Pollination and Yield Enhancement for High Tunnel Tomatoes

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The Problem: I have been growing high tunnel (HT) tomatoes in Maryland for the last 10 years and something that I noticed is that there are always a great deal more flowers than tomato fruit that develop from those flowers. Usually a cluster consists of 5-6 flowers, but only 2-3 develop into fruit (the overall average is between 40-60% of flowers into fruit). Figure one shows 3 clusters growing closely together that consisted of 18 flowers that developed into only 7 fruit. The flowers you see in the picture did not develop into fruit. This does not happen just to HT tomatoes but also to field grown tomatoes. Much of this fruit deficit is due to poor pollination and fruit set. Tomatoes are usually self-fertilized with their pollen being well hidden. It takes some decent wind or a bumble bee to come along and vibrate (known as buzz pollination) the tomato flower in order for the pollen to be released. In the field this can be accomplished by the action of wind or by insects visiting the tomato flowers. But in a HT that may be closed up during the early flowering period of tomatoes because it is overcast and cool it is much more difficult to get the needed vibration for the flower to be pollinated. But even if the sides of the HT are up it can still be difficult to get enough air movement into the center of the HT to have effective pollination. So I was looking for a simple easy method of increasing pollen release from tomato flowers to see if that increased the number and or size of tomato fruit being produced and if it did could the plant support nutritionally the increase in tomato fruit (measured as fruit quality). The way in which I enhanced pollination and fruit set was by using a leaf blower, yes a leaf blower.

Methods: I conducted this study for 2 years. The first year of the study only one HT was used while in the 2nd year 2 HTs--i.e., HT-A and HT-B, were used. One HT was on the eastern shore while the other was on the western shore. I’ll be reporting only on the 2nd year of the study as it shows the same results as the first year and I was able to reduce the number of variables I was looking at after the first year. Four different cultivars of tomatoes were used in both HTs, 2 hybrids (Mt Fresh+ and Crista) and 2 heirlooms (Cherokee Purple and Big Beef), I used a Craftsman 235/150 mph electric blower (fig 2). An ‘enhanced pollination treatment’ consisted of taking the leaf blower and placing it on low (150 mph) with the end of the blower 2-3 ft from a plant moving it back and forth and up and down concentrating the movement in the area of the flowers. Plants were treated either 0, 2, 4 or 6 times a week and for either 0, 5, 10, or 20 seconds with the blower. Treatments started 5-days after the first flower cluster appeared and were treated for 4 weeks. There were 4 replications of each treatment, 4-5 plants per rep.
Results: Overall 2015 was a good year for HT tomatoes in these trials. The average for the 4 tomato cultivars in each HT will be examined first. At both HT sites - A and B using the leaf blower at least 4 times a week resulted in significantly greater fruit set (fig 3) and yields than not enhancing pollination (Tables 1 and 3). The pollination enhancement increased yields by 44% in HT-A and 60% in HT-B vs. the control. The percentage of culls was significantly reduced when tomatoes were treated 4-times a week in HT-B and when treated 2, 4 and 6 times a week in HT-A. Average fruit size was significantly greater when pollination enhancement techniques were used for 2, 4 or 6 days a week vs no enhancement in HT-A and HT-B (Tables 1 and 3). There was at least a 40% increase in the average fruit size in both HTs when plants were treated for 4-days a week vs when they were not treated at all. There was no significant difference between a plant being treated for 5 secs vs being treated longer (Tables 2 and 4). Treating a plant for 5, 10, or 20 seconds resulted in a significant yield increase compared with not treating the plant at all. As far as cultivars are concerned the 2 hybrids did better--responded more favorably to the pollination enhancement technique compared with the two heirlooms. The two hybrids had a yield increase of ~60% vs no enhancement while the heirloom cultivars had yield increases of ~40% vs no enhancement techniques. High tunnel B generally had better yields than high tunnel A, but they were not significant.

Discussion: Overall yields were good in these two HTs compared with previous seasons. Normally I would have expected 19.6 lbs/plant in these HTs, but instead got 21.8 lbs per plant. Research in the eastern United States has demonstrated that the yield per plant from a HT tomato should be between 20 and 30 lbs per plant. As you can see I was at the bottom end of this range with an average of 19.6 lbs/plant. The average increased to as much as 33.7 lbs per plant with the pollination enhancement technique. It would seem that the low end of the scale that I was at before was mostly due to poor pollination in these HTs. By enhancing the pollination I was able to increase my yields by as much as 72%. The pollination enhancement technique also improved fruit quality by reducing the percentage of culls and increasing the average size of fruit (fig 4). This also demonstrates one of the concerns I had about the technique in that if fruit set was increased and plants were supporting more fruit per plant would they be able to size those tomatoes and would the tomatoes have good quality and the answer appears to be yes to both questions. We did not add any extra nutrients to either HT compared with how we normally fertilize. We may have added a bit more water than we normally do, but this also could be because of the very dry conditions in July. While this technique certainly would not be for everyone it could be utilized very easily in a HT and be carried out by just about anyone that can hold and point a leaf blower. The plants would need to be treated for 5-10 seconds at least 4 times a week for there to be a good possibility of yield and quality enhancement. Treating the plants longer than 20 seconds ended up decreasing yields compared with doing nothing (data from year 1). Plants could undergo this enhancement technique in the early part of the season when the HT sides are often down. This technique did appear to work better on the first 8-10 fruit clusters the plant produced vs using the technique on later fruit clusters. This technique should not be used if your HT tomatoes are low in any nutrient by the first harvest or you often have fruit ripening problems with later harvests.
Employing Marigold as Part of a Push Pull Sting Operation to Subdue the Mexican Bean Beetle

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Introduction

Lima bean growers deal with a diversity of crop pests (e.g., insect gangs, plant diseases, etc.) and must rely mainly on synthetic weapons for their survival. Integrated Pest Management (IPM) strategies developed for dealing with pests impacting lima bean are not always practical. For instance, growers interested in IPM are generally told to stake out their fields and act before pests reach economic injury levels (EILs). The EIL is the pest population at which the cost of reducing their population is equal to the loss of revenue due to their presence. Unfortunately, variation observed in yield-loss estimates hinders our ability to establish consistent EILs for pests inhabiting bean crops. Some of these issues may be overcome by using tactics that center on pest prevention as opposed to reactionary measures.

A notorious insect gang in bean crops is the MBB (a.k.a. Mexican bean beetle). The MBB established themselves in Mid-Atlantic States in the 1920’s, and their relentless appetite for destruction brought carnage to many bean fields. By the early 1990’s, the MBB was rampant in bean habitats throughout the US and became recognized as one of the most important economically debilitating insect gangs. The MBB continues to be a serious threat and destroyer of lima and snap bean fields in some areas. In some Northeastern states, MBB reaches dangerous levels regularly during the growing season; and at high populations will totally defoliate bean plants if effective and timely intervention is not taken.

In 2014, four former law enforcement experts were asked to rejoin the force for a temporary assignment to deal with a pocket of MBBs trying to get a foothold in lima bean producing areas in Delaware. There was fear that once established in Delaware they would expand their operation to the state of Maryland and shake down lima bean producers on the eastern shore. Former Detective Alan Leslie was reluctant to leave his job as a lactation analyst and part time professional snuggler for such a dangerous assignment. Eventually the Governors of Delaware and Maryland granted Detective Leslie a temporary license so that he could continue his work as a part time snuggler in their states until the assignment was completed and/or he was killed in the line of duty. Former Agent Kelly Hamby, who was known on the force for her sensitive handling of relatives whose deceased love ones were victims of crime, was the CEO of a very successful professional mourning business in the state of California. Former Deputy Chief of the Wilmington Delaware Police Department, Joanne Whalen, could not be directly involved in the assignment as she felt it conflicted with her new position as the Delmarva Peninsula Sunday School Superintendent. Thus, she was hired as a MBB onsite consultant and limited her duties to those of a desk officer. Former Inspector Cerruti Hooks had recently started his pet funeral business where he proudly displayed his modified black Mini Clubman Pet Hearse and was leading a funeral possession for a famous dog film star when he got the call for the assignment.

The Plan

While reviewing files on the MBB, the team of misfit investigators noted some weak links that they felt could be exploited. Early investigations of the MBB showed that they preferred shaking down snap bean operations over lima beans, and that wax snap beans were their most preferred snap bean. Additional investigations uncovered the fact that MBB did not like operating in snap bean habitats neighboring French marigold. Based on this information, the team of investigators felt they could set up a trap for the MBB. They called their plan O.P.P. not after the Naughty by Nature hit song but for Operation Push Pull. Push-pull is a pest management tactic in which pests are repelled (pushed) from the main crop by using stimuli that mask the crop or act as a repellent; and concurrently lured (pulled) to an attractive stimulus such as a trap crop. For this particular operation, the investigators felt that French marigold could be used as a repellent “push” and wax beans as a trap crop “pull” plant. To their knowledge, the push-pull tactic had never been evaluated for its potential to subdue MBB. Their ultimate goal was to develop an effective ecological solution to end the threat imposed by the MBB. Former Deputy Chief Whalen was reluctant to endorse the plan as she felt it was borderline entrapment but after meeting with the district attorney, she was satisfied that...
O.P.P. was a legal maneuver that would hold up in a court of law and thus gave the plan her blessing.

