown/green swellings that ultimately turn into hard black knots that encircle the trees limbs. Spores are spread by

wind and rain , but there are several preventative fungicides that can be sprayed at bloom, petal fall and shuck split. When swellings or black knots are observed on the tree they should be pruned out immediately at least 12 inches beyond where the knot is observed.

Insect Considerations

Plum Curculio

The primary insect pest for beach plums is plum curculio. Plum curculio is a weevil insect that overwinters in leaf litter near fence rows and orchard borders. They emerge at bloom at which time they will feed on flowers, foliage and young fruit. Once fruit begins to form they begin to lay their eggs in the fruit. After which time larvae bore into the fruit. Plum curculio can be managed in beach plum orchards with insecticide sprays.

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Harvest Considerations

The fruit is small (.5 to 1 inch in diameter) at maturity. The color ranges from red to dark purple (Figure 1 and 2). They are sweet but depending on the variety the skin may be thick and tannic in flavor. Fruit is harvested in late August through early September depending on the variety.

Figure 1. Beach plum fruit at maturity.

Figure 2. Beach plum fruit in a variety of colors.

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Nursery Crop Production I

IRRIGATION WATER QUALITY: ESSENTIAL FOR THE GROWTH AND QUALITY OF ORNAMENTAL CROPS

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While a good supply of water is essential to grow vigorous crops – as water is the main driver of plant growth through cell expansion (Hsiao, 1973) – the chemical quality of irrigation water can also significantly impact the productivity and aesthetic quality of ornamental crops (Cabrera, 2021). In fact, water quality is crucial in determining which crops, if any, can be grown, and how irrigation and fertilization must be managed in a nursery or greenhouse growing operation (Cabrera and Johnson. 2014). Ornamental plant growers should become familiar with some of the key concepts and guidelines pertaining to irrigation water quality.

More often than not, pH is the first chemical property of water that is often in the mind of most growers. However, its proper interpretation also requires knowing the alkalinity value of that water (Table 1). The pH of irrigation water, particularly once it becomes part of the soil solution (water found in the pore space of both field soils and soilless substrates) largely defines the chemical availability of essential plant nutrients, impacting to a larger extent that of micronutrients (iron, manganese, boron, zinc, copper, molybdenum and nickel). However, the stability of the water pH (chemically known as its buffering capacity) is chiefly related to the alkalinity concentration (which includes bicarbonates and carbonates). Thus, the higher the alkalinity concentration in an irrigation water, the more stable the pH, and the more challenging it will be to change or modify it. Customarily, moderate to high alkalinity values are associated with neutral or basic pH values, starting around 7 and higher, a range that significantly reduces (and eventually nullifies) the availability of micronutrients for plant uptake. Therefore, irrigation waters with moderate (120-150 ppm) or high (>150 ppm) alkalinity will require neutralization with acid additions to bring the pH values to a horticulturally desirable range (like 5.5 to 6.5 depending on crop requirements) where micronutrients will be effectively available, and also benefit soil microbiology (the activity of soil microorganisms).

Another major consideration on irrigation water quality is the content of total soluble salts (TSS, expressed in chemical units of concentration like millimoles or milliequivalents per liter), also referred as total dissolved solids (TDS, expressed in milligrams per liter or ppm). Dissolved salts are directly related to the ability of water to conduct electricity, which is very easy to measure with an electrical conductivity (EC) meter, and nowadays reported in Siemen (S) units, like mS/cm or dS/m, which are the same as the older millimhos/cm units. These salts, or more appropriately ions, dissolved in water define the salinity of water, significantly impacting crop growth by imposing a general osmotic (chemical) effect, which effectively reduces the availability of water to the plant, even when it is present in adequate supply in the plant's rootzone. For most ornamental crops, the general consensus in the horticulture literature indicates that irrigation waters with EC values approaching or surpassing 1 dS/m (Table 1) will be considered troublesome, leading to significant crop growth reductions. The use of irrigation waters with moderately high EC could be managed with the use of heavy and frequent irrigation events (i.e. high leaching fractions), trying to maintain rootzone salinity values below growth-limiting values. Waters with high EC values will have to be blended and/or diluted to a desirable EC range if reductions in plant growth and aesthetic quality are to be avoided.

Table 1. Guidelines for interpretation of the chemical quality of irrigation sources used in the production of ornamental crops (Based on data from Bailey, 1996; Cabrera and Johnson, 2014, Duncan et al., 2009; Farnham et al., 1985; Petersen, 1996).

Type of problem	Potential hazard	
	None to negligible	Moderate to high
Soil/substrate pH maintenance		
pH	5.0 - 8.0	< 5.0 and > 8.0
Alkalinity (ppm as $CaCO_3$)	60 - 120	180 - 360
Salinity		
EC (dS/m or mmhos/cm)	< 0.5	0.75 - 3.0
Ion toxicity due to root and/or foliar absorption		
Chloride (ppm)	< 110	140 - 360
Sodium (ppm)	< 70	115 - 210
Boron (ppm)	0.3 - 0.5	0.5 - 2.0
Aluminum (ppm) (in soils with pH< 5.5)	< 5.0	10 - 20
Fluoride (ppm)	< 1.0	> 1.0
Unsightly foliar deposits and plugging of drippers		
Bicarbonate (ppm)	< 120	180 - 360
Iron (ppm)	< 1.0	> 1.0
Manganese (ppm)	< 1.0	> 1.0
Permeability		
Sodium adsorption ratio (unitless)	< 3.0	6.0 - 9.0

Among the various ions dissolved in water, some of them can lead to specific foliar toxicities in leaf tissues (scorching, chlorosis, spotting, necrosis, flecking) once their concentrations exceed threshold values (Table 1). Sodium and chloride are the ions most commonly associated with some of these disorders and symptoms, particularly in coastal regions, often due to sea water intrusion into aquifers, and sea breeze deposition. In addition to crop phytotoxicity, high sodium concentrations in water can also significantly impair the permeability of water into soils with moderate to high clay content, but rarely in modern soilless substrates (for container production).

Despite being found in relatively small concentrations, boron is another element in irrigation water that can lead to significant specific leaf tissue toxicities, particularly in woody ornamental plant species, when it exceeds over 1 ppm. Interestingly, symptoms of boron deficiency can occur when irrigation water and nutrient solutions have boron concentrations below 0.2 ppm.

The presence of aluminum concentrations over 10 ppm in irrigation water can also lead to potential plant tissue toxicities if the pH of the soils (or substrates) drops below 5.5, conditions that could be observed in some soils of New Jersey, including large tracts along the Delaware River and in Monmouth County (NJDEP, 2023). Fluoride is another element that could be fairly toxic to many ornamental crop species, but its concentration in typical irrigation waters in New Jersey rarely exceeds 0.2 ppm, except in some municipal (tap water) fluoridated systems where its concentrations could range up to 2.8 ppm (NJDEP, 2011).

Unsightly (non-toxic) white deposits (stains, blotches) can be observed on leaf surfaces when bicarbonate ion concentrations in irrigation water surpass over 150 ppm (Table 1). Fortunately, as these bicarbonate concentrations are the main culprits leading to the range of irrigation water alkalinity levels that would require neutralization with acid injections, this action will drop bicarbonate concentrations below the levels that cause those unsightly white deposits.

High iron levels (over 1 ppm) are a common occurrence in New Jersey groundwaters, often leading to non-toxic, but unsightly reddish deposits in the leaves of plants and surfaces of equipment and buildings (Zinati and Shuai, 2005). This happens because the iron in water oxidizes when exposed to air, generating a distinctive reddish-brown product (effectively an iron oxide, like rust on metals). Iron concentrations as low as 0.1 to 0.3 ppm can also result in the plugging of drip irrigation emitters (albeit not affecting the performance of regular overhead sprinkler heads). The need for pre/treatment options to precipitate, filter, sequester and ultimately reduce the level of troublesome iron concentrations output by micro-irrigation emitters will depend on the irrigation water source(s) and irrigation methods being employed.

Similar to iron, some undesirable manganese (Mn) concentrations can be naturally present in some NJ irrigation (ground)waters, particularly those from shallow aquifers near recharge areas (DeSimone and Ransom, 2021). Manganese concentrations of 0.05 to 0.3 ppm could lead to brown-black staining of plant foliage and equipment surfaces, and clog drip emitters. However, concentrations of 1.0 to 3.0 ppm can be phytotoxic for some crops in poorly drained soils (or substrates) with acidic pH (under 5.5). The pre/treatments options to deal with high manganese concentrations in irrigation water are similar to those used for high iron.

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BOXWOOD PROGRAM INSIGHTS – BOX TREE MOTH AND ALTERNATIVE CROPS

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Boxwoods are a valuable nursery crop in New Jersey, and throughout the United States. Over 11 million boxwood plants are sold nationally each year, with a value of over $126 million. Boxwoods are very commonly planted in landscapes throughout the state due to their broad customer appeal as a hedge plant and their high deer resistance. However, the cost of producing and maintaining boxwoods is high, due to their susceptibility to numerous disease and insect pest issues. Of particular concern are the boxwood blight disease (caused by the fungal pathogens *Calonectria pseudonaviculata and C. henricotiae*) and the box tree moth (*Cydalima perspectalis*), which have the potential to cause devastating economic losses for this important ornamental crop.

Boxwood blight was first introduced to the United States in 2011 and has since spread to NJ. It causes boxwood leaves develop darks lesions and eventually defoliates the plants. It thrives in warm humid conditions and its spores are usually spread via infested plant material, soil, tools, or clothing. Preventative fungicides can help to protect boxwoods from this pathogen, however they must be applied at the right time and control materials must be rotated appropriately to maintain their efficacy. While there are some boxwood cultivars that are reported to have greater resistance to boxwood blight, they have not been evaluated for their performance in New Jersey.
Box tree moth is a destructive invasive insect pest that is native to Eastern Asia. In 2021, USDA APHIS confirmed the presence of box tree moth in Niagara County, NY. The caterpillars of box tree moth feed mostly on boxwoods and can defoliate the plants. Once the leaves are consumed, the caterpillars feed on the bark, which results in girdling and plant death. While box tree moth has not been detected in NJ yet, its close proximity and high potential for economic losses make this an insect pest of primary concern for nursery growers and landscape professionals.

Recent research has screened boxwood accessions from The National Boxwood Collection at the U.S. Arboretum for their resistance or susceptibility to boxwood blight resistance (Kramer et al., 2020). Through this effort, they were able to identify several boxwood accessions that demonstrated strong resistance to boxwood blight. However, the performance of these boxwood accessions in NJ is still unknown, requiring field trials to determine their suitability for local growing conditions. Some *Buxus* cultivars that have rated well for boxwood blight resistance include ‘Golden Dream’, ‘Little Missy’, and ‘Winter Gem’. The Newgen boxwood series has also been developed with superior resistance traits, and includes cultivars such as ‘Independence’, ‘Freedom’, and ‘Liberty Bell’. The Better Boxwood collection offers another source of blight resistant cultivars that have been developed over two decades of selection and testing. This collection includes the cultivars ‘Babylon Beauty’, ‘Heritage’, ‘Renaissance’, and ‘Skylight’.

Additional efforts also involve looking at alternative plants to boxwood that exhibit similar aesthetic characteristics and landscape functions, but are not susceptible to damage from boxwood blight or boxtree moth. One of the leading industry options for an alternative to boxwoods is the native inkberry holly (*Ilex glabra*). Specific cultivars of *I. glabra* have been developed to emphasize the desirable compact, dense, rounded shape of boxwoods, without the associated pest and disease problems. Inkberry holly can also grow in wetter locations that may not be suitable for boxwoods. 'Gem Box' and 'Strong Box' are two compact female inkberry hollies that have potential as boxwood alternatives, while 'Squeeze Box' is an upright male inkberry that is part of the same series. Inkberry holly is dioecious, meaning that male and female flowers develop on separate plants. The female plants will produce small black berries in the fall that are a good food source for birds, but only if they have a male plant within close proximity to provide pollen. 'Shamrock' and 'Forever Emerald' are two additional cultivars of *I. glabra* that have boxwood-like qualities and have potential to grow well in our area. Japanese Holly (*Ilex crenata*) may also function as a suitable boxwood alternative, with compact cultivars, such as 'Bennett's Compact', 'Green Lustre', and 'Soft Touch' all being good options. Dwarf conifers provide yet another option, including globe arborvitae cultivars 'Anna's Magic Ball' and 'Tater Tot'.

These blight resistant boxwoods and alternatives are currently being evaluated in field trials that are replicated at the Rutgers Specialty Crop Research and Extension Center in Cream Ridge, NJ and at the Rutgers Agricultural Research and Extension Center in Bridgeton, NJ. While blight resistance is a very important trait to select for, these plants must also demonstrate other desirable qualities, including resistance to abiotic stress, such as heat, drought, wind, and cold damage, resistance to insect pests, including boxwood leafminer, deer resistance, and the ability to maintain the compactness and density characteristics that make boxwoods so popular.

<u>Additional Resources</u>
Boxwood Blight https://sites.rutgers.edu/nursery-ipm/boxwood-blight/
Box Tree Moth https://sites.rutgers.edu/nursery-ipm/box-tree-moth/
Boxwood Leafminer https://sites.rutgers.edu/nursery-ipm/boxwood-leafminer/

Greenhouse Management

HIGH TUNNEL INVESTMENT DECISIONS

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High tunnels require substantial upfront investment, yet their potential benefits can be difficult to measure because they vary widely across crops and growing conditions. High tunnels can improve crop timing and quality and create opportunities for premium prices through early- or late-season production. At the same time, they involve significant costs, not only for construction, but also for ongoing management, ventilation, and the possibility of increased pest or disease pressure.

Growers can use this article as a starting point for evaluating whether a high tunnel makes sense for their operation. It provides benchmark construction costs, examples of potential revenue benefits, and information on available cost-share programs, along with a simple framework for calculating NPV and payback time. While every farm's situation is different, these reference points can help growers plug in their own numbers and assess the profitability of a high-tunnel investment based on their specific crops, markets, and site conditions.

Costs of High Tunnel

High tunnels are highly customizable, and even two structures of the same size and materials can differ substantially in cost if one site requires additional work, such as grading, drainage, or other preparation. Construction expenses generally fall into three major categories: materials, labor for installation, and site preparation. Estimates from the University of Florida suggest that the basic structure accounts for around 40% of total construction costs, with installation costs and additional features making up the remainder.

To provide a sense of market prices, I collected cost information from ten companies selling DIY high-tunnel kits. The focus is on the basic structure with manual side roll-ups and sliding-door end walls. Delivery and installation fees are excluded. Basic structures typically range from $3 to $6 per square foot, while upgrades such as extra trusses, automated ventilation, fans, heaters, thermostats, or longer-lasting plastic coverings can raise the cost. Many of these features can also be added later as needed.

Cost Sharing from NRCS EQIP

The USDA's Environmental Quality Incentives Program (EQIP) offers cost-share assistance that can significantly reduce the upfront investment required for a high tunnel. Through its High Tunnel System Initiative, EQIP typically covers a portion of the installation cost, often in the range of 50–75%. To qualify, producers must meet NRCS eligibility requirements, which generally include owning or leasing the land, having control of the site for the lifespan of the structure, and completing a conservation plan with NRCS. Payments vary based on tunnel size and local payment rates. EQIP funding aims to support high tunnels as a conservation practice, helping farmers extend the growing season, reduce nutrient runoff, and improve soil health.
In New Jersey, the average EQIP high-tunnel contract amount has risen substantially over time. Before 2021, most contracts were under $10,000, but funding levels jumped sharply in 2021 and have remained elevated since then. By 2023, the average contract amount reached approximately $30,000. Looking at total EQIP obligations for high tunnels since 2014,

Gloucester County has received the largest share of funding, followed by Cumberland and Burlington counties.

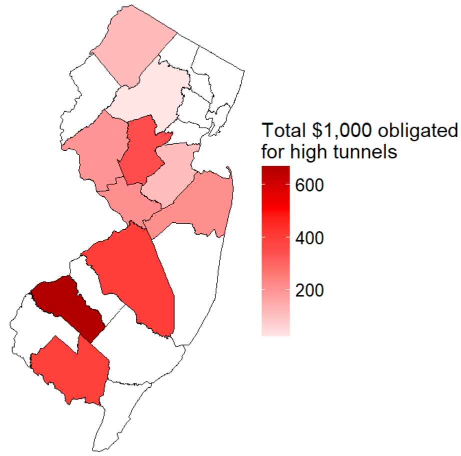


Figure 3: Total NRCS High Tunnel Payment in New Jersey since 2014

Seasonal Price Premiums for High Tunnel Crops

Analysis of weekly prices at the New York and Philadelphia terminal markets (2022–2025 averages) shows strong premium-price opportunities for growers who can supply tomatoes and bell peppers early or late in the season. For New Jersey tomatoes, the market opens in July with peak prices around $30 per 25-lb box, then falls to about $15 by mid-August before climbing again to roughly $22 after late September, creating profitable windows in July, early August and again after late September. Bell peppers show a similar pattern: prices peak in late June at over $30 per 1 1/9-bushel box, fall to $15–$20 from August through October, and then rise sharply again in late October. These seasonal swings indicate consistent $10–15 per unit price premiums for producers able to supply the market in early summer or late fall.

Figure 4: Average Weekly Tomato Price at NY terminal

Making Decisions

To evaluate whether investing in a high tunnel makes financial sense, first you need to estimate the total construction cost, the annual crop revenue, and the annual production costs. You can then calculate the net present value (NPV) and the number of years required to recover the initial investment. NPV represents the value of future net returns in today's dollars; when NPV is greater than zero, the investment is expected to be profitable. Once you have these numbers, you can use the investment calculator at: https://farmmgmt.rutgers.edu/resources/ to estimate NPV and the payoff period.

In conclusion, accurately estimating high tunnel construction costs should come first when evaluating a high tunnel investment. Changes in revenue and crop production costs are difficult to predict with precision, so growers should begin with a solid understanding of their current costs and returns. From there, using reasonable assumptions and break-even analysis, they can assess whether a high tunnel is likely to be a sound investment for their operation.

<u>Example Case of Growing Tomato in 2,000sqft High Tunnel</u>

Below is an example crop budget for tomatoes grown in a high tunnel. In this scenario, the investment yields a net present value of $2,818 and reaches payback in year 7.

