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Using Reduced Tillage and Cover Crop Residue to Manage Weeds in Vegetable Production

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Introduction

Weed control is listed consistently as a priority for vegetable growers. Cultivation is the most commonly used method for weed control and is practical when plants are small. However, cultivation can create problems such as soil erosion and compaction (such as disking layer, a dense soil layer that develops at 4-8" depth due to machine cultivation) and reduce soil organic matter. Herbicide options are limited in vegetable plantings compared to field crops due to limited registered products; and the high cost of organic herbicides makes their use impractical. Manual weeding is the most effective method of weed suppression but is labor intensive and very costly. Plastic mulches are effective in managing weeds within crop rows and promote crop growth and early harvest. However, the use of plastic mulch will increase the cost of crop production and removal and disposal can cause major problems if the plastic is not degradable and is disked in the soil. Therefore, more cost efficient and practical weed management programs are needed.

In Maryland and the Mid-Atlantic region, cover crops are widely used in crop rotation schemes with field and vegetable crops. Winter cover crops forage radish (*Raphanus sativus* var. longipinnatus, cv. 'Daikon'), crimson clover (*Trifolium incarnatum* L.), and rye (*Secale cereal* L., cv. 'Wheeler') have been reported to control weeds through different mechanisms such as mulching which prevents weed seed germination by forming a physical barrier and allelopathy ("any direct or indirect harmful effect produced in one plant through toxic chemicals released into the environment by another", Rice, E.L. 1974.), or both. Moreover, the addition of cover crop residue may change the incidence and severity of soil-borne diseases by increasing the activity density of beneficial organisms. These beneficial organisms compete with pathogens for nutrients, space, and/or direct parasitism and thus directly inhibit their development. Though tillage is widely used for weed control, this farming practice may alter the vertical distribution of weed seeds resulting in greater weed seed bank populations. This suggests that fewer weed seeds will be produced per unit area and weeds will be managed easier in no-till and reduced-tillage systems. Therefore, our interest includes determining whether combining reduced tillage and cover crops would provide a more sustainable weed management option.

Field trials

Field trials were conducted at a field site at the University of Maryland, Upper Marlboro Research and Education Facility from September 2011 to September 2013. The trials consisted of the following four treatments: conventional tillage without any surface mulch [bare-ground (BG)], conventional tillage with black plastic mulch (BP), strip-till (ST) [reduced tillage in which only the planting rows are tilled (~ 10" wide)], and no-till (NT). Each treatment was replicated four times. On September 19, 2011, a cover crop mixture consisting of forage radish and crimson clover were planted in the entire field at seeding rates of 4 and 11 lb/A, respectively. However, the field contained some voluntary rye. In 2012, forage radish was frost-killed in January and decomposed rapidly during the spring as the temperature became warmer. Rye and crimson clover in BG and BP treatment plots were flail-mowed on April 30, about 12 days earlier than in NT and ST plots. Conventional tillage (chisel plowing plus disking) was conducted in the BG and BP plots on May 7 and the strip-till was performed in the ST plots on May 24. Eggplant seedlings were transplanted in treatment plots on May 25. On August 29, at the end of eggplant growing season, all plants were mowed. The BG and BP treatment plots were plowed prior to planting the cover crops. On September 9, 2012, forage radish, crimson clover, and rye cover crop mixture was planted. The seeding rate for rye was 60 lb/A and for crimson clover and forage radish remain the same as in 2011. From January to May 2013, the same procedures were followed as in 2012 for cover crop management and treatment application. Sweet corn seeds were drilled in BG, NT and ST plots and hand-seeded in the BP plots on May 17, 2013. Drip irrigation was used both years.

Cover crop dry matter and carbon to nitrogen (C/N) ratio

Weed suppression through cover crop mulching depends on the quantity and the composition of cover crop residues. The heavier the surface mulch (or greater dry matter), the more effective weed suppression it provides. The Carbon to Nitrogen ratio (C:N), represents the relative proportion of carbon to nitrogen mass within the residue, determines the rate by which the residue decomposes and also how soon the nitrogen will be available. The greater the C/N ratio, the longer the period of time that plant residue will remain and weed suppression will persist. Cover crop dry matter data can provide good insight with respect to the quantity and quality of the cover crop residue.

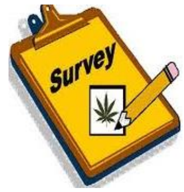
To obtain biomass data, cover crop plants were sampled in late December before the forage radish was winter-killed and again in late April or early May before cover crops was flail-mowed. Samples were sorted by cover crop species and oven-dried to determine their dry biomass. Samples were then machine ground to powder and analyzed for total carbon, nitrogen, and the C/N ratio in the plant tissue.

Table 1. Cover crop dry matter and components in the two winter-spring seasons

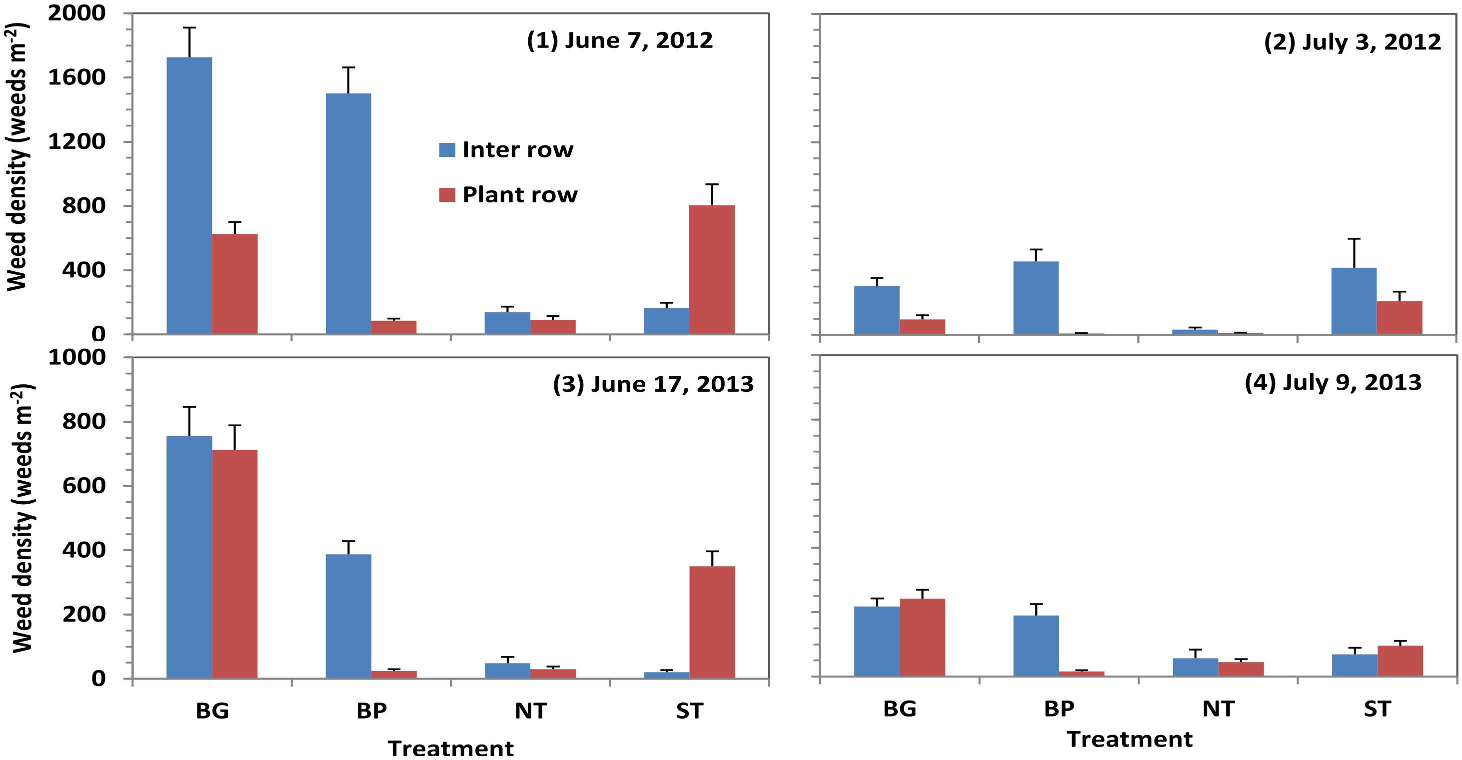
Cover crop components	2011 -2012		2012 -2013	
	Dec. 05	Apr. 30	Nov. 26	May 6
% crimson clover	17.9	80.7	6.4	40.2
% forage radish	50.0	0.0	64.1	0.0
% rye	25.8	19.3	29.4	58.9
Total DM (Mg ha^{-1})	**1.37**	**2.93**	**3.56**	**3.20**
C/N ratio	**-**	**21.4**	**-**	**30.6**

During the first half of the cover crop growing season, forage radish accumulated ~ 50% or more of its total cover crop dry matter due to rapid growth in late fall. During this period, rye and crimson clover were still in their early growth stage. By early May, most of the forage radish residue had decomposed and the rye and crimson clover were approaching seed set. This is a good time to terminate the cover crops because biomass accumulation slows down at this time and cover crop re-growth can be prevented. As shown above, rye had a greater proportion of the total dry matter in 2013 than in 2012 (58.9% vs. 19.3%). Therefore, it is not surprising that the cover crop C/N ratio was greater in 2013 than in 2012 (30.6 vs. 21.4). The higher C/N ratio in 2013 may have slowed the decomposition rate of the cover crop residue. Because the residues' C/N ratios were in the range of 20-35 during both years, there should be no issues with respect to nitrogen being tied up by soil organisms or being released slowly. Generally nitrogen in organic residue may get tied up when the C/N ratio reaches 35 or greater, according to the studies by scientists at University of California at Davis.

Weed survey and management



Weed communities were surveyed at eight randomly selected locations within the plant row and inter row area in each treatment plot. Weed surveys were conducted on June 7 and July 3 in 2012, and June 17 and July 9 in 2013. In 2012, shortly after each survey task, cultivation was performed to control weeds in inter row areas of the BG and BP plots. Hand-hoeing was used to remove weeds within the plant rows of all plots and inter row areas in the NT and ST plots. In 2013, only hand-weeding was used to control weeds. Weeds in the BG and BP plots were hand-hoed and hand pulled in the NT and ST plots if the weed population was small to minimize soil disturbance. In 2013, the percent soil surface covered by cover crop residue was visually estimated in each plot.



Several interesting findings can be observed in the figures. First, total weed density in 2013 was only half of that in 2012 on both sampling dates. The C/N ratio of the cover crop residue was about 50% higher in 2013 than 2012, which helped slow down the decomposition rate in 2013. The longer the cover crop residue remains in the field, the better the weed suppression as fewer weed seeds could germinate. Secondly, total weed density was similar in 2012 and 2013: they were in the order of BG > BP ≥ ST > NT. Cultivation can be used to control weeds, but may only offer a short term solution. Further, cultivation encourages weed seed emergence due to soil disturbances. Black plastic mulch effectively controlled weeds in the plant rows because it prevented light from reaching the soil surface which is required for weed seeds to germinate. Strip-till disturbs soils in a limited area within the plant row and leaves some residue coverage, thus providing better weed control than BG in the entire plots. However, during the second sampling date in 2012, weed density (averaged the intra and inter rows) was similar in ST and BG plots. This probably occurred because during hand hoeing, soils were disturbed while the cover crop residue conserved more moisture in the ST plots, which provided better conditions for weed seed germination. We did not observe similar occurrences on the second sampling date in 2013 because hand-hoeing was not used. Instead, weeds were removed by hand to minimize soil disturbance. Thus, this helps explain why fewer weeds were found in the NT and the inter row area of ST plots where weeds were removed only by hand.

Conclusions and recommendations

From the field trials, we found that integrating cover crop residue with NT provided the best weed control during the crop growing season. This combination required the least amount of energy input and cost. However, plant growth in the NT plots occurred more slowly and the yield was also lower, compared to the other treatments. Conventional-tillage with black plastic mulch effectively decreased weed density within the plant rows, but not the inter row spaces. The combination of cover crop residue and ST provided the second best weed control within intra and inter row spaces. Plant growth and yield in the ST plots did not differ from those in the BG and BP plots but the quality of eggplant was better in ST plots. One could achieve better weed control from strip-tilling if the initial weed flush is controlled in the intra row area prior to planting the crop and there are minimum soil disturbances during and after the weed flush is suppressed. Increasing the C/N ratio of cover crop residue composition could lead to better results by slowing down the decomposition of the cover crop residue.

Therefore, a cover crop mixture consisting of legume and grass species integrated with strip-tilling may be used to achieve good weed control in vegetable plantings. A single cover crop species is less desirable because the residue either decomposes too quickly such as with a legume species or too slowly in the case of using rye or another grass cover crop with a high C/N ratio. Simply using a single cover crop could result in poorer weed suppression or crop nitrogen deficiency. There are management tactics such as the stale seedbed technique (http://marylandorganic.org/2013/10/18/ the-stale-seedbed-technique-a-relatively-underused-alternative-weed-management-tactic-for-vegetable-production/) that can be used for managing the initial weed flush after the field is strip-tilled. Moreover, in addition to its weed management benefits, mixed cover cropping plus strip tilling can be used to help build a healthier soil community.