To test their plan a sting operation was conducted at the University of Delaware Research Farm in Newark, DE. They decided to target the MBB in Newark because residents and owners of lima bean fields in the town of Newark have complained about increased activity from MBB. The field plan they devised consisted of two treatments: 1) Lima bean monoculture planting and 2) lima bean inter-planted with marigold and bordered by two rows of wax beans (push-pull) (Figure 1). Thus, lima bean served as the main cash crop, marigold the repellent plant, and wax bean the trap crop. Each treatment was replicated four times and arranged in a randomized complete block design. One of the concerns was that if the plan worked too well MBB may overrun the wax bean trap then double back and wreak havoc on the lima bean. In anticipation of this, the plan included spraying the wax bean trap with an organic product known as Azera to suppress their numbers as needed. This product had been evaluated earlier by two MBB rivals, Galen “Graffiti” Dively and Terry “Body Chalk” Patton, who have been battling MBB over control of the lima and snap bean trade in central Maryland for over a decade.

How it went down

Once the stage was set, direct visual counts and sweep net samples were used to quantify MBB and some of their rivals (natural enemies) on lima bean and the wax bean trap crop. Mexican bean beetles were counted according to their life stage (eggs, larvae, and adults). Bean plants in each plot were searched at 7 day intervals once MBB were spotted continuing until final harvest. Yield data was taken on the lima and wax bean plants and for lima yield included a fresh and dry harvest. At this time, we are still going through tape and entering data to determine the success of O.P.P. One official familiar with O.P.P., who spoke on condition of anonymity because they were not authorized to speak, indicated that preliminary findings from a team of Forensic and Crime Scene Investigators suggest that immature MBBs (larva + pupa) were more prevalent on border rows of each treatment plot as opposed to the internal rows of bean plants. Additionally, more immature MBBs were found on wax bean as opposed to lima bean border rows. It is unclear at this time what role, if any, French marigold played and because the team is still in the early stage of the investigation, any conclusions will have to wait for further/complete analysis. Later it was determined that Officer Hanna Kahl leaked the information to the editor of the Vegetable and Fruit Headline News. She was terminated from the force and is now a mixed martial artist, who competes as a Strawweight in the Ultimate Fighting Championship (UFC). She dreams of one day becoming a Bantamweight and defeating Ronda Rousey, and has stated that Ronda’s armbar is no match to her windmill fighting style.

Funding for this investigation was provided via a Northeast IPM partnership grant entitled “Multitasking marigold to strengthen organic IPM in lima bean and other bean crops”. The award and sub-award number for this project are 2014-70006-22484 and 73984-10398, respectively.

Red Clover as Living Mulch:
A Pollinator & Natural Enemy Haven

By Hanna Kahl and Cerruti R2 Hooks*
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Red clover is a widely adaptable and durable cover crop that has the potential to grow in most climates (Fig. 1). Since red clover is a short-lived perennial, it has a longer growing season than annual clovers. This allows for its many benefits to extend over a longer period.

It grows in dense mass-flowering mattes and if mowed or cut rapidly regrows. Red clover’s prized ability to provide fodder for livestock, add nitrogen to the soil, suppress weeds, and decrease erosion has made red clover a favorite cover crop. Many farmers who grow red clover in otherwise fallow fields plow it under or spray it with an herbicide prior to planting the cash crop. However, using red clover as an inter-planted living mulch is less common (Fig. 2). Yet, if allowed to grow continuously as a living mulch, some of the aforementioned benefits can be sustained over a longer time period. In addition, red clover can serve as a paradise for pollinators (Fig. 3), provide a home for natural enemies (Fig. 4), and serve as a natural butterfly garden. By inter-planting red clover with a main crop, you can possibly reap greater rewards from its presence.

Figure 1. Red clover.
This year, I am comparing green bell peppers interplanted with red clover living mulch to bell peppers grown without a cover crop (monoculture) in western Maryland. Throughout the summer, pest, natural enemy, and pollinator assemblages were monitored by visual observation of pepper plants, collection with bee bowls, and sweep net samples. Currently, pepper fruits are being harvested and rated according to quality, size, and damage. It is hypothesized that the red clover will result in increased pollinator visitation and natural enemy recruitment, resulting in increased yield compared with monoculture pepper plots.

Although bell pepper flowers can self-pollinate, they can benefit from increased pollinator visits. Greenhouse studies have shown that peppers with bee visits produce larger, heavier, and better quality fruits than peppers grown without bees and peppers that were hand-pollinated. Several crops depend on pollinators to produce fruits. Luckily for us, there are several wild pollinators such as bees, butterflies, and certain flies that enthusiastically and efficiently do this job for free. In helping to produce our food, these native pollinators get food in return from nectar and pollen found in flowers. However, pollinators are struggling nationwide due to a combination of factors including pesticides, disease, loss of habitat and floral resources, and climate change. Hence, crops are sometimes inadequately pollinated. Pollinators may need an extra enticement to visit flowers of crops, especially those that are not rich in pollen or nectar. Red clover is a feast of pollen and nectar for pollinators and natural enemies. By inter-planting red clover with bell pepper, we hope to lure wild pollinators to these plots, and subsequently increase their visits to bell pepper flowers inducing better fruit set. This year, several pollinators were observed visiting red clover flowers including bumble bees, carpenter bees, leaf-cutter bees, silver spotted skippers, and sulfur butterflies. Pollinators were rarely observed visiting monoculture pepper plots. However, further analysis is needed to determine whether bees drawn to the red clover were also drawn to bell pepper flowers and contributed to fruit set.

Bell peppers could benefit also from natural enemies, such as predaceous insects and other arthropods such as spiders, which eat insect pests (Fig. 4).

Similar to humans, natural enemies prefer to have a “roof” over their head. In this case, the red clover canopy could serve as a roof or shelter and subsequently harbor more natural enemies. Previous research found that eggplant grown with crimson clover had a greater proportion of generalist predators to insect herbivores than eggplant monoculture. Having increased natural enemies could reduce pests such as the brown marmorated stink bug that would otherwise damage peppers (Fig. 5). Natural enemies regularly found in bell
pepper plots this year included spiders, long-legged flies, hoverflies, damsel bugs, assassin bugs, and ladybugs. Alternatively, red clover can serve as a trap crop for some insect pests and subsequently attract them away from the pepper.

During the study, monoculture plots appeared to have experienced greater early season cutworm damage and late season damage by European corn borers. However, pepper fruits in red clover plots suffered greater stink bug damage. Further data analysis is needed to verify these casual observations. Next year further studies will be conducted to evaluate the use of red clover living mulch to promote pollinators and suppress pests in cucumber. Most cucumbers, similar to other cucurbits, rely entirely on pollinators to produce fruit. Thus, increasing pollinator visitation to this crop is especially relevant. In summary, before plowing under the entire field of red clover, consider allowing strips of it to remain as a living mulch to serve as a haven for wild pollinators and natural enemies and a butterfly garden for you and your family to enjoy.

### Using Cover Crops, Strip-Tillage and the Stale-Seedbed Method as Part of an Integrated Weed Management Program in Vegetables

Peter Coffey, Lauren Hunt, and Cerruti R Hooks

Conventional and organic farmers alike do not like weeds growing in their vegetable fields. Peter Coffey intends to explore sustainable weed management techniques that are adaptable by both conventional and organic producers to mitigate weed problems. He understands that managing weeds effectively during the growing season is critical for maximizing vegetable yields. Herbicides can be helpful when used judiciously as part of an integrated weed management (IWM) program, yet herbicides are not effective on all weeds. There is a limited selection of herbicides registered for use in vegetable fields, and for organic vegetable production the list is even shorter. Furthermore, as weed species become resistant to various classes of herbicides, this tool is becoming less dependable.

Organic producers, unlike their conventional counterparts, typically don’t use herbicides but rely heavily on tillage, cultivation and hand weeding to manage weeds in their vegetable fields. Tillage, which disrupts the soil community and reduces soil health, is the most energy-consuming task among all field operations. Conventional tillage practices perpetuate weed problems by burying weed seeds throughout the soil matrix. In reduced-tillage (RT)/minimum tillage (MT) systems, most weed seeds remain at or near the soil surface where they are more susceptible to weed seed predation and where the weeds might be remedied with stale-seedbed methods. The stale-seedbed method is executed by preparing a field and delaying crop planting to allow weed flushes that can be killed just before planting the cash crop. If killed with slight soil disturbances, the weed seedbank in the upper few centimeters of the soil will be depleted, restricting weed germination after the ensuing crop is planted. Although RT offers many environmental friendly benefits, a major compromise to operating under less tillage for organic producers is loss of weed control. Moreover, yields under RT may not be comparable with conventional tillage (CT) practices if weeds are not adequately suppressed.

By integrating several integrated weed management tactics, Peter hopes to create a truly IWM program for vegetable producers that will help them lose most of their dependency on herbicide sprays and/or tillage. His project revolves around planting winter cover crops, which he then terminates in the spring by using a flail mower. Most of the cover crop residue is allowed to remain on the soil surface as organic/hay mulch until it breaks down. The mulch helps suppress weeds by behaving as a physical barrier to block light and prevent weed seed germination. However, if properly managed, cover crops can contribute more farm services during the growing season, including: conserving soil moisture, supplying organic matter and plant-available nitrogen and attracting weed seed predators.