Table 3: Example Budget

Revenue ($)	2,000
Price ($/lb)	1
Tomato harvested (lb)	2,000
Production costs ($)	175
High Tunnel Construction Costs ($)	10,000

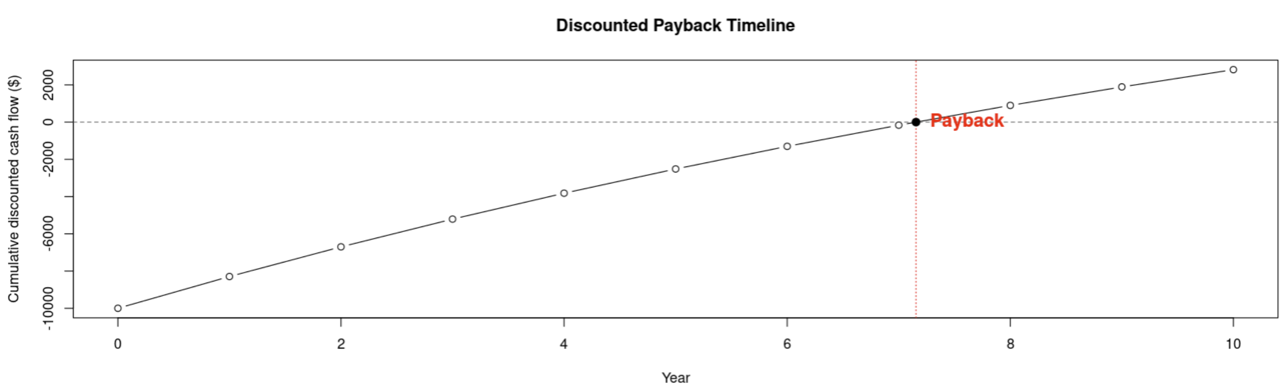
Net Present Value

$2,818.04

Payback year

7.15 years

Cash flow over time



PEST COUNTS & ACTION THRESHOLDS IN THE GREENHOUSE

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Scouting Options and Methods

There are essentially three options available when scouting your greenhouse crops for insect/mite pests. 1- No scouting performed with pesticides being applied on a calendar timetable. 2- Simply scouting for pest existence with pesticides applied when presence is observed. 3- Scouting crop and making pesticide application decisions based on pest counts and action thresholds. The third option is part of an integrated pest management (IPM) approach that has been promoted throughout the green industry for several decades.

Greenhouse pest populations are measured by trapping or direct plant inspection, both of which involve determining the number of pests. Counting pests and using action thresholds requires time and knowledge, but results in less pesticide use, reduced potential for insect resistance, and can improve plant quality. It is important to remember that while yellow or blue sticky cards enhance efficiency in greenhouse monitoring, they are not a substitute for thorough inspection of individual crop plants. This is particularly the case when scouting for aphids and mites.

Benefits of Counting Pests

The scouting and counting of insects/mites help to detect when they are first present. Therefore, treatments are made before large populations build up, but not before it becomes necessary. Tracking pest numbers over time allows for the use of action thresholds, or when pest density levels threaten crop salability and economic loss. When pest densities and damage are low, it is not efficient to spend 95% of your time controlling the last 5% of the pest.

The use of biological controls (e.g., beneficial insect/mite augmentation) is most effective when applied preventatively & pest numbers are low or have not yet even been observed. When using biological controls, pest count estimates are required to determine if the beneficials are adequately maintaining low pest densities.
Finally, instead of guessing, scouting, and estimating pest counts makes it possible to evaluate the effectiveness of chemical pest control interventions after they are applied.

Using Sticky Cards to Trap Adults

One (1) sticky card is placed within each 1,000 sq. ft. area and near greenhouse vent and door openings, as well as along the periphery of the house. Ideally, the card should be placed at the level of the crop canopy or slightly below to effectively trap many of the major adult pests found in the greenhouse. Each of the sticky cards should be examined at least once per week. Using stakes and wooden clothespins to support the traps & sticking them into the media is an effective approach. Also, be certain to number and date each trap card to a specific location. When pest counts are low, it is acceptable to reuse the trap card for additional weeks.

Counts and Action Threshold for the Primary Greenhouse Pests

Western Flower Thrips:

There are no universally accepted thresholds for the western flower thrips (WFT) because of numerous variables that cause the threshold number to change. A general guideline to start with might be 15 thrips per yellow sticky card per week per 1000 sq. ft. This arbitrary number is only a suggested starting point, and it may often be necessary to refine your own action thresholds with experience.

If releasing predatory mites for biological controls, it may be necessary to begin when as few as 2 thrips/ysc/wk/1000sqft are observed. Plants that are sensitive to thrips damage such as African violet and streptocarpus crops may have a threshold of less than 10 adult thrips captured on sticky traps per week per 1000 sq. ft. Alternatively, moderately sensitive plants such as impatiens, rose, gerbera, mum, and gloxinia crops may have action thresholds ranging as high as between 18 to 30 thrips/trap/wk/1000sqft. (If tospoviruses (INSV or TSSV) are present within a crop, then thrips thresholds are one (1). A poinsettia crop has a low sensitivity to thrips damage after leaves have matured and can have an action threshold of 40 or more adults captured per trap/wk/1000sqft.

When these various threshold guidelines are reached, it should be a signal to begin examining individual crop plants more closely, especially those plants closest to the sticky traps. However, the distribution pattern of the Western Flower Thrips in the greenhouse is random. Therefore, the thrips could potentially be found anywhere throughout the greenhouse. Some methods to scout for thrips on plants include the following: 1- Tapping the plant (especially flowers) over a piece of white paper to dislodge the thrips. 2- Exhaling carbon dioxide on the flowers to agitate the thrips and coerce them to leave their cryptic hiding places (e.g., composite flowers). 3- Pulling back and closely examining the nectar-producing flower organs with a hand lens to detect thrips presence (e.g., New Guinea impatiens).

Aphids:

It is not possible to use action thresholds to manage aphid populations. If winged aphids are found on sticky cards, then populations are usually already high. As a result, plant inspections are the only reliable way to scout for aphids. To simplify scouting efforts, attempt to group aphid-susceptible plant species together (e.g., chrysanthemum, sunflower, gazania, portulaca, pepper, calibrachoa, petunia, and others).

The distribution pattern of aphids in the greenhouse is typically spotty, with clumped populations (e.g., Melon aphids). On the other hand, Green Peach aphid species have a greater tendency to sometimes move throughout the crop & may have winged adults sooner. This behavior forces scouting to be more widespread. Look for plant symptoms such as distorted, discolored terminal tissue and for various aphid signs such as honeydew, sooty mold, cast skins, and the actual aphids themselves.

Fungus Gnats:

When using yellow sticky traps to capture adult fungus gnats, it is most effective to place traps horizontally (flat) near the root medium. Sticky traps placed in this position typically increase catch by 50% over traps set up in the traditional vertical position at canopy level. Adult fungus gnats are weak flyers and will not be found in high numbers around the tops of crop canopies. Yellow traps should also be placed under benches if the floor is not cement.

Potato disks or wedges placed within the medium to attract fungus gnat larvae can determine density counts. The disks are typically 1 to 2 inches in diameter and are pressed ½ inch into the root medium. The wedges (French fry shape) are ½ inch square and 1.5 to 2 inches long. The disks are best used in propagation areas, while the wedges are best used with more established, deeper-rooted crops. Place the disks every 100 sq. ft. in propagation areas and the wedges every 1000 sq. ft. in production areas. Count fungus gnat larvae feeding on potato 48 hours after placement in media. It has been shown that after 72 hours, the potato pieces may dry out and lose their drawing capabilities. Or worse yet, the pieces may begin to rot, promoting a breeding ground for the larvae.

Some action thresholds have been determined for fungus gnat larvae when using the potato disks. Within propagation areas, as few as 3-5 larvae per disk (after 48 hours) can cause considerable damage to the small, shallow root systems. Alternatively, when using the potato wedges (i.e., French fry shape) in a 6-inch pot, it may require as many as 15-20 larvae per wedge (after 48 hours) before any meaningful root damage occurs.

Whiteflies:

Although the use of yellow sticky traps can improve scouting efficiency, when scouting for whitefly, it is especially important to also inspect crop foliage. It is critical to start scouting early so whitefly populations are not allowed to build up. High populations of whiteflies are one of the more difficult pests to suppress in the greenhouse. With a poinsettia crop, any previous whitefly infestations need to be under control by November.

Typically, on infested plant foliage, a consistent top-to-bottom distribution of whitefly growth stages can be observed. For example, adults will usually be found on the undersides of the upper canopy leaves. When inspecting for eggs, concentrate on the undersides of lower adjacent leaves just below the upper canopy. Smaller scales (1^{st}/2^{nd} instar nymphs) are then found on the undersides of foliage below the leaves containing eggs. Larger scales (3^{rd}/4^{th} instar nymphs) are found on the undersides of the next level of lower/older foliage. Finally, whitefly adults will emerge from pupae found on the lowest/oldest leaves closest to the soil media.
Like aphids, whiteflies often produce sticky honeydew with the corresponding growth of the black sooty mold fungus. If this becomes readily visible, then it is certain that high whitefly infestations (or aphids) are already present within the crop.

When using biological controls (e.g., *Encarsia formosa* (parasitic wasps)), it is necessary to estimate counts of whitefly scales (nymphs) within a pest management unit to determine how many beneficials to release. How to rapidly estimate the total number of whitefly scales in your greenhouse will not be discussed in this article. Nevertheless, it has been determined that a release ratio of 30:1 (scale to wasp) will prevent a population build-up of whiteflies. A lower release ratio of 150:1 (scale to wasp) is needed if most scale nymphs are early 1st or 2nd instars. When using any kind of biological control tactic, it is crucial to start releases early before high pest levels are reached.

Two-spotted Spider Mites on Ivy Geraniums:

Obviously, since spider mites are unable to fly during any life stage, they will not be observed on sticky traps. Hence, when scouting for mites, it is necessary to inspect individual plants within the crop. Looking for symptoms and signs, such as leaf stippling and webbing, helps to indicate which plants to inspect more closely with a 10x-15x magnifying hand-lens.

Some specific thresholds of two-spotted spider mites on ivy geraniums have been determined through research. It was shown that action thresholds of 7 mites per leaf are reached on plants greater than 5 weeks in production. Alternatively, action thresholds of only 2 mites per leaf are reached on plants less than 5 weeks in production. Estimated pest mite counts are required when releasing beneficial predatory mites (e.g., *Phytoseiulus persimilis*). Release one (1) predatory mite for every 4 to 10 twospotted mites counted.

(Adapted from presentations delivered by J. Nechols & K. Williams (Kansas State Univ. Research & Ext.) @ the OFA Short Course (July 2003)

Greenhouse Heating and Cooling

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After labor costs, energy costs are typically the second largest expense for greenhouse growers. Energy costs are incurred due to operating the heating and cooling (ventilation) systems, the supplemental lighting system (if installed), as well as running pumps. This presentation will focus on heating and cooling systems. Note that for most year-round greenhouse operations in New Jersey, the heating costs will be much higher than the cooling (ventilation) costs.

Heating systems are designed with sufficient capacity to provide most the necessary heat on the coldest day of the year. The presentation will review how the heating system capacity can be calculated. And once the heating system capacity is known, it is possible to estimate the annual heating cost for a particular greenhouse operation based on greenhouse characteristics and the crop production strategy.

If a greenhouse heating system were designed to provide all the heat needed to maintain the set point temperature on the coldest day ever recorded for the greenhouse location, that maximum heating capacity would not be needed for most hours of the heating season. That is, the peak heating capacity would not be used very often. In order to reduce the cost associated with installing a heating system capable of delivering this peak capacity, heating system designers use a calculation method that results in a heating system capacity that is able to provide enough heat for most heating hours during the year. And during the few hours of an average year when the heating system capacity is insufficient to maintain the set point temperature, growers have two options: 1. Temporarily add additional heating capacity (e.g., bring in portable unit heaters), or 2. Accept a lower set point temperature. Unless the crop is not able to survive when the set point temperature cannot be maintained (uncommon), most growers opt for option 2 with little negative impact on plant growth and development. Greenhouse cooling is commonly accomplished with either natural or mechanical ventilation. While natural ventilation requires less energy, it relies on adequate wind speed and direction to be effective. However, the typical summer weather conditions in New Jersey make mechanical ventilation the preferred choice. This presentation will review the design calculations for a mechanical ventilation system. It will touch on the impact of insect screening on greenhouse ventilation and it will discuss how evaporative cooling can be used to further lower the greenhouse temperature during the summer months. But since evaporative cooling increases the humidity of the greenhouse air, pest and disease pressures can increase. In addition, high humidity reduces plant transpiration, increases the opportunity for condensation, and can affect pollination. Therefore, evaporative cooling can be a double-edged sword and growers are encouraged to carefully observe plant performance when operating an evaporative cooling system.

Gas-fired unit heater that blows hot air into the greenhouse production area.

Gas-fired boiler that delivers hot water to the greenhouse production area.

Evaporative cooling pad used to lower the greenhouse temperature when the ventilation system alone is not sufficient to maintain the set point temperature.

Sensors and Data Acquisition

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Like most of society today, the greenhouse industry is increasingly dependent on data collection and processing. Not only is this data used for immediate decisions (e.g., to adjust the greenhouse temperature) but it is also used for longer-term decisions (e.g., to decide which plant varieties to grow next season based on performance metrics collected during previous seasons). In order to collect reliable data, we need to use sensors that measure conditions with high precision and accuracy. This presentation will review the most common (and some not so common) sensors deployed in greenhouses. It will touch on sensor installation, maintenance, and calibration. While data collection can seem like a complicated and cumbersome task, and sensors can be expensive, accurate environmental data, combined with plant performance data, can improve the bottom line.

Clockwise, starting with the top left image: A combined temperature/humidity sensor, a photosynthetically active radiation sensor, a digital sensor display that is part of a greenhouse control system, and an infrared sensor that measures canopy temperature. Note: Company names do not constitute an endorsement. The images are merely used for demonstration purposes.

Vegetable Crop Production II

SPECIALTY WINTER SQUASH FOR NJ GROWERS

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Winter squash are grown on approximately 1,100 acres in New Jersey and much of that acreage consists of popular types such as butternut, acorn, and spaghetti squash. In New Jersey, these squash are grown for both wholesale markets and direct sales to consumers. Winter squash, unlike summer squash, have a long storage potential (up to several months) and help to extend markets into the late fall and winter. While common winter squash types such as butternut make up a majority of winter squash sales and acreage in New Jersey, specialty vegetable growers may want to consider growing a wider variety of winter squashes. These squashes may be especially attractive to smaller-scale growers who direct market at roadside stands and farmers' markets, where it may be possible to secure a premium price, especially during late-season markets.

Specialty winter squash are usually considered any winter squashes besides butternut, acorn, and spaghetti squash. They include squashes such as honeynut and koginut, which have been bred recently with flavor and small size as primary breeding objectives. Another small squash, the delicata, declined in production in the early 1900s but experienced a recent resurgence with the introduction of disease-resistant lines. Specialty winter squash also includes Japanese winter squashes such as kabocha and black futsu, which are prized for their flavor. Additionally, there are smaller cultivars of butternut and spaghetti squash available that are closer in size (1-2 lbs) to the honeynut and delicata squash mentioned above and would also be considered specialty winter squashes. Other specialty winter squashes include sweet dumpling, carnival, and hubbard.

There are several opportunities and challenges to consider related to growing specialty winter squashes compared to traditional types. One major advantage is the premium price that can be demanded for specialty winter squashes, which can be sold for as much as $2 to $4 per pound, compared to around $1 per pound for traditional winter squashes. This price premium can be charged due to the improved flavors of these specialty squashes compared to traditional types. Additionally, many specialty winter squash cultivars have edible skins, making more of the product edible and reducing preparation time for the consumer. The small size of many specialty winter squashes also make them an idea size for many consumers who are cooking for 1-2 people and may help reduce food waste. Lastly, the exclusivity of cultivars and flavors could drive sales for a small grower.

While specialty winter squash may have some advantages for growers, they also come with a set of challenges. While novel types could be an advantage in some markets, they could also be a marketing challenge for consumer adoption in markets where customers are used to the more traditional winter squash types such as butternut. Therefore, to get a higher price premium, the grower may need to spend additional time to educate their customers on the qualities of these new cultivars. Some of these cultivars also produce much smaller squash (1 lb or less) and may require more labor to harvest the same volume of squash. Additionally, some of the specialty winter squashes with edible skins may not hold up as long in storage as butternut or other squashes due to thinner skins, so time from harvest to sale is an important consideration. Before planting new cultivars of specialty winter squash, growers should carefully consider the trade-offs discussed above and consider planting them in limited quantities to determine how plants perform at their farms and how the squashes sell in their marketing channels.

EVALUATING BIODEGRADABLE PLASTIC MULCHES IN BELL PEPPER PRODUCTION

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Plasticulture Vegetable Production

Polyethylene (PE) mulch has been widely used in vegetable production for decades due to its numerous agronomic benefits, including effective weed suppression, improved soil moisture retention, reduced disease pressure, earlier harvests, and increased yield and crop quality. Despite these advantages, the removal and disposal of PE mulch at the end of the season is both costly and labor-intensive. Biodegradable plastic mulches (BDMs) were developed as a potential solution to these challenges. BDMs are intended to provide many of the same production benefits as PE mulch while allowing the material to be tilled into the soil or composted after use, thereby eliminating labor and disposal costs and environmental burdens associated with plastic waste.

However, adoption of BDMs by growers remains relatively low, largely due to reports of inconsistent product durability combined with greater initial purchasing costs. Reports of premature tearing and early-season degradation have raised concerns, and limited independent data is available to help growers evaluate the season-long performance of the various commercially available BDM products. To address this gap, this project evaluated the full-season performance of four locally available BDM products.

Trial Methodology

The trial was conducted at the University of Maryland's Lower Eastern Shore Research and Education Center (LESREC) in Salisbury, MD. All biodegradable mulch products were laid on 5 May 2025 using a standard tractor-mounted plastic mulch layer. Rows were 200ft in length and each mulch treatment was replicated three times. Biodegradable mulch treatments included: 1) Bio360 - 0.6mm, 2) Bio360- 0.8mm, 3) BioGuard, and 4) BioGold. A bell pepper test crop (variety: 'Red Knight') was transplanted using a water wheel transplanter on 6 June 2025. Plots were managed according to recommended production practices and overhead irrigated to increase moisture stress on the plastic. Mulch durability was assessed via visual tearing observations at the time of plastic laying and through visual evaluations of exposed soil on: 6 Jun, 30 June, 16 July, 8 August, and 28 August.

Trial Results

No tearing issues were encountered during the plastic laying process for any of the BDM products tested. Over the duration of the experiment period, BioGold demonstrated the greatest season-long durability with an average of 7% exposed soil at the conclusion of the trial period (Figure 1). Rows established with BioGuard biodegradable mulch remained mostly intact through mid-season but showed substantial tearing and plastic degradation beginning around 11 weeks after plastic laying. An average of 49% of the soil was visible in rows containing BioGuard biodegradable mulch on the final sampling date. Both thicknesses of Bio360 biodegradable mulch products began experiencing extensive tearing by early-July, and an estimated 76% and 81% of the in-row soil was exposed in the 0.6mm and the 0.8mm Bio360 products, respectively, by the end of the trial period. Figure 2. shows representative images of the appearance of each product at the conclusion of the trial period.