***This study is being funded by an* USDA National Institute of Food and Agriculture (NIFA) grant (2011-51106-31203) that was awarded through the Organic Transitions (ORG) program. The goal of this program is to support the development and implementation of research, extension and higher education programs to improve the competitiveness of organic livestock and crop producers, as well as those who are adopting organic practices. If there are any questions regarding this project and mechanical weed suppression techniques, feel free to email Guihua at "gchen2@umd.edu". More information on these and related projects can be found at cerrutirrhookslab.umd.edu/.**

Managing the Weed Seedbank with Cover Crops and Tillage

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Weed control is a principal concern for vegetable growers. The adoption of sustainable agricultural techniques can reduce land managers' dependency on expensive or harmful chemicals, but may also result in increased weed presence. Weed control is not just a matter of preventing weed emergence or killing weeds that arise during the growing season. A good management strategy should include reducing the size of the existing weed seedbank. Adopting techniques that reduce the weed seedbank is a necessary step toward long term weed management solutions.

Weed Seedbank

Every plot of land has a seedbank which is made up of seeds that are lying in the soil awaiting acceptable conditions to germinate. Seeds may require specific levels of moisture, temperature, light, disturbance, or sometimes special conditions such as fire to germinate, and seeds of some plant species may lie dormant for years before germinating. Several techniques have been tested for reducing the weed seedbank. One way is to disturb the soil prior to planting crops, allowing weed seeds to germinate. Weed seedlings can then be killed either by mechanical or chemical means. This reduces the weed seedbank and prevents weeds from emerging later in the season and competing with the crop. This is called the "stale seedbed" technique. The stale seedbed takes advantage of another strategy to reduce the weed seedbank, which centers on preventing seeds from entering into the soil. This can be accomplished by killing weeds before they release seeds or using cover crops to suppress weed emergence. Both methods if used appropriately will prevent weeds from replenishing the seedbank.

In two separate field experiments at the University of Maryland Upper Marlboro Research and Education Facility we tested the effects of cover crops (Cover Crop Experiment) and tillage techniques (Tillage Experiment) on the weed seedbank. To accomplish this, we took soil cores (depth = 15 cm) from treatment plots in both experiments prior to mowing cover crops. The soil was evenly spread in plastic flats and placed in favorable greenhouse conditions for six weeks. This allowed the weed seeds present in the seedbank to germinate, after which they were counted and identified. We have three and two years of seedbank data from the Cover Crop and Tillage Experiment, respectively, giving us some early clues as to whether cover crops and tillage can influence the weed seedbank.

Figure 1. Soil core sampling in the Cover Crop Experiment (upper left panel, graduate student L. Hunt) and separating soil from roots and debris prior to transport to greenhouse (bottom panel, field assistant G. Polley). Flats of soil with emerging seedlings in the University of Maryland greenhouse (upper right panel).

Cover Crop Experiment

The Cover Crop Experiment consisted of field plots grown with one of three cover crop treatments and a no cover crop check treatment. The three cover crops treatments were (1) barley, seeded at 100lb/A, (2) crimson clover, seeded at 20 lbs/A, and (3) a mixture of barley and crimson clover, seeded at 60 and 40 lb/A respectively. Cover crops were planted in the fall of 2011 and 2012, and flail mowed and strip tilled each spring. A vegetable crop was then planted into the tilled strips, leaving cover crop residue between planted rows. We collected seedbank soil cores in 2011 (for a pre-treatment baseline), 2012, and 2013, prior to planting the vegetable crop in early spring or summer.

Tillage Experiment

The Tillage Experiment consisted of field plots planted with a forage radish, rye, and crimson clover cover crop mixture. In the spring, cover crops were flail-mowed and the plots tilled using one of four techniques: (1) no till, where crops were seeded directly into the cover crop residue, (2) strip till, where narrow strips (~12 inches) were tilled before planting the crop, leaving most of the plot covered by cover crop residue, (3) black plastic, where transplants or seed were planted on black plastic mulch after the plots were chiseled plowed and disked, and (4) bare ground, where the plots were plowed and disked after the cover crops were flail-mowed. (For additional details on this experiment, see the article by G. Chen et al. in this issue).

Results

Two years of data from the cover crop study showed that plots grown with crimson clover germinated fewer seeds compared to the other treatments (Figure 2, left panel). Two years of data from the tillage study showed that plots containing black plastic have the greatest reduction in the weed seedbank compared to the other treatments (Figure 2, right panel). These two experiments had very different numbers of germinating seeds, despite being less than 1 km (~ 0.6 miles) apart. The two experimental field sites were grown under very different conditions prior to these experiments, highlighting the importance of historical land use for the current weed seedbank.

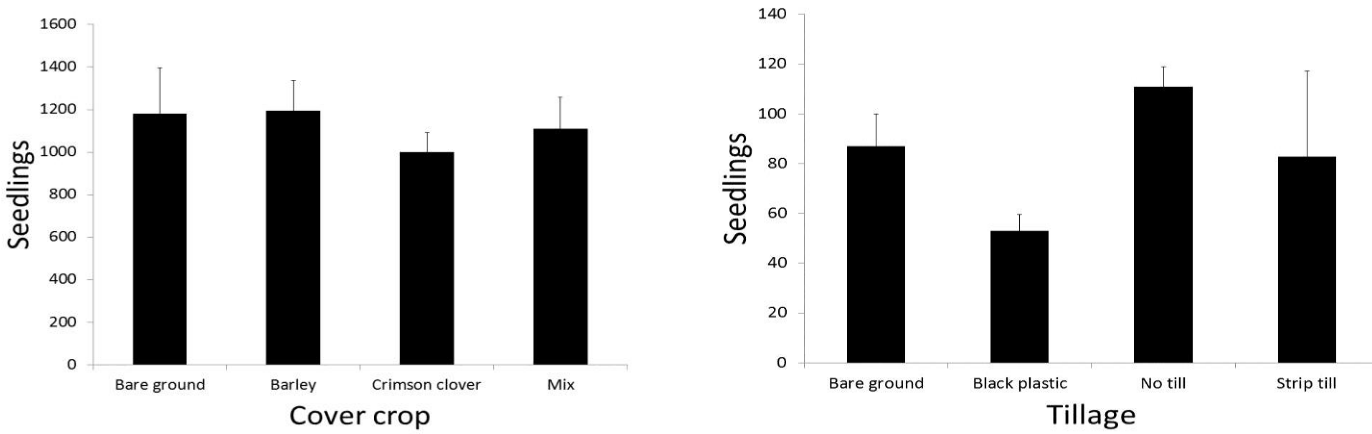

Figure 2: Number of seedlings emerging from soil cores taken from the Cover Crop Experiment (left panel) and Tillage Experiment (right panel), after six weeks of greenhouse conditions. Error bars are ± 1 SE.

Conclusions

Managing the weed seedbank is a long-term endeavor, but can provide long-term benefits. While these two to three years of data can only serve as an early indication as to how different cover crops and tillage methods might influence the weed seedbank, we do see that techniques offering greater soil coverage might be most effective at managing the weed seedbank. Soil coverage can suppress weed emergence and growth, preventing weeds from releasing seeds back into the soil. Over time, this can reduce the size of the weed seedbank and help provide long term weed management.

Acknowledgements

These studies are funded by **USDA National Institute of Food and Agriculture (NIFA) grants 2011-51106-31203 (Tillage study) and 2010-51300-21412 (Cover crop experiment) that were awarded through the Organic Transitions (ORG) and Organic Research and Extension Initiative (OREI) programs. The goal of these programs are to support the development and implementation of research, extension and higher education programs to improve the competitiveness of organic livestock and crop producers, as well as those who are adopting organic practices. If there are any questions regarding these projects and managing the weed seed bed, feel free to email Amanda Buchanan at abuchana@umd.edu. More information on these and related projects can be found at cerrutirrhookslab.umd.edu/.**

Efficacy of Organic Insecticides for Control of Nymphal and Adult Stages of Brown Marmorated Stink Bugs (BMSB) on Bell Pepper - 2013

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An experiment to evaluate the control efficacy of selected organic insecticides against nymph and adult stages of the brown marmorated stink bug (*Halyomorpha halys* (Stål) was conducted at the Central Maryland Research and Education facility, Beltsville, Maryland. Bell pepper (var. Intruder) was grown in the greenhouse and transplanted into black plastic mulch on 27 June. Fertilizer and drip irrigation were applied according to commercial practices, and plants were staked and tied after 4 weeks of growth to prevent lodging. Thirteen treatments plus an untreated control were arranged in a randomized complete block design with four replicates. Individual plots measured one row 10 ft long spaced 5 ft apart. Each plot contained 8 plants, spaced 12 inches apart.

Since natural BMSB populations at the Beltsville farm have varied widely during past years, and infestations are strongly aggregated along field edges, plots were manually infested with nymphs to provide consistently similar pre-treatment densities per plot. On 14 August, when crown fruit reached near marketable size, approximately 100 young 2nd instars were evenly released on the top canopy leaves of the 8 plants in each plot. The nymphs were reared in a laboratory colony in deli trays, each containing cohorts of nymphs from five egg masses (each 28 eggs). After several days to allow nymphs to acclimate, all treatments were applied on 19 August using a CO_2 backpack sprayer calibrated to deliver 26 gal/acre at 40 psi. Three hollow cone nozzles covered each row, one directed on each side of the foliage and one over the top. Azera at the 32 oz rate was tested as a single application. Plots of Azera, F-7470, F-2994, Entrust, and Entrust + M-Pede received a second application 3 days later on 22 August, while second and third treatments of Azera, M-Pede, Azera + M-Pede, MBI-206, PFR

97, Garlic, and PyGanic were applied 2 days apart on 21 and 23 August. To evaluate each treatment schedule, all plants in each row was carefully examined on 20, 22 and 26 August to record on the number of live nymphs.

On 29 August, a second release of older nymphs was made at the rate of 5 stink bugs per plant. Stink bugs were collected by hand from field corn at the Clarksville Research and Education facility on the same day and consisted of approx. 5% adults, 25% 4th instars, and 70% 5th instars. All treatments were applied twice on 30 August (1 day later) and 4 September according to the methods described above. The effectiveness of the treatments was evaluated on 2 and 5 September by the counting the small nymphs (2nd - 3rd instars), large nymphs (4th – 5th instars), and adults in the entire plots. On 9 September, all marketable fruit was picked from each plot and carefully examined for stink bug injury. Data were recorded on: total number of fruit harvested; number damaged by stink bugs showing minor (1-2 feeding sites or cloud spots) and major (3 or more feeding sites on >1/3 of the fruit surface) injury; and number damaged by fruitworms.

Mixed model SAS procedure was used to test for treatment effects after adjustments were made for lack of normality and auto-correlation among repeated sampling dates. Separate analyses were performed on counts of bugs recorded after each manual introduction and the fruit injury data. The Tukey option was used to test for significance among multiple mean comparisons.

The native BMSB population was very low based on the few adults and egg masses recorded during plant inspections. A total of 16 adults and 11 egg masses were observed in all 56 plots pooled over all sampling dates, and most of the eggs were either parasitized or predated. Thus, almost all nymphs recorded were those introduced on 14 August. Counts of early instars averaged 29.3, 24 and 18.8 per 8 plants in the untreated plots on 20, 22 and 26 August, respectively (**Fig. 1**). The treatment interaction effect with sampling date was not significant ($P= 0.94$), indicating that treatment differences were consistent across dates. All treatments resulted in significant suppression of early nymphs, except for MBI-206, PFR 97, and Garlic. Based on overall percent reduction relative to the untreated control, the most effective insecticides were F-2994 (95%), Entrust + M-Pede (92%), Azera + M-Pede (90%), Entrust (89%), Azera applied twice and three times (84%), and PyGanic (79%) (**Table 1**). However, these treatments were not significantly different from each other. Lower levels of control were provided by the single application of Azera (56%), and the three applications of F-7470 (48%) and M-Pede (49%). The multiple spray schedules of Azera increased control efficacy but the gain between two and three applications was insignificant. Mixtures of M-Pede with Azera or Entrust also slightly increased control, but differences were not significant and all treatments of M-Pede caused moderate to severe levels of phytotoxicity on the foliage.

Counts following the second release of late nymphs showed similar treatment differences in the number of early nymphs, of which the majority were 3rd instars that carried over from the first introduction (**Table 2**). All treatments provided less overall control of late nymphs, with F-2994 (81%), Azera applied three times (74%), Entrust + M-Pede (68%), Entrust (68%), and Azera + M-Pede (65%) showing significant reductions compared to the untreated control. None of the treatments significantly suppressed adults, of which almost all were newly-enclosed from the introduced 5th instars. Of noteworthy, however, the plots treated with the experimental F-2994 product had consistently fewer nymphs and adults, and provided the overall best control of BMSB.

The percentage of marketable fruit showing stink bug injury in untreated plots averaged 92.7%, of which the majority of fruit showed minor injury (1-2 feeding sites or cloud spots). In treated plots, the relative reduction in injury roughly paralleled the percent control afforded by each treatment (**Table 3**). All treatments resulted in significant reductions in fruit injury, except for F-7470, M-Pede, MBI-206, PFR 97, and Garlic. The experimental F-2994 again provided the highest reduction, with only 26.2% of the fruit injured. Most of this injury was probably caused by adults which were not effectively controlled by any treatment. Harvested fruit in untreated plots also showed some superficial injury on the stem and calyx end due to feeding by webworms but results indicated no significant differences among treatments or compared to the control (**Table 3**).

With the exception of the M-Pede treatments, there were no signs of phytotoxicity or effects of treatments on the overall plant health and vigor. Although there was no treatment effect on the total number of marketable fruit, the size and quality of fruit in plots treated with M-Pede appeared to be affected by the phytotoxic injury to the foliage.

Summary.

Based of the study results, organic farmers have insecticide options for controlling BMSB but the tested products were only effective against the nymph stages and provided relatively poor control of adults. The most effective insecticides (% control) available to organic farmers were Entrust + M-Pede (68-92%), Azera + M-Pede (65-90%), Entrust (68-89%), Azera alone (74-84%), and PyGanic (58-79%). However, controlling nymph development in a cash or trap crop will be expensive, given that two or three applications of product mixtures may be needed. The experimental F-2994 product (which is a plant extract) looks very promising and further refinement of this formulation may increase its efficacy against both nymphs and adults.