In addition to using cover crop residue as a weed management tool, Peter is investigating a RT practice known as strip-tilling in combination with the stale-seedbed method.

Strip tilled beans planted into winter rye cover crop.

Strip-tilling involves tilling narrow zones in a field that will serve as crop rows while leaving the ground between rows undisturbed. Strip-tilling has been proposed as an alternative to no-till in instances where residue cover within the crop row lowers soil temperature which slows the growth of the crop consequently reducing yield or hardpan development is a concern.

Peter’s experimental plan includes preparing strip-tilled zones with a two-row strip-tiller, two to three weeks prior to crop planting, consequently allowing weed seeds buried in the crop rows to germinate and then, using the stale-seedbed technique, killing them with a banded organic herbicide application. For organic growers, the
use of organic herbicides is more economically feasible when the spray is limited to a narrow zone, rather than used over the entire field. However, some may question whether the stale-seedbed technique is really needed for fast growing cold tolerant vegetables such as lima beans. Solanaceous vegetable crops such as eggplant and pepper grow slowly under cool spring temperatures but beans -especially lima beans- are more adaptable to cooler temperatures. Thus, if lima beans are seeded just after strip-tilling, they may be able to germinate and cover the soil surface. In doing so, this method may prevent significant weed seed germination and establishment without the aid of the stale-seedbed method. Four integrated tactics (cover cropping, flail mowing, strip-tillage, and the stale-seedbed with a banded herbicide spray) were evaluated for their weed suppression potential in lima beans, which included determining whether the stale-seedbed method is necessary if lima beans are planted within 24 hours of rows being strip-tilled. Peter hypothesized that this integrated strategy could have a synergistic effect on weeds while reducing overall management cost compared with conventional tillng methods or total field application of herbicides. Still, other tools, such as adjusting crop planting time or seeding rate, using narrow row spacing, crop rotation, clean crop seeds and agriculture equipment, managing weeds outside the crop field, growing superior crop cultivars, etc., are all needed to optimize weed management. As such, it is recommended that management strategies, such as those Peter is investigating, should be promoted as additional tools for use in a truly IWM program.

**Abbreviated methods.** In 2013, an experiment with a split plot design layout was initiated at the Upper Marlboro research facility to investigate the use of strip-tilling and the stale-seedbed technique to manage weeds in lima beans. Cover crop treatments included rye (R), crimson clover (CC), or a no cover crop check (C). Cover crops were planted in the fall of 2013 in a field that previously consisted of field corn. Thus, all treatment plots contained corn residue and stalk stubbles that remained after corn harvesting. The subplot treatment included the stale-seedbed with herbicide spray (H) or no herbicide (NH) spray. Each treatment was replicated four times. In the spring of 2014, each treatment plot was flailed mowed and strip-tilled, and half of each plot (H subplots) subjected to the stale-seedbed method. A citrus-oil based organic herbicide was applied in the strip-till rows as part of the stale-seedbed method in H subplots prior to seeding the lima beans.

**Findings and discussion.** Although the data has yet to be analyzed, it is noted that the field selected for conducting the study had limited weed pressure during the lima bean growth cycle and thus it is anticipated that there may not be a significant treatment effect on yield. Prior to the study, the field site consisted of a soybean-corn rotation in which weeds were managed with a combination of pre- and post-emergent herbicides. These findings may reiterate the importance of using crop rotation as part of an IWM program for vegetables. However, it is important to note that crop rotation for weed management involves more than just rotating a different crop in each field from one season to the next.

An IWM program includes a more elaborate crop rotation commitment which includes alternating: 1) crops with different type of vegetation, 2) grass and dicots, 3) crops with different cropping cycles, 3) poor and high weed competitors, 4) vegetable with agronomic crops, and 5) avoiding succeeding crops of the same family. If the study site had been planted in vegetables the prior two seasons, it is most likely that the weed populations would have been much more severe during the study. **This particular project and resulting extension activities were supported by a Maryland Agriculture Experiment Station (MAES) grant and USDA NI FA El PM grant award number 2013-41534-21512.**

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2015 Spotted Wing Drosophila Adult and Larval Monitoring

By Kelly Hamby
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Spotted wing drosophila (SWD) adults and larvae were monitored weekly at two central Maryland diversified farm sites from May 14 to October 8, 2015. Adults were monitored using the Pherocon*SWD trap with the 2015 Trécé SWD lure and apple cider vinegar (Figure 1). The apple cider vinegar was replaced weekly and the lures were replaced every 6 weeks. Three traps were placed in each fruit planting [cherries (tart at one site, sweet at the other), blackberries, blueberries, red raspberries (fall bearing), and strawberries], prior to ripe fruit being present at each site. Strawberry traps were removed when beds were renovated after harvest and red raspberry traps were not deployed until the trellis system was up. When ripe fruit were available fruit were sampled for larvae from three locations in each fruit planting and a sugar water flotation method was used to extract the larvae (see Vegetable and Fruit News article “Spotted Wing Drosophila Fruit Monitoring” for more information on this method). Larvae were reared out in the laboratory on media to confirm that they were SWD. For blueberries and raspberries (red and black) ten fruit were taken from each location. For cherries, strawberries, and blackberries five fruit were taken from each location. As

![Figure 1. SWD adult trap.](image-url)
much as possible fruit were collected at “market” ripeness, which means that fruit that appeared fully ripe and undamaged were selected. At the beginning of the harvest period fruit samples may have been under ripe and at the end of the harvest period fruit may have been overripe or damaged.

As in previous years, mid to late season blackberries and red raspberries experienced the most pressure and damage (Figure 4). Looking at adult trap captures, you can see that the population builds through July and August and that crops that fruit during this period are at the highest risk for damage (Figure 5).

The first larvae were found in site 2 cherries on 6/25 (Figure 3) and the first larvae were found in site 1 cherries on 7/2. Strawberry harvest was finished on 7/2 and early season strawberries escape SWD pressure. SWD first became an issue during commercial blueberry harvest (first larvae found 7/16, population remained fairly low in market ripe fruit until 7/30), with black raspberries and cherries escaping damage during the majority of the harvest season.

At diversified farms it is particularly important to pay attention to SWD populations in pre and post-harvest fruit plantings because these are places populations can build on-farm. Post-harvest cherries that are not managed can be a source of adult SWD, and many SWD were found in post-harvest cherries. Post-harvest cherries were also the only fruit sampled that contained other vinegar fly (Drosophila) larvae. Another source of SWD adults is early season fruit in fall bearing red raspberries. This can be seen with the early season larval counts in fall bearing red raspberries at site 2 (Figure 3).
The earlier populations get out of hand the harder it is to manage SWD and earlier ripening fruit are easier to manage. If you are selecting varieties for new plantings consider planting early ripening varieties. For management recommendations including tables of effective materials see Vegetable and Fruit News article “Spotted Wing Drosophila Management.” Insecticides continue to be the most reliable management option for SWD, and researchers around the country are working on alternative management solutions for SWD. We will be evaluating potential cultural controls in 2016, so stay tuned to 2016 Vegetable and Fruit News for SWD management updates.

The Bee Story: Facts and Answers about Declining Bee Populations

By Galen P. Dively, Emeritus Professor, Department of Entomology, University of Maryland

Quick Facts:
- Insect pollinators have been declining across the US for over 2 decades, according to a 2006 National Academy Science Report.
- Honey bees specifically have been in decline since WW II, with numbers declining from 5 million to a low of 2.3 million in 2007.
- Continued losses threaten the economic viability of the beekeeping industry and have serious implications to pollination services for both cultivated and wild flowering plants.
- Honey bees and native bees pollinate more than 130 commercial crops vital to the US agriculture, amounting to $18 billion in crop production.

CDMS:
Pesticide Labels and MSDS On-Line at: http://www.cdmss.net/
• 1/3 of the human diet comes from insect pollinated plants, and the honey bee is responsible for 80% of that pollination.

• Annual surveys conducted in the US, since the appearance of colony collapse disorder (CCD) in 2006, continue to show consistent losses of colonies exceeding 30%, although the incidence of CCD has declined in recent years.

• Even with loss rates in excess of 30%, the number of colonies managed in the summer each year has gradually increased since 2006. This is explained by beekeepers’ ability to split living colonies to make up lost colonies. In anticipation of heavy winter losses, beekeepers are building their colony numbers over the summer so if they have a 30% winter kill they will still have enough colonies to meet pollination contracts the following spring.

• Consensus among bee scientists is that colony declines are the result of multiple stressors, working alone, in combination, or synergistically to impact honey bee health.

• Stress factors include parasitic mites (predominantly Varroa destructor), pathogens (viruses and Nosema spp.), poor nutrition resulting from loss of foraging habitat, and pesticide exposure.

• Parasitic mites along with multiple viruses they transmit are considered the major cause of bee mortality according to most bee experts.

• Despite lack of evidence implicating pesticides as a major causal factor, beekeepers and many scientists assert that the extensive use of pesticides, particularly neonicotinoid insecticides, has had negative impacts on the health of honey bees and other pollinators. There is growing evidence that native bee pollinators are being negatively impacted by the use of these products.