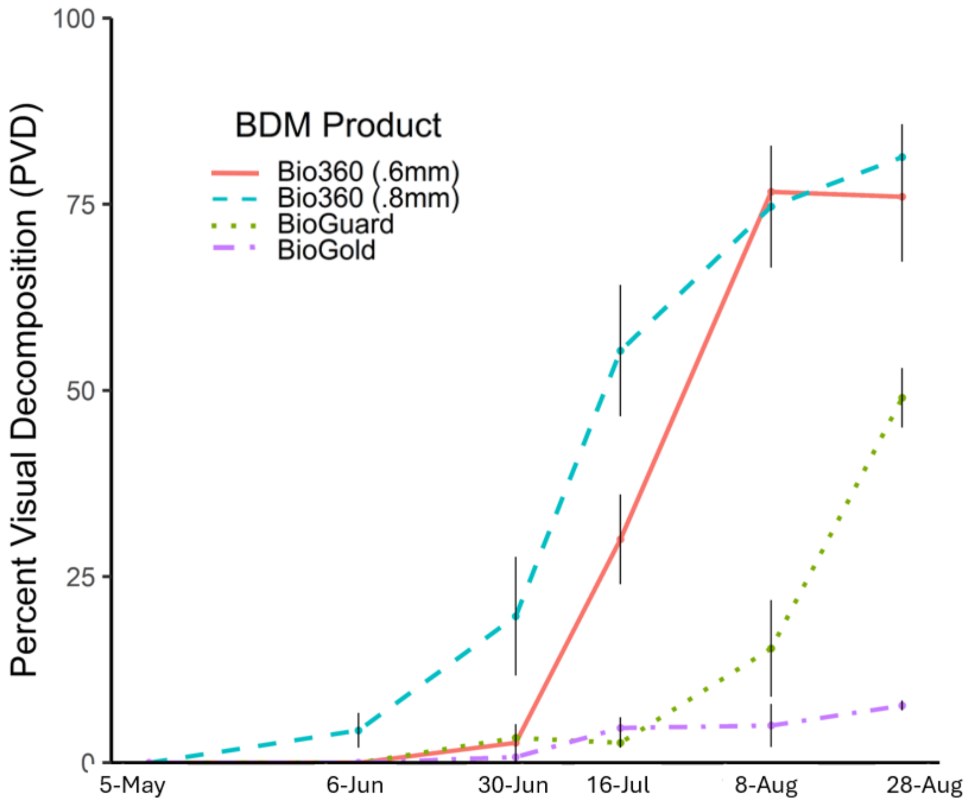

Figure 1. Percent visual decomposition of four biodegradable plastic mulch products between 5-May and 28-Aug.

Future directions

The post-tillage decomposition time for each of the BDM products tested is currently being evaluated to determine if any products are more persistent in the soil, potentially leading to crop establishment challenges the following growing season. The trial will be repeated in 2026 will feature additional BDM products, including several white on black biodegradable mulches, as well as performance evaluations at an additional location. The additional location will provide insight into the potential role of different soil types and irrigation methods on mulch performance throughout the growing season.

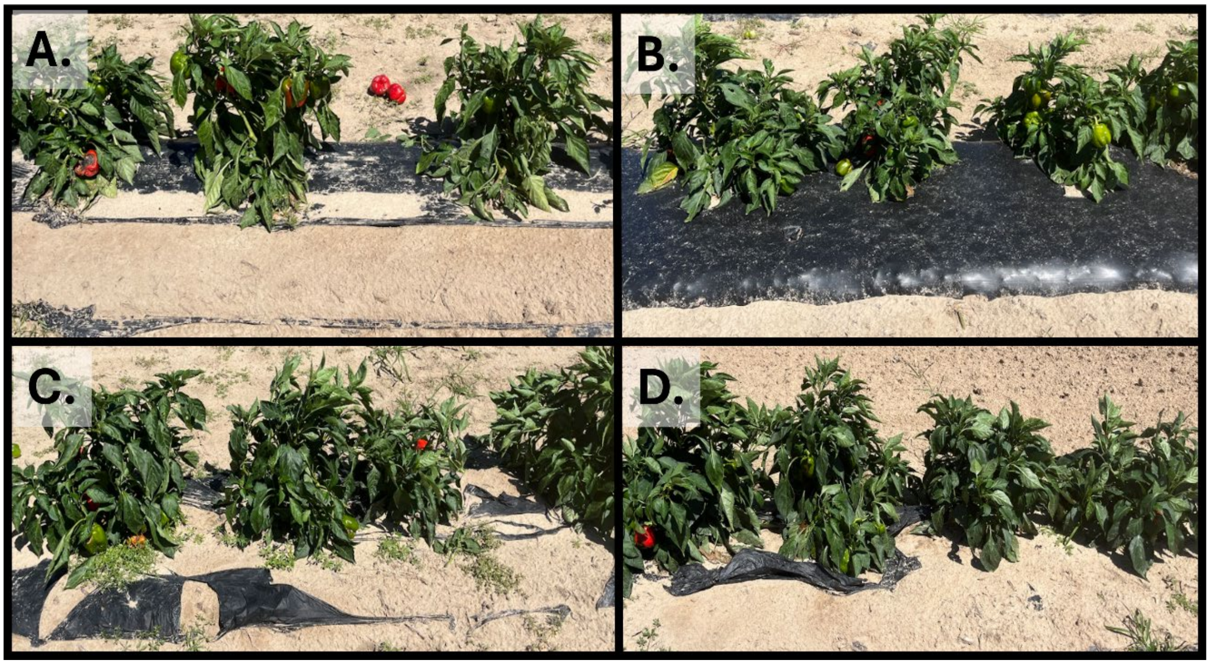

Figure 2. Representative images of the average amount of tearing and soil exposure at the conclusion of the trial on August 28, 2025 for (A.) BioGuard, (B.) BioGold, (C.) Bio360 – 0.8mm, and (D.) Bio360 – 0.6mm.

Field Crop Production II

Effects of Balancing Nitrogen Rate and Timing on Corn Productivity

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Abstract

Nutrient management is pivotal in optimizing crop inputs to ensure profitable field operations in any cropping system. So, improved corn yields and profitability are also tied to efficient nitrogen (N) management. So far, N has been applied in one or at maximum two splits in New Jersey corn systems. Yet, there is an upmounting interest in exploring the suitability of additional split applications to see whether it can improve N utilization efficiency, grain yield, and profitability. Undoubtedly, more split applications of N are seen as better agronomic potential but are also tied to increased operational costs, including labor, equipment, fuel, and logistical complexity. Therefore, this study is designed to focus on evaluating the economic and agronomic balance of increasing N split frequency from two to four applications in corn production. Field trials were conducted to equate three total N rates (150, 200, 250 lbs./acre) against three split arrangements: 2 (50% N at V2 + 50% N at V6), 3 (33% N at V2 + 33% N at V6 + 33% N at VT), and 4 (25% N at V2 + 25% N at V6 + 25% N at VT + 25% N at R1)-way splits. V2, V6, VT, and R1 are the different corn growth stages, referred to as the 2-leaf stage, 6-leaf stage, tasseling stage, and silking stage. Research experiments were conducted following a randomized complete block design, testing the aforesaid treatments, making ten (including a check plot with no N) treatments replicated four times in plots sized 30 feet long by 10 feet wide. Primary stakeholders for this study include New Jersey corn producers, agriculture consultants, and agriculture extension educators, all interested in practical findings on optimizing N management without compromising on economic benefits. The data on grain yield, N costs, labor/equipment costs per operation, and net return on investment (ROI) per acre were collected and yet to be statistically analyzed. The expected outcome is to provide farmers with data-driven recommendations and share field experiences on the effects of increasing split frequency within three different N rates on grain yield and ROI.

IMPROVING FIELD CROP WEED MANAGEMENT PRACTICES IN THE MID-ATLANTIC

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Mixing different types of herbicides in the same spray tank provides several benefits to a weed control program. It helps control a wider range of weeds, slows the development of herbicide-resistant weeds, and can save time and money. Because tank mixes work more efficiently, applicators may also be able to delay spraying. This delay allows more time to identify which weeds are present while still giving longer-lasting control. Studies were conducted in both corn and soybeans to show how tank mixing and careful application timing can provide effective weed control.

Tank Mix Options for Postemergence and Residual Weed Control in Soybean
This study looked at both conventional and organic options for postemergence weed control in soybean. The conventional treatments used herbicides like Reflex and Enlist One. These were applied alone, mixed together, or mixed with Dual Magnum. The organic treatments used Axxe and Homeplate, either by themselves or in combination. The study also tested flame-weeding as a non-chemical method. Results showed that any treatment containing Reflex and Enlist One controlled Palmer amaranth extremely well, over 99% control, at 21 days after treatment (DAT). The Reflex + Dual Magnum treatment also kept Palmer numbers from increasing between 7 and 21 DAT. Organic herbicides gave up to 90% control at 7 DAT, and flame-weeding gave up to 73% control. However, by 21 DAT, neither the organic herbicides nor flame-weeding provided any lasting control of Palmer amaranth.

Demonstrating Tank-Mixes for Late POST Weed Control in Corn
This study looked at how well different herbicides controlled weeds in V4 corn when no preemergence products were used. The treatments included Roundup PowerMax 3 and Callisto, sprayed either alone or tank mixed with each other or with atrazine. Results showed that Callisto alone, Roundup + Callisto, Roundup + atrazine, Callisto + atrazine, Roundup + Callisto + atrazine, and Roundup + Callisto + atrazine + Dual all controlled common lambsquarters by more than 99% at 25 DAT. Roundup alone provided 93% control. For giant foxtail, all of these mixtures, except Callisto + atrazine, provided 87% to 99% control. Roundup alone gave similar control. However, Callisto by itself did not provide any control of giant foxtail.

Zidua Plus Programs for Weed Control in Soybean
Zidua Plus is a new herbicide premix containing the active ingredients pyroxasulfone and imazethapyr. This study looked at how well Zidua Plus worked when it was applied either preemergence or at the V1 growth stage. These applications were followed by postemergence applications at the V3 or V5 stage with either Liberty Ultra + Roundup PowerMax 3 or Liberty Ultra + Enlist One. Across all treatments, regardless application

date, control of common lambsquarters was over 96%, and control of grasses was over 84% at 58 days after planting. However, morningglory control was better when Zidua Plus was applied at V1 and then followed by Liberty + Enlist.

Differentiated Timing of Corn Herbicide Applications

This study involved three prepackaged herbicide mixtures, SureStart II, Acuron, Storen, as well as SureStart II + atrazine applied preemergence or at the V4 growth stage of corn. No matter which herbicide was used or when it was applied, all treatments controlled common lambsquarters by 94% or more and smooth pigweed by 89% or more at 51 days after planting. However, both weeds were controlled slightly less when SureStart was applied at the V4 stage. For morningglory, SureStart and SureStart + atrazine actually worked better when applied at V4, providing 94–96% control. The same treatments applied preemergence only provided 76–82% control. Acuron and Storen controlled morningglory up to 97%, with no difference between application timings. For giant foxtail, Acuron and Storen provided better control than SureStart applied at the V4 stage, regardless of whether they were applied preemergence or at V4.

Conclusion

Mixing herbicides usually gave better weed control than using a single product, with tank mixes like Roundup + Callisto or Reflex + Enlist providing strong weed control. Timing is also important, some weeds, like morningglory, respond best when herbicides are applied at the right growth stage rather than relying on preemergence herbicides alone. Different weeds may require different strategies: broadleaf weeds like lambsquarters were easier to control, while grasses and morningglory often need tank mixes or carefully timed applications. Organic or non-chemical options can provide early control but usually don't last through the season. Overall, there is no one-size-fits-all solution; knowing which herbicides to include in the tank and applying them at the right stage is key to controlling multiple weed types and keeping them from returning later.

Commercial products are mentioned in solely for the purpose of providing specific information. Mention of a product does not constitute a guarantee or warranty of products, nor does it imply that uses discussed in this publication have been registered. All uses or pesticides must be registered by appropriate state and federal agencies before they can be recommended. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by University of Maryland Extension or the Maryland Agricultural Experiment Station is implied.

Small Fruit Specialty Crop Production

TECHNIQUES FOR GROWING AND OVERWINTERING JAPANESE FIG TREE ESPALIER IN THE NORTHEAST

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The project "Techniques for Growing and Overwintering Japanese Fig Tree Espalier in the Northeast" investigated whether fig trees trained using the Japanese Stepover Espalier method could become a reliable and commercially viable crop for growers in the northeastern United States. The primary objective was to determine whether a combination of high tunnels, low tunnels, and protective row coverings could create a stable microclimate capable of sustaining fig production through winter and promoting earlier seasonal growth.

This research was conducted inside a 5,000-square-foot high tunnel where newly established fig trees were trained from rooted cuttings beginning in 2022. The Japanese Stepover Espalier system was selected for its unique low-cordon architecture. Trees were trained horizontally at ground level along tensioned wires, allowing for efficient overwintering and simplified management. The cordons rested on black woven polypropylene ground fabric, a material known for warming soil temperatures through solar gain while effectively suppressing weeds.

A dual-layer protection system was implemented to safeguard the cordons throughout winter. Steel hoops were inserted into the ground at regular intervals, supporting DeWitt floating row covers that were secured using clamps. Temperature sensors were installed in multiple locations—inside low tunnels, inside the high tunnel but outside the low tunnels, and outdoors in open field conditions. Monitoring continued throughout winter and early spring, revealing substantial thermal benefits. During February and March, soil temperatures under the row covers were consistently 20–23°F warmer than outdoor soil temperatures during daylight hours. Even at night, temperatures remained meaningfully elevated. These findings indicated that the combined tunnel system successfully insulated the cordons against damaging winter lows.

The warmer microclimate significantly advanced bud break. In late February 2024, the first swelling buds were recorded inside the dual-tunnel system—nearly eight weeks earlier than fig trees growing unprotected outdoors and approximately four weeks earlier than those inside the high tunnel alone. This early bud break allowed trees to gain valuable lead time, resulting in a strong, early start to the growing season. By July 21, 2024, the orchard produced its first harvest of the year, totaling 230 lbs of figs. Yields are expected to increase substantially in 2025 as the cordons continue maturing and fruiting wood becomes more established.

The project also documented challenges that growers should anticipate. One notable event occurred in mid-April 2024 when unusually warm weather coincided with the row covers remaining in place for too long. The resulting heat buildup caused leaf damage to several early-pushing shoots. This event highlighted the importance of attentive spring management, including timely removal or venting of protective covers as temperatures rise. Despite this setback, trees recovered well and continued fruiting normally throughout summer.

When evaluating long-term commercial feasibility, several findings emerged. First, figs demonstrate strong potential as a high-value specialty crop for the Northeast when given adequate overwintering protection. The Japanese Espalier method simplifies pruning, improves access to fruiting wood, and creates an ideal architecture for protecting buds during harsh winters. Second, the microclimate created by combining high tunnels with low tunnels offers a cost-effective means of advancing harvest windows without relying on supplemental heating. While the approach requires significant labor during establishment, ongoing maintenance is manageable and becomes increasingly efficient once cordons reach full length.

Beyond figs, the project suggests broader opportunities for northeastern growers. Many Mediterranean and subtropical fruit species—such as citrus, pomegranates, and olives—face similar climatic limitations. With climate-controlled infrastructure and strategic low-height training systems, these crops may become more accessible to small and mid-scale farms seeking diversification. Shortening supply chains may also reduce carbon emissions associated with long-distance transportation while offering communities fresher, peak-ripeness fruit.

In conclusion, the project demonstrated that Japanese Stepover Fig Espalier grown inside protected tunnel systems is a viable strategy for commercial fig production in the Northeast. Earlier bud break, season extension, and reliable overwintering were all achieved without fossil-fuel-based heating. For growers willing to invest in infrastructure and labor during establishment, this system offers an innovative and sustainable pathway to producing high-quality figs and potentially other warm-climate fruits in colder regions.

Nursery Crop Production II

PROMOTING TREE & SHRUB HEALTH AND NATURAL RESILIENCE AS PART OF INTEGRATED PEST MANAGEMENT IN THE LANDSCAPE

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Trees and shrubs evolved alongside complex ecosystem services, such as soil microbe–driven nutrient cycling, that have supported plant health for millions of years. Today, however, many trees and shrubs in developed landscapes struggle because the natural processes essential to woody plant health are often hindered or overlooked. Common landscape installation and management practices can weaken plant immunity and encourage the onset of disease. Rather than relying on synthetic treatments to address symptoms, many disease-promoting stressors can be avoided through proper installation and maintenance that support natural plant health. Appropriate planting, mulching, and watering practices significantly improve vigor and reduce stress that leads to disease.

Improper planting remains one of the most frequent causes of disease and rapid decline in landscape trees and shrubs. Woody plants are often planted too deep, left wrapped in burlap, or allowed to become girdled. These mistakes are commonly followed by volcano mulching (Figure 1), which is used to disguise the buried root flare or the failure to remove burlap. Such practices restrict root expansion and respiration, suffocate soil microbes, and ultimately impair plant health. A buried root flare increases the risk of buttress rot, dieback, and disease. Proper planting requires root collar excavation before digging the hole, full removal of burlap and wire baskets, careful backfilling, and correct mulching. Selecting appropriate stock sizes is also essential for minimizing transplant shock, and smaller containerized plants often establish more quickly and grow more vigorously than larger stock.

Post-planting maintenance must include expansion of planting beds or tree rings. Tree root systems extend far beyond the trunk, and when forced to grow beneath lawn, both root function and plant health decline. Soil under turf becomes severely compacted from weekly mowing and the removal of organic matter inputs. Compaction limits gas exchange, suppresses soil microbial activity, and reduces the soil's ability to store and deliver water. Small tree rings therefore contribute to drought stress. While rainwater rapidly runs off lawn areas, it infiltrates readily into mulched zones. Reducing lawn to create adequate space for tree and shrub roots is critical, and using natural mulches—such as fallen leaves—enhances both soil and plant health.

It takes up to five years for a tree to recover from a single drought event and drought stress greatly increases disease susceptibility in the years that follow. To mitigate this, woody plants must be watered deeply, two to three times per week during droughts at both the base and the drip line. Lawn irrigation systems do not provide adequate hydration for trees and shrubs and can promote foliar diseases, whereas drip irrigation is far more effective. By aligning landscape practices with how woody plants naturally grow, we can restore their resilience and promote long-term health.

Figure 1. Improper “volcano” mulching (left) with more than four inches of mulch, in a tree ring that is not wide enough, in comparison to proper mulching (right) not touching the trunk bark, has an exposed root flare, mulch surface is flat, width of the tree ring is to the drip line, and no more than two inches of mulch is applied.