Table 1. Overall efficacy of organic insecticides applied alone and in combination via different application schedules on early instars of the brown marmorated stink bug in bell pepper. Central Maryland Research and Education Center, Beltsville, MD. 2013.

Treatments (rate/acre) and Application Schedule	**Number of early instars per 8 plants**
Azera (32 oz) 1X	10.5 cde
Azera (32 oz) 2X 3 days apart	3.9 ef
Azera (32 oz) 3X 2 days apart	3.8 ef
F-7470 (5.6 oz) 2X 3 days apart	12.6 bcd
F-2994 (15 lb) 2X 3 days apart	1.3 f
M-Pede (2% V/V) 3X 2 days apart	12.3 bcd
M-Pede + Azera (32 oz) 3X 2 days apart	2.5 f
MBI-206 (8 qts) 3X 2 days apart	17.8 abc
PFR 97 (1.5 lb) 3X 2 days apart	18.3 ab
Garlic (35 oz) 3X 2 days apart	23.4 a
Entrust (5 oz) 2X 3 days apart	2.6 f
Entrust (5 oz) + M-Pede (2% V/V) 2X 3 days apart	2.0 f
PyGanic (32 oz) 3X 2 days apart	5.1 def
Untreated	24.0 a

Treatment by date interaction effect was not significant (*P* = 0.94); thus means given are pooled over the three sampling dates.
Means within a column followed by the same letter are not significantly different (*P* > 05).
Significance of treatment effects: nymphs - $F_{(13,123)}$ = 26.3, *P* <0.001.

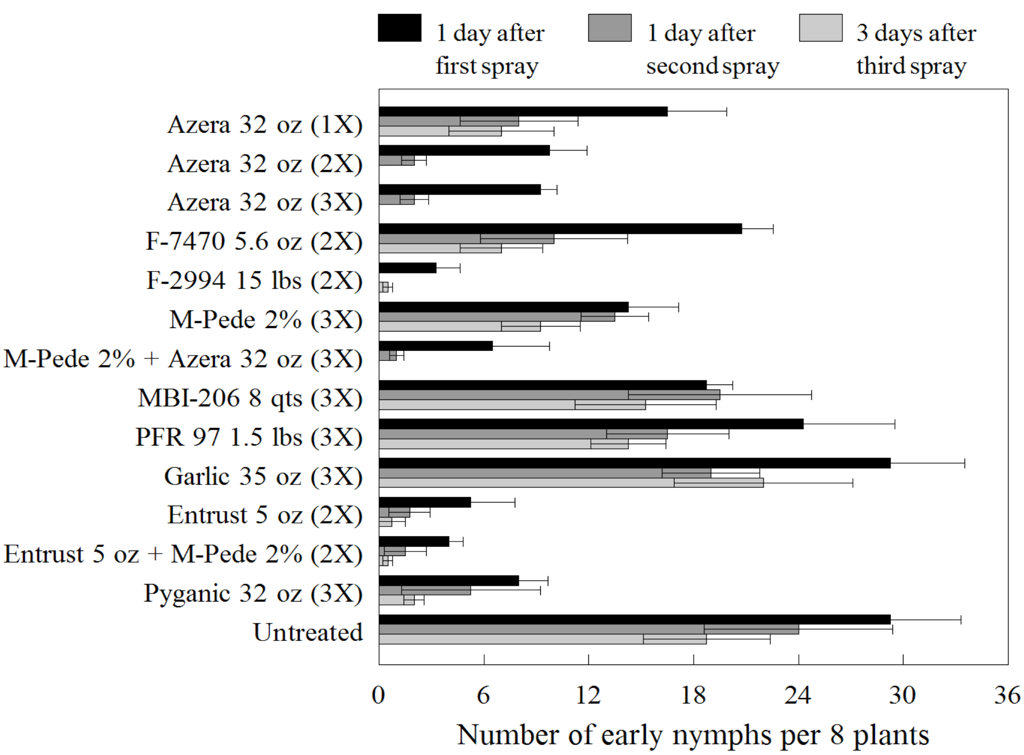


Figure 1. Effects of different application schedules of organic insecticides applied alone and in combination on early instars of the brown marmorated stink bug in bell pepper. Central Maryland Research and Education Center, Beltsville, MD. 2013.

Table 2. Effects of organic insecticides applied alone and in combination via different application schedules on nymphs and adults of the brown marmorated stink bug in bell pepper. Central Maryland Research and Education Center, Beltsville, MD. 2013.

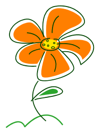
Treatments (Rate/acre) All applied twice	Stink bug stages: Early instars	Late instars	Adults
Azera (32 oz)	1.1 c	2.6 bcd	9.5 a
Azera (45 oz)	0.5 c	2.9 bcd	7.5 a
Azera (64 oz)	0.6 c	1.9 cd	7.6 a
F-7470 (5.6 oz)	3.6 abc	4.6 abcd	7.3 a
F-2994 (15 lb)	0.1 c	1.4 d	4.8 a
M-Pede (2% V/V)	3.1 abc	4.3 abcd	8.8 a
M-Pede + Azera (32 oz)	2.0 bc	2.5 cd	5.9 a
MBI-206 (8 qts)	5.9 a	4.9 abcd	7.6 a
PFR 97 (1.5 lb)	5.1 ab	6.4 abc	7.5 a
Garlic (35 oz)	5.9 a	7.5 a	6.5 a
Entrust (5 oz)	0.4 c	2.3 cd	6.8 a
Entrust (5 oz) + M-Pede (2% V/V)	0.6 c	2.3 cd	6.4 a
PyGanic (32 oz)	1.3 c	3.0 abcd	7.5 a
Untreated	6.3 a	7.1 ab	8.1 a

Treatment by date interaction effect was not significant or showed no change in relative differences; thus means are pooled over the two sampling dates. Means within a column followed by the same letter are not significantly different (P > 05). Significance of treatment effects: early instars - $F_{(13,81)}$ = 9.55, P <0.001; late nymphs - $F_{(13,81)}$ = 4.74, P <0.001; adults - $F_{(13,81)}$ = 0.856, P =0.61.

Table 3. Cumulative effects of selected organic insecticides via different application schedules for suppression of fruit damage caused by brown marmorated stink bugs and fruitworms in bell pepper. Central Maryland Research and Education Center, Beltsville, MD. 2013.

Treatment (Rate/acre) Total number of applications	Percentage of fruit damaged by stink bugs	Percentage of fruit damaged by fruitworms
Azera (32 oz) 3X	43.7 cde	20.0 a
Azera (32 oz) 2X + (45 oz) 2X	43.7 cde	11.0 a
Azera (32 oz) 3X + (64 oz) 2X	46.3 cde	21.6 a
F-7470 (5.6 oz) 4X	70.6 abcd	23.5 a
F-2994 (15 lb) 4X	26.2 e	22.5 a
M-Pede (2% V/V) 5X	74.7 abc	17.1 a
M-Pede + Azera (32 oz) 5X	45.5 cde	12.3 a
MBI-206 (8 qts) 5X	81.2 ab	15.8 a
PFR 97 (1.5 lb) 5X	90.5 a	33.6 a
Garlic (35 oz) 5X	93.0 a	15.7 a
Entrust (5 oz) 4X	39.7 de	11.8 a
Entrust (5 oz) + M-Pede (2% V/V) 4X	40.4 de	16.3 a
PyGanic (32 oz) 5X	51.2 bcde	14.0 a
Untreated	92.7 a	18.4 a

Means within columns followed by the same letter are not significantly different (P > 0.05).
Significance of treatment effects: stink bug damage - $F_{(13,39)}$ = 13.62, P <0.001; fruitworm damage - $F_{(13,39)}$ = 1.43, P =0.188.



Using Flowering Plants to Help Parasitic Wasps Attack Stink Bug Eggs

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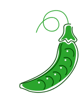
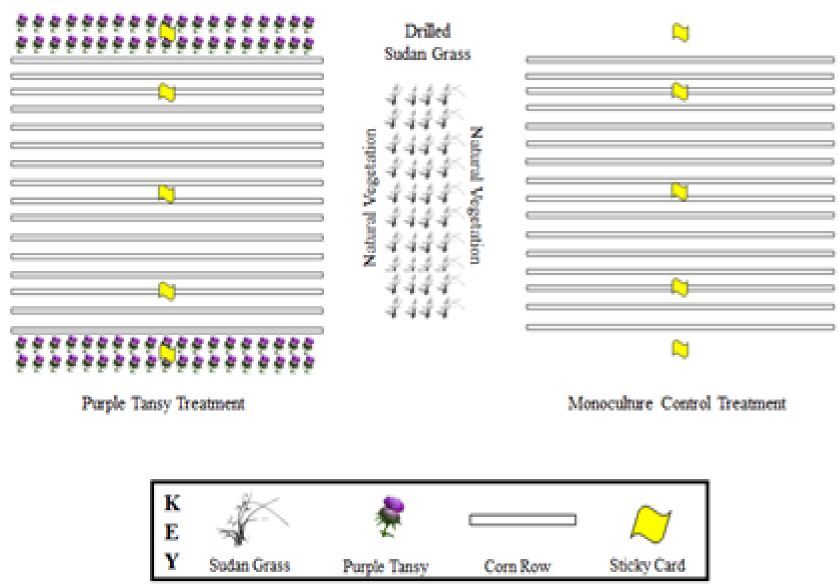
Parasitic wasps are beneficial wasps that generally lay their eggs inside the egg, immature or adult stage of another insect commonly called its *host*. Eggs of these wasps then hatch, leaving the larval wasp which resembles a maggot to consume the contents of the host egg. After consuming the host, parasitic wasps complete their development within the host and later chew their way out and emerge as adult wasps. Parasitic wasps that attack stink bugs and other insect hosts typically consume nectar during their adult life. Studies have shown that the *longevity* (lifespan) and *fecundity* (reproductive capacity) of some parasitic wasps are enhanced when they are allowed to feed on nectar from flowering plants. This need for nectar suggests that the maintenance of nectar producing plants that can be readily assessed by stink bug and other insect parasitoids will support their conservation. Conservation of parasitoids through the provision of nectar increases the likelihood that insect pest eggs will get parasitized and consumed by developing wasps. Plants that are grown near crops for the purpose of attracting and providing a nutritious food source for beneficial insects are often called *insectary plants*. Thus, we hypothesize that parasitism of stink bug eggs can be increased in crops containing *insectary plants* along their periphery.



Our current study focuses on the use of insectary plant strips planted along crop borders for managing the invasive brown marmorated stink bug (BMSB) *Halyomorpha halys* and other stink bug pests [e.g., brown stink bug (*Euschitus servus*), rice stink bug (*Oebalus pugnax*), green stink bug (*Acrosternum hilare*), etc.] in conventional soybean and organic field corn plantings. Using a *conservation biological control* strategy, we developed an experimental design to determine if nectar-producing plants, French marigold (*Tagetes patula*) "Single Gold" also sold under the brand name Nema-Gone, or buckwheat (*Fagopyrum esculentum*) and a purple tansy (*Phacelia tanacetifolia*) + buckwheat mixture when planted on the perimeter of soybean and corn plots, respectively, can attract and increase the effectiveness of predators and wasp parasitoids mainly belonging to the Scelionidae family (please see corn study design, **Fig. 1**). These beneficial wasps are very small, approximately 1/16 to 1/2 inch in length. Wasps from this family of insects are known to parasitize stink bug eggs including the BMSB and by doing so, effectively eliminate members of the stink bug population. We hope to provide these beneficial wasps a food source by planting these flowering strips, and subsequently increasing the suppression of stink bug populations within corn and soybean plantings.

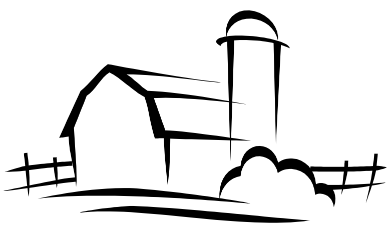
Marigold is mostly known for its ability to suppress populations of plant-parasitic nematodes. Limited studies have been conducted on its ability to serve as an *insectary plant.* However, laboratory experiments have shown that the life span of one Scelionid wasp, *Trissolcus basalis* can be enhanced when they are allowed to feed on nectar from French marigold flowers. Thus, we hypothesize that French marigold flowers may benefit other parasitic wasps in the family Scelionidae. On the other hand, purple tansy and buckwheat flowers have been found to attract beneficial wasps; and in Maryland, purple tansy has been shown to specifically attract Scelionid wasps. Our goals include establishing whether the presence of these *insectary plants* will have a significant impact on the fauna of insect pests and beneficial arthropods (insects and spiders) associated with corn and soybean plantings. Additional objectives include determining whether these insectary plants will impact final crop yield and quality.



Though data is still being collected and has not been analyzed, from casual observation it is relatively apparent that buckwheat attracts a number of "hungry wasps". However, purple tansy may be incompatible with MD climate as we noticed that the majority of plants were unable to flourish under field conditions. Most appeared to senesce or die within a few weeks following transplanting and displayed limited flowering. Thus, future plans include replacing the purple tansy + buckwheat mixture with partridge pea (*Chamaecrista fasciculate*).