Questions and Answers

Q1: Has the demographics of the beekeeping industry changed over the past decades?
A: The number of honey bee colonies has steadily declined over the past 60 years from 5.5 million hives in 1950 to about 2.7 million today. Contributing factors include socioeconomic factors, such as lower honey prices, and urbanization, as well as the introduction of honey bee diseases and parasites. However, the number of colonies managed each year has gradually increased over the past decade as beekeepers are splitting strong hives to make up for lost ones.

Q2: Has the rate of colony losses changed from a historical perspective and especially since the occurrence of colony collapse disorder reported in 2006?
A: Prior to the introduction of parasitic mites in mid-1980s, annual colony loss rates were 10 to 15%, which was considered sustainable. After mites were introduced, loss rates increased to 20-25%. Since 2006, the Bee Informed Partnership project (http://beeinformed.org), in collaboration with the Apiary Inspectors and USDA, has conducted annual national surveys of honey bee colony losses (see chart). Commercial beekeepers in the US have seen honey bee colony winter loss rates increase to an average of 30%, although overwintering losses have dropped to around 23% in the past two years. However, total annual losses (42%) including summer losses, are still greater than historical averages. Colony losses also are not consistent across the country, with annual losses exceeding 60% in several states.

Q3: What is colony collapse disorder and has it continued to contribute to colony losses?
A: Colony Collapse Disorder (CCD) is a syndrome characterized by the unexplained rapid loss of worker bees, with no dead bees in or around the hive. The collapsing colony always consists of a small cluster of young workers with a queen in the presence of brood and food stores, which are not immediately robbed by other bees. Other occurrences resembling CCD have been documented as early as 1869 but were given different names, so CCD is not a new phenomenon. Current scientific consensus is that no single factor is causing CCD. Higher pathogen loads, specifically viruses, are associated with collapsed colonies and are thought to be the cause of these symptoms. But what predisposes bees to higher rates of susceptibility remains unknown. Currently, documented cases of CCD have declined and contribute only a minor role in recent colony losses.

Q4: What are the primary drivers of honey bee losses?
A: The scientific evidence based on more than 170 studies present a strong argument that varroa mite, poor nutrition and pesticides are the primary drivers. Of the three, parasitic mites along with multiple viruses they transmit are considered the major cause of bee mortality according to most bee experts. These ectoparasites were introduced into the US during the mid-1980s and have virtually eliminated feral bee colonies in many areas. They feed on the hemolymph of both immature and adult bees, causing decreased body
weight and lifespan, nutritional deficiencies, weaken immune system, and altered cognitive abilities. Viruses transmitted by mites may be responsible for the majority of stress to bees.

**Stress Factors contributing to Bee Declines**

- **Management and Nutrition**
- **Varroa Mites**
- **Pesticides**
  - Secondary Pathogens
  - Viruses
  - Nosema
  - Fungi

**Poor nutrition** is also considered an important contributing factor to poor bee health, especially for commercially managed honey bees. Honey bees require a diverse diet of different pollens and nectar sources. Unfortunately, large-scale agriculture, monocultures and urbanization have resulted in a loss of foraging habitat. This loss has been particularly pronounced in traditional bee states like the Dakotas, where high commodity prices have driven a huge increase the number of acres planted in corn and soybean. These row crops are being planted in marginal lands that once supported forage for honey bees. Field crops produce little if any quality feed for bees, and such restricted diets weaken honey bee colonies and makes them more susceptible to the ravages of mites, pathogens, and pesticides.

The role of **pesticides** has received considerable attention, especially the widely used class of insecticides - neonicotinoids. While these insecticides are relatively safe for humans, especially when compared to the older products they replaced, they are toxic to bees. While several studies have shown sublethal effects of these products, there is no evidence that real world exposures to these produces kills honey bee colonies outright. There is evidence that these same levels of exposure directly affect the abundance of non-honey bee pollinators, such as bumble bees and other wild bees.

**Q5: How are bees exposed to pesticides?**

**A:** Honey bees are exposed directly to pesticides used within the hive by beekeepers to control parasitic mites and pathogens, as well as to pesticides used to control pests and diseases of cultivated plants on which bees visit for nectar and pollen. Primary routes of exposure include direct contact while foraging on treated crops during bloom, exposure to spray residues after heavy dew, and from spray drift on non-crop flowering vegetation. Secondary exposure routes include pesticide residues in contaminated water, treated-seed dusts emitted from air planters during sowing, and residues in plant fluids released by guttation droplets. For the systemic neonicotinoids, residues in nectar, pollen and extrafloral nectaries represent the major route of exposure.

**Q6: What are the major pesticides found in honey bee colonies?**

**A:** Multiple studies conducted in Europe and the U.S. showed that both healthy and unhealthy colonies contained a diverse range of pesticides in pollen, honey, beewax, and bees. In U.S. hive surveys, miticides (fluvalinate and coumaphos) used by beekeepers were the most frequently found, followed by pyrethroids, organophosphates, fungicides (mainly chlorothalonil), carbamates, and herbicides. In a recent study that collected pollen from bee hives in seven major crops, 35 different pesticides were detected with a total residue load ranging from 23.6 to 51,310 ppb from an average of 9.1 pesticides per pollen sample.

Honey bees have probably been exposed to these pesticide loads for as long as pesticides have been used in agriculture. Beekeepers have a long history of experiencing heavy pesticide kills. But these kills have usually been acute and easily identifiable, with 10,000s of dead bees found outside of the affected hives. While acute mortality of colonies still occurs, there is growing concern that exposure to sublethal quantities of pesticides may predispose colonies to other ailments. Quantifying the effects of sublethal exposure from real world field conditions is difficult, and to date no studies has shown conclusive evidence for the role of sublethal exposure to pesticides on colony health. In fact, some studies have shown that residue levels of coumaphos and esfenvalerate were lower in CCD-affected colonies, and expression of genes involved in pesticide detoxification in collapsed colonies was not different compared to control colonies.

**Q7: How are neonicotinoid insecticides used in ways that potentially expose bees?**

**A:** Six neonicotinoids (imidacloprid, thiamethoxam, clothianidin, acetamiprid, thiacloprid, and dinotefuran)
are extensively used worldwide on many crops that require managed honey bee colonies and native bees to attain economic yields. Imidacloprid is also used on home gardens, turf, ornamental shrubs and trees at application rates much higher than label rates for agricultural crops. Neonicotinoids can be applied as seed coatings and soil treatments at planting and also by chemigation, side-dress and drench treatments, or foliar spray during the crop cycle. Due to their systemic activity, they may persist for weeks or months following application depending on the application rate and abiotic conditions. For this reason, residues can move to the fruiting structures of treated plants, and to some extent into pollen and nectar.

Q8: At what levels are neonicotinoid residues found in pollen and nectar?
A: Most residue studies address levels of imidacloprid residues because it is the most widely used. Residue levels change depending on how the product is applied. Imidacloprid has been found at rates of 2-4 ppb in pollen and less than 2 ppb in nectar of seed-treated corn, sunflowers and canola. More recent studies of treated cucurbit crops revealed higher residues of imidacloprid and other neonicotinoids in field-collected pollen and nectar (see Table below), particularly when insecticides are applied as a soil drench or foliar spray closer to flowering. Studies also show that the range of residues found in pollen and nectar are much higher in ornamental plants following soil drench and trunk injection treatments.

Q9: At what levels are neonicotinoid residues found inside honey bee colonies?
A: Residues in bees, bee bread, wax and honey have been consistently lower than residues in pollen collected directly from flowers and also lower and much less frequent than other commonly-used pesticides. The highest levels in pollen collected at the hive entrance have been reported in France, where imidacloprid residues were detected in 40.5% of the samples, with levels ranging from 0.9 to 3.1 ppb. Other studies in Europe reported lower detection frequencies in bee bread and wax, and less than 3% of the pollen samples collected from U.S. colonies contained neonicotinoid residues. In these studies, levels were either below the limit of detection or <2 ppb.

Q10: Can levels of neonicotinoid residues found in pollen and nectar or inside honey bee colonies cause harm to bees?
A: Reported concentrations of imidacloprid in pollen and nectar from seed-treated crops (<5 ppb) are not acutely lethal to honey bees based on dietary LD50 values. However, some studies show residues near to levels that cause sublethal effects in laboratory studies. In general, exposure levels above 20 ppb of imidacloprid can lead to subtle physiological and behavioral abnormalities in honey bees, as well as increased susceptibility to other stresses. However, laboratory results are conflicting and some disagreed with the no effects observed in field studies. Furthermore, most laboratory studies measured sublethal effects on individual bees (or larvae) or small cohorts of workers by exposing them orally or topically to single doses of pesticides in sucrose solution or contaminated pollen. These effects are likely less disruptive to the overall health of a functional colony which can compensate for many stress factors. For this reason, results of sublethal effects from neonicotinoids in laboratory tests cannot be extrapolated to a real exposure scenario under field conditions at the colony level. A colony of bees has many individuals, and can survive even if a good number of adult bees are lost. This is why the effects of these products are more pronounced in native bees.