MITES: MAGNIFICENT MARVELS OF MINATURE MALEVOLENCE

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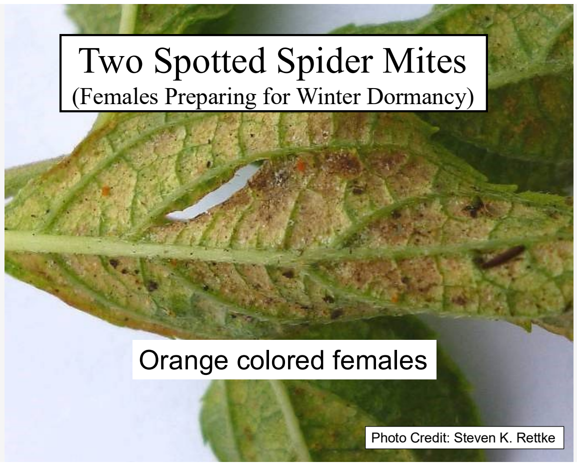
In the New Jersey region, the late weeks of September & early weeks of October are transition periods for the warm-season & cool-season spider mite species found in Christmas tree farms, as well as landscapes & nurseries. The spruce spider mite & the southern red spider mite are the most common cool-season species, & they will "wake up" during the fall months from their summer inactive periods. Alternatively, the warm-season two-spotted spider mite will stop feeding or will soon cease & will rapidly decline & and will prepare to depart the leaves of their host plants as cooler temperatures arrive.

Two-spotted spider mites that produced these stippling symptoms on burning bush during the summer will enter dormancy with the arrival of autumn.
(Photo: Steven K. Rettke of RCE)

Spruce spider mites that were previously in a summer dormancy will resume activity again on this Fraser fir as the autumn season arrives. (Photo: Steven K. Rettke of RCE)

Two-Spotted Spider Mites:

Two-spotted spider mites (*Tetranychus urticae*) are warm-season mites that are most active from June through September. They are commonly seen feeding on burning bush, rose, forsythia, & many perennial plants. In some areas, the two-spotted spider mite populations may still be active in early October. If they are still active, then closely observe with a hand lens the infested leaf undersides for the appearance of mites with a reddish-orange coloration. This color change is a sign indicating adult females are preparing to enter the overwintering dormant stage.



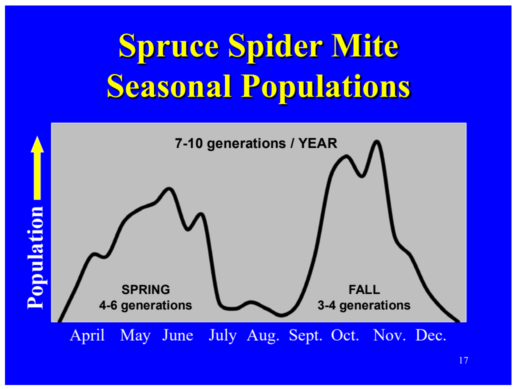
Two-spotted spider mites change to a reddish-orange coloration as the adult females prepare for winter dormancy (Photo: Steven K. Rettke)

As the night temperatures cool during the early autumn weeks, the two-spotted spider mite slows activity, stops laying eggs & begins to go into dormancy. Adult females overwinter beneath the host plant in the soil/mulch. In these concealed areas, the overwintering mites will be out of reach from any miticide applications (including dormant oil sprays). By October, any further plant damage caused by two-spotted spider mites will be slight. Therefore, control treatments applied at this time will have limited value. Also, the reddish-orange adult females still on leaf undersides have essentially stopped feeding & spray treatments of miticides will have reduced efficacy.

Avoid the potential of confusing the similar colors of the two-spotted spider mite dormancy preparation with the *Phytoseiulus persimilis* predatory mite species, as shown above (Photo: Denise Crawford)

Spruce & Southern Red Spider Mites:
On the other hand, with the arrival of autumn & cooler temperatures, both spruce & southern red spider mites begin to "wake up" from their summer dormancy & can be observed feeding & laying eggs. Spruce spider mites (*Oligonychus ununguis*) will feed exclusively on various conifers, whereas southern red spider mites (*Oligonychus ilicis*) will feed on broadleaf evergreens.

Feeding damage to the foliage from these cool-season mite species occurs during the spring & fall months. Some landscape & nursery managers may not realize significant damage to conifers & broadleaf evergreens can occur late in the season. Monitor for the resumption of mite activity in the fall on previously injured host plants by using a beating tray & 16X hand-lens.



Both cool-season spider mite species show similar seasonal population fluctuations.

The early summer photograph below of the Andromeda plant shows the leaf stippling symptoms on the older inner growth from southern red spider mites. These cool-season mites fed on the older growth of this plant during the previous fall & spring. When the newer, outer growth emerged during the later spring season, the mites did not have the opportunity to do much feeding damage before they became dormant in late spring. For example, when June temperatures reach highs of 85°F. & above, this signals the southern red & spruce spider mites to begin to move into the summer dormant stage. Furthermore, the new needles of conifers often contain toxins that deter spruce spider mite feeding. The toxins dissipate after the needle tissues mature.

Southern red spider mites produced fall & spring stippling symptoms on the lower, inner leaves on this Andromeda. The new growth during the summer has partially covered the damaged leaves. During the fall, the mites will infest the newer, upper foliage. (Photo: Steven K. Rettke of RCE)

The emerging southern red & spruce spider mites can potentially continue to feed until the late weeks of fall. Some of the most damaging symptoms can occur from late October through November. Overwintering eggs are laid in late fall when colder temperatures begin to occur. The eggs of spruce spider mites will be found primarily near the base of needles on woody twigs. Conversely, the eggs of southern red spider mites will be on the undersides of broadleaf leaves. These red-colored eggs are easily observed beneath the foliage. Both mite species can produce a few generations during the fall season.

During the late weeks of spring, southern red spider mite feedings show obvious symptoms on this Azalea.
(Photo: Steven K. Rettke of RCE)

Signs of southern red spider mite infestation on Azalea, showing active mites, eggs, & cast skins.
(Photo: Steven K. Rettke of RCE)

On this Colorado blue spruce, the newer summer needle growth is partially covering the older needle stippling symptoms caused by spruce spider mites during the previous fall & spring seasons.
(Photo: Steven K. Rettke of RCE)

CORE of Nursery Integrated Pest Management

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What is Integrated Pest Management (IPM) – and why is pesticide safety important? Integrated pest management, or IPM, refers to a comprehensive and dynamic approach to pest mitigation that balances pest thresholds, cultural practices, scouting and monitoring, and the effective selection, utilization, and minimization of pesticides to safeguard the greatest quality product, in this case the producers of ornamental plants. IPM is not focused specifically on pesticide usage. However, understanding how to safely utilize pesticides and avoid exposure is critically important especially in a nursery setting where there are often overlapping pest mitigation programs. To determine pesticide safety approaches first we must understand what we are targeting, what materials are to be selected for specific problem pests, their safe application, and balancing REIs and shipping needs. Once a material is selected, the label must clearly state the application method - **The Label is The Law.**

Understanding Nursery Pests. Chemical use does not guarantee complete pest control, and selecting the wrong material can often trigger secondary pest population explosions. When pesticides have been identified as a critical next step in the IPM process, understanding where these pests overlap in management timeframes greatly aids in increased efficacy per management pass. Keeping good logs of this information year over year will greatly aid in troubleshooting why this issue has been a regular problem. Another key factor is determining if they are part of a quarantine or actionable pest list as this can greatly impact overall regime design.

Insect and arachnid pests - How and where do the pests feed, are they chewing, sucking, laying eggs in xylem tissues, feeding on roots, etc.? This will greatly impact what pesticide classes are most effective. What is their lifecycle, when is the most important management timeframe, what do they look like at the critical control window? This will allow scouts to track when a vulnerable life stage may be, or when adults are preparing to lay eggs to cause the next wave of problems. The Rutgers Pest Scouting Guides – Scouting with Growing Degree-days are great tools for this application.

Diseases - Has this disease been a problem before, which years or seasons? What is the host range of the disease? What is the disease lifecycle, does this overlap with other regularly managed diseases? In terms of pesticide safety to applicators and handlers, protectant fungicides often have longer periods of worker safety measures as compared to systemic fungicides which have less residues.

Weeds – Where are they most prevalent- everywhere, greenhouse / prop. area, in hoop-houses? Have control measures failed previously? In terms of worker safety chronic exposure to any pesticide can have dangerous outcomes. Given the sheer volume of potential weeds on the perimeters of greenhouses, in tree rows, or in travel areas exposure should be monitored, and applicators should implement all PPE.

Understanding your specific worker safety and harvesting needs? All materials have different timeframes for reentry (Restricted Entry Interval (REI)) and personal protective equipment requirements (PPE) that must be followed. In some cases, it may be advisable to use a material with a longer REI if that material has proven success with a given pest, i.e., managing wants versus needs for a particular pest issue. PPE should always be top of mind for all potential handlers and those designing the application regimes. In some cases, a production technique such as granular pesticide incorporation into the potting process may alleviate pest pressures but will certainly increase exposure risks, if not handled correctly, therefore must be carefully considered. **Understanding how any pesticide moves** (translocated), or does not move, in plant tissues is critically important to how a pest will be controlled. Delivery methods are predicated on this, for example if a xylem mobile root disease material is used, the root systems must be targeted as xylem mobile materials will not translocate to the root system. Another example, if a translaminar insecticide is used, the material must be reapplied to actively growing areas as the material does not translocate along with the growing region, potentially increasing the number of times a handler may be exposed. **Selecting the right material is just as important as utilizing safe application techniques and commonsense worker handling methods, because humans are the most important part, i.e. the CORE, of nursery IPM.**

References:

Adapted from: Waller, T. 2024. Whole Nursery Pesticide Regime Considerations**.** 2024 Proceedings of the NJ State Agricultural Convention, Atlantic City, NJ. pp. 105-107. https://go.rutgers.edu/h3dths34

Rutgers Pest Scouting Guides – Scouting with Growing Degree-days: https://go.rutgers.edu/iz41f8pr

Rutgers Ornamental IPM Program: https://sites.rutgers.edu/nursery-ipm/

Rutgers Pesticide Safety Education Program -
https://pestmanagement.rutgers.edu/rutgers-pesticide-safety-education-program/

Blueberry Pest Management

MAINTAINING GRASS ROW MIDDLES IN BLUEBERRY FIELDS AND THE IMPACT ON WHITE GRUBS

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Blueberries are grown on approximately 11,500 acres of farmland in New Jersey generating more than $92 million in production value (USDA NASS 2023). Pest management is among the most important and time-consuming tasks for commercial farmers. White grubs from the beetle family Scarabaeidae can be economic pests of this high value crop in the major blueberry production regions across the United States. The adults feed on the leaves of the plant, but significant damage occurs when the larval (grub) stage feeds on plant roots causing wilting and reduced plant growth. Information on the impact of white grubs on blueberry production in New Jersey is limited and the quantifiable damage to the crop is not known.

Typically, the pest is managed by insecticide (neonicotinoid) soil drenches applied to the blueberry row. Presently, there are increasing concerns on reduced efficacy and impact on pollinators and non-target organisms from neonicotinoids. Mulches are commonly used in blueberry production in the major blueberry producing states across the county, either applying organic materials like pine bark or cover crops, or as synthetic materials such as weed fabric. Mulches can be used for improved weed control and fertility. Using mulches can also improve plant growth and yield, provide pest control and benefit natural enemy populations. Planting grasses in row middles could be a good strategy for weed control, enhance plant productivity, and also reduce the need for herbicides. Some potential grass species includes sheep fescue, which shows greater acid-tolerance than most grasses and a very acidic soil pH is required for blueberry production. However, row middles planted with grasses are likely to harbor white grub populations.

This project is important and timely because recent declines have been reported in blueberry yield and plant health, and there are concerns this could be linked to issues with soil health. Efforts to improve soil health have been proposed through the establishment of cover crops, particularly as sodded row middles between blueberry plants. Research is lacking that demonstrates whether establishing grasses in blueberry row middles may have a negative impact on white grub pest management in blueberries.

We evaluated white grub densities in blueberries in New Jersey in fields that have grass grown as a cover crop and planted into row middles. Field trials were conducted during the 2025 field season on a commercial farm. We identified six plots that contained 12 rows and measured 0.1 hectares. Plots were randomized and consisted of either 1) blueberry rows with fescue grass grown as a cover crop and seeded into row middles

(O-V-N landscape turf mixture, Seedway, Inc.), or 2) blueberry rows with tilled row middles to maintain clean cultivated bare ground. In plots planted with grasses in the row middles, the O-V-N mixture (40% Proprietary Perennial Ryegrass 30% Creeping Red Fescue 30% Chewings Fescue) was established in previous seasons at a rate of 75 lb. per acre.

Additionally, a baseline of soil health was established for each plot by collecting soil samples from between rows and in rows using a soil probe (JMC 36" Soil Sampler W/ Step, Gempler's Inc). Soil samples were submitted to the Rutgers Soil Testing Laboratory to report pH and organic matter content.

During the season, bucket traps baited with oriental beetle pheromone (Trece Pherocon Oriental Beetle; Great Lakes IPM, Vestaburg, MI) were set up and checked weekly to monitor for adult flight activity. There were four traps per plot. The number of adult beetles collected weekly per trap were recorded. Post season, soil samples were collected in the fall to measure larval grub densities around blueberry roots and in the row middles using a Carbon Steel Hole Turf Cutter. Each plot was divided into four subplots, and 6 samples were taken from each subplot from each location (blueberry plant and row middles). The number of beetle grubs collected per sample were recorded.

There was no significant difference in the number of adult beetles caught per trap between plots with seeded grass row middles and bareground row middles. Peak flight was observed in late June with an average of 293 adult beetles caught per trap in plots with seeded grass row middles and an average of 274 adult beetles caught per trap in bareground row middles. There were more beetle grubs collected from the roots of blueberry plants in plots that had bareground row middles compared to plots with grass seeded row middles. There were also more grubs found in soil samples collected from blueberry plant roots compared to samples collected from in the row middles.

The findings from this research provide a better understanding of the activity and impact of white grubs on blueberry plants in New Jersey. This project has the potential to impact approximately 350 blueberry growers over 11,400 acres throughout the state. The outcome of this project will be beneficial to growers in New Jersey and will aid in the sustainability and expansion of blueberry production in the state.

INTEGRATED POLLINATION AND PEST MANAGEMENT (IPPM) FOR HIGHBUSH BLUEBERRIES

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Introduction

Plum curculio, *Conotrachelus nenuphar* (PC), is a major pest of blueberries in the mid-Atlantic region. Adults move into blueberry fields during bloom and begin feeding on flowers and developing fruit as well as ovipositing into fruitlets. Yield losses from PC occurs in multiple ways: cosmetic damage to the berries from the crescent-shaped oviposition scar (Fig. 1), presence of larvae in the fruit, and premature drop of infested fruit. While effective insecticides are available for use, they cannot be applied while bees are present during bloom. Currently, honey bees are kept until >95% of bloom has completed. We sought to determine if honey bees could be removed earlier without negatively impacting yields, which would also allow for earlier treatment of PC.

Figure 1. Plum curculio oviposition damage.

Methods

At eight farms in the primary blueberry growing region of New Jersey, plots of cvs. 'Duke' and 'Bluecrop' were selected that were adjacent to the woods. Farms were chosen due to known, historical PC activity. Bloom phenology was taken weekly for each cultivar by selecting 5 random bud clusters and counting the number of buds, bloom, and spent flowers.

To assess effects of bee removal/earlier PC treatment, 5 bushes from the edge row and 5 from the interior rows were selected that represented an 'average' bush for the plot. On each bush, a cane was covered with a mesh bag at 35-45, 50-60, 65-75, 80-90, >95% bloom progression (n=6 canes/bush). Bags served both to exclude pollination activity and to simulate an insecticide application for PC.

Results

The bloom period for 'Duke' and 'Bluecrop' in 2025 was 2-3 weeks, which is 1-1.5 weeks shorter than an average year. 'Bluecrop' bloom began and ended 1-3 days after 'Duke.' Bee activity was dominated by honey bees with 92-100% of visits in 'Duke' and 89-100% in 'Bluecrop' performed by honey bees. Bee visitation had ceased by 70-85% bloom in both 'Duke' and 'Bluecrop.'

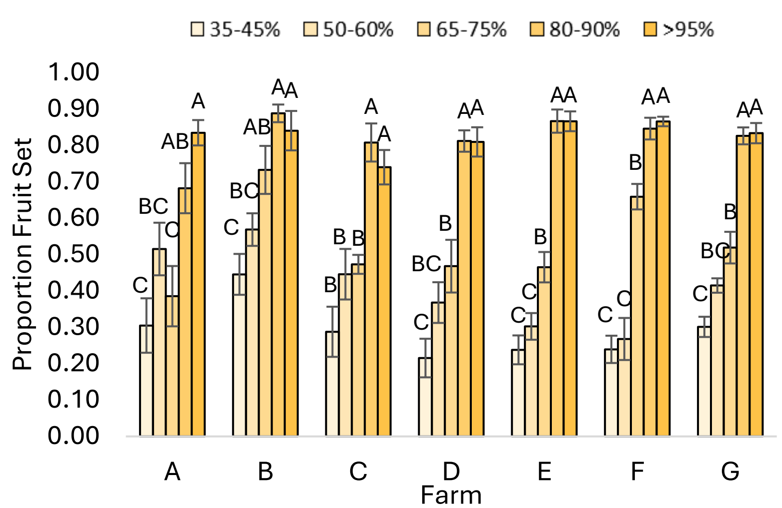

Figure 2. Blueberry fruit set after exclusion bagging.

Bee exclusion did not have a consistent impact on fruit weight in 'Duke,' with later bee exclusion resulting in fruit size that decreased (2 farms), increased (2 farms), or was unchanged (4 farms). However, no change in berry size occurred as an effect of exclusion at any farm for 'Bluecrop.' Fruit set increased the later bees were excluded up to bags placed at 80-90% bloom (Fig. 2). At this point, no further improvements in set were observed despite longer access of the flowers to the bees.

PC damage ranged from <1% to 8% of fruit collected from a given cane. There was no effect of exclusion bagging time on proportion of damaged fruit (Fig. 3).

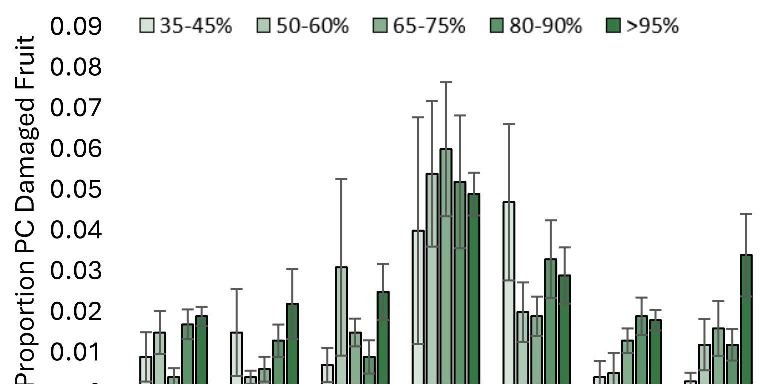

Figure 3. Average proportion fruit damaged by plum curculio.