Field studies conducted in Maryland showed that *partridge pea* have some of the characteristics of a good *insectary plant. It is compatible with MD growing conditions, flowers for the entire growing season given enough water and attracts beneficial parasitoids and predators.* Partridge pea is a native annual legume found throughout the eastern United States. It is additionally reported to be drought tolerant and grows in disturbed and sandy areas such as roadsides, suggesting hardiness. Partridge pea produces yellow flowers and is considered an important contributor to honey production. The nectar source of partridge pea is found in glands at the leaf base called *extrafloral nectaries* (EFN), not in the flowers. Extrafloral nectaries are nectar-producing glands on a plant that is physically separate from the flower*.* Beginning with the third or fourth true leaf, a saucer shaped extrafloral nectary can be found at the base of each petiole of the partridge pea. These nectaries are very small (0.5–4 mm across), secrete up to three microliters of nectar a day, and almost every leaf has one nectary. In addition to other arthropods, partridge pea plants are visited by many different ant species which can only obtain nectar from the plant's EFN*.* Though partridge pea attracts beneficial insects, it has been reported to be an important summer and fall host plant for the brown stink bug suggesting that partridge pea can serve potentially as both an *insectary plant* and *trap crop. Trap cropping* involves planting a plant species that is known to attract a pest near a *crop* susceptible to that pest, in order to lure it away from the *crop. Next field season, we will investigate the potential of partridge pea to serve concurrently as an insectary plant and trap crop in organic field corn plantings.*

The corn research project is being conducted in collaboration with Dr. Anne Nielsen at Rutgers University and is funded by a **USDA National Institute of Food and Agriculture (NIFA) grant (2012-51300-20097) that was awarded through the Organic Research and Extension Initiative (OREI) program. This program focuses on helping producers and processors who have already adopted organic standards to grow and market high quality organic agricultural products. The soybean research project is made possible through funding by the Maryland Soybean board. If there are any questions regarding these projects and the use of insectary plants feel free to email Lauren, Armando or Cerruti. Their email addresses can be found under personnel at www.cerrutirrhookslab.umd.edu/**



WyeREC Horticultural Crops Research Projects

By Michael Newell
Horticultural Crop Program Manager,
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mnewell@umd.edu

WyeREC has 40 acres devoted to Horticultural crops research. Crops include; small fruits, tree fruits, annual and perennial vegetables, forestry and ornamental material. In any given year about 20 acres are used for active research, with the remainder in rotations with cover crops for soil improvement. In general, the research is divided into Integrated Pest Management (IPM), variety evaluations, nutrient management, culture and management. Research is conducted by University of Maryland College of Agriculture and Natural Resource (AGNR) scientist which include Plant Sciences and Landscape Architecture (PSLA) personnel, University of Maryland Extension (UME) personnel and Maryland Agricultural Experiment Station (MAES) personnel. In any giving year, scientist from these departments, graduate students and cooperating institutions such as the USDA and other Land grant colleges may be conducting research at this Center.

IPM

With the increasing availability of genetically enhanced crops, the ever evolving list of new pesticide chemistries and the introduction of exotic pest into our food production systems, IPM practices become more important. Several sweet corn trials conducted by Galen Dively (Department of Entomology) are investigating and monitoring new BT sweet corn varieties for insect resistance to this technology and how some of our current insecticides may be losing their effectiveness.

Ornamental pumpkins are an important crop for many growers in Maryland. New varieties that offer disease resistance or tolerance may change our approach to controlling diseases in this crop. Kate Everts, vegetable plant pathologist (PSLA) has research investigating several spray programs based on IPM scouting procedures and using fungicides that target specific organisms as opposed to general use fungicides.

Stink bugs, both native and exotic types can be a problem in sweet corn production. Cerruti Hooks (Department of Entomology) is investigating the use of companion crops that are habitat for predators of the stink bug.

Nutrient Management

The quality of fresh market fruits and vegetables grown in the field and/or high tunnels can be affected by the fertility program used. Jerry Brust (UME) is investigating various nutrient regimes and how they affect fruit quality when grown in high tunnels. Watermelon quality can also be affected by various nutrient programs, and Jerry has a trial investigating this.

A new crop being investigated here at WyeREC is Aronia, *Aronia melanocarpa*. Andrew Ristvey (UME) is breaking ground on the nutrient requirements of this new small fruit bushberry with his research trials.

Annual plasticulture strawberry production is a high-yielding, high-value crop with specific requirements for achieving success. Strawberry fruit quality is directly linked to several nutrients and when they are applied in the growth cycle. Research conducted by Michael Newell (AES/UME) is evaluating different fertility sources and combinations to maximize fruit quality.

Variety selections and evaluations

New varieties of fruits, rootstocks and vegetables are constantly being introduced by private and public institutions. Variety resistance to insect and diseases are our first defense and it's important that we provide unbiased information about new introductions.

University of Maryland (Chris Walsh PSLA) has been involved with the NC140 fruit tree rootstock research group for the past 30 years. NC140 is the National research group that breeds and evaluates rootstocks for apple, pear, cherry, plum and peach. WyeREC and WMREC have hosted several NC140 trials over the years. Currently WyeREC and WMREC are evaluating size-controlling apple rootstock developed through the Cornell breeding program. Other fruit variety trails at WyeREC include Asian pear, strawberry, wine grape and peach. Fruit from these variety trials are also being used for post-harvest evaluations.

Vegetable variety trials at WyeREC include asparagus and pumpkins.

Culture and Management

Several graduate students have trials going this season at WyeREC. Two PSLA students have trials with lettuce and tomato. The lettuce trials are using three sources of local compost and its impact on lettuce quality. The tomato study is investigating the use of an antagonistic naturally occurring bacterium and its effects on Salmonella in tomato production. A graduate student in ENST department is investigating the use of Tillage radish and its impact on the direct seeding of small seeded spring crops.

Galen Dively's (Entomology) lab is screening organically based insecticides on pest in cole crops.

Shirley Micallef (PSLA) and her team are investigating food safety issues in the production of fresh vegetables both in conventional and organic production of lettuce, spinach and tomato.

Chris Walsh (PSLA) and Michael Newell (AES) are involved in a multi-state NC140 peach project looking at meteorology influences and its use in predicting harvest date and final fruit size. In addition we have several peach tree training systems set up for teaching and production evaluations.

Jerry Brust is using several varieties of tomatoes in high tunnels to evaluate insect pressures and their effect on fruit quality.

Results of research trials at WyeREC and other UM research farms.

Results from trials conducted at the various UM research farms are disseminated in several ways. UME sponsored growers meetings are held throughout the year at the REC's, where interested parties can see the field research and hear the investigators discuss their research. These on-farm meetings are great opportunities to interact with the researchers and discuss one-on-one the research objectives and results. County Extension newsletters provide current conditions, meeting announcements and also present research results. AGNR, UME and REC websites also provide research results. These can be found at *agnr.umd.edu*. The web address for WyeREC is www.*wrec.umd.edu*. Currently you can access the presentations from past strawberry twilight meetings, the annual Bay Area Fruit School, Pumpkin and Sweet Corn twilight meetings and the Aronia twilight meetings.

Current Trend with Bt Sweet Corn Control

By Galen P. Dively
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College Park, MD 20742

Sweet corn producers must rely on timely pest monitoring and effective insecticide sprays to minimize ear damage by corn earworm, European corn borer, and fall armyworm. The fresh market and processing industry can tolerate only minimal damage to the ears. Pyrethroids are the popular choice for worm control but efficacy has declined in recent years due to resistance in corn earworm populations. Spray mixtures of Lannate plus a pyrethroid have become a common practice to circumvent a potential resistance problem. Lannate is also added to spray programs when sap beetles are the problem. Rotations and mixtures with newer but more expensive insecticides such as Coragen, Belt and Radiant, as well as some premix products (i.e. Besiege, Voliam Xpress, Hero EC) are also recommended options and provide excellent control. However, despite what insecticide is used, timing the first spray at the first signs of silking, followed by a prescribed schedule based on moth pressure, and adequate spray coverage of the ear zone are critical steps to achieve effective control. For example, most corn earworm eggs are oviposited directly on corn silks; once larvae hatch, they quickly move down the silk channel, and begin feeding on the ear tip, where they are protected from insecticidal sprays. It is thus important to maintain a residual level of insecticide on silk tissue at all times.

The problems with conventionally applied insecticides have been solved by transgenic delivery of insecticide within the sweet corn plant. As an alternative, the most potent bioinsecticide for sweet corn insect control is provided by transgenic hybrids expressing one or more insect-active toxins from the bacterium, *Bacillus thuringiensis* (Bt sweet corn). Attribute® Insect Protected hybrids from Syngenta Seeds have been commercially available since 1996. Acreage of Bt sweet corn has increased significantly in recent years with the introduction of improved fresh market hybrids. The availability of seed in 25K units has also made it easier for the small producer to use the Bt technology. Attribute Bt hybrids express a single Cry1Ab toxin (event Bt11) that is highly effective against European corn borer but this toxin alone does not provide 100% control of corn earworm or fall armyworm. Based on multiple-year field trials in Maryland, Attribute® hybrids eliminates all whorl treatments and reduces silk sprays by at least four applications, when insect pressure is high. Although these hybrids provide excellent protection against the caterpillar complex, two and sometimes three supplemental insecticide sprays are needed to ensure fresh market quality ears during high moth activity. Moreover, corn earworm populations are developing tolerance to the Cry1Ab toxin in mid-Atlantic region, where this insect successfully overwinters. Compared to their isogenic non-Bt counterparts, ear damage in Attribute Bt hybrids has increased since 1996, based on untreated demonstration plots planted each year on Maryland research farms.

Biotech and seed companies are continually working on new Bt gene combinations in corn to broaden the spectrum of activity and to prevent resistance development. The development and commercialization of new Bt field corn events by Syngenta Seeds have isolated a novel vegetative insecticidal protein from the bacterium Bt – Vip3A (MIR162 event). This toxin is highly effective against a broad range of agriculturally important lepidopteran larvae including black cutworm, fall armyworm, corn earworm, western bean cutworm, and others. In field studies conducted in Maryland and Minnesota, hybrids expressing the Vip3A trait and pyramided with the Cry1Ab Bt protein were compared to near isogenic non-Bt hybrids. Over all years and locations, the non-Bt hybrids, without insecticide protection, averaged between 43 and 100% ears infested with a range of 0.24 to 1.74 earworms per ear. By comparison, no larvae were found in the pyramided Vip3A x Cry1Ab hybrids, indicating virtually 100% of all lepidopteran larvae.

Compared to the single gene Bt11 event, this combination of Bt proteins significantly increases control efficacy against a broader spectrum of lepidopteran pests for several reasons. First, the MIR162 event has been shown to express a high dose of Vip3A protein against fall armyworm and a "near high dose" against corn earworm. Second, the average expression per ear in the endosperm of the kernels is higher due to the segregation pattern of the two independent genes encoding the Cry1Ab and Vip3A proteins compared to the segregation pattern of a single gene. For example, Attribute Cry1Ab sweet corn hybrids are hemizygous for the Bt11 trait. Due to open pollination and gene segregation in the ear, approximately 75% of the kernels per ear express the Bt11 trait (50% hemizygous and 25% homozygous), while 25% of kernels will not inherit the gene. This is true for any single insect resistance trait sold as a hemizygous hybrid. Hybrids containing two unlinked insect resistance traits, such as the pyramided Bt11 x MIR162 hybrids will have only 6% of the kernels that do not inherit at least one trait, with 94% expressing either Cry1Ab, the Vip3A or both insecticidal proteins. This is an important point because larvae hatching later in the crop cycle can invade the ear without feeding on silk tissue, depending on the ear tip coverage and tightness of the silk channel. Reducing the number of non-protein expressing kernels increases the average Bt expression per ear and thus the likelihood of larval mortality via consumption of protein-expressing kernels. The pyramided Vip3A x Cry1Ab hybrids are marketed under the Attribute II trade name and Syngenta Seeds plans to commercialize several hybrids of this technology in 2014.

Monsanto's Seminis Seeds also has developed and is marketing pyramided Bt sweet corn under the Performance Series trade name. Bt hybrids available are Temptation, Obsession, and Passion. These hybrids express three insecticidal proteins: Cry1A.105 and Cry2Ab (events MON89034/ MON88017) to control lepidopteran larvae, and Cry3Bb1 to control rootworms, as well as herbicide tolerant traits. Maryland studies have shown that the Performance Series hybrids provide 100% control of corn borers, virtually 100% control of fall armyworms, and more than 95% control of corn earworms, of which the few surviving larvae are small and cause only minor injury on the ear tip. Depending upon insect pressure, Performance Series hybrids may show a little more ear damage compared with the pyramided Attribute II sweet corn. The reason is that protein expression per ear is lower than Attribute II because the Cry1A.105 and Cry2Ab genes were vectored together into the plant and thus the segregation pattern is the same as a single gene (that is 25% of kernels do not express).

Attribute II and Performance Series sweet corn hybrids ideally fit the IPM philosophy by combining host plant resistance traits, different modes of action to prevent resistance, and a reduced risk bioinsecticide; and they provide an environmental safe option to conserves beneficial insects. Clearly, the Bt technology can significantly reduce pesticide use and control costs, but control efficacy may vary under adverse growing conditions or very high insect pressure. And finally, these Bt hybrids will not be insect pest free, so regular monitoring of insect pests not affected by the expressed proteins (especially sap beetles, stink bugs) will be essential for successful IPM.

Sustainable Lettuce Production: Summer Varieties and Vermicompost

Anna Wallis, Graduate Student,
University of Maryland, College Park

Introduction

Sustainable farming is a growing industry in our region. This research aims to evaluate two agricultural practices with the potential to increase the sustainability of lettuce production, currently a top vegetable crop in the U.S., for local growers.

Lettuce

Four cultivars of heat tolerant romaine (Cos) lettuce are being evaluated across three growing times: spring, summer, and fall. Cultivars that do not bolt and get bitter during the hot weather will be recommended for use during the summer months. Extending the growing season through summer will decrease dependence on west coast based industry and provide a new summer crop for local growers. The performance of these four cultivars is being evaluated on yield and quality, including a taste test at the USDA facility in Beltsville, MD.