Q11: Is there evidence of chronic lethal and sublethal effects of neonicotinoid exposure at the colony level in the field?
A: Several field studies using honey bee colonies have examined sublethal effects of dietary exposure to imidacloprid or other neonicotinoids over multiple brood cycles. In one study, chronic exposure of honey bee hives for 39 days to field realistic concentrations of imidacloprid (2-20 ppb) in sunflower nectar did not result in increased worker mortality or overwintering loss. Another study fed colonies with repeated doses of 0.5 and 5 ppb of imidacloprid in sucrose syrup and showed no immediate or delayed mortality differences between imidacloprid-fed and control colonies. Several studies in Europe found no significant effects on honey bee health.
and overwintering success in colonies placed during flowering in fields of clothianidin-seed treated, or in apiaries surrounded by variable land use of imidacloprid seed-treated corn fields.

Most recently, a three year field study conducted at the University of Maryland examined the chronic sublethal effects on honey bee colonies fed supplemental pollen diet containing imidacloprid at field realistic doses for 12 weeks. Results showed that exposure doses up to 100 ppb had no significant effects on foraging activity or colony health during and shortly after exposure. Residues of imidacloprid became diluted or non-detectable within colonies due to the processing of bee bread and honey and the rapid metabolism of the chemical. Later in the summer, however, there was evidence that exposure to 20 and 100 ppb led to weaker colonies going into the winter. Winter survival of colonies averaged 85.7, 72.4, 61.2 and 59.2% in the control, 5, 20 and 100 ppb treatment groups, respectively. This study concluded that chronic exposure to imidacloprid at the higher range of field doses (>100 ppb) in pollen of certain treated crops may contribute to reduced overwintering success, but the most likely encountered field doses of <20 ppb, especially relevant for seed-treated crops, had negligible effects on colony health and are unlikely a sole cause of colony declines.

Q12: Is there evidence of interactions with pesticides and other stress factors that could adversely affect honey bees?
A: Bees encounter multiple stressors, so scientists are now focusing research on the most obvious interactions that bees have to cope with. For example, studies have reported synergistic interactions between in-hive medications used by beekeepers and neonicotinoids that can increase toxicity and potential sublethal effects to bees. Other studies have shown interactions of sublethal doses of imidacloprid with the gut parasite Nosema, resulting in increased disease infection levels. Although fungicides have been considered safe to bees, we now know that certain azole fungicides can synergize neonicotinoids and increase their toxicity to honey bees. New research has shown that some fungicides alter honey bee foraging behavior, queen survival, and susceptibility to Nosema infections. Most concerning is the mounting evidence that fungicides may interfere with the fermentation process of converting pollen into bee bread. Studies have shown that accumulation of coumaphos in hive wax alters certain metabolic pathways in bee larvae and pupae. As time will tell, the synergistic and additive effects of these exposures may have major ramifications on honey bee colony health.

Q13: What do we know about the exposure and adverse effects to native bees by neonicotinoids?
A: There are over 4,000 native bee species in North America that provide pollination to 80% of flowering plants. Examples include bumble bees, squash bees, leafcutter bees, alkali bees, mason bees, digger bees and carpenter bees. Their life histories differ from that of honey bees in many ways, which may expose them more to pesticides. Unlike honey bee colonies that can sustain high losses of foraging bees before showing adverse effects, native bees are solitary with no workers or hive, or have smaller colonies (bumblebees); thus, are more vulnerable to bee losses. Most native bees feed unprocessed food (pollen, nectar, salivary) to their young, so neonicotinoid residues are less likely to degrade before consumed compared to the processed food (beebread, royal jelly) made by honey bees. Many species build nests underground in crop fields or nearby where they may be directly exposed. Certain native bees are also active very earlier in the morning and work later in the day than honey bees, and some actually sleep overnight in crops where they are foraging. This means that native bees may be exposed to insecticide sprays applied when honey bees are not foraging, such as very early morning or after sunset.

There is less known about the adverse effects of neonicotinoids on native bees, though this is an increasing focus of research. Several studies have reported that colonies of bumblebees exposed to sublethal doses of imidacloprid in food exhibit reduced colony growth and nesting behavior. A recent study in Sweden examined the performance of honey bees, solitary bees, and bumblebees in fields of oilseed rape sown with clothianidin-treated seeds compared to fields sown with untreated seeds. Researchers reported no effects on honey bees but native bee density, solitary bee nesting, and bumblebee colony growth were significantly reduced in treated fields.

Q14: What do we know about the exposure to bees by neonicotinoids used on turf, greenhouse and nursery plants?
A: Recent studies have reported relatively high residue levels of imidacloprid and other neonicotinoids in soil drench nursery plants, clover in treated lawns, and greenhouse grown flowers. Results show that these treatments can adversely affect the survival and fecundity of butterfly species and beneficial insects and reduce the size and number of queens and bumble bee colonies produced. Residue analysis show that exposure to imidacloprid in pollen and nectar of greenhouse-grown flowering plants can be minimized by avoiding spraying plants 2-3 weeks before shipping or stop applying soil drenches to hanging baskets 5 weeks before shipping. These studies also suggest there may be good reasons to restrict the use of imidacloprid (applied as a soil drench) to flowering trees and shrubs that attract bees.

Q15: What steps has EPA taken to minimize neonicotinoid exposure to bees and other pollinators?
A: There are now new label changes and additional restrictions on all neonicotinoid products containing clothianidin, dinofuran, imidacloprid, and thiamethoxam that are registered for outdoor foliar use. Label changes include a Pollinator Protection Box and the
Q16: How will the new label changes for foliar neonicotinoids affect insect control options for bee attractive vegetable crops?

A: Fruiting vegetable crops, such as dry beans, eggplant, peppers, tomatoes, squash, and pumpkins, are highly attractive to honey bees, bumble bees, and solitary bees. Other vegetables that are attractive to bees to a lesser extent include peas, snap/lima beans, okra, potato, cucumber, muskmelons, and watermelon. Most of these crops have indeterminate growth patterns and thus flower over a long period of the crop cycle when both pests and bees are active (some flower right up to harvest). The following neonicotinoid foliar products can be used to control insect pests on one or more of these crops: Admire Pro (imidacloprid), Belay (clothianidin), Scorpion and Venom (dinotefuran), Actara (thiamethoxam), Voliam Flexi (thiamethoxam+chlorantraniliprole), Endigo (lambda-cyhalothrin+thiamethoxam), Brigadier (bifenthrin + imidacloprid), and Leverage360 (imidacloprid+beta-cyfluthrin). The new label changes would prohibit applications of these products when bees are foraging in the crop unless the beekeeper notification requirement and/or other conditions outlined above are met. Some manufacturers have removed uses from their labels due to the new restrictions, so check the label for changes and restrictions. The label is the law, so as soon as the product container displays the new label changes, applicators are required to comply with the new directions for use. In certain treatment situations, applicators may have to consider non-neonicotinoid products; however, many of these products cannot be applied if bees are foraging in the crop. For example, pyrethroids are highly toxic to bees and commonly used in sweet corn, a crop that is attractive to bees during pollen shed. According to the label, pyrethroid products cannot be applied during this period if bees are visiting the crop.

Q17: What steps has USDA taken to enhance pollinator habitat and provide sources of pollen and nectar?

A: The USDA's Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) provide financial and technical assistance to support conservation efforts for pollinators and other wildlife on farms. Conservation programs such as the Environmental Quality Incentives Program, Grasslands Reserve Program, Wetlands Reserve Program, Conservation Stewardship Program, and Conservation Reserve Program all provide support for farmers and landowners who want to establish pollinator-friendly habitat on their land. These programs support more than 60 conservation practices to enhance pollination habitat as sources of pollen and nectar as well as nesting and overwintering sites for native bees.

Q18: What additional steps are needed by federal, state and local governments to protect honey bees and other pollinators?

A: Seed coatings with neonicotinoids are widely used today and represent the main reason why this class of insecticides is being blamed for bee declines. Many entomologists agree that they are overused and not warranted in most planting situations. However, farmers don't have a choice particularly in corn production because virtually all seed comes treated whether you need it or not. Steps are needed to ensure that the seed industry makes available untreated seed of the better hybrids in a timely way if requested by farmers. Further, crop insurance provides incentives, in the form of reduced rates to farmers who use “standard” preventative management practices, such as seed treatments, even if there is no need for the treatment. Incentives should be designed to minimize pesticide use, not maximize it.

Other label uses of neonicotinoid products, such as chemigation through drip irrigation during bloom and high rates of drench and foliar treatments applied to trees and ornamental plants, need to be reviewed by EPA and labels uses revised or restricted. Additional restrictions and label changes on other pesticides including widely used fungicides and pyrethroids may be needed to further mitigate exposure to bees.

State and local governments need to revise regulations that restrict beekeeping in towns and suburban areas and prevent homeowners from planting bee friendly natural habitat instead of manicured turf in their yards.

State Departments of Agriculture and Extension Programs need to step up their education of pesticide stewardship and integrated pest management practices that have significantly declined during the past decade. Efforts are also needed to educate beekeepers about the need to control varroa mites. Astonishingly, 60% of small scale beekeepers (who collectively represent 95% of the beekeepers in the country) do not treat or otherwise control varroa mites with a known control product. These
untreated hives represent varroa “bombs”, because when they die, the mites they contain spread to neighbor colonies compounding the damage caused by these parasites.