Conclusions

Bee activity was shown to cease well before the typical point in bloom that hives are removed. First-year results show little effect of earlier removal on fruit set; however, there was an inconsistent pattern of fruit weight. This could be a result of lower fruit set producing larger berries due to less nutrition needed. Given the warmer than average season, abiotic stressors like heat and water stress may have contributed to inconsistencies observed. While there was no clear pattern of benefit for treating PC earlier, the study did not account for movement beyond the exterior fields further into farms. Current evidence suggests that removing bees earlier does not negatively affect yield, but it also does not lead to a clear improvement in PC control.

Future Plans

This is the first year of a two-year study, and additional data will be collected in 2026. These results will be essential before considering any changes to current management practices.

Acknowledgements

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DEVELOPMENT OF A DEGREE-DAY MODEL FOR PLUM CURCULIO AS A PEST AND ITS POTENTIAL APPLICATION IN OPTIMIZING HONEY BEE POLLINATION TIMING IN BLUEBERRY

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Introduction

Plum curculio (*Conotrachelus nenuphar*, PC) is a major pest of multiple fruits, such as apples, cherries, and blueberries (Racette et al. 1992). Optimal timing for insecticide applications targeting PC frequently overlap with the bloom period leading to either pollinator mortality or PC feeding damage (Besancon et al. 2022). We hypothesized that if honey bees could be removed prior to the end of bloom this would enable an earlier window for PC control. To test this hypothesis, we developed degree day models for blueberry bloom and PC activity to identify possible windows for pollinator removal and PC targeted management. Having developed these models, we are able to assess how the bloom and PC progression may change under a warming climate.

Methods

Seasonal PC captures were conducted from 2016–2024 at 76 blueberry farm locations in New Jersey. Weekly blueberry bloom data (cv. ‘Duke’) were collected from 2012–2024. The cumulative progression of PC capture and bloom was computed as the percent of either total capture or total buds bloomed per season (i.e., a 0% to 100% scale).

Annual cumulative degree days were calculated using weather data from the Office of the New Jersey State Climatologist weather station in Hammonton, NJ. Projections of future degree days were extracted from 16 climate models for 2035–2065 at the same location (DeGaetano et al. 2015; Pierce et al. 2023). PC degree days were calculated using a base temperature of 50°F with an upper threshold of 86°F and blueberry bloom degree days used a base temperature of 45°F (Kirk and Isaacs 2012).

PC and bloom seasonal progressions were fit to two-parameter logistic mixed-effect models, relating cumulative degree days to bloom and PC progression. These models were also combined with climate projections to determine the change in peak bloom and

PC activity. Finally, in the 2023 and 2024 sampling season, the last observed date of honey bee activity in fields were converted into degree days to compare with the models.

Results

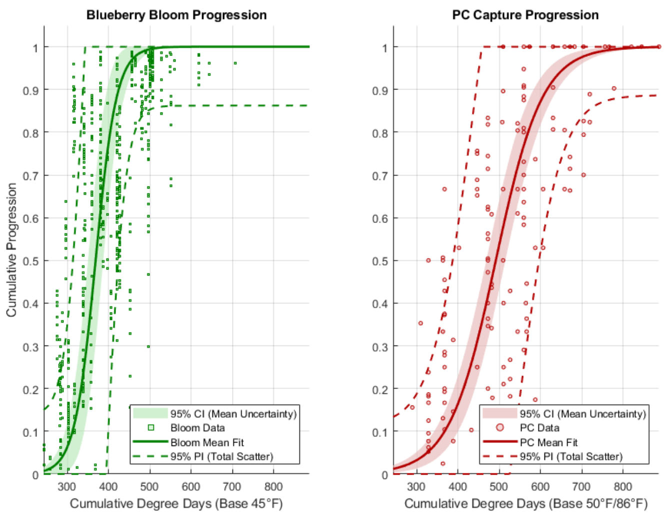

Figure 1. *Logistic model fits of degree days to bloom progression (left) and PC capture (right). Points represent observed data, the solid lines represent the mean model fit using just fixed effects, the shading around each mean fit represents the 95th percentile confidence interval when considering mean effects while the dashed lines represent the 95th percentile prediction interval for each based on the data scatter.*

The models represented fit observed data well (Figure 1), with R^2 values of 0.66–0.69. The generalized degree day of the 50th percentile (DD_{50}) of bloom progression occurred at 368 degree days and 491 degree days for PC. On average, modeled peak bloom occurs around day 117 and peak PC occurs around day 145. However, the exact start of PC or bloom progression can differ substantially by location or year

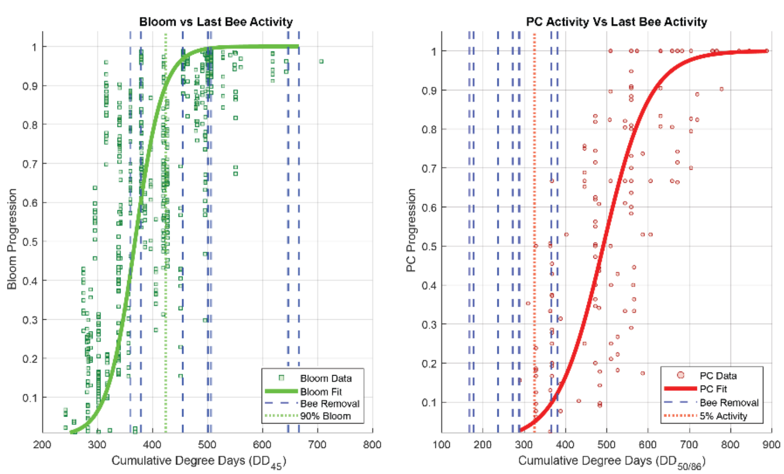

Figure 2. *Logistic model fits of bloom (left) and PC activity (right) compared with dates of observed last honey bee activity (blue dotted lines) in 2023 and 2024 by degree day.*

Bloom progression and PC capture rarely overlap. Comparing the last date of bee activity, bees often remain until >90% bloom completion, well after peak bloom (Figure 2). Bee activity often ends before modeled PC captures reach 5%. By 2050, peak bloom and PC activity are projected to occur 10–12 days earlier under moderate/high warming.

Conclusions

Based on the bloom and PC models we demonstrate minimal overlap, however, from a practical standpoint we anticipate a 15-30% margin of safety (~9 days) is needed to effectively pollinate the crop, manage PC and protect pollinators from insecticide exposure (Figure 3). Honey bee activity in blueberry fields often persists well past peak bloom, frequently beyond 90% completion. At that point, there is minimal benefit of keeping bees and PC management will be necessary in areas at high risk for infestation. Our findings support removing honeybees at 90% pollination and beginning integrated pest management before PC activity starts. These models help predict seasonal progression and identify timings for bee removal and pest control. Finally, combining degree-day models with climate projections suggests bloom and PC development will occur earlier by 2050, informing adaptive pest management strategies that balance crop protection and pollinator safety.

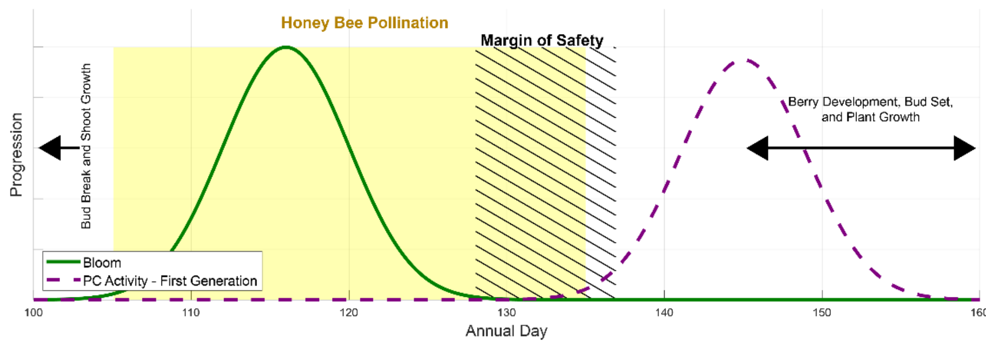

Figure 3. *Schematic showing honeybee activity overlap with bloom and PC activity, with a margin of safety window indicated.*

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Forage and Pastures for Equine Health

IMPORTANCE OF FORAGE FOR HORSES

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Introduction

Forage is the cornerstone of equine nutrition and plays a vital role in maintaining health, reducing feed costs, and supporting natural behaviors. Horses evolved as grazing animals, consuming forage in small, frequent meals for 12 to 16 hours per day. Properly managed forage can meet most nutrient requirements for horses at maintenance and significantly contribute to the well-being of lactating, growing, and exercising horses. Horses typically consume 1.5 to 3.3% of their body weight in forage daily, which means a 1,000-pound horse should eat at least 15 pounds of hay or pasture each day.

Nutritional Role of Forage

Pasture or good-quality hay can provide horses with 100% of their nutrient needs (see Figure 1). Forage supplies essential fiber, vitamins, and minerals, and feeding quality forage reduces reliance on grain, lowering feeding costs. Conversely, low-forage diets increase the risk of colic, gastric ulcers, gastrointestinal and metabolic acidosis, laminitis, and tying-up (rhabdomyolysis). Lack of fiber and chew time can also lead to undesirable behaviors such as wood chewing and other vices. Forage is not only a source of nutrients but also critical for maintaining gut motility and mental well-being.

Figure 1. Average nutrition composition of a grass pasture in the Northeast.

Nutrient	Average %
Protein	15.3
Crude fiber	33.1
Sugar	10.2
Starch	3.5
Non-structural carbs	12.7
Crude fat	3.6
Calcium	0.6
Phosphorous	0.3
Magnesium	0.2
Potassium	2.0

(Dairy One Feed Composition Library)

Types of Forage and Alternatives

Forage options include fresh pasture, dry hay, silage, and haylage. Pasture provides high moisture and essential vitamins, while hay offers a convenient, stored option when pasture is unavailable. Grass hays such as timothy, orchard grass, and fescue vary in palatability and nutrient content, while legume hays like alfalfa and clover are higher in protein and calcium (See Table 1 for a general overview of nutrient content of different forages). Hay should be harvested when plants are young, green, and free of mold or foreign objects. Forage substitutes such as hay cubes, beet pulp, and straw can supplement poor-quality forage but should be introduced carefully to avoid digestive issues. Beet pulp and wheat bran are excellent sources of fermentable fiber, while straw provides fiber but is very low in energy and can cause impaction colic if fed improperly. Lawn clippings should never be fed due to the risk of toxic plants and rapid fermentation.

Table 1. Overview of nutrition content of forages and forage substitutes.

Feed Type	Crude Fiber (%)	Crude Protein (%)	Calcium	Phosphorus	DE (Mcal/kg)	Notes
Complete Feed	≥25	Varies	Balanced	Balanced	2.8 - 3.2	Designed to replace forage; feed in multiple small meals
Hay Cubes (Grass)	>20	8-12	Moderate	Moderate	1.8 - 2.0	Good forage substitute; soak to prevent choke
Hay Cubes (Alfalfa)	>20	15-18	High	Moderate	2.2 - 2.3	Best for lactating/growing horses; avoid excess for maintenance
Straw	>30	<4	Very Low	Very Low	1.2 - 1.3	Fiber only; risk of impaction if introduced suddenly
Beet Pulp	High	~8	High	Low	2.8 - 3.0	Good fiber source; not complete feed
Wheat Bran	Moderate	~16	Low	Very High	2.8 - 3.0	Limit to ≤1 lb/day; risk of Ca:P imbalance
Rice Bran	Moderate	Moderate	Low	Very High	3.2 - 3.4	Used for fat; not a forage substitute

Pasture Management and Benefits

Well-managed pastures promote normal behavior, reduce vices, and provide exercise and social interaction. They also lower feed costs, reduce manure handling, and improve farm aesthetics. Pastures recycle nutrients, reduce erosion, and support groundwater recharge. Economic benefits include reducing hay costs by $60–$100 per month and lowering fertilizer costs when manure is spread properly. However, poor management can lead to parasite spread and exposure to toxic plants such as jimsonweed, endophytic tall fescue, and alsike clover. Stocking rates vary based on turnout time, ranging from half an acre per horse for limited turnout to two acres for full-time grazing. Higher stocking densities require intensive management practices such as mowing, irrigating, fertilizing, and rotating pastures to maintain vegetative cover.

Special Considerations

Carbohydrate levels in forage fluctuate with species, season, and time of day, influencing laminitis risk. Cool-season grasses tend to accumulate more non-structural carbohydrates (NSC), especially in the afternoon or during drought. NSC levels are highest in seed heads and during flowering stages. Horses prone to metabolic disorders or laminitis should avoid high-NSC forage and be managed carefully during spring and fall when sugar levels peak. Testing forage for NSC is essential for these horses, and laboratories such as Equi-Analytical (http://www.equi-analytical.com) offer affordable testing options. Laminitis is a serious condition that can lead to rotation of the coffin bone and is often associated with overweight ponies and high carbohydrate intake.

Conclusion

Forage is essential for horse health, supporting digestion, behavior, and overall well-being. By prioritizing quality forage and implementing sound pasture management practices, horse owners can reduce feed costs, minimize health risks, and create a sustainable feeding program. Understanding forage types, risks of low forage diets, and carbohydrate-related issues ensures horses receive optimal nutrition and care.

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MANAGING PASTURES FOR OPTIMAL GROWTH FOR EQUINE OPERATIONS

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Summary
Equine health and farm sustainability depend on how effectively pastures are managed. When managed well, nearly eighty to ninety percent of forage needs, especially for small equine farms, can be supplied by cool-season grass pastures. This article highlights ways to maximize pasture yields by learning about crop growth stages, applying best management practices in grazing, optimizing soil fertilizer inputs, and implementing practical measures for small farming systems. Focus will be on grazing-by-rotation, managing soil nutrients, applying soil conservation practices, and considering equine behavioral factors that influence pastures.

Introduction
The importance of pastures in equine nutrition can be understood from the fact that, on average, a thousand-pound horse eats fifteen to twenty pounds of dry matter every day, and if a cool-season pasture is well-managed, it can easily provide most of the needed dry matter (Nadeau et al., 2006; Allen et al., 2012). But from the perspective of maintaining good forage quality, cutting down the feeding expenses, and safeguarding the soil health, the role of strategic management is important, but it becomes even more important when managing horse farms, which are typically small, *i.e.*, two to five acres horse^{-1} (Teutsch and Hoffman, 2009). On the other hand, if our grazing practices are not up to the mark or poor, it can lead to overgrazing, soil erosion will come into play, more weed issues will emerge, and crop productivity will decrease (Smith et al., 2012). So, this article will go through some practices that, if the farm can adopt, will impart good pasture health and improve equines' well-being.

Why Proper Management of Pastures is Important for Equine Needs
The digestive system of horses is so good that it is naturally supposed to digest fiber ceaselessly, and if the horses are provided with ample pasture, it can cut down the annual hay feeding cost in the tune of five hundred to seven hundred dollars. On the other hand, if the pastures are not appropriately managed or if the horses are grazed on patchy grounds, it can lead to a yield loss to the extent of one and a half tons per acre (Parson et al., 1983).

Understanding Growth Stages of Cool-Season Grass
Learning the crop growth stages can be useful in aligning the grazing needs with the forage supply (Charif et al., 2021). Spring is a good time for the cool season grasses to grow strong. For instance, orchardgrass gains two to three inches every week, and the height of approximately six to eight inches is a good time to start grazing, which leaves three to four inches aboveground height for regrowth purposes. In Summer, grasses like ryegrass or bluegrass undergo a negative growth in the range of half to one inch every week. So, it stretches the rest time, and two to three pounds of hay reserve is needed every day. In the Fall, the temperatures are low, and moisture is appropriate, so grasses like brome or tall fescue can easily accumulate one to two tons of biomass per acre,

especially if a low dose of nitrogen is applied. In winter, the pastures stop growing, so that's the time when horses need to be provided with already stockpiled feed.

Strategies for Managing Grazing
It is helpful to keep in mind that, on average, two to three acres of pasture (cool season) is good to take care of one horse. Another point to keep in mind is grazing by rotation, which means that the pasture area can be divided into four to six paddocks, and then the horses are rotated after three to seven days in these paddocks. This will help in aligning with the time that the grass needs to regrow, ultimately minimizing the days of having nothing to feed the horses. Also, keep in mind that the lower three to four inches of aboveground height should be left ungrazed to protect the growing point from being cut to allow it to regrow.

Considerations from a Soil Fertility Perspective
Just like for any other crop, soil conditions are pivotal to the productivity of pastures. Make sure to test your soils once in two or three years to stay informed on lime and fertilizer requirements as well as pH numbers. Add on here is that cool-season grasses need a pH number to lie somewhere between six to seven, and consider applying lime only if the pH gets lower than six. Generally, forty to sixty pounds of nitrogen is suggested in spring starting (orchargrass), and it can be applied for the second time in fall if still deficient.

Few Points for Managing Small Horse Farms
Some strategic considerations for small farms can be beneficial, such as using electric or wooden fencing (four to five feet) to subdivide paddocks into multiple paddocks, supplying enough water to every paddock can help rule out the possibility of gathering in watering areas, and trimming the pastures twice or thrice every year can improve the tillering rate of orchardgrass.

How Understanding the Behavioral and Well-Being of Horses Helps Pasture Management
Horses are picky and spotty when it comes to grazing, so they sometimes favor some species more than others, and sometimes they don't even touch the least favored ones. To minimize the patchy spots and to make the pasture ground look more uniform, grazing in rotations is helpful. So being aware of these behavioral aspects is useful in making our pastures look healthy and reducing the chances of injuries caused by mud, and in enhancing horses' safety.

Calendar to Plan Seasonal Activities for Better Management of Pastures

Season	Things to keep in mind
Spring	Test your soil, put in your fertilizer, apply weed control measures, wait for the grass to attain three to four inches of height, to start bringing in horses
Summer	Make sure to do frequent rotation of horses to different paddocks to protect less vegetative areas and to feed the horses with stored hay

Fall	Identify areas with thin vegetation and consider supplementing P and K fertilizer to ensure enough vegetation comes up before winter
Winter	It is time to give rest to all the main pastureland and use the supplemental hay.

Conclusions
To have better yields and sustainability in pastures, it is essential to follow a combined approach incorporating strategic grazing management, soil nutrient optimization, improved on-farm infrastructure, and understanding behavioral traits of horses. With optimal management, it is possible to get all-year-round needs of a horse from a three-acre pasture, which can substantially cut down the farmer's expense on feed, simultaneously improving the horse's well-being. Very small changes in management practices, for example, replacing continuous grazing with grazing five days in rotation, have the potential to enhance forage productivity.

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EFFECT OF QUALITY FORAGE ON THE REPRODUCTIVE PERFORMANCE OF HORSES

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SUMMARY

High quality of forage plays a fundamental role in the reproductive performance of horses by directly influencing body condition score, hormonal function, and nutrient availability. It provides adequate energy, protein, vitamins, and minerals that support estrus expression, regular estrous cycles, higher conception rates, pregnancy maintenance, enhance early embryonic survival and fetal development in mares. Similarly, nutrient dense forage contributes to improved libido, stable testosterone levels, enhanced semen characteristics and fertility in stallions. Overall, the evidence indicates that forage quality is a critical determinant of reproductive performance in horses, underscoring the necessity of well managed pasture systems and nutrient rich hay to optimize breeding outcomes and sustain long-term reproductive health.