Cultivars


Solid King


Sun Belt


Green Forest


Dov

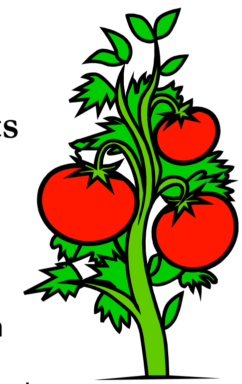
Vermicompost

Vermicompost is a novel technology being used by some farmers today as an organic amendment to enhance vegetable production. It is a high quality soil amendment produced using earthworms to decompose and recycle organic wastes such as livestock manure and food scraps. It has been demonstrated to improve the quality and yield of many crops, especially

fruiting crops such as tomatoes. This research is evaluating the effects of several industry sources on lettuce as compared to a comparable windrowed compost.
Additionally, research is being conducted to determine nutrient release rates of these materials across a full growing season. Data collected will be used to generate a graph and system that can be used by specialists to provide nutrient management recommendations when using vermicompost.

Preliminary Results and Further Work

The spring and summer crops have been harvested and the data is being processed. A recently planted fall crop will be harvested in early October. Preliminary data on heat tolerant cultivars indicates that all lettuces in the spring planting were far superior to grocery store selections. Lettuces from the summer plantings were approximately equivalent in size and taste. Vermicompost results so far indicate that vermicompost is equivalent in beneficial effects to standard soil amendments for lettuce grown in the field. Due to the high demands of producing this product, it may not be cost effective for farmers to use it as a replacement for traditional soil amendments.



Biocontrol of *Salmonella* and Microbial Ecology of Tomato Plants

Sarah Allard, Graduate Student at UMD in PLSC
Advised by Dr. Chris Walsh, Funded by JIFSAN

Through previous laboratory, growth chamber, and field studies, a strain of the bacteria *Paenibacillus alvei* (termed TS-15), has demonstrated potential to decrease the incidence of human pathogen *Salmonella enterica* and plant pathogen, *Ralstonia solanacearum* (bacterial wilt) infection in tomato plants. Although TS-15 was isolated from the environment in which it will likely be used as a biocontrol (eastern US tomato field soil), when applied its concentration is magnified in the environment. Microbes associated with plants can influence many processes important to plants including nutrient cycling, plant growth, and pathogen resistance. For this study, half of the plots were amended with multi-source poultry litter, and tomato plants were treated at the seedling stage, early fruiting stage, both, or not at all, with TS-15. This study seeks to further evaluate the effectiveness of TS-15 by monitoring *E. coli*, *Salmonella*, and *Enterococcus* levels on the roots, leaves, and fruits of the tomato plants throughout the season. Furthermore, microbial community structure will be profiled by examining the total DNA from each anatomical region of the tomato plant across treatments using metagenomics. This will broaden our understanding of how live biocontrols used in agriculture affect microbial communities associated with plants, which could have significant impacts on plant health and disease management.

Asian Pear Research at the University of Maryland

Christopher Walsh and Julia Harshman
Department of Plant Science and Landscape Architecture
Michael Newell
Maryland Agricultural Experiment Station, WyeREC
Wayne M. Jurick II
USDA-ARS, Food Quality Laboratory

The goal of this trial is to test the adaptation of Asian pear trees to the typical management practices used by small-scale, direct-market operators. Trees set at WyeREC are one trial orchard in a multi-state replicated trial set in eight locations across the eastern United States in April, 2010. This research will provide valuable information for fruit growers in the Eastern United States.

Asian pear trees are quite precocious and productive. Trees in this study began flowering and fruiting in their second leaf and measurements of postharvest quality began in the third leaf.

As expected, tree survival varied considerably among cultivars. At this location, we have observed great variability in tree survival. Both European cultivars have lost 3 of 5 trees planted. On the other hand, about half of the Asian pear cultivars have better tree survival. Survivability of the trees is most likely due to inherent differences in fire blight tolerance among these cultivars and species.

Cultivar	First Picking, 2012	Tree Survival (%)
Asian Pears		
Isi'iwase	August 3	100
Shinsui	August 3	100
Kosui	August 9	100
Hosui	August 10	40
Yoinashi	August 13	80
Atago	September 10	60
Shinko	September 12	100
Ya Li	September 24	40
European Pears		
Bartlett	August 27	40
Golden Russett	No crop	40

Fruits were harvested at Wye in 2012 and stored at 4ºC (40ºF) until early October. At that time they were evaluated by consumers at the University of Maryland's open house at the Clarksville Farm, in Howard County. This was our second year of taste-testing Asian pears and we had similar results both years. Asian consumers showed little interest in tasting apples, but were drawn to Asian pears tasting. Others who participated in the taste tests reported some awareness of the crop and had seen it on sale in supermarkets but had neither tasted nor purchased the fruit previously. After tasting these pears, most people reported that they would be interested in purchasing fruit and requested the names of local pear growers.

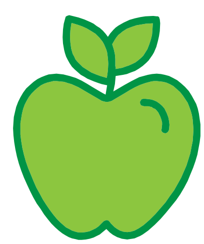
'Olympic' was ranked as the best-tasting cultivar. This result is similar to grower observations and is particularly notable as this cultivar also appears to have good field tolerance to fire blight.

Postharvest quality measurements and disease susceptibility trials began in the third leaf, in August, 2012. Postharvest trials are currently being conducted by Wayne M. Jurick II at the USDA-ARS laboratory at Beltsville. Fruits are harvested at WyeREC and held under refrigeration until they can be analyzed at the USDA lab.

Shinsui and Atago were the most tolerant to blue mold when stored at 1ºC (34ºF) for 2 weeks although Hosui and Isi'iwase performed the best at resisting decay at 25ºC (77ºF) These results indicate that different varieties could be grown to suit the needs of the producer depending on accessibility to cold storage or if the fruit will be marketed directly to the consumer.

Asian pear research at the University of Maryland has been supported by the Harry R. Hughes Center for AgroEcology, the Joint Institute for Food Safety and Nutrition (JIFSAN) and the Maryland Agricultural Experiment Station competitive grants program. We wish to express our gratitude to these three organizations for their assistance with this research.

Incorporating Surround® into an IPM Program for Control of BMSB in Apples



Bryan Butler Bryan Butler *and Doug Price
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I have continued my work with Surround® and "soft insecticides" for the 2013 season on apple and peaches. Although that data is not in yet, I wanted to share the 2012 information as we go into the final weeks of the 2013 season and just give a word of warning. BMSB pressure appears to be increasing in many areas. This is especially true in Keedysville where this work is being done. It is important that you be extremely vigilant as the season comes to a close because even if you haven't had damage to this point it is possible for large numbers of BMSB to move in late and do a lot of damage at the end of the season.

Following the 2010 growing season with its devastating losses in peaches and apples caused by Brown Marmorated Stink Bug (BMSB), many growers in Maryland were ready to use any chemistry required to produce a crop in 2011. The 2011 season proved to be frustrating for growers that experienced BMSB infestations with regard to: pick your own spray schedules, days to harvest, IPM programs being damaged by broad spectrum pesticide application leading to loss of beneficial insects, increased exposure to high toxicity products, cost, increased number of applications, fuel, time, loss of some of these products, and public perception. Thus, growers have been forced to spend significantly more on production costs such as labor, fuel, materials, and maintenance.

This project examines the potential to return to pre-2009 timing, interval, and material selection by incorporating Surround® as a tool to combat our newest and most insidious pest, Brown Marmorated Stink Bug (BMSB).

Current recommendations for the control of BMSB in apples include the use of Synthetic Pyrethroids, Organochlorines and Organophosphates. These chemical families have been replaced in orchard spray programs in recent years by products with more specific modes of action that are generally less harmful to beneficial organisms. The use of the more general insecticides that appear to reduce the level of BMSB damage may potentially lead to the destruction of Integrated Pest Management (IPM) programs that have been in place for nearly thirty years as beneficial populations are decimated. The purpose of this experiment is to determine if the addition of Surround® (an organically certified kaolin clay product) to insecticide materials used to control traditional orchard pests can reduce the level of damage to fruit caused by BMSB.

The Surround® was used at a rate of 12.5 pounds per 100 gallons as a tank mix that may be acting as a repellent or tactile deterrent and could offer greater protection of the fruit, particularly if used as a bridge treatment between, or a replacement for insecticide applications, or as part of a push-pull management strategy. Thus, the addition of the clay to the surface of the fruit and foliage may result in behavioral modification of BMSB. It is well documented that BMBS is very mobile and moves into the orchard causing the most severe damage on the perimeter rows. The clay barrier from Surround® could be deterring BMSB from moving into the orchard, or possibly reduce the time spent in the trees, leading to a reduction in feeding damage. In order to examine this, samples evaluated were paired with samples from trees in similar positions in the orchard, i.e. exterior bordering to corn, exterior bordering woods, and interior. This was done to compare fruit that should be receiving comparable pressure form BMSB based on the environment.

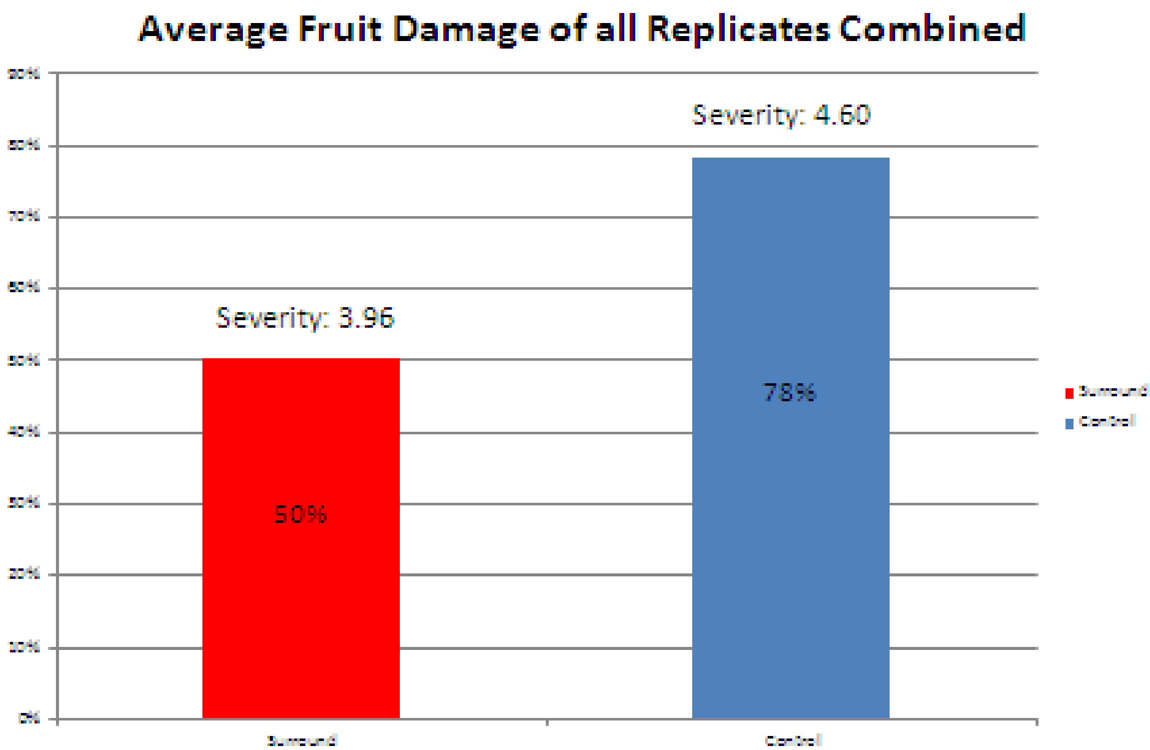
The insecticide applications were made based on an IPM program using traditional monitoring tools for lepidopteron pests with visual observations for BMSB being added to the program and material selection being based on need for control of the pests present. Pheromone traps for Coddling Moth, Tufted Apple Bud Moth and Oriental Fruit Moth were placed in the block and monitored weekly to determine need for application. BMSB were monitored using three minute surveys of five trees weekly to determine presence and damage to fruit.

Half of the trees received the program without Surround® added and half received the program with Surround® added. Fifty fruit per tree were destructively sampled at harvest and, although damage was still above what would be considered acceptable economic threshold, severity of damage was very low, yielding a high percentage of salable fruit.

Although we are in the process of evaluating the data, initially it appears that there was nearly 30% less damage by BMSB on the fruit that received the program with Surround® and larger differences when like replicates are paired for comparison.