With federal funding now available for many conservation practices to provide bee friendly habitat, state agencies need to develop technical notes and other educational materials to help local conservationists, farmers and landowners to properly implement these practices. Additional research is also needed to determine the most competitive, locally-adapted flower species for providing season-long blooming events that are attractive to bees.

State regulatory agencies need to better monitor and enforce the compliance of the new label changes of neonicotinoid products used for outdoor foliar treatments. Unfortunately, many foliar applications are still being applied during the day when bees are active.

Preliminary Data from the 2015 Annual plasticulture Variety Trial

By Michael Newell
College of Agriculture and Natural Resources
Wye Research and Education Center

This project was supported by the North American Strawberry Growers Association. A full report will be available at the 2016 Annual Strawberry Twilight Meeting

Methods:
Standard protocol for establishment of the annual system on plastic was used, 12 x 12 spacing.
Four week old plug plants of seventeen named and/or breeding selections were planted on September 15, 2014. Ten plants per plot were used to collect yield data.

Preliminary yield data:

<table>
<thead>
<tr>
<th>Selection **</th>
<th>Yield per Plant</th>
<th>Fruit number</th>
<th>Average fruit size (oz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLAVORFEST</td>
<td>1.21 a</td>
<td>36</td>
<td>0.54</td>
</tr>
<tr>
<td>RUTGERS SCARLETT</td>
<td>1.19 ab</td>
<td>40</td>
<td>0.47</td>
</tr>
<tr>
<td>RUTGERS #5</td>
<td>1.16 abc</td>
<td>33</td>
<td>0.56</td>
</tr>
<tr>
<td>CAMAROSA</td>
<td>1.16 abc</td>
<td>39</td>
<td>0.47</td>
</tr>
<tr>
<td>RUTGERS #7</td>
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<td>0.57</td>
</tr>
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<td>RUTGERS #4</td>
<td>0.96 abcd</td>
<td>29</td>
<td>0.52</td>
</tr>
<tr>
<td>BENICIA</td>
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<td>0.52</td>
</tr>
<tr>
<td>RUTGERS #2</td>
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<td>0.43</td>
</tr>
<tr>
<td>ALLSTAR</td>
<td>0.89 abcd</td>
<td>40</td>
<td>0.35</td>
</tr>
<tr>
<td>AC WENDY</td>
<td>0.82 abcdf</td>
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</tr>
<tr>
<td>CHANDLER</td>
<td>0.81 bcdef</td>
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<td>0.45</td>
</tr>
<tr>
<td>SAN ANDREUS</td>
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</tr>
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<tr>
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<td>14</td>
<td>0.63</td>
</tr>
<tr>
<td>FLORIDA RADIANCE</td>
<td>0.48 g</td>
<td>20</td>
<td>0.38</td>
</tr>
</tbody>
</table>

* The Tukey Test at the 5% level for statistical significance between plant yield averages (Lbs. of fruit). Yield averages followed by the same letter do not differ statistically between themselves.

** Named selections and selections from the Rutgers University breeding program. The Rutgers# listed are only used for identification purposes of this trial and do not mean anything to Rutgers personnel. If you want to discuss this breeding material with Rutgers berry specialist, you will need to cross reference these assigned numbers with the breeding line key that I can provide.
emergent herbicides were applied on June 11 and consisted of Strategy (4 pints/a) + Prepar (5 quarts/a). Sandea (1 ounce/a) + Gramoxone (2.25 pints/a) were banded on July 5 before the plants flopped and vine running. Warrior (1.9 ounce/a) was applied at this time also as a directed spray at the base of the plant for control of Squash Vine Borer. On June 29th, 30% liquid nitrogen was side-dressed to add 30 lbs nitrogen/a.

The first 2 fungicide sprays were on July 12 and July 22 with Bravo + Kocide and Manzate + Kocide respectively. Powdery mildew was detected on August 5 in all varieties and targeted powdery mildew spray materials were used in the IPM spray plots. Powdery mildew materials were alternated between Rally and Quinctec combined with Bravo and Kocide on August 5th, 12th, 22nd and 30th. Standard sprays were Bravo + Kocide only. Downy mildew sprays were used only once on August 30th and consisted of Ranman.

Harvest began on September 14th. All fruit was cut, leaving a long stem (handle) attached. Fruit was moved to the end of the row for counts, weights and evaluation. Individual fruit weights and stem quality was recorded in addition to observations made on fruit color and shape.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Total lbs</th>
<th>Average lbs</th>
<th># of Fruit</th>
<th>Fruit Weight &quot;per plant&quot;</th>
<th>Fruit Weight &quot;per acre&quot;</th>
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</thead>
<tbody>
<tr>
<td>Phatso 3</td>
<td>3224</td>
<td>1452</td>
<td>9</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>Cargo</td>
<td>3224</td>
<td>1452</td>
<td>9</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
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<td>3224</td>
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<tr>
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<td>9</td>
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<tr>
<td>Expert</td>
<td>3224</td>
<td>1452</td>
<td>9</td>
<td>14</td>
<td>27</td>
</tr>
</tbody>
</table>

**Discussion:**
At the WyeREC location, rain fall amounts were near normal with the exception of June. Precipitation amounts were 2.84, 6.73, 3.35, 3.0, 0.98 inches of rain in May, June, July, August and through September 15th respectively. Excessive precipitation can leach nitrogen provided from legume cover crops. In most years, the nitrogen provided from a good stand of hairy vetch can provide sufficient nitrogen for a pumpkin crop. The addition of 30lbs of nitrogen side-dressed on June 29th to compensate for the reduced hairy vetch stand and
excessive June rainfall. The additional nitrogen appeared to stimulate more vegetative growth reducing early fruit set. A later fruit set resulting in fruit sizing during a hotter, drier August and more fruit per plant, but lower average fruit size.

Fruit quality was generally very good. Low incidence of foliage diseases (powdery and downy mildew) keep leaves intact until harvest on September 14th. Dry weather during August and September minimized fruit rots also. Overhead irrigation was used 3 x's during the season. Post-planting to incorporate herbicides and 2 x's in August when plants were wilting in the afternoon on two occasions.

With the low incidence of powdery mildew, no differences in average fruit size or fruit color could be discerned between the PMR and standard pumpkin varieties even with targeted powdery mildew sprays.

The cost for PMR pumpkin seed compared to standard non-PMR types can range from 4% to 70% more for similar type pumpkin varieties. Although it’s difficult at times to discern if the increased cost is for the technology or because of a unique type of pumpkin. Even when growing PMR type pumpkins, scouting for powdery mildew is still warranted. We may not need to spray as soon as with non-PMR types and sprays may be able to be stretched from 7-10 days to 10-14 days with PMR types, the only way to be certain is to scout the fields. Materials that specifically target powdery mildew can also be subject to the pathogen becoming less sensitive to the chemistry if over-used (always read, understand and follow the label). The PMR technology is another tool to help manage powdery mildew and help keep existing materials for mildew control relevant.
A New Raspberry Fruit Rot to the Region: Characterization and Loss Evaluations for *Cladosporium* Fruit Rot in Red Raspberries, a Previously Unrecognized Pre and Post-Harvest Disease

By Dr. Cassandra Swett and Ms. Christa Carignan
University of Maryland, College Park. Plant Science and Landscape Architecture, Berry Pathology Program.

Raspberry production in the region is challenged by diverse pathogens and insect pests. The most notable of these are *Botrytis* fruit rot, on the pathogen team, and spotted wing drosophila, on the insect team. In 2015, we initiated surveys of losses due to *Botrytis* fruit rot in fall red raspberries, and were surprised when we found more than just *Botrytis*—another disease was also observed. Where *Botrytis* fruit rot was grey and fluffy, the fungus that caused this disease had green-grey growth and lacked the fluffy appears (Figure 1). The growth was observed both on the external surface of the fruit and the internal surface, when removed from the plant (Figure 1).

The fungus was cultured from five to twenty fall red raspberries from each of three farms, and was identified as the genus *Cladosporium*, based on morphology. Species identification is currently underway using molecular techniques. In discussions with regional and statewide advisors, the disease was unfamiliar to the region. Since this new disease has a similar appearance to *Botrytis* fruit rot, it may have been attributed to *Botrytis* in the past (Figure 2).