INTRODUCTION

High quality forage is one of the most critical foundations of equine nutrition, and its importance becomes even greater when the goal is to optimize health, fertility, pregnancy, lactation, and reproductive performance.

The success of an equine breeding program depends on the health of stallions, broodmares, and foals. The equine reproductive system cannot function properly if the horse's health is compromised by poor digestive function. Gastrointestinal dysfunction can lead to poor nutrient absorption. Without balanced nutrition, fertility can suffer in breeding horses and developmental disorders can occur in foals (Robles et al., 2021). Supporting hindgut health in breeding horses is critical for meeting increased energy demands to support reproductive processes. Stallions and mares can't maintain the body condition necessary for optimal fertility without efficient fiber digestion by a balanced hindgut microbiota (Morley and Murray, 2014). These horses also require balanced nutrition to get the nutrients they need to support sperm motility in stallions and foal development in pregnant mares. Nutrition changes to support reproduction should begin before breeding season and continue throughout gestation and lactation (Robles et al., 2021).

The horses need a balanced diet that meets NRC nutrient requirements. But deficiencies in certain nutrients active in equine fertility and gestation can significantly decrease the chances of reproductive success. These deficiencies can contribute to poor sperm quality, reduced broodmare fertility, and abnormal foal development (Robles et al., 2021). Sperm production relies on several nutrients from the diet, including omega-3 fatty acids, polar lipids, and antioxidants. The studies demonstrates that deficiencies in these nutrients can reduce sperm concentration and motility (Bazzano et al., 2021). Nutrients that aren't absorbed in the small intestine rely on the microbiota of the hindgut for

digestion. However, the equine gut microbiota also plays a role in overall immunity, which significantly influences reproductive health (Venable et al., 2016).
Body condition is one the best predictors of reproductive performance in horses. Stallions should maintain a body condition score of 5–6 to support fertility. Stallions often lose condition during the breeding season due to the demands of covering mares if their diets don't meet their energy and protein requirements (Bazzano et al., 2021). Studies evaluating salivary cortisol in horses found elevated stress hormone levels in stallions during the breeding season. These results suggest that breeding duties can increase stress levels in stallions (Aurich et al., 2015). Other studies have established a link between higher stress hormones and an increased risk of gastric ulceration and other gastrointestinal diseases. These digestive health conditions can contribute to weight loss and prevent stallions from getting the energy they need from their diets (Malmkvist et al., 2012). Targeted management to support optimal digestive function during stressful periods can help prevent weight loss in stallions.

Mares with a body condition score above five have increased fertility, and research shows that mares with lower body condition scores are more likely to conceive while gaining weight (Morley and Murray, 2014). Studies also show that feeding patterns can impact fertility in broodmares. One study found that continuous foraging increased conception rates in mares. Free choice forage is also associated with optimal digestive function in horses, which suggests that management practices that promote gut health can also increase reproductive success (Benhajali et al., 2013). Foals rely on a passive transfer of antibodies from their mother's colostrum to start building a robust immune system. Research shows broodmare gut health significantly influences colostrum quality and that digestive support can positively impact colostrum production (Bacvarova and Buechner-Maxwell, 2012).

Therefore, high quality forage is essential for equine gut health, and it becomes even more important when the goal is to support optimal reproductive performance in horses.

CONCLUSION

High quality of forage plays a fundamental role in the reproductive performance of horses by directly influencing body condition score, hormonal function, and nutrient availability. Studies consistently show that better gut health translates to better outcomes for equine reproduction.

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IMPORTANCE OF FORAGE FOR IMPROVING THE QUALITY OF LIFE, BEHAVIOR, AND WELFARE OF THE HORSE

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The term welfare has many definitions, but it can generally be understood as an animal's ability to cope with its environment, ultimately determining its overall quality of life. Numerous frameworks exist to evaluate welfare, but the most recent and comprehensive is the Five Domains Model. Mellor and colleagues outline how four functional domains—nutrition, environment, health, and behavior—combine to influence the fifth domain, the animal's mental state. These domains overlap and interact, meaning that changes in any area of the animal's life can influence how it perceives and copes with real or perceived stressors.

Throughout equine evolution, the horse transitioned from a small, multi-toed, swamp-dwelling animal into the large, single-toed athlete we recognize today. These anatomical and physiological changes were driven by environmental pressures such as forage availability and predation risk. Additional changes occurred as horses became domesticated, with humans selecting traits desirable for work, temperament, and athleticism. While domestication has altered selective pressures, horses retain the natural behaviors of their wild ancestors. As a result, it is essential to consider how horses evolved to use forage as the foundation of their diet—and how their behavioral needs persist even when removed from their traditional open-plain habitats.

The most obvious domain influenced by forage is nutrition. Horses require adequate forage for optimal physiological functioning. Inadequate access to high-quality forage can negatively affect not only nutrition but also the other domains. However, forage also contributes positively to health, environment, and especially the behavioral domain.

Pasture is the ideal environment for horses because it most closely mimics the landscape in which they evolved. Forage supports proper digestive health, and offering frequent, small amounts helps reduce the risk of negative health outcomes. Yet the behavioral benefits of forage may be the most impactful.

Domestication may alter the frequency or threshold of behavioral expression, but it does not eliminate the innate drive to perform these behaviors. When horses are prevented from expressing natural behaviors, frustration can develop and may lead to a decline in mental well-being. In many cases, behavioral issues arise because the environment does not allow for these natural behaviors.

Common natural equine behaviors include:

- Large, varied movement

- Frequent eating and chewing (oral-motor behavior)
- Social interaction with peers

When horses cannot perform these behaviors, they may experience frustration that manifests subtly or through the development of stereotypies—abnormal, repetitive behaviors commonly seen in captive animals and often called "vices" in horses. Examples include:

- Weaving: swinging the head and shifting weight between the front legs
- Wood Chewing: chewing on stall or paddock structures
- Stall Kicking: striking walls, doors, or other surfaces
- Box Walking: pacing patterns along stall or paddock edges
- Pawing: repetitively digging with a forelimb
- Cribbing (Windsucking): grasping a vertical surface with the teeth, arching the neck, and sucking in air

These behaviors may serve as coping mechanisms. While some stereotypies can result from medical issues or nutritional imbalances, most arise due to environmental stressors. Increasing forage availability or providing enrichment can reduce these behaviors, as many forms of enrichment naturally overlap with foraging activity. Slow-feeder hay nets, puzzle feeders, and distributing forage across multiple locations can increase oral-motor activity, promote movement, and provide cognitive engagement.

Another framework emphasizing the importance of forage is the 3 Fs: *friends, freedom, forage*. Providing these three elements supports natural behaviors and decreases the likelihood of developing stereotypies. Ideally, horses should be kept in group turnout with access to pasture, closely replicating their natural environment. However, even when full turnout is not possible, forage and enrichment can be offered in structured ways to help meet these core needs.

Managing Soil Health for Improved Production

USING BENEFICIAL MICROBES TO IMPROVE STRESS TOLERANCE

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Abiotic stresses, including heat, drought, and salinity are major factors limiting plant growth and productivity, with the severity of each of these stresses predicted to increase as a result of climate change. Mycorrhizal fungi and plant growth promoting rhizobacteria (PGPR) can form beneficial associations with the roots of plants to improve growth and increase tolerance to abiotic stress. Incorporating these beneficial microbes into agricultural systems to enhance growth and promote stress tolerance has arisen as a sustainable approach to improving plant health and crop yield, while reducing the use of water, fertilizer, and agrochemicals. Mechanisms involved in bacteria-mediated stress tolerance include enhanced acquisition of nutrients, such as N and P, production of exopolysaccharides (EPS), and the modulation of phytohormones. Considerable focus is being directed towards the regulation of ethylene through bacterial ACC deaminase (ACCd) activity in reducing the plant stress response.

Mycorrhizal Fungi can perform several important ecosystem functions that support increased plant stress tolerance, including decomposition and nutrient mobilization, improvement of soil structure, and enhanced access for plant roots to obtain water and nutrients. Fungi form long thread-like strands called hyphae by joining individual cells together in chains. Mycorrhizal fungi colonize plant roots and their hyphae function as an extension of the plant's root system, thus improving the ability of the plant to acquire water and nutrients. Fungal hyphae can secrete sticky substances that help to promote soil aggregation and structure, which can lead to better water infiltration and holding capacity. Some fungi can also help to control diseases, either by out-competing pathogens or by directly parasitizing disease causing organisms. Fungi are sensitive to soil disturbances that break up the chains of fungal hyphae, so fields that employ reduced tillage practices typically have higher fungal populations.

Bacteria are single-celled organisms that are generally the most abundant microbes in agricultural soils. Many species of bacteria function as decomposers, consuming root exudates and plant residues, then converting those materials into nutrients that are available to plants or other soil organisms. Bacteria can improve soil structure and water dynamics by secreting sticky compounds that help to bind soil particles into stable aggregates. Some bacteria can also fix nitrogen from the atmosphere and make it available to plants. These bacteria are called diazotrophs. A common example of nitrogen-fixing bacteria are *Rhizobia spp.* which form a relationship with the roots of legumes and convert nitrogen gas into a form that the plants can use. There are also free-living diazotrophs, such as *Azotobacter spp.* that exist in the soil and fix nitrogen without forming a direct symbiosis with the roots of legumes. Some PGPR also have the ability to increase the solubility of phosphorus and potassium, increasing the availability of these nutrients to the plant. The production of iron siderophores is employed by various PGPR to chelate iron, thus making it more absorbable by the plants' roots. Enhanced uptake of Fe, Zn, Mg, Ca, and K by crop plants inoculated by strains of *Pseudomonas* and *Acinetobacter* has also been reported. By improving plant nutrition, PGPR can increase physiological function and growth during periods of stress, while reducing the need for synthetic fertilizers.

Some microbes can produce diverse polysaccharides that coat their cell walls and are excreted into the environment. These substances are referred to as exopolysaccharides and play a valuable role in improving both microbial and plant tolerance to various abiotic stresses, including drought and salinity, by effectively coating microbial cells and plant tissues that are sensitive to desiccation in a polysaccharide film. Exopolysaccharide producing bacteria have been found in symbiotic relationships with many plants. Drought stress has been found to increase bacterial EPS production and to change the concentration and composition of EPS, functioning as a bacterial survival mechanism in conditions with reduced moisture and creating rhizosheath in conjunction with plant roots. As soil moisture decreases, increased EPS production composed of high molecular weight carbohydrate complexes protects the bacteria from drought stress while increasing soil water holding capacity and aggregation.

Some soil bacteria can also produce an enzyme called ACC deaminase, which is able to help improve stress tolerance in plants by reducing ethylene levels. Ethylene is produced in low concentrations in plants under optimal growth conditions, but its production can be stimulated to detrimental levels by various abiotic stresses, including heat, drought, and salinity stress. While an initial induction of ethylene synthesis at low concertation is thought to trigger plant protective responses, an excessive amount of ethylene accumulation during a prolonged period or severe stress can have inhibitory effects on plant growth and yield. Some endophytic PGPR are particularly effective in suppressing ethylene production within the host plant by breaking down the ethylene precursor, ACC, using the bacterial ACCd enzyme. ACCd-rhizobacteria include a large variety of bacteria species, which are known to promote shoot and root growth, as well as plant tolerance to abiotic stress. The ACCd-rhizobacteria offer a sustainable approach to mitigating the adverse effects of stress-induced ethylene accumulation in plants. However, the mechanisms of ACCd-rhizobacteria interaction with plants and how ACCd-rhizobacteria may promote plant tolerance to abiotic stress are still under investigation. Further research in these areas will advance our understanding of how endophytic rhizobacteria interact with plant hosts enabling the promotion of plant growth and the underlying factors controlling successful colonization of the bacteria in the host plant, which is important for improving PGPR efficacy.

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WHO BENEFITS FROM PRECISION CONSERVATION?

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Precision conservation targets low yielding zones of a crop field. Agronomic research has demonstrated significant yield variability within fields and has shown that low-yielding areas can reliably be identified for targeted conservation. This targeted approach allows farmers to simultaneously engage in both farming and conservation. In so doing, it diverges from conventional conservation policy, which focuses on conserving entire fields.

This study estimates the opportunity cost of such precision conservation on 29 commercial fields in Michigan, USA, using fine-scale yield maps collected between 2020 and 2024. Results show that under a corn-soybean crop rotation, precision conservation improves profitability in 19 of 29 fields, indicating potential for adoption without government subsidies.

This article examines the effects of precision conservation on (1) crop yield, (2) deer crop damage, and (3) farm profitability. The tables below summarize the cost and price assumptions applied in the analysis.

Table 1: Costs associated with conservation area establishments and maintenance

Tasks		Charge ($/ac)	Source
Maintenance	Mowing	25	Plastina and Johanns (2024)
Establishment	Tillage	20	
	Planting	13	
	Seed	250	From this study

Table 2: Farmer reported price parameters (in 2024$)

	Corn		Soybeans	
	Farm A	Farm B	Farm A	Farm B
Grain price ($/bu)	4.40	5.30	12.60	12.60
Input costs ($/ac)	534	840	340	478

1. Impact on Crop Yield

The implementation of conservation areas adjacent to cropland had a positive effect on crop yields within a 10-meter buffer zone. The yield impacts that evolve over time are observed in both corn and soybeans (Figure 1). For corn, the impact increases over time and becomes statistically significant in year 4. In year 4, the estimated yield impact is 12 bu/ac, corresponding to a revenue gain of $60/ac. In contrast, soybeans exhibit an earlier response. The impact is statistically significant and positive beginning year 1 and continues to grow through year 3. The revenue increase from these positive yield impacts amount to $39 to $48 per acre. However, the yield impact is statistically insignificant in year 4. As this study does not measure ecosystem services directly, the exact mechanism driving the observed yield increases remains unknown. However, the positive yield impacts can be partly explained by the role of conservation areas in providing habitat for beneficial species, such as pollinators and natural enemies of pests.

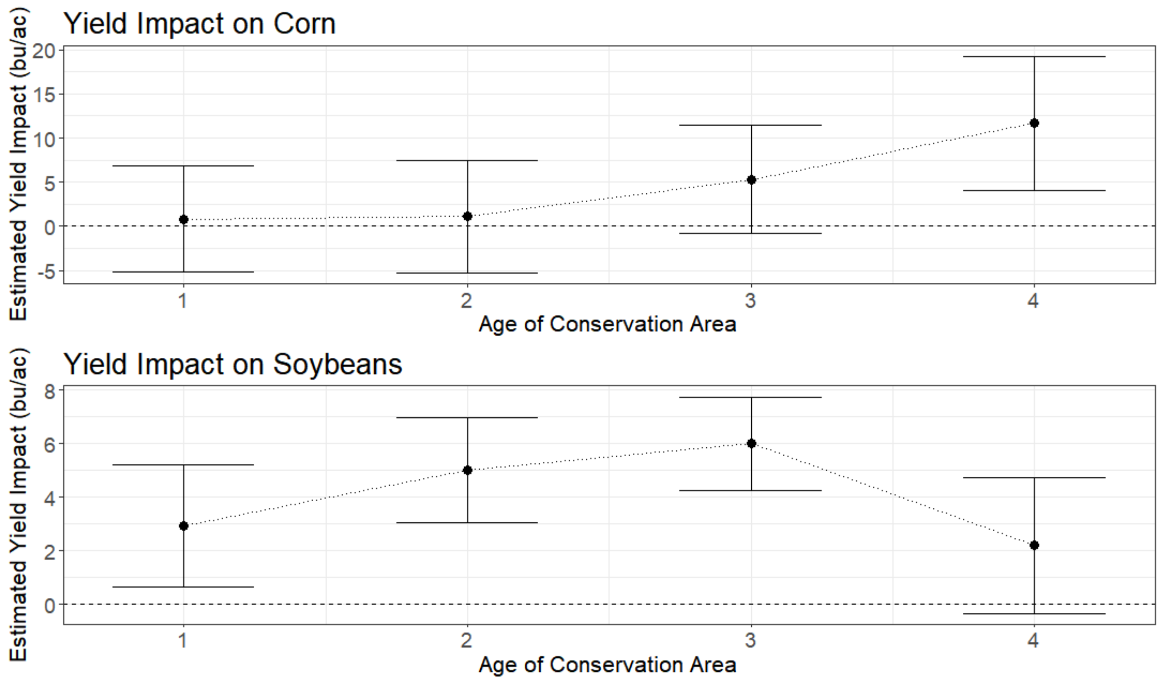

Figure 5 Impact on crop yield across year

2. Impact on Deer-related Crop Damage

One of the most common concerns among farmers when first introduced to precision conservation is that it may attract more deer their fields and increase crop damage. To assess whether conservation areas contribute to increased deer-related crop damage, we compared yield between areas located within 500 meters of the nearest woodland and those situated farther away, based on the assumption that deer pressure would be higher closer to woodland habitats. The results show no statistically significant yield differences near conservation areas between these two groups, indicating that conservation areas did not lead to increased deer-related crop damage.

3. Impact on Field Profitability

Precision conservation improves profitability in 19 of 29 fields by removing low yielding part of the field from production and reducing input costs that would otherwise have been applied to those marginal lands. When starting with a corn year, the ten-year conservation opportunity costs range from -$424/ac to $233/ac, with an average of -$74/acre, indicating that, on average, field profitability increases by $74 per acre of conserved land.