2012 Apple Timeline

3/12/12 – Late dormant/silver tip – Lorsban Advanced + Tenn Cop 5E + Dam Oil
3/22/12 – Tight cluster – Manzate Pro-Stick + Vintage SC
4/3/12 – Bloom – Manzate Pro-Stick + Rally 40WSP + Agri-Mycin 17
4/16/12 – Late Bloom – Syllit 65W + Captan 50W + Agri-Mycin 17
4/25/12 – Petal fall – Manzate Pro-Stick + Vintage SC + Assail 30SG
5/4/12 – Rally 40WSP + Syllit 65W + Imidan 70W + Agri-Mycin 17 + Surround WP*
5/16/12 – Penncozeb 75DF + Rally 40WSP + Assail 30SG + Surround WP*
5/24/12 – Penncozeb 75DF + Flint + Actara + Surround WP*
6/4/12 – Rally 40WSP + Captan 50 + Altacor + Surround WP*
6/14/12 – Captan 50 + Delegate + Surround WP*
6/22/12 – Rally 40 WSP + Captan 50 + Delegate + Surround WP*
7/2/12 – Ziram 76DF + Assail 30SG + Surround WP*
7/12/12 – Rally 40WSP + Captan 50 + Assail 30SG + Surround WP*
7/24/12 – Pristine + Ziram 76DF + Actara + Surround WP*
8/3/12 – Captan 50 + Topsin M WSB + Assail 30SG + Surround WP*
8/13/12 – Pristine + Topsin M WSB + Captan 50W + Altacor + Surround WP*
9/7/12 – Pristine (Goldrush/Enterprise only)
9/7/12 – Pristine + Brigade WSB (Granny Smith/Pink Lady only)
***Surround WP was not applied to designated blocks of Goldrush and Enterprise**



Acknowledgements: Greg Krawczyk, Ph.D. Extension Tree Fruit Entomologist Research Associate Professor Penn State University
Starker Wright USDA-ARS Appalachian Fruit Research Station
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Biological Control of Mites in Pennsylvania and Maryland Apple Orchards

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Introduction

Natural enemies and environmental factors limit populations of insect and mite pests in natural systems. When natural enemies are killed by man's actions in any crop such as through pesticide applications or when pests are introduced to new habitats without their natural enemies (i.e. Asian species such as the Brown Marmorated Stink Bug (BMSB) or Spotted Wing Drosophila (SWD)), natural control often fails and results in pest outbreaks. Biological control of pest species by predators, parasitoids, and pathogens has been a cornerstone of IPM since its inception. It has been difficult to utilize the full potential of biological control in tree fruit and other crops that receive periodic sprays of broad-spectrum pesticides and/or have high quality standards. The best pest targets for biological control in tree fruits are generally the secondary foliage-feeding pests that do not cause direct fruit injury (i.e. mites, aphids, & leafminers) and for which low level populations can be tolerated. Populations of pests that feed directly on the fruit (i.e. codling moth, oriental fruit moth, & plum curculio) generally can't be tolerated at levels high enough to sustain populations of biological control agents because of stringent fruit quality standards.

The most successful biological control programs in U.S. tree fruits have centered on the conservation of mite predators to control the European red mite and two-spotted spider mite. After 40 years of use, some of these predators developed resistance to organophosphate insecticides, but are suppressed or eliminated when broad-spectrum carbamate and pyrethroid insecticides are used. The use of pheromone mating disruption, horticultural oils and some of the more selective reduced-risk insecticides and miticides will allow a natural increase of predators capable of regulating pest mite populations to tolerable levels without the use of miticides. The potential savings to Pennsylvania apple growers is approximately $1 million per year and a reduction of almost 1 ton of miticide active ingredient into the environment. Mite control through biological control in apple has the additional advantage of stopping the development of miticide resistance and, once established, is sustainable long-term if the use of certain harmful pesticides is avoided. **The routine use of carbamate and pyrethroid insecticides in stone fruits, pears, grapes, and small fruits currently prevent reliable biological mite control, even though many of the same predators found in apple can be present.**

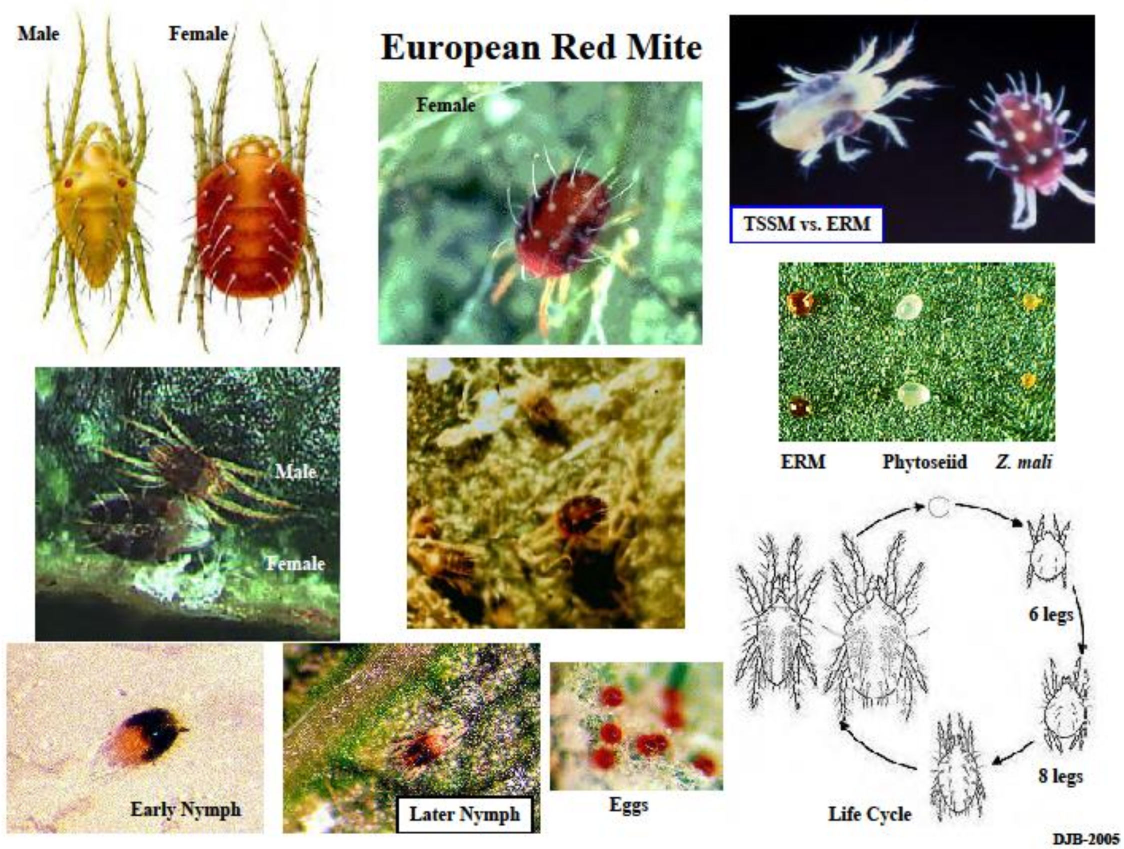
Heavy infestations and fruit injury in some areas of Pennsylvania and Maryland by BMSB in 2010-12 forced many apple growers to move away from the softer, more environmentally benign reduced risk insecticides that promoted biological control of spider mites, woolly apple aphid and summer green aphids. The introduction of SWD is causing a similar situation in small fruit such as blueberries and brambles. Pheromone mating disruption and products such as Altacor®, Belt®, Intrepid®, Delegate®, Assail® and Calypso® that had been the core of our summer insecticide programs to control codling moth, Oriental fruit moth, and leafrollers were not effective on this new pest. They were replaced to some extent by older, more toxic, broad-spectrum insecticides such as Lannate® and Thionex® and many apple growers also began to use pyrethroids for the first time post-bloom, or with increased frequency. The relatively soft neonicotinoid insecticides like Assail and Calypso were replaced by other products in the same class such as Venom®, Scorpion®, and Actara® which were more effective on BMSB, but much more toxic to bees and parasitic wasps/flies and occasionally flared pest mites. The result was not only a big jump in the cost of a grower insecticide programs, but also a loss of biological mite control by the predatory mite *Typhlodromus pyri*. Flare-ups of European red mite (ERM) and increased miticide use and costs were the result. Increases in Woolly Apple Aphids and San Jose Scale have also been noted in Pennsylvania for the same reason.

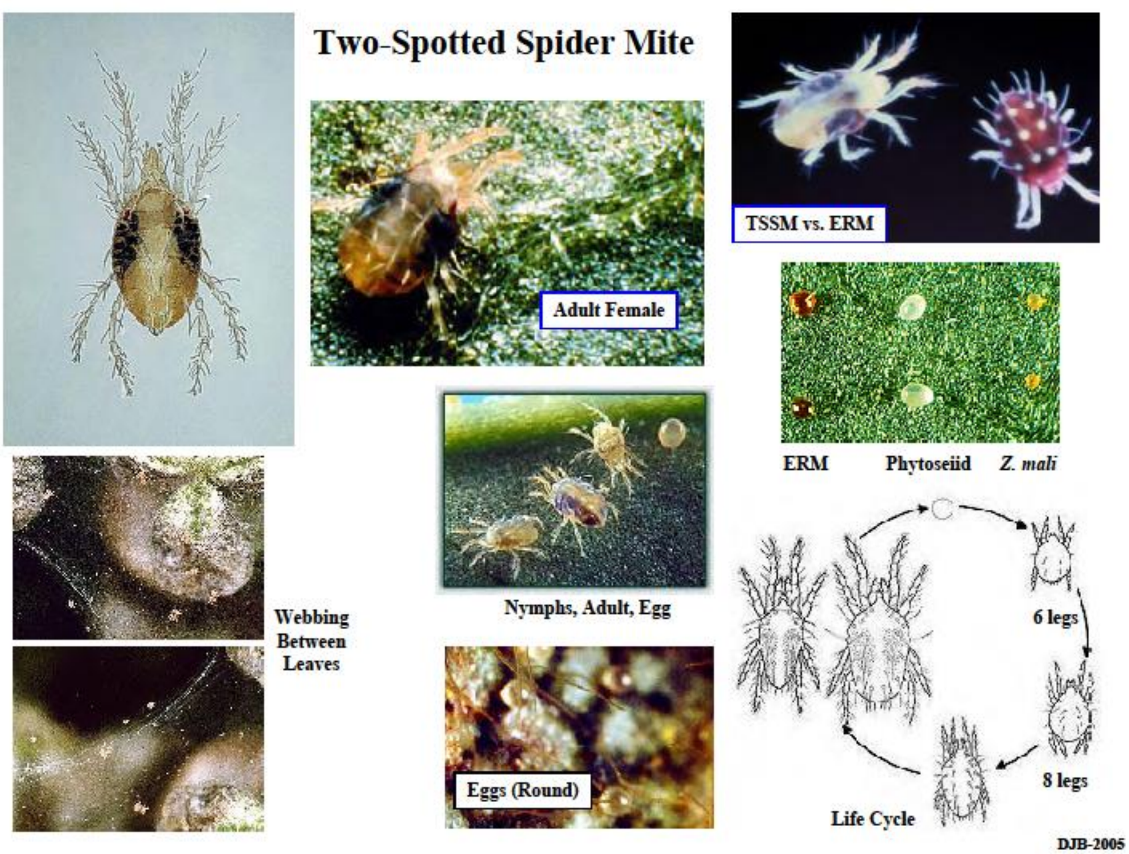
Biological Mite Control in Pennsylvania Apple Orchards

The two main spider mite pests of apple in the eastern U.S. are the European Red Mite and the Two-Spotted Mite. They feed on the chlorophyll and other cell contents in leaves that gather sunlight energy which is then converted to food for the plant. The lack of green chlorophyll causes a yellowing or 'bronzing' of the leaves which generally occurs when spider mites reach 20-30 mites per leaf (mpl). The level at which 'bronzing' occurs, however, depends on many factors including the time of the year, size and variety of the tree, drought stress, and crop load. As a general rule in apple, a spray threshold of only 2.5 mpl exists early season before June; it increases to 5 mpl from June through mid July; and up to 7.5 mpl through the rest of the season.. Higher levels of spider mite damage can reduce fruit quality, color and size at harvest and reduce return bloom the following season.

Penn State University is internationally known its biological mite control program in apple based on the small black lady beetle, *Stethorus punctum.* Developed by Asquith, Colburn, Hull and Biddinger from the 1970's through the late 1990's at the Fruit Research and Extension Center at Biglerville, *S. punctum* biological control of pest mites reduced miticide use by over 50% (almost 2 million pounds) and saved apple growers about $20 million in pesticide costs during this period. Biological mite control by *Stethorus*, however, declined in the late 1990's due primarily to the registration of neonicotinoid insecticides (Provado®, Calypso, Assail etc.), Rimon®, Spintor® and Delegate which were all very toxic to *S. punctum*, and to the development of a number of more effective miticides which prevented the higher pest mite populations and low levels of mite injury commonly associated with reliance on *Stethorus* alone. Historically, *Stethorus* also used to be abundant in peach orchards before the widespread use of pyrethroids in that crop.

Around 2005, another even more effective biological control program was developed around the Phytoseiid predatory mite, *T. pyri*. This was predator was new to Pennsylvania, but had been an effective biological control agent of European red mite (ERM) and two-spotted spider mite (TSSM) on apple in New York, New England and Europe. Much of the effectiveness of *T. pyri* has been lost in New York over the last 10-15 years due to increased use of Lannate and pyrethroid sprays for the control of OP resistant oblique-banded leafroller. *T. pyri* has never been found in Michigan due to long-term use of both of these types of compounds, despite favorable weather conditions. In the more humid apple growing areas of Washington and British Columbia, *T. pyri* is also gives dependable control of spider mites where OPs and softer insecticides are used. Our current population of *T. pyri* probably came to Pennsylvania on apple bins moved between states or on nursery stock and a survey of 40+ Pennsylvania apple orchards in 2005 found *T. pyri* to be present in over half. A program developed by Penn State and funded by USDA-NRCS conservation programs moved *T. pyri* from known "seed" orchards (including FREC orchards) to many new grower orchards and as of 2009, it was estimated that over 80% of Pennsylvania apple orchards have this predator present at some level. Where conserved by the use of selective insecticides & miticides, *T. pyri* has reduced the use of miticides by over 90% and some growers have not sprayed mite susceptible varieties like Red Delicious for more than 10 years.