*Cladosporium* is reported as a post-harvest fruit rot, but pre-harvest symptoms were clearly seen in our studies. We conducted pathogenicity trials to confirm the ability to cause pre-harvest symptoms. Canes were cut the same day as inoculation, and cut stems were placed in water in the lab. We inoculated up to five ripe and unripe fruit on each of three canes, using both a wound and non-wound inoculation method. We confirmed that *Cladosporium* could initiate rot on both wounded and unwounded fruit (Figure 3); there was some background *Cladosporium* infection on control (non-inoculated) fruit, but the inoculated treatment had consistently greater disease incidence (Figure 3). When wound-inoculated, both ripe and unripe fruit become infected, and disease incidence increased as fruit ripeness increased (Figure 4). In addition, wounding greatly increased disease development in unripe fruit (Figure 5), indicating that wounding is important to the epidemiology of this disease.
To determine potential impacts on the industry, we evaluated losses due to *Cladosporium* in two fall red raspberry varieties, at two farms. Losses were based on disease ratings for 40 randomly selected fruit in each of three rows; we examined 20 fruit in the lower portion of the hedge, which typically gets less fungicide coverage, and 20 fruit in the upper portion which typically gets better coverage. Ratings were conducted on August 28, 2015. We also collected fruit from one farm at two dates (September 11 and 24, 2015) and incubated them at 17°C to evaluate losses post-harvest. Based on these evaluations, *Cladosporium* fruit rot was present at both locations; the disease affected about 5% of fruit in the field in our single evaluation, and developed on 35 to 60% of fruit post-harvest across the two collections (Figures 6 and 7). There were no differences in fruit rot between spray zones, with between 0 and 4% of fruit with rot in the poor spray zone and about 2% fruit rot in the well sprayed zone (Figure 6). These results indicate that the pathogen can cause disease pre-harvest at fairly low incidence, but can result in high losses after harvest.

This study was limited to one survey data, and only two varieties of fall red raspberries; observations indicate that other varieties may be more affected than those surveyed and that disease may be more severe later in the season. Surveys with a wider range of varieties over a longer time frame would provide a more comprehensive evaluation of the pre and post-harvest impacts of this disease in the region.

The goals of these studies were to confirm for extension educators and growers that there is an additional, non-*Botrytis*, fruit rot of raspberries in our region, and to gain a tentative estimate of disease impacts on raspberry production, so that we could provide information to growers on control options if they are having a problem. In looking for information for controlling *Cladosporium* in raspberries, we found that there is little raspberry-specific information, since this disease is not very common in other regions. However, we can extrapolate from other crops to get some insights. For fungicide control, work that I conducted with Dr. Douglas Gubler in grapes in California indicates that *Cladosporium* is not easily controlled with fungicides; for instance, Captan, one of our staple broad spectrum compounds, had poor efficacy. However, some of the compounds we use in raspberries, such as the strobilurins, have moderate efficacy both in grapes. The take home for fungicides is: some of what you are already using could work, but compounds that work great for *Botrytis* may not be effective at controlling *Cladosporium*, and we need more information.

Fungicides are not the only option for control. Wound management also appears to be important. In our studies (above), wounding greatly enhances disease development in under-ripe fruit. Preliminary studies with entomologist Dr. Kelly Hamby indicate that pre-harvest disease development may be initiated by wounding insects, in particular, spotted wing drosophila (Figure 8). If SWD is important to the development of *Cladosporium* fruit rot, this may mean that (1) the disease is less severe in early season raspberries that are less affected by SWD and (2) controlling SWD (and other wounding insects) could help to minimize pre-harvest losses.
In upcoming studies, we hope to: (1) conduct more comprehensive loss evaluations for this disease across the season on additional varieties, at several more farms; (2) determine whether there are differences in varietal susceptibility; (3) assess whether there is an epidemiologically significant relationship between *Cladosporium* and SWD and; (4) evaluate which of the presently used fungicides are (and are not) effective in controlling *Cladosporium* in raspberries.

Seasonal updates on this disease and ongoing research can be found at the berry pathology twitter site: https://twitter.com/berry_pathology or by email Dr. Cassandra Swett at clswett@umd.edu.

### Can Post Harvest Practices Alter the Degradation of Cry Proteins in Genetically Engineered Corn Debris?

Veronica Johnson*, Galen Dively*, William Lamp* & Cerruti R² Hooks+

Graduate student*, Professor Emeritus* and Associate Professor+ University of Maryland Dept. of Entomology

Significant developments in biotechnology in recent decades have resulted in increased adoption of genetically modified (GM) crops. Transgenic corn that expresses insecticidal proteins from the bacterium *Bacillus thuringiensis* (Bt) is grown on more than 90% of the corn acreage in the US. GM crops can be defined as crops in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural rearrangement of genetic material. The transferred gene, known as a transgene, is inserted into Bt corn to express proteins to control specific insect pests. However, there are concerns that these proteins can remain biologically active after harvest and thus may negatively impact non-target insects and other organisms such as those spending most of their time on or below the soil surface. This could subsequently impact their ability to carry out normal ecosystem services, such as breaking down plant material and recycling nutrients, so that it is available for plant uptake.

Previous studies have shown that the bioactivity of Bt proteins in leaf material can last for several months after harvest, especially when multiple transgenes are present. For example, Bt activity from pyramided corn hybrids (those expressing multiple proteins) can persist in the environment for up to six months following corn harvest. However, the stability of these proteins in crop residue following harvest may vary with different post-harvest field practices. Tillage practices, residue management, and planting winter cover crops after harvest may impact how long the Bt proteins remain biologically active.

One of our goals includes developing strategies to decrease the persistence of Cry proteins in corn residue. Fall plowing or heavy disking after harvest will incorporate crop residue directly into the soil, thus increasing chances of microbial degradation. However, in no-till corn production systems, crop residue remains on the surface as undisturbed stalks or cut using rotary or flail mowers. Mowing stalks increases the amount of fine residue and places it in closer contact with the soil surface. In production areas where growers use winter cover crops for conservation purposes, seeding occurs shortly after harvest. The planted cover crop may influence the degradation rate of the remaining proteins.

Thus one of our research objectives determines how long Bt proteins remain active in the soil environment following corn harvest. It is hypothesized that the degradation rates of toxic Cry proteins in genetically engineered corn will differ according to the post-harvest field management practices. Below is a description of a field experiment carried out to examine this hypothesis and some casual findings.

### Field experiment

To better understand factors affecting the post-harvest fate of Bt proteins, a field study was conducted to determine the bioactivity of proteins expressed in crop residue of Bt SmartStax corn, when subjected to different post-harvest practices. SmartStax corn contains genes expressing three proteins active against corn rootworm (CRW), genes expressing three proteins to a complex of lepidopteran pests, as well as two traits providing tolerance to Liberty Link and Roundup herbicides. The experiment was conducted at the Central Maryland Research and Education Center in Beltsville, MD during the fall and winter of 2014-15. The experimental layout was a split-plot design with hybrid type (SmartStax, non-Bt near isoline) as whole plot factors, post-harvest practices following harvest as the subplot factors, and each treatment combination replicated three times. Plots measuring 50 ft by 30 ft (Fig 1) were planted and harvested on May 20 and
September 27, 2014, respectively. Following harvest, the post-harvest practices included: 1) heavy disk to incorporate crop residue (chisel plow); 2) flail mowing to shred surface residue (flail mow); 3) cover crop planting of rye, hairy vetch, tillage radish mix (cover crop); and 4) undisturbed crop residue left by the combine (no-till).

**Figure 1. Layout of corn study at Beltsville**

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For the chisel plow treatment, litter bags stuffed with corn leaf tissue collected at harvest time were buried in each subplot to mimic degrading tissue following heavy disk. For the remaining treatments, corn leaf tissue was collected within each subplot on each sampling date, except for the flail-mowed treatment, where different plant parts could not be differentiated and thus all available surface litter was collected. Sampling was carried out every two weeks for the initial eight weeks following the post-harvest treatment applications, and then every four weeks thereafter until mid-April.

At each sampling date, collected corn tissue was taken back to the lab, cut into small pieces and homogenized. A subsample was then removed and placed in a freeze drier to remove all moisture from the tissue. The dry leaf tissue was then ground into a fine powder by a commercial blender and used in an enzyme-linked immunosorbent assay (ELISA) and a bioassay feeding assay to measure the persistence of protein bioactivity in the tissue. The presence of the Cry1Ab, Cry1F, and Cry2Ab2 proteins was detected individually by a specific ELISA strip test, whereas a feeding bioassay measured the growth inhibition of the pyramided proteins in corn leaf tissue.

For the feeding bioassay, European corn borer (ECB) was used as a sensitive indicator of the toxins. A meridic diet for ECB was mixed with the lyophilized leaf powder at a sub lethal concentration resulting in 60-80% growth inhibition of first instars after seven days of feeding (if fed on biologically-active tissue). ECB eggs were obtained from a commercial insectary and incubated in a growth chamber to supply first instar larvae for bioassay.

For each treatment combination by replicate, representing one experimental unit, cohorts of 16 first instars were reared individually in Bio-Serv bioassay trays, with each well containing 1.5 ml of diet. After seven days, sets of four live larvae were weighed and averaged over each treatment combination. Relative growth inhibition was calculated by the weight gain difference between larval cohorts feeding on diets with Bt and non-Bt tissue of each hybrid group for each replicate.

A similar field study was planned during the 2015 field season. However, 75% of the post-harvest tissue was burned in the field due to a brush fire (Fig. 2). Thus, we are planning to repeat this field trial during the 2016 growing season.