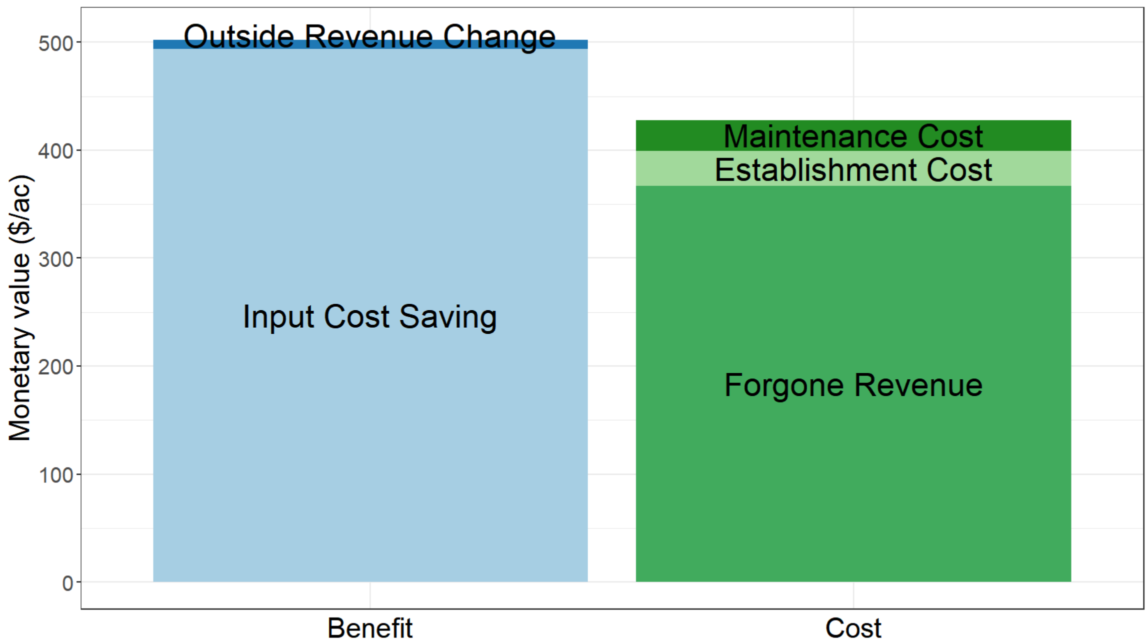

Figure 2: Breakdown of opportunity costs, averaged across 29 Michigan fields

Input cost savings and forgone crop revenue within conservation areas account for the largest portions of total opportunity costs, averaging $494 per acre and $367 per acre, respectively (Figure 2). These results highlight that careful selection of low-yielding field areas is critical for ensuring the economic viability of precision conservation. Conservation areas also generate positive yield effects on adjacent crops, which help offset opportunity costs. However, the magnitude of this benefit is relatively modest, reducing annual costs by an average of $8.50 per acre of conservation area, with the largest observed reduction reaching $25 per ac

USING LIVING AND DEAD COVER CROPS FOR WEED SUPPRESSION AND INSECT PEST MANAGEMENT IN SWEET CORN

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Introduction and Project Rationale

Vegetable growers today face rising costs and increasing pressure to reduce their reliance on tillage and synthetic inputs for managing weeds and insect pests. At the same time, long-term use of monocultures and intensive field practices has reduced the total in-field diversity of plant species, which can limit necessary resources for insect natural enemies (predators and parasitoids) and make crops more vulnerable to pest outbreaks. Cover crops and living mulches offer growers additional tools by helping suppress weeds, potentially reducing the need for herbicides and hand labor, and by creating a more diverse habitat that supports greater populations of natural enemies. In this study, we tested several practical approaches for diversifying sweet corn fields—including living mulches, dead cover crop residues, and alternating strips of living mulch with either spring-terminated or frost-killed cover crops—to see how well they suppress weeds, support beneficial insects, and affect the broader insect community compared with conventional sweet corn production practices.

Methodology

This study took place over three seasons (2019–2021) at two University of Maryland research farms in Upper Marlboro and Beltsville, Maryland on typical Mid-Atlantic loam and silt-loam soils. We compared four sweet corn production systems—conventional tillage, no-till with cover crop residue, red clover living mulch in combination with a rolled rye residue or red clover in combination with a winter-killed forage radish. Each system was tested both with and without a standard pre-emergence herbicide program. Herbicides were broadcast over conventional-till and no-till treatments and banded between living mulch strips in both living mulch treatments. Cover crops were planted each fall, and in spring the residue or living mulch was managed using practices appropriate to each treatment. Sweet corn ('Providence') was then planted directly into the residue or tilled seedbed.

The study objectives were to evaluate how different approaches to cover cropping, residue management, and living mulches influenced (1) weed suppression, (2) sweet corn growth and yield, and (3) the abundance and activity of insect pests and beneficial insects. To do this, we measured cover crop biomass, monitored weed growth in managed and unmanaged areas, tracked sweet corn emergence and development, and measured yield. Insect communities were assessed using a combination of in-field observations and trapping methods to compare how each system affected both pests and natural enemies. Ear damage from major sweet corn pests was also recorded at harvest.

Results

Across all three years, the conventional tillage plots *without* herbicide had the highest weed pressure throughout the season and the only other treatment with similarly high weed biomass was the no-till (NT) system without herbicides. In contrast, both living mulch treatments, with and without herbicides, kept weed biomass low with total pressure in these systems similar to the herbicide-treated CT plots whether herbicide was used or not. Sweet corn emergence was slightly slower in residue-heavy treatments but the final stand was similar across all systems. Total sweet corn yield was similar across all treatments in 2020 but was reduced in all cover-crop treatments without herbicides in 2021, most likely as a result of competition with the more vigorous living mulch in plots without herbicides. Harvest maturity in both years was delayed by one to two days in the living mulch systems compared to CT.

Across all arthropod sampling methods, thousands of insects representing a wide range of species were collected. Most insects were either herbivores or beneficial predators and parasitoids. Living mulch treatments tended to attract more total insects than CT or NT systems. These systems also supported higher species richness (more types of insects). However, this increase in insect abundance had no impact on pest damage to harvested ears, with similar amounts of ear feeding by corn earworm and other pests across all treatments. Additionally, observations of foraging pollinators highlighted an abundant and diverse community of bees and butterflies was supported by the addition of flowering living mulches.

Overall, the results suggest that living mulches and cover crop residues can help suppress weeds as effectively as herbicide-treated conventional tillage, increase on-farm insect diversity, and maintain comparable yields when used in combination with conventional herbicides. However, in a no-herbicide system, especially vigorous stands of living mulches may reduce sweet corn yield due to competition, highlighting the need for careful management when adopting these practices.

Enhancing Farm Marketing and Business Management

HOW TO TELL YOUR FARM STORY: TIPS FOR SOCIAL MEDIA MARKETING

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As widespread use of digital marketing through social media continues to increase in all industries, growers can benefit from utilizing online platforms and storytelling techniques to expand their customer base and market reach. Especially for new and beginning farmers just entering the agricultural industry, constructing a reliable market can pose a significant challenge; a polished social media presence can be instrumental for success. Established growers who have already overcome the initial market startup challenges can also benefit from implementing new digital marketing strategies to expand their reach and target a larger customer base. This presentation will cover (1) a technical tutorial of social media platforms and photography/videography tips and (2) fundamentals of effective agricultural storytelling through social media.

1. Technical Tutorial

Instagram and Facebook are currently the most popular and effective social media platforms for digital agricultural marketing. Instagram and Facebook cater to different demographics, but both involve short-form content production that can reach a wider audience beyond page followers.

Considerations to elevate an Instagram and Facebook page include creating an informative bio, adding important links, and (on Instagram only) using the story highlight feature. The story highlights can function as an “about” page, give an overview of the business, answer FAQs, feature accomplishments, etc. Instagram and Facebook accounts can be linked through settings, which automatically publishes content on both accounts instead of users needing to manually post on each page.

The available formats for publishing content are posts, reels, and stories. Posts and reels stay on the page forever unless deleted and construct the overall “look” of the page, while stories disappear after 24 hours. Because of their impermanence, stories can be used for more informal, spur-of-the-moment content or quick announcements. Posts are generally still photographs and tend to mostly reach page followers, while reels contain video content and are favored by the algorithm for wider distribution. Hashtags can be utilized for both posts and reels to extend reach beyond active followers; content will be recommended to users who follow a certain hashtag even if they do not follow the specific business page. Photos and videos with human subjects tend to be more engaging to a wider audience, but high-quality content of products can also be effective.

Smartphones offer a convenient way to easily capture content; integrating the habit of taking some quick photos or videos into an already established working process is a simple way to generate content for posts. When taking photos and videos, tips for visually pleasing compositions include: positioning the subject to face the sun to ensure it is best illuminated, assessing the background for distracting or unsightly elements, and placing the subject either in the center or on one of the thirds of the frame. While these considerations are good to keep in mind and can add to a polished, professional look, ultimately a fun, dynamic photo is more important than perfect composition for best engagement.

2. Storytelling Fundamentals

In a world where customers are constantly inundated with options, providing an opportunity for people to become invested in a personal journey can significantly increase the likelihood of standing out. Telling a story adds an element of human connection to products that can generate customer interest and loyalty. The method of presenting a story on social media can generally follow one of two main directions: humorous and relatable or highly polished and professional. A page can certainly include elements of each, but it is important to decide on an overall brand identity for consistency.

A page that leans into humor can give a less professional appearance, but has the benefit of creating a more genuine impression that encourages personal connection. Humorous or relatable content has the potential to be enjoyed by a broader audience as general entertainment. Even if a large part of this audience won't ever become customers, creating posts that are enjoyable for a wide range of social media users can raise visibility and boost overall engagement, which increases the likelihood that content will reach users who *will* become customers.

A page that instead offers a streamlined visual portfolio of products can establish greater professionalism, but might struggle to reach a wider audience. Image quality and composition are much more important to consider; the appearance of the media on the page becomes the main selling point for engagement. To best generate interest, post captions should still tell a story and offer a glimpse into the behind-the-scenes experiences that have resulted in the product being sold.

Overall, allowing customers to forge a connection with a personal journey by exhibiting the realities of farming—the good, the bad, and the ugly—is what can ultimately encourage customers to turn away from their grocery store to buy locally-grown produce. Once they have become invested in the story *behind* the product, they are more likely to experience the emotional motivation that can lead to longer-lasting customer loyalty.

VEGGIE COMPASS: A TOOL TO STEER MARKETING & BUSINESS DECISIONS ON THE FARM

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Diversified vegetable farms often grow dozens of different crops, each with its own unique management strategy. Additionally, these farms may market their produce through varied marketing channels, including roadside stands, farmers markets, community supported agriculture (CSA) shares, and wholesale markets. Production of varied crops using the same equipment and labor force can sometimes make it challenging to determine the profitability of each individual crop in each market channel. Veggie Compass is a spreadsheet-based tool developed at the University of Wisconsin that can assist growers in determining production costs and profitability using personalized input costs and sales numbers from the grower's farm. The Veggie Compass spreadsheet tool is available at: https://cias.wisc.edu/our-work/farming-systems/farm-viability/veggie-compass/

The first step in using the Veggie Compass tool is input of total farm expenses. These expenses include labor, seed, crop supplies, insurance, vehicles, marketing costs, and other expenses. These costs are then allotted to individual marketing channels and may apply to all marketing channels or only one or a few. For example, if a box truck is only used to move wholesale produce, all associated costs would apply to the wholesale category and not the farmstand or farmers markets categories. In contrast, a tractor's cost may be applied to all marketing channels if it is used in production of the crops for all of the channels. Total costs are then assigned to each marketing channel.

Next, expected sales are inserted by crop type and unit of measurement (pounds, head, bunch, etc.). Sales are broken down by market channel and include a dollar amount for sales in that specific market channel, units sold, and average unit price in that market channel. Total crop sales are calculated per crop as well as per market channel. Then, production inputs related to the greenhouse, the field, and additional harvest and packing steps are input.

The data input in the previously described steps is then used to calculate the cost of production by crop, sales outputs, and profits/losses by market channel. Crops are assigned a percentage of total costs for individual steps in the production process, including greenhouse costs, field growing costs, and harvesting/packing costs. For example, greenhouse costs are assigned based on number of plants of each crop raised in the greenhouse. Total costs before harvest are calculated, as well as including harvest and packing, to determine a total unit cost up until the packing step. Next, the spreadsheet generates a sales output that includes crop gross profit, unit net profit, and crop net profit.

There are several benefits to using Veggie Compass or a similar tool to analyze profits on your farm. It is advantageous to determine which crops on your farm are most profitable to grow in order to make better decisions on which crops you may want to increase production and which ones you may want to reduce or eliminate. Additionally, for a particular crop, you may find that one market channel such as direct sales at farmers markets is profitable, but wholesale is not, especially in the case where harvest labor makes up a significant portion of production costs. You may even use profitability information to decide whether to continue producing a few crops that yield minimal profits, but are a major draw for acquiring customers. For example, sweet corn grown on a small scale may not yield significant profit, but customers often expect it at roadside stands or farmers markets where they will also buy higher profit items from the farm business. Other crops, such as cut flowers, may be grown for aesthetic reasons and may help draw customers in, even if they are not a large profit/revenue source for the business. Accurate estimates of profitability for all crops grown on a farm are an important step towards making decisions that lead to the financial sustainability of the business.

Ag Technology

FIELD-TESTING THE URI LASER SCARECROW TO REDUCE BIRD DAMAGE IN FRUIT PRODUCTION

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Flocking bird damage is a prevalent issue for many agricultural producers across the country, with annual damage estimates ranging in the hundreds of millions of dollars. [1] Fruit growers often report experiencing the highest levels of yield loss due to avian feeding damage. [2] Many of the bird deterrents available to commercial growers are often cost-prohibitive, not suitable for use in areas with nearby residences, or can be overcome through habituation. One emerging technology that has shown promise to bypass these issues while reducing bird damage is the University of Rhode Island Vegetable Program's (URI) Laser Scarecrow. [3]

Materials & Methods

The URI Laser Scarecrow is an experimental unit, designed specifically with small to medium-scale growers in mind. The design of the laser unit consists of a modified covered bucket that houses the necessary circuit board along with various sensors inside, while at the base there is an exposed rotating arm assembly with two mounted green 532 nm lasers. The unit also includes a wired control box, allowing users to modify the set angle parameters and rotational speed of the lasers, along with a prominent emergency shutoff switch. The laser system is currently available at cost to growers who are willing to work with and contribute towards the URI Program Team's research efforts. To power the unit, growers must purchase or provide their own power supply, typically consisting of a deep-cycle marine 12-volt battery with a 20-30-watt capacity solar panel. After acquiring any necessary mounting hardware and supplies, growers can expect direct costs to be approximately $1,000 per URI Laser Scarecrow installation. The expected range of protection is estimated to be at around a maximum radius of 200 feet, or up to roughly 3 acres.

Due to the system's use of class 3B lasers, necessary safety precautions must be taken in order to comply with the applicable American National Standards Institute (ANSI) regulations. [4] This includes preventing the laser pathing from coming in contact with any reflective surfaces, preventing offsite or aerial laser projection, and having workers utilize proper eyewear protection within a set hazard zone while the laser is active. Additional safety precautions and guidance were given by the Rutgers Environmental and Health Safety Department (REHS). The URI Laser Scarecrow model utilized in this study, the 2025 Berry Prototype, had additional sensors that would shut off the laser unit if any excessive swaying, tipping, or obstruction of the rotating arm assembly was detected.

To test the potential efficacy of the URI Laser Scarecrow on fruit production operations, three field trials were conducted throughout the 2025 growing season. Because of safety concerns and limitations of collecting quantifiable data on active direct market farm operations, field trials were conducted solely at Rutgers New Jersey Agriculture Experiment Station (NJAES) research field stations. The first field trial occurred during the spring on established northern highbush blueberry fields at the Rutgers Philip E. Marucci Center for Blueberry and Cranberry Research and Extension in Chatsworth, NJ. Following that initial study, two sequential field trials were conducted at the Clifford E. & Melda C. Snyder Research & Extension Farm in Pittstown, NJ to study the laser system's impact on high-density peach and apple production systems.

For the efficacy study on blueberries, two adjacent blueberry fields were utilized during the spring and summer of 2025. Fields 1 and 2 were approximately 0.8 acres and 1.25 acres, respectively. Field 1 was in its sixth year of production and was planted with the northern highbush variety 'Duke', while Field 2 was in its fourth year and was planted with the variety 'Draper.' Neither field received supplemental irrigation, nor were harvested fully on a regular basis. A split-block design for each field was implemented, with half the field being treated with laser coverage and the remainder serving as an untreated control. To uncover any differences in feeding due to location, blocks were further divided into an inner and outer stratum. Both fields were noted for experiencing high levels of bird damage in the past, likely due to their location between a woodland border and an irrigation canal, making an ideal habitat for supporting bird populations. Based on previously established protocols [5], individual branches were randomly selected and marked across both fields. Exterior strata were allocated 24 replicates per block, while the interior strata had 12. Due to the loss of a few plants prior to the end of the harvest season, the total replicates for Fields 1 and 2 ended up being 70 and 71, respectively. Initial berry counts were taken around the green fruit stage of development on June 13th and 16th. Once fruit had begun to ripen, four weekly harvest events were conducted between June17th and July 11th. Berry loss percentages per replicate were calculated by comparing total fruit harvest data to initial berry counts, providing an estimate of bird damage.

Results & Conclusion

The two bird species predominantly observed during the field trials were red-winged blackbirds (*Agelaius phoeniceus*) and brown-headed cowbirds (*Molothrus ater*.) Larger flocking bird species that were commonly found in the area, such as Canada geese (*Branta canadensis*) and a variety of gull species, were rarely observed in the laser-treated field areas. Across both fields, harvest data indicated reduced berry loss in laser-covered blocks when compared to the control blocks. For Field 1, the laser-covered block experienced 9.10% yield loss, while the control was 18.40%. Field 2 experienced losses of 19.38% and 25.01%, respectively. Using a three-way ANOVA, the effect of the field location was found to be significant, with a p-value of 0.02. More importantly, the treatment effect was found to be significant as well, with a p-value of 0.04. There were no significant differences in bird damage found between the interior and exterior strata, and no significant interaction effects among the treatments were observed.

Unfortunately, the two following efficacy trials on high-density apple and peach orchards at Snyder Research and Extension Farm experienced no observable bird pressure as reported in previous years. After discussing these findings with other commercial orchard growers, it appears bird damage in most tree crops is not as prevalent as it is in other small fruiting crops. Due to these reasons, orchard crops will likely not be a research focus in future bird laser deterrent efficacy trials. A major takeaway stemming from conducting these orchard trials was the farm technician crew's utilization of a staking technique, like basic tree staking methodology. This allowed the laser unit to be mounted with minimal swaying on a ½" steel pipe at a height of roughly 5 meters, possibly opening the door to future applications.

In conclusion, the use of the URI Laser Scarecrow appeared to be an effective measure for reducing bird damage to blueberries. One major limitation of the study was the fields' infrequent harvesting which would not be comparable to a commercial setting but may relate more with a Pick-Your-Own (PYO) operation. To further strengthen these findings, additional field trials across diverse environments are warranted. If differences in bird damage can be quantified, efficacy field trials on small farm operations, such as PYO's, should be explored as well. Other crops of interest heavily impacted by bird damage, such as wine grapes, should also be explored as candidates for future laser deterrent efficacy trials.

Acknowledgements

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Livestock Production and Marketing

BREEDING FOR THE FUTURE: STRATEGIES FOR SUSTAINABLE HERD REPLACEMENT AND PROFITABILITY

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INTRODUCTION

Selective breeding in livestock has greatly increased farm productivity and helped reduce the carbon footprint in recent decades. However, further refinement of current selection indexes and breeding objectives is needed to place stronger emphasis on traits related to animal welfare, health, longevity, environmental efficiency, and overall resilience. Managing heifer inventory is crucial for the long-term success and sustainability of livestock farming operations. Breeding programs that incorporate sexed and beef semen can deliver significant economic gains, but only when guided by solid data, realistic projections, and clearly defined farm objectives. Decision-support tools play a crucial role in turning complex biological and market dynamics into practical, actionable guidance.