Surveys are under way this season to determine if *T. pyri* exists in Maryland apple orchards and can be conserved using the same guidelines developed in Pennsylvania. It is possible some areas of Maryland may be too hot in the summer for *T. pyri* and that another equally effective, but less pesticide tolerant species, *Amblyseius andersonii*, may be dominant. This is the case in northern and southern Europe, where *T. pyri* is dominant in apple orchards north of Italy, and *A. andersonii* is dominant from Italy south. Another related phytoseiid predatory mite, *Amblyseius fallacis,* is present in Maryland, but as a pure predator that does not feed on alternative food sources such as apple rust mites, mold spores or pollen as with the other 2 species, it does not persist on the trees year round. Because of this and because it is less pesticide tolerant than *T. pyri*, *A. fallacis* has not been a reliable mite predator in Pennsylvania. All three species are closely related and can only be distinguished from slide mounted samples with a specialized phased-contrast microscope found only at the FREC currently.

Using official Pennsylvania NASS statistics on the use of miticides in the years before and after implementation of the *T. pyri* biological mite control system, it was estimated that miticide use declined by over 1 ton active ingredient each season and that the savings to growers was approximately $1 million/year before the big BMSB invasion of 2010. This level is similar to that saved during the *Stethorus* period, but the typical low to moderated level of leaf injury associated with 15-20 mites/leaf typically reached with *Stethorus* is much higher than the typical peak of only 1-2 mites/leaf under the *T. pyri* system. *T. pyri* overwinters on the tree as females in deep bark crevices where it is protected from most pesticides applied prior to bloom and then comes out to feed on apple pollen during bloom. It is probably most susceptible to toxic sprays at petal fall, before the eggs are laid and populations begin to build. Unfortunately, toxic sprays late in August and September (BMSB timing) can also greatly reduce the number of overwintering *T. pyri* females.

Problems With Pyrethroids – Hormolygosis

Results from field trials in 2012 also demonstrated increases in overwintering ERM eggs of over 10-fold with only a single application of pyrethroids and some neonicotinoid insecticides due not only to toxicity to predatory mites, but to a process called hormolygosis where ERM and TSSM are stimulated hormonally to have more generations in a season and lay more overwintering eggs. Hormolygosis was demonstrated in the spring of 2012 in some grower orchards after fall 2011 applications of Endigo® (Actara®/Warrior® mixture) for BMSB the previous season. Extremely high numbers (25 mites/leaf) of overwintering ERM eggs hatched during pink and bloom with one grower to cause heavy injury very early in the season when apple trees are most susceptible to injury. This grower had conserved *T. pyri* for over 10 years with almost no miticide use, but applied one or two alternate row-middle (ARM) sprays Endigo for BMSB control without realizing it was also pyrethroid. Some *T. pyri* survived the sprays, but numbers were reduced and overwintering *T. pyri* females emerging from bark crevices at bloom and petal fall, could not reproduce quickly enough to keep up with the high numbers of ERM eggs which hatched in the spring, slightly before those of *T. pyri*. On the parts of the farm where only one side of Endigo was applied the previous fall, a single ARM application of the miticide Envidor (which is very safe to *T. pyri* – see table below) was necessary at bloom to reduce ERM populations enough to where *T. pyri* were able to build and establish mite control for the rest of the season. Where two ARM applications of Endigo was used elsewhere on the same farm, however, *T. pyri* was almost eliminated and two ARM applications of Envidor were necessary to reduce ERM populations until the predators could re-establish in the fall. Even so, ERM counts in the spring of 2013 in the blocks that had received two applications were still significantly lower than in parts of the farm that had only a single application of Endigo in the fall of 2011. This case study shows how even a single toxic spray may cause disruption of mite control for more than a single season.

While saving $50-100/A in miticide use is a big advantage to growers, another unseen benefit is in miticide resistance management. In orchards without biological mite control resistance to miticides can develop in as little as 2-3 seasons as we saw with Pyramite®/Nexter® and Acramite® about 10 years ago. The one exception has been Agri-Mek® which we have not seen develop resistance despite over 15 years of use. Unfortunately, this product has only a short window after petal fall in which it can be used, and it is very toxic to predatory mites. Other miticides with exception of Envidor and Zeal® are also toxic to predators, and most of the other products have similar modes of action to Pyramite/Nexter and thus have resistance issues (See table from the Pennsylvania Tree Fruit Production Guide below). Miticide resistance has not been an issue in orchards under biological mite control because of their infrequent use and because the mite predators negate selection pressure for resistance by eating both miticide susceptible individuals and those that are resistant to miticides. Thus, Envidor and Zeal are the products of choice to conserve predatory mites on the infrequent occasions when pest mites flare in orchards under biological mite control. Both Apollo® and Savey® miticides are also safe to predatory mites as well, but like Agri-mek have a limited window for application early in the season which means that applications are made before you know you have a problem.

Another phytoseiid predatory mite, *Amblyseius fallacis*, had been present in PA apple orchards during the period of biological mite control by *Stethorus*, but was generally reduced to ineffective levels due to multiple applications of Lannate which was used to control OP resistant tufted apple budmoth. It was probably due to the elimination of this pesticide for leafroller control and replacement by Confirm®, that *T. pyri* was finally able to establish itself in Pennsylvania apple orchards. *A. fallacis* is very similar in appearance to *T. pyri*, but has a very different biology that limits it effectiveness on pest mites. *A. fallacis* is a pure predator that can't exist on fruit trees when ERM or TSSM are low. It generally leaves the trees to feed on mites in the ground cover during most of the season and is often slow to move back into the apple canopy to feed on pest mites when populations build. *T. pyri*, however, is a long-lived generalist feeder that will subsist on pollen, rust mites, powdery mildew spores, San Jose scale crawlers etc. if pest mite populations become low and thus is always present in the canopy. This makes it a very reliable predator if conserved by using selective pesticides. *A. andersonii* is very similar in biology to *T. pyri*, but is better adapted to warmer regions and from a few sites in Pennsylvania where it was found, it appears to be tolerant to OP sprays, but less tolerant to other insecticides. *T. pyri, A. andersonii* and *A. fallacis* are all effective at levels of only 1 predator mite to 10 pest mites. A bright yellow, slow moving stigmaeid predatory mite, *Zetzallia mali*, is often also common in apple orchards, and although more resistant to Lannate and pyrethroid than the other predators, it is slow to reproduce and feeds only on spider mite eggs or rust mites. It is usually does not give effective biological mite control by itself, but may be a useful supplement to control by other predators.

Listed below are descriptions of the main biological mite predators found in Pennsylvania apple orchards:

***Typhlodromus pyri* (Phytoseiidae)**

Discovered in Pennsylvania in 2003, this predatory mite is by far the most reliable and effective mite predator. It is very similar in appearance to *Amblyseius fallacis* (see below) also commonly found in apple orchards, but is an omnivore and more closely associated with its apple host. It is very active and moves very rapidly to consume up to 350 mite prey in a lifespan of about 75 days. Females may lays up to 70 eggs each and have several generations per season. Populations, therefore, can build very rapidly in response to pest mite populations. Most effective in the cooler weather of the spring and fall, *T. pyri* is somewhat less effective in the summer months. It overwinters on the apple tree under the bark where it is less susceptible to dormant oil applications and is very tolerant of Pennsylvania's relatively mild winters.

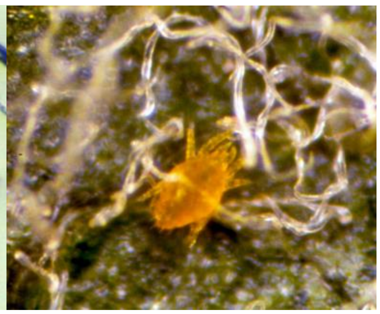
Able to regulate pest mite populations well below injury thresholds of less than 5 pest mites per leaf, it is able to subsist on harmless apple rust mite populations, pollen or fungal spores when pest mite populations are low. Well adapted to living in apple, *T. pyri* do not leave the tree during the season and once populations are established, sustainable mite control is virtually ensured when the predator to prey ratio is at least 1:5 and probable at 1:10. This seasonal association with its apple host, however, makes them very susceptible to toxic pesticides. Because they do not disperse quickly, they may take several growing seasons to re-establish after extinction by harmful pesticides unless artificially re-introduced. Once populations are identified or artificially established, conservation is therefore very important and applications of certain pesticides have to be avoided. Natural populations are most likely to be found in grower orchards relying primarily on organophosphate and reduced-risk insecticides and where pheromone mating disruption is being used. Establishment of *T. pyri* into orchards where it is absent is relatively simple and can be accomplished in 1-2 seasons once "donor" orchards with abundant *T. pyri* populations have been identified as a source. Transfers of *T. pyri* from these orchards can be successful by physically moving blossom clusters or shoots in May and June. (See Pennsylvania Fruit Monitoring Guide or PSU Fruit Research & Extension Center website for pesticide susceptibility and orchard transfer methodology).

***Amblyseius fallacis* (Phytoseiidae)**

Almost indistinguishable from *T. pyri* except under microscope slide mounts, this predator has a widespread in distribution in Pennsylvania apple orchards due the use of alternative plant hosts such as weeds in the ground cover or non-fruit trees along the edges of orchards. Like *T. pyri*, it is also very active, but is able to build populations 3 times faster during the hotter summer months. It is not as tolerant of cool weather in the spring and fall and is susceptible to winter kill in Pennsylvania. Purely a predator, *A. fallacis* is not able to co-exist on apple trees without pest mite populations to feed on and will often leave the tree to feed on mites in the orchard ground cover. Because its association with the apple host is not nearly as close as that of *T. pyri*, *A. fallacis* populations often do not build until mid to late summer leaving trees the trees susceptible to early season mite injury. Because it can also survive in the orchard ground cover, however, *A. fallacis* is not as susceptible to extinction in the orchard due to applications of toxic pesticides applied to the tree. The predator to prey ratio of *T. pyri* also applies to *A. fallacis* and distinguishing between the 2 species is not important as long as this ratio is reached.

***Zetzellia mali* (Stigmaeidae)**

An omnivore like *T. pyri* that is able to exist on pollen, fungi and rust mites when spider mite populations are absent, *Z. mali* is very slow and feeds on the eggs of pest mites. Its diamond shape and bright yellow coloration make it easy to distinguish from other predatory mites. Because it is less active, it is able to exist on pest mite populations even lower than *T. pyri.* Like *T. pyri*, it is also more active in the cooler spring and fall months. However, with only a couple of generations each season and a consumption rate of only 2-3 eggs per day, it can not be relied upon to control mite pests alone. It is, however, a valuable supplement to control by other mite predators and is much more tolerant of most pesticides, including pyrethroids.

***Stethorus punctum* (Coccinellidae)**

Once the cornerstone of biological mite control in Pennsylvania apple orchards, this small, black ladybeetle predator has greatly declined in importance over the last 10 years. While tolerant of many organophosphate insecticides, this decline has been mainly due to the greater use of pyrethroids and the introduction of several new neonicitinoid and IGR insecticides which are also toxic. Reproducing only when populations of pest mites exceed 8-10 mites per leaf, relying on this predator alone required the tolerance by growers of some foliar injury. With the registration of newer, more effective miticides in recent years, most growers are not willing to tolerate this injury, despite the high cost of miticides. *S. punctum* is now much less common in orchards and generally in small localized "hot spots" of mites along the borders of orchards. The main advantage now of this predator is it ability to fly and quickly colonize these areas.


Establishing, Conserving & Augmenting *Typhlodromus pyri* in Apple Orchards

While a number of mite predators such as *Stethorus punctum, Amblyseius fallacis*, and *Zetzellia mali* may contribute to the biological control of European red mite and two-spotted spider mites in apple, only the conservation of native populations of *Typhlodromus pyri* have proven to give consistent, long-term control. Once established, *T. pyri* can almost completely regulate pest mite populations without the need for miticides, if the use of certain toxic pesticides is avoided.

1. The first step for apple growers in establishing mite control with *T. pyri* is to determine if it exists in significant numbers in their orchards.

The most likely sites are:

- Those that have not received pyrethroid or methomyl applications for several seasons.
- Older orchards with large trees where spray coverage is not complete.

- Abandoned orchards.
- Reduced-risk pesticide orchards or those relying mostly on pheromone mating disruption to control codling moth and Oriental fruit moth.

Sample several trees in each block by examining the underside, mid-veins of 25 leaves/tree for fast-moving tear-drop shaped mites with a hand lens (10-15X). They will appear to be clear or slightly reddish, but not red or bright yellow in color or have spots. (See the PSU Fruit Research & Extension Center website or attached identification sheet). The best time to sample would be early-season (late May or June) or when pest mites are beginning to build. Samples taken early in the spring and in the fall may have relatively low populations that are hard to detect. If detected, bring 25 leaf samples from several trees to the Penn State Fruit Research & Extension center in Biglerville where they will leaf-brushed in a special machine and slide mounted to distinguish if you have *A. fallacis* or *T. pyri* under a microscope.

2. If you have *T. pyri*, do not use pyrethroids or carbamate insecticides after bloom (exception of carbaryl for fruit thinning).

T. pyri begins to emerge from overwintering sites deep in bark crevices at the beginning of bloom, so pre-bloom pesticides have little effect on them. The exception to this is Lorsban, which is toxic if applied past ½ inch green (after this time, they can also be toxic to bees). Dormant & summer oil applications (<1%) have little effect on *T. pyri*, but help suppress pest mite populations. Applications of pyrethroids and methomyl can cause near complete extinction of populations (although some tolerance to Lannate has been seen in some orchards), and may require 2-3 seasons to return naturally. Although toxic at insecticidal rates, the lower rates of carbaryl used for fruit thinning appear to have minimal effect on *T. pyri* populations and 1-2 applications can be made mid-season as a rescue treatment for Japanese beetle control if necessary. Mancozeb fungicides, however, are slightly to moderately toxic (depending on the rate) to *T. pyri* eggs if applied past bloom. If a ratio of at least 1 predator to every 10 pest mites is not reached, it may be necessary to suppress the pest populations with a selective miticide (sampling procedures pesticide safety information for biological control in the PSU Tree Fruit Production Guide & PSU Fruit Research & Extension Center website).