**Fig. 2. Fire Department dousing experimental corn plots in Beltsville following postharvest treatment.**

**Findings**

Though it is too early to make any concrete conclusions, results from the initial field study suggest that Bt tissue in plots receiving the flail mow treatment lost biological activity significantly quicker than the other treatments. Flail mowing cut the corn litter into smaller pieces, compacting the tissue and providing more tissue surface area in direct contact with the soil surface, presumably allowing more direct contact with soil microbes. Chisel plow treatments were expected to lose biologically activity more rapidly than any other treatment, however, litter bags were most likely packed too tight, constricting the ability of soil microbes to access the tissue, and did not show tissue degradation until week 12. The cover crop treatments showed near similar breakdown of Bt proteins as the flail mowed treatments, because the drill used the plant the cover crop pressed a significant amount of tissue closer to the soil surface. The no-till treatment left all tissue intact, and therefore little came in contact with the soil, resulting in the highest levels of remaining Bt activity at the end of the 22-week period.

Funding for this project was provided via an USDA NIFA Extension Integrated Pest Management Coordination and Support Program (EIPM-CS) award number 2013-41534-21512 and USDA NIFA Biotechnology Risk Assessment Research Grants Program (BRAG) award number 2014-33522-22220.
Late Planting Window for Legume Cover Crop Species
By Guihua Chen and Cerruti R. Hooks
University of Maryland Dept. of Entomology

Benefits of rotating cover crops with cash crops are well known for their ability to prevent soil erosion, protect water quality, conserve soil moisture, improve soil fertility and health and reduce weed pressure. Vegetable growers may be more willing to adopt cover crops into their production systems than other producers because of some additional benefits that cover crops can bring: additional N (nitrogen) to the soil, attraction of pollinators and other beneficial arthropods, and an array of pretty bedding flowers. However, there are sometimes conflicts between the most suitable period for cover crop planting and the availability of fields. The recommended planting period for most cover crops is from late August to early September. However, to achieve maximum yield benefits, some vegetable crops such as bell pepper and eggplants must be harvested till late September or later such as first frost. Two common questions that vegetable growers often ask are: Is it too late for me to plant legume cover crops? What cover crop(s) should I plant?

A field trial was initiated at the Central Maryland Research and Education Center, Upper Marlboro facility in the fall of 2014 in order to address these questions. The field trial used a completely randomized design with three replicates. Four legume cover crops and three planting dates were included in the study. The cover crops were (A) Austrian winter pea (AWP, Pisum sativum L. subsp. sativum var. arvense), (B) crimson clover (CC, Trifolium incarnatum L.), (C) hairy vetch (HV, Vicia villosa Roth subsp. Villosa), and (D) red clover (RC, Trifolium pratense L., medium). They are all annual crops except red clover which is a short term perennial (biennial). The three planting dates were October 1st, 15th, and 30th. Seeding rates were 80, 20, 20 and 12 lb/acre for AWP, CC, HV and RC, respectively. Before cover crop termination, above ground cover crop biomass samples were taken from three randomly selected areas in each plot using a 10” x 10” quadrat.

Samples were then dried at 65°C for 3-5 days, weighed for dry matter determination and ground to a powder form for analyses of total C and N content. Because of the unusual cold weather in spring 2015 (Fig. 1), cover crop biomass was taken on May 22nd, about a month later than usual.

![Figure 1 Monthly air temperature in the 2014-2015 winter cover crop growing season](image)

**Biomass production.** There was a significant interaction effect between planting date and species on total dry biomass. Figure 2 presents dry biomass for each cover crop species at three planting dates. For planting date of October 1st, crimson clover had the highest biomass while red clover had the lowest; there was no difference between AWP and HV. For the October 15th planting date, biomass was reduced significantly for all species except AWP, compared to the October 1st planting date. Biomass did not differ between CC and AWP on Oct. 15 and both had greater biomass than HV and RC. Total biomass for planting date October 30th was significantly less for all four species than for planting date of October 15th. Compared to the first planting date, the reduction of total biomass for the 2nd and 3rd planting dates was 11.3 and 59.6% for AWP, 23.2 and 76.6% for CC, 40.0 and 75.2% for HV, and 51.8 and 100% for RC. Though earlier planting dates such as August or September were not included in this study, previous studies in Maryland indicate that optimum dry matter production for AWP, CC, HV and RC is about 6,000, 7,000, 5,500 and 2,500 lb/acre, respectively. Our findings suggest that CC is the best option of the four cover crop tested if planting beyond the month of September under environmental weather conditions experienced during this trial. After October 15th, AWP and CC still offer better options than HV and RC, but planting is not recommended if it is later than October 20th. Red clover, however, can be planted if allowed to grow as a living mulch or companion plant in the summer to attract beneficial arthropods and pollinators, suppress weeds or if being used in a field that will be allowed to "rest" or seeded with a late summer or fall crop.
Nitrogen availability. Nitrogen availability to cash crops depends not only on the total dry biomass produced by a cover crop, but also N content (%) and C:N (carbon:nitrogen) ratio in the biomass. Higher N content would lead to greater total N fixed by a cover crop, while a lower C:N ratio means that plant residue would decompose more rapidly and thus, release N to the soil at a faster pace. It is interesting that unlike what we have seen for the total dry biomass, there was no interaction effect between planting date and cover crop species on N content and C:N ratio. However, there were significant main effects of planting date and cover crop species on N content and C:N ratio. This is the same for the total N (lb/A, product of N content and the total dry biomass) for each cover crop species.

The N content was lower in the CC biomass than in any of the other three species, while the C:N ratio was greater for CC. However, total N fixed was less by RC and not different among AWP, CC and HV. The reason for lower N content but higher C:N ratio in the CC biomass than in the other species is probably because it matures earlier than the other three species, as observed in the study site. If you plan to have your vegetables planted early in the spring and enjoy the pretty flower, or want to feed your neighbor's honey bees, CC provides a good option. Otherwise, AWP and HV would be better than CC for total N fixation and earlier release of N because of their lower C:N ratios.

Tissue N content did not differ the first two planting dates and was greatest at the last planting date (Fig. 3). This is understandable as the later cover crops were planted, the less mature their plant tissue will be. Young plants usually have higher N content in their biomass. The C:N ratio in the tissue was 17.1, 17.3 and 15.9 for planting dates October 1st, 15th, and 30th, respectively. This is consistent with higher tissue N content for the October 30th planting date. The difference of total N accumulation, however, was different among three planting dates: the earlier the planting date, the more N fixation.

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>AWP</th>
<th>CC</th>
<th>HV</th>
<th>RC</th>
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<tr>
<td>N content (%)</td>
<td>2.91 (+0.14)</td>
<td>1.92 (+0.10)</td>
<td>3.18 (+0.17)</td>
<td>2.81 (+0.09)</td>
</tr>
<tr>
<td>C:N ratio</td>
<td>15.2 (+0.86)</td>
<td>22.9 (+1.22)</td>
<td>13.6 (+0.66)</td>
<td>17.1 (+0.65)</td>
</tr>
<tr>
<td>Total N (lb/A)</td>
<td>82.3 (+11.6)</td>
<td>56.4 (+13.1)</td>
<td>72.6 (+14.5)</td>
<td>35.4 (+9.3)</td>
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Recommendations. When selecting a cover crop species for a late planting window, a list of pros and cons may be needed for comparison. Besides the agronomic concerns presented above, you may take in consideration also seed cost. The estimated cost per acre seeds is $264 ($3.3/lb), $39 ($2.3/lb), $79 ($3.95/lb), and $24 ($2.3/lb) for AWP, CC, HV, and RC, respectively based on our seeding rates. Nitrogen fixation was 0.3, 1.5, 0.9, and 1.5 lb/$ for AWP, CC, HV, and RC, respectively. For this particular study, there was no effort to specifically locate very winter hardy cultivars. This may be another option for some legume cover crop species, if the situation requires they be planted later than the recommended time period. However, the cost of these cultivars may be much higher than the "regular" ones. Based on results of this trial, CC would be recommended as the best choice for a "late" planted cover crop among species evaluated. The rapid plant establishment and greater biomass production of CC would also help protect soils from erosion and increase soil organic matter content. However, CC does not grow well in poorly drained soils, so we caution using CC as a winter cover crop in poorly drained fields. Austrian winter pea higher seed cost is of concern. In addition, AWP is susceptible to spring frost damage, as was shown in the field experiment conducted by Dr. Hooks in 2012. Therefore, the recommendation among the four tested cover crops is CC > HV > RC > AWP. In conditions where no-till or strip till will be used for growing cash crops, RC is recommended if the interest is using the cover crop as a living mulch or companion plant to provide other ecosystem services during the cash crop growth cycle.

Acknowledgement Thanks go to Mr. Alfred Hawkins at The CMREC Upper Marlboro facility who planted all the cover crops. This project was supported by a USDA NIFA EIP Grant award number: 2014-70006-22551 and USDA NEIPM Center grant award number 2013-34103-21480.
Researchers identify potential alternative to CRISPR-Cas genome editing tools

An international team of CRISPR-Cas researchers has identified three new naturally-occurring systems that show potential for genome editing. The discovery and characterization of these systems is expected to further expand the genome editing toolbox, opening new avenues for biomedical research. The research, published today in the journal Molecular Cell, was supported in part by the National Institutes of Health…


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Contact Kim Rush Lynch at klmrush@umd.edu or 301-868-8780 for details.
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Register by November 24th, 2015.

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A timely publication for the commercial vegetable and fruit industry available electronically in 2015 from April through October. Archived online at: https://extension.umd.edu/anne-arundel-county/agriculture/vegetable-fruit-headline-news

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