EVALUATING BREEDING STRATEGIES

The decision to use beef or sexed semen extends beyond biological efficiency, being heavily influenced by market factors. With beef-on-dairy calves often fetching premium prices, producers are increasingly factoring calf value into their breeding strategies. Sexed semen promotes genetic progress by producing more heifers from elite animals, whereas beef semen boosts short-term income from calves that do not carry genetic value for future replacements. This combined approach effectively balances both biological and economic objectives.

HEIFERS REPLACEMENT

Over the past two decades, gains in reproductive efficiency have led to an oversupply of replacement heifers, creating both management challenges and financial strain. Producing more replacements than required increases raising costs and weakens selection intensity, while overusing beef semen to capitalize on premium calf prices can result in a shortage of herd replacements. The key objective is to generate the optimal number of replacements from the highest-quality animals, while also taking advantage of the added value from beef-on-dairy crossbred calves.

SELECTIVE BREEDING

Selective breeding has long been a cost-effective way to boost livestock productivity (Hill & Kirkpatrick, 2010). Improving livestock genetics for production, reproductive efficiency, health, and lifespan enhances efficiency and reduces emissions per unit of product (Herrero et al., 2016). In the 20th century, breeding focused mainly on productivity, which often harmed health, fertility, and longevity (Oltenacu & Broom, 2010). Over the past 20 years, balanced selection for both production and fitness traits has gained importance for economic, environmental, and social reasons (Miglior et al., 2017). Healthy, resilient animals improve welfare, reduce inefficiencies, and support sustainable systems (Brito et al., 2021).

CONCLUSION

In conclusion, the continued advancement of livestock breeding requires a balanced approach that integrates productivity with animal welfare, health, longevity, and environmental efficiency. Strategic heifer management, the informed use of reproductive technologies, and data-driven decision-support tools are essential for maximizing economic gains while ensuring the long-term sustainability and resilience of farming operations.

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CARCASS TO CONSUMER: UNDERSTANDING MEAT EVALUATION FOR BETTER MARKETING

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In this session we will discuss live animal evaluation comparing breeds, feeding methods and length of time to a “finished” product and how to tell what the finished animal should look like. We will try to discuss beef, pork, lamb and goat, but will mainly concentrate on beef for all discussions.

We will go over how to evaluate the finished carcass, what to look for compared to your end customer’s use.

Quality grading of meat will be demonstrated and explained using fresh meat and photos. USDA grading and yield guidelines will be explained.

Marketing will be discussed from general sales to direct to consumers. This will include variations in cutting of the animal.

Specialty Crops

SPECIALTY VEGETABLE SEED AS A CROP

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Producing seed for on-farm use, to sell to a seed company, or the many uses in between may be a path to diversification for specialty crop growers. Growing crops to full maturity and then harvesting seed is in many cases surprisingly easy and has the bonus of being quite rewarding if you enjoy working with plants through their complete life cycle.

There are a few crops that are quite easy to start the seed saving journey with, both because growing the seed is relatively simple and because there are many popular open pollinated varieties available. From a genetic perspective lettuce is amongst the easiest because all varieties are open pollinated. Horticulturally, starting with a crop that is already grown to full maturity will be simplest. Tomatoes, peppers, and melons are classic examples. From there, another question might be whether there are crops that you use a lot of seed of, such as baby greens, or whether there are open pollinated crops you struggle to find seed from, such as a rare local heirloom tomatoes. For this presentation we will use lettuce and tomatoes as examples.

Knowing how you plan to use the seed you produce is a key first step, not just financially but also in creating isolation distances for your seed crop. If you plan to harvest seed for yourself, you may be able to tolerate 5% off-types. If you sell to a company, you are expected to produce absolutely pure seed and will need to follow the isolation distances specified in your seed contract.

Tomato seed production:

Tomatoes will largely self-pollinate because of their flower structure, but bees may move pollen from flower to flower, resulting in around 5% of fruit being off-type if you are growing different varieties in beds next to each other (1). Commercial contracts will require growers to keep different varieties between 160 and 320 feet apart, depending on the variety and the conditions. These isolation distances ensure no cross-pollination.

Tomato seed is extracted from fully ripe fruit in a variety of ways. If you only want to save a few hundred or even a few thousand seeds, the easiest way is to cut the fruit into pieces and scoop out the seed and surrounding jelly. This mixture can be fermented in a small, ventilated container for around three days at room temperature to separate the jelly from the seed, which will fall to the bottom of the container. Water can be added repeatedly to float (decant) the lighter organic material out and leave clean seed. After air drying in front of a fan, seed can be stored as usual for 4-5 years. If processing larger amounts, whole fruit may be macerated in bins, fermented, and screened to remove pulp and separate seed. Mechanical maceration and separation is accomplished with machines such as the Millet wet seed extractor.

Lettuce seed production:

Lettuce is a naturally self-pollinating crop and seed can be saved from adjacent beds for on-farm use with little self-pollinating. Seed companies may require 20 feet of isolation between varieties. Lettuce seed is produced by allowing lettuce plants to bolt and go to seed, a process that takes an additional 45 to 60 days beyond harvest maturity. For this reason, plantings destined for seed are often planted very early in the season. As plants bolt air circulation is important. Plants should be thinned so that there is air movement around the entire flower stalk, 1-2 feet depending on the variety. This can be accomplished by planting seedlings further apart or by harvesting some plants for food at regular maturity. Lettuce flowers and developing seed benefit from being protected from precipitation, making tunnel production ideal if possible. When seed is mature small white “feathers” will appear. Plants can be bulk harvested by cutting the entire flower stalk when 50% of seed is mature and “feathered”, and moved to a warm and dry location with good air movement to complete dry-down. Seed can be extracted by knocking plants into a tote upside down, stomping on plants in a bin, hand threshing (rubbing), or using a mechanical thresher. Lettuce plants produce latex which is quite irritating, and proper PPE includes a dust mask and close-fitting eyewear such as safety glasses.

Dry seeded crops like lettuce are run through screens to remove pieces of leaf, flower, and stem which are larger than the seed. They may then be winnowed using natural wind, a box fan, or equipment such as a Winnow Wizzard to remove chaff that is of similar size but lighter weight than the seed. Lettuce seed will keep for 2-4 years.

Many other seed crops including brassica greens will readily produce seed in a single growing season. Some crops such as cabbage, carrots, beets, and alliums are biennials and require two years to make seed. Starting with simple annuals is a great path to producing some seed for on-farm use and determining if seed production fits into your systems and is of personal interest.

Excellent resources to learn more include The Seed Farmer, by Dan Brisebois; seed production factsheets on the Organic Seed Alliance website (https://seedalliance.org/all-publications/); and The Organic Seed Grower by John Navazzio.

Agricultural Environmental Issues

SOURCES AND IMPACTS OF SALINITY IN COASTAL SOILS

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Salts are natural components of soil, surface water, and groundwater. While agricultural production generally relies on soluble salts for essential plant nutrients (such as Ca^{2+}, K^{+}, and NO_3^{-}), the accumulation of excessive salts—specifically sodium (Na^{+}) and chloride (Cl^{-})—presents a growing challenge for coastal agriculture. Coastal regions receive salts through various pathways, including atmospheric salt spray, tidal flooding, and hurricane storm surges.

A growing concern is direct surface inundation and groundwater intrusion by seawater. On the Delmarva Peninsula and throughout the Mid-Atlantic, the gently sloping, poorly drained coastal landscape makes these regions highly vulnerable. Combined with rising sea levels, these conditions have accelerated saltwater intrusion and inundation (SWI).

SALINITY CLASSIFICATIONS AND SOIL TESTING

Salt-affected soils are classified using saturated paste measurements, including electrical conductivity (ECe), pH (pHe), the sodium adsorption ratio (SAR), and the exchangeable sodium percentage (ESP). These measurements indicate whether salts are dominated by general soluble salts or specifically by sodium. **Saline soils** are high in salts such as Ca, Mg, and K, while **sodic soils** are dominated by Na. **Saline-sodic soils** exhibit both high salinity and high sodium. While these classifications are based on saturated paste extractions, we can convert regional soil tests values (i.e. Mehlich3 Na) to saturated paste measurements. This includes the following equations:

Class	ECe (dS cm^{-1})	SAR $mmol_c\ L^{-1}$	ESP (%)	pH_e
Non Saline	< 4.0	< 13	< 15	< 8.5
Saline	> 4.0	< 13	< 15	< 8.5
Sodic	< 4.0	> 13	> 15	> 8.5
Saline-Sodic	> 4.0	> 13	> 15	< 8.5

$$\boldsymbol{ECe} = (0.0048 * \text{Mehlich3} - \text{Na}) + 0.068$$

$$\boldsymbol{SAR} = (0.46 * \%Na) + 0.55$$

EFFECTS ON CROP PHYSIOLOGY AND THEIR TOLERANCES TO SALTS

Salinity affects crops through two primary mechanisms: osmotic stress and ionic toxicity. For osmotic stress, salts make it difficult for plant roots to extract moisture. At the seed germination stage, this limits water absorption (imbibition), delaying or halting germination entirely. Ion toxicity is related to high concentrations of any ion, but some are more toxic than others, such as Na or Cl. These ions can accumulate in plant tissues to toxic levels, causing necrosis, leaf firing, and tip burn. Furthermore, the specific ionic composition of seawater leads to nutrient antagonism. Seawater is high in magnesium (Mg2+). In salt-affected soils on Delmarva, we observe that excess soil magnesium competes with potassium (K+) for uptake.

Crop	EC_e (dS m^{-1})	M3-Na (mg kg^{-1})
Orchardgrass	1.5	~299
Corn	1.7	~340
Alfalfa	2.0	~402
Tomato	2.5	~507
Asparagus	4.1	~840
Soybean	5.0	~1027
Wheat	6.0	~1,235
Sorghum	6.8	~1,402
Cotton	7.7	~1590
Rye (cereal)	11.4	~2361

Crops salt tolerances are based on EC_e, where the value predicts where yields will begin to decline. These values come from greenhouse or laboratory studies, so they may not fully reflect field conditions. For example, orchardgrass is highly sensitive to salinity, while cereal rye is considerably more tolerant.

ELEVATION THRESHOLDS AND SALINITY

Along the Delmarva Peninsula, high tides, hurricanes, and storm surges are increasingly inundating fields with brackish or saline water. Field EC mapping allows us to estimate sodium levels and assign salinity classifications across affected areas. Grain crop production typically begins to decline when soil Na reaches around 234 ppm, and reduced plant growth is often observed as far as 3 feet above the tidal high-water line. The lowest portions of fields—those most frequently flooded—are commonly classified as saline-sodic, and these zones generally do not respond to gypsum amendments. Because drainage options are limited along wetland margins, reducing salinity in these areas will continue to be a significant challenge.

POLLINATOR CONSERVATION FOR FARMERS

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Pollinating animals, including bees, butterflies, bats, and beetles, are keystone organisms that are responsible for the reproduction of almost 90% of the world's flowering plants and about 35% of all crops[1,2]. The economic value of insect pollination has been estimated at over $27 billion in the U.S. per year, and over $217 billion worldwide. While a percentage of that can be attributed to managed honey bees (*Apis spp.*), which are non-native to the Americas, the 4,000 species of native bees in the United States play a significant, often overlooked role[3]. Native bees, for example bumblebees (*Bombus spp.*) and mason bees (*Osmia spp.*) have been shown to increase production of many crops, for example, tripling the production of sungold tomatoes and increasing fruit weight and seed set in apple orchards[4,5]. Native bees play a vital role in producing the food which provides many of our vitamins and minerals, such as cucumbers, squash, blueberries, and cranberries, and are crucial for many seed and forage crops.

However, it is well documented that pollinator populations are in decline worldwide. Estimates suggest that over one fifth of all North American pollinating animals and at least 28% of bumblebees are at risk of extinction[6,7]. In general, it is estimated that over 40% of all insect species are at risk of extinction, with intensive agricultural development and practices such as pesticide use driving these declines[8] . Habitat loss due to other types of development, climate change, and disease also pose a threat to invertebrate populations. This means we need to act now to prevent losses that will have cascading effects on biodiversity and the food systems we rely on.

Luckily, there are many opportunities for creating habitat and implementing practices that help to support pollinator populations, especially on agricultural lands. The Xerces Society is a non-profit organization that works to conserve invertebrates. In the Pollinator and Agricultural Biodiversity Program at Xerces, we focus on conserving pollinating invertebrates on working lands. In New Jersey alone, about 80% of land is privately owned and almost 16% is farmland, which creates an opportunity for landowners and farmers to make management decisions to conserve and support native pollinator populations.

Xerces has a 20-year relationship with USDA Natural Resource Conservation Service (NRCS), which provides important financial assistance for wildlife using Farm Bill funds. As Partner Biologists providing support from NRCS field offices, we assist with pollinator habitat evaluation, enhancement, and protection in and around farms, and work together with landowners to implement these practices. Creating and protecting native pollinator habitat has the benefit of conserving biodiversity while also improving agricultural productivity through pollination services. Not only do these practices protect pollinators, but they also support the diversity of other beneficial insects. Parasitoid wasps, predaceous beetles and spiders will use this habitat as well, and provide free pest control services.

Pollinator habitat encompasses several elements, including pollen & nectar, nesting & overwintering habitat, and protection from pesticides. Identifying, recognizing, and protecting existing nesting, overwintering and foraging habitat is one of the first steps during a site evaluation. A Xerces biologist helps to identify the gaps in pollinator resource availability which are most urgent to address to help ensure the full life cycle needs of the important pollinators on a farm. Then, these habitat enhancements and protections can take several forms.

One option is to establish diverse native flowering perennial plants from seed in old cool-season pastures or crop fields. Conversion of unused or unproductive fields into a native meadow has the potential to create acres of valuable pollinator habitat, with minimal maintenance needed once the plants are established. For smaller areas, or to diversify an existing habitat, we may recommend planting with herbaceous plugs which help to complete a particular missing habitat element. In the northeast, trees and shrubs are particularly important early-season spring pollen and nectar sources, and we strongly recommend including pollinator attractive trees and shrubs to create or diversify existing hedgerows, and to consider the health, resilience, and diversity of forested areas on your property. If you have a field that is only available for a short-term planting rather than a permanent meadow conversion, seeding a pollinator-attractive covercrop, such as buckwheat, will boost the amount of pollen and nectar available on your farm, while also suppressing undesirable weeds and preventing soil erosion.

When adding plants to create pollinator habitat, either with seeds or live plants, we recommend sourcing straight species of native plants from local ecotypes whenever possible. These are the plants that are adapted to survive in an area, and will provide food for the native, naturally occurring pollinators that have evolved alongside them for tens of thousands of years. Some native bee species are specialists, relying on just one single species of plant to feed on in order to survive and reproduce, while other bees have more of a generalist diet. Creating pollinator habitat also requires season-long blooming resources, to support the full diversity of bees and butterflies that are active at different times during the spring through the fall. We recommend planting at least three species that bloom per season, and to include a wide range of plant families, flower shapes, and colors, to ensure there will be forage for a wide range of pollinators.

Exposure to pesticides is one of the biggest threats to pollinator populations as well as other wildlife so limiting or eliminating pesticide use and sticking to wildlife-friendly pest management practices will make a huge impact. Pollinators also need safe places to rest and lay their eggs to rear new generations. Many people are not aware that most bees don’t live in beehives, but are solitary and make individual nests to lay just one or a few eggs. About 70% of bees nest in the ground in tunnels they build in bare soil. The rest are cavity nesters, and tunnel into dead wood or hollow stems for shelter and to lay their eggs. Leaving snags, dead and downed wood, brush piles, and bare soil provides that much needed nesting habitat for a variety of native bees.

Because of their importance and the threats they are facing, native pollinator and invertebrate conservation should be considered a priority when it comes to land-management decisions. Each farm is unique and opportunities for pollinator habitat will differ based on the available space to convert to pollinator habitat, available equipment, current vegetation and weed or invasive species pressure, other resource concerns like soil health or stormwater management, as well as aesthetic desires. If you are interested in adding pollinator habitat, you may be eligible for financial assistance for plant material or seeds. Please reach out to your local NRCS field office to explore your options!

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AGRICULTURAL PLASTICS AND PESTICIDE CONTAINER RECYCLING IN NEW JERSEY

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The New Jersey Pesticide Container Recycling Program, administered by the New Jersey Department of Agriculture's (NJDA) Division of Agricultural and Natural Resources, provides licensed applicators and governmental agencies with a statewide mechanism for recycling pesticide containers. The program currently operates three container collection sites across the state, and is offered to agricultural, professional and commercial pesticide applicators who hold a valid NJDEP applicator license. Other entities that qualify for program participation also include state, county, and municipal government agencies. As an incentive for program participation, licensed pesticide applicators can receive one CORE credit once annually for container drop-off.

To obtain the CORE credit, applicators must fill out a "Course Attendance Form" at the time of container drop-off. Applicators must provide their name, applicator license number, and date of birth. Completed forms are retained at the collection site, with the office administrator, until they are collected by NJDA personnel and submitted to the New Jersey Department of Environmental Protection (NJDEP).

Pesticide container recycling occurs from April through October at three collection sites:

Atlantic County
Helena Chemical Company
66 Route 206
Hammonton, NJ

Monmouth County
Rutgers Fruit and Ornamental Research Extension Center
283 Route 539
Cream Ridge, NJ

Salem County
Helena Chemical Company
440 N. Main Street
Woodstown, NJ

The annual collection schedule is released each March through the following outlets:

- Rutgers Plant and Pest Advisory - https://plant-pest-advisory.rutgers.edu/
- NJDA Facebook page - https://www.facebook.com/NJDeptofAgriculture/
- The Gardener News (print and online) - https://www.gardenernews.com/
- State and County Boards of Agriculture
- County Agriculture and Development Boards

Container Preparation Requirements
Only pesticide containers bearing the #2 high-density polyethylene (HDPE), are accepted. Containers up to 55 gallons are accepted. Volumes of 5-gallons and up will require processing (consolidation) prior to drop-off. 5-gallon containers cut in half; 30-gallon = cut into quarters; 55-gallon cut into eight pieces. Those containers, less than 5-gallons, must have either a 6-inch slit, or ¼-inch hole at the bottom. All containers must be triple-rinsed, emptied, and free of pesticide residue, particularly around containers' mouth and neck (staining is acceptable). Triple rinsing rinsate should be added to a sprayer, rather than down a drain. Foil seals and EPA labels should be removed.

Program Expansion
For the 2026 season, NJDA anticipates adding two new collection sites in Mercer and Morris Counties, with details forthcoming. Additional NJDEP Continuing Education Credit (CEU) opportunities may also be available at the Monmouth County site. Looking ahead to 2027 and beyond, NJDA plans to identify ways to expand collection for other agricultural plastics, including high tunnel films, weed barrier fabrics, and drip irrigation tubing.

Other Plastics
Other agricultural plastics such as pots, trays, hanging baskets, and tags can currently be recycled through retail programs at major home improvement stores, such as Lowe's or Home Depot.

For more information, please reach out to:

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