3. If *T. pyri* is not present in particular orchards, they can be introduced from shoots or blossom clusters cut from PSU identified 'donor' sites.

Although easiest to cut from other sites on the same farm that have been identified by PSU to have *T. pyri*, in cases where none exist or have been identified, specific sites on the PSU Fruit Research & Extension Center at Biglerville are available to all Pennsylvania apple growers for cutting and transferring shoots (contact David Biddinger at djb134@psu.edu). In order to have the best chance of establishing *T. pyri* populations in a single season, transfers of shoots & leaf spurs are best made early season after petal fall (May- June), but before the hot weather of summer (July & August). Transfers after July appear to be less likely to establish populations. Also effective are transfers of flower clusters during bloom when *T. pyri* are concentrated in order to feed on pollen. Transfers should be made at 2 shoots or clusters to every 6th tree in high density plantings and every 3rd tree in normal plantings. Cutting with hand-pruners from a *T. pyri* donor orchard and placing the shoots or flower clusters in the tree canopy of a new orchard takes approximately 1.5 hours per person/acre (exclusive of travel time)

Penn State Tree Fruit Production Guide

Table 4-4. Toxicity of pesticides to mite and aphid predators, at rates recommended in Part V. *(Modified 7/1/13)*

Material	*Stethorus* adults	*Stethorus* larvae	*Typhlodromus pyri*	*Neoseiulus fallacis*	*Zetzellia mali*
Insecticides/ Miticides					
Actara	+++	+++	+	**0**	**0**
Altacor	**0**	**0**	**0**	**0**	**0**
Asana XL	+++	+++	+++	+++	++
Assail	++	++	+	**0**	**0**
Avaunt	++	++	**0**	**0**	**0**
azadirachtin	+	+	—	—	—
Azinphosmethyl	+	+	**0**	**0**	**0**
Beleaf	—	—	—	—	—
Belt	**0**	**0**	**0**	**0**	**0**
Bt	**0**	**0**	**0**	**0**	**0**
Calypso	++	++	**0**	**0**	**0**

carbaryl	+++	+++	++	++	+
Centaur	++	++	+	+	+
Clutch	++	++	+	**0**	**0**
codling moth granulosis virus	**0**	**0**	**0**	**0**	**0**
cyfluthrin	+++	+++	+++	+++	++
Danitol	+++	+++	+++	+++	++
Delegate	+	+	++	++	+
deltamethrin	+++	+++	+++	+++	++
diazinon	+	+	+	+	+
endosulfan	++	++	++	++	+
Esteem	++	+++	**0**	**0**	**0**
Imidan	+	+	**0**	**0**	**0**
Intrepid	**0**	**0**	**0**	**0**	**0**
Lannate	++	++	++	+++	++
Leverage	+++	+++	+++	+++	—
Lorsban pre-pink	+	+	+	**0**	**0**
malathion	+	+	**0**	**0**	**0**
Movento	+	+	**0**	**0**	**0**
Permethrin	+++	+++	+++	+++	++
Provado	++	++	+	+	**0**
Proaxis	+++	+++	+++	+++	++
Rimon	**0**	+++	**0**	**0**	**0**
Sevin XLR	+++	+++	++	++	++
SpinTor	**0**	**0**	+	+	**0**
Surround	++	++	++	++	++
Tourismo	++	++	+	+	+
Voliam Flexi	++	++	+	**0**	**0**
Warrior II	+++	+++	++	+++	++
Acramite	**0**	**0**	++	++	++
Agri-Mek	++	++	++	++	+
Apollo SC	**0**	**0**	+	+	+
Envidor	++	++	**0**	**0**	**0**
Kanemite	+	+	+	+	+
Kelthane	+	+	++	++	+
Nexter	++	++	+++	+++	++
Portal	++	++	++	++	+
Savey	**0**	**0**	+	+	+
summer oil	+	+	++	++	+
Tourismo	++	++	+	+	+
Vendex	+	+	++	++	++
Voliam Flexi	++	++	+	**0**	**0**
Vydate	++	++	+++	+++	+++
Zeal	**0**	**0**	++	++	++
Fungicides					
Bayleton	+	+	+	+	—
captan	+	+	+	+	+
Flint	+	+	**0**	**0**	**0**
lime sulfur	++	++	+++	+++	+++

mancozeb	+	+	++	++	+
Polyram	+	+	++	++	+
Procure	—	—	**0**	**0**	**0**
Rally	+	+	**0**	**0**	**0**
Rubigan	**0**	**0**	**0**	**0**	**0**
Sovran	**0**	**0**	**0**	**0**	**0**
sulfur	++	++	++	++	+
Thiram	+	+	+	+	—
Topsin M	+	+	+	+	++
Vangard	**0**	**0**	**0**	**0**	**0**
Ziram	+	+	+	+	+

+ = slightly toxic, ++ = moderately toxic, +++ = highly toxic, — = no data available, 0 = nontoxic
For toxicity to honey bees, see Table 1-9.
Some information adapted from New York Agricultural Experiment Station data, Midwest Biological Control News, and Washington State University Tree Fruit and Extension Center.

2013 SWD Season Monitoring Summary for Central & Western Maryland

By Bryan Butler, Principal Agent, UME
Carroll County & Mid-Maryland Tree Fruit Agent

Our monitoring efforts began in early May and I attempted to cover as many types of soft fruit as I could, so I selected 8 orchards with the most crop diversity I could logistically handle. Traps were deployed and monitored on a weekly basis until the fruit was gone and a fruit sample of each crop was taken at peak harvest time. These samples were taken to the fruit lab in Biglerville where any larva in the fruit were given a chance to develop and were then identified and counted.

The good news from 2012 and 13 was that it appeared well managed crops like tart cherries, sweet cherries, strawberries (both plasticulture and matted row), and black raspberries made it through with little to no damage in Central and Western Maryland. Having said that, I would like to address the term "well managed." In plantings that were not harvested in a timely fashion, or received little or no insecticide applications, problems were identified. Another important point here is to be sure there is positive identification of this pest. In all of the early cases where SWD was first detected it could be associated with a management issue. Although SWD was identified in the samples, there were significant numbers of other types of fruit flies that were found in the fruit when the larva were reared in a laboratory.

Now as for blackberries, blueberries, and primocane bearing raspberries, even well managed plantings began to run into trouble, particularly as the season progressed. Our first trap detection was June 14th in 2012 and June 21st in 2013 in Central Maryland and there were already larva in the fruit in blackberries. At this point it is important to note that the vinegar traps are not very good. They are a tool that helps, but in the end I found myself simply breaking up a lot of fruit and looking closely for the larva in the fruit if I really wanted to know what was going on in a planting. Populations generally increased all summer and into the fall with what appeared to be drops during extended very hot periods.

The take home message is that SWD is going to pose a serious challenge to small fruit producers but is not the end of the world. The intensity of management in small fruit will certainly increase in order to produce fruit without "worms". It appears to be critical from my personal experiences and those shared with me from other states that this pest must be addressed early and not allowed to get a good foothold in your planting. Through trapping, scouting, timely harvest, sanitation, and consistent insecticide applications that provide thorough coverage, including the lower part of the plant once the infestations are identified, production and quality can be maintained. In the long run, hopefully sooner than later, research will identify beneficials and predators that will create a more natural balance with this pest that will help reduce pesticide application. However, for now it is important to remember to be on the lookout in small fruit as soon as fruit begins to show color because it appears this is a pest that is more readily held to acceptable levels if caught early. If it becomes very established in a planting, control can become almost impossible. Thorough coverage with both pressure and water volume is critical.

These scouting efforts were made possible in substantial partly through funding by the Maryland State Horticulture Society (MSHS). MSHS provided the bulk of the money required to cover the travel needed to these sites each week and to take samples for positive identification to the Penn State Fruit Lab in Biglerville, Pa.

Frost, Freezes and Fall Vegetables

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As we move into October, frost becomes a factor in harvest and recovery of vegetables. Later in the fall, freezes can become a concern. The first frost on inland sites generally occurs by the third week in October in the middle of Delmarva. However, this can vary quite a bit. For example, the first temperature below freezing in the Laurel DE area occurred on Oct13 (28.9°F) in 2012, Oct 30 (30.7°F) in 2011, Nov 1 (31.6°F) in 2010, Oct 20 (31.5°F) in 2009 and Oct 20 (29.8 F°) in 2008. The first hard freeze (below 28°F) in the Laurel area occurred on 11/5, 10/31, 11/14, 11/6, and 10/31 from 2012 to 2008 respectively. Coastal areas will see a delay in frost. For example, Kitts Hummock, near the Delaware Bay, had first frosts on 11/6, 10/31, 11/2, 11/6, and 10/31 over the last 5 years.

Light to moderate frosts will not affect cool season vegetables such as cole crops, lettuce, and spinach. Some cool season crops, such as broccoli, kale, and collards will handle freezing conditions. In contrast, cauliflower, once frozen, will deteriorate quickly. Warm season vegetables vary considerably in their ability to tolerate a light frost. For example, pepper is more cold tolerant in the fall than tomato which is severely damaged by frost. Pumpkins and winter squash will have leaf and vine kill with light frost but fruits will remain marketable. Heavier frosts and freezes will damage the fruit. Sweet potatoes must be dug quickly after a frost kills vines and will suffer root damage if soil temperature drops below 40°F. We often have significant acreage of beans still out in the fall. Snap beans and lima beans will have leaf damage but still can be harvested with a light frost. It is when temperatures drop below 28°F and pods freeze that harvest recovery is affected. When lima beans are frosted, you may have several weeks to get into the field and harvest. However, if there is pod freezing, the harvest window drops to a few days, depending on the day temperatures, before seeds start to "sour".

For unprotected frost sensitive vegetables, it is important to follow weather forecasts closely for risk of frost or freeze. Clear sky conditions after a cold front moves through will be the highest risk for frost or freeze. When risk is high, growers should harvest all marketable produce ahead of the frost or freeze with crops like tomato (ripe, breakers, and mature greens).
Floating row covers offer the best protection of sensitive vegetables against frost and freeze injury, depending on the thickness of the row cover, expect 2-6°F degrees of protection. Moist soil also can store some heat, lessening frost, and sprinklers can be used for fall frost protection (see past articles of spring frost protection).

TPM/IPM Weekly Report for Arborists, Landscape Managers & Nursery Managers

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Long Range Weather Prediction (10/25/2013 excerpt)

Several people have sent me in long range predictions they found on the web. Two weeks ago I got one that said the long range prediction is that we will have a colder than normal winter with more snow than normal. Last week someone forwarded me a linked to a site that predicted the complete opposite with a milder than normal winter with less than normal rainfall. On Saturday, I spoke with a friend that is an oceanographer with NOAA in Silver Spring, Maryland. I asked him, as a NOAA employee, what the long range prediction was. His answer was that it very difficult to predict because our weather is control by the North Atlantic Oscillation pattern. I went to the web to find out what is the North Atlantic Oscillation and here is what I found:

The **North Atlantic Oscillation (NAO)** is a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea level between the Icelandic low and the Azores high. Through east-west oscillation motions of the Icelandic low and the Azores high, it controls the strength and direction of westerly winds and storm tracks across the North Atlantic. It is part of the Arctic oscillation, and varies over time with no particular periodicity.

My friend form NOAA pointed out that since it oscillates with no particular periodicity it just about anyone's best guess as to what type of winter we will experience. He said this does not stop many people from making predictions; Lots of luck trying to figure out what is coming this winter.

Groundhogs: The Inquiry (10/18/2013 excerpt)

We had an inquiry come in via email asking about groundhog damage in nurseries. This brings up an interesting topic on pest control. The reason for the animosity between some nursery managers and groundhogs can be traced to the fact that groundhogs are pretty good at taking advantage of areas plowed or loosened by nursery practices. As a consequence, they tend to start new burrows anywhere a nursery manager has already disturbed the ground. This means that groundhogs see new nursery trees as construction opportunities; places where new burrows can be dug quickly and with a minimum of effort.

The average groundhog excavates over 700 pounds of dirt digging just one den, and a single groundhog may have four or five dens scattered across its territory, moving in and out of them as crops and weather change. The really interesting thing if they are removing 700 lbs of soil where do they put it all? The mound outside their opening is really not extremely high, in most cases.

It is hard to think as groundhogs as beneficial but keep in mind that groundhog burrows are important shelter resources for red fox, gray fox, opossum, raccoon, and skunk, most of whom do not dig their own burrows, but simply occupy those of groundhogs.

That said, most nursery managers try to control groundhogs in the nursery row. If you have an interesting, and legal method of taking out groundhogs that you are willing to share we would love to hear about your "best methods."

Groundhogs: Grower Response (10/25/2013 excerpt)

Last week we put out an article on groundhog damage in nurseries and asked for input on solutions people have tried. First off, thanks for those reader who took the time to send input on groundhog control. Several novel ways of eliminating groundhogs were sent in with some bordering on legally.

Since there are no restriction on groundhog hunting in Maryland, several nursery managers reporting shooting was the most common way of dispatching groundhogs. Of course this is in areas where discharging guns is legal. Two different people sent in links for Rodenator. **www.rodenator.com/extermination-groundhogs-woodchucks-pest-control**.

The rodenator looks like a rather expensive way of dispatching groundhogs but appears to be effective from the video.

Several people mentioned using the humane "Have-A-Heart" traps. We asked DNR wildlife experts about these traps and it was pointed out that if you catch a groundhog it is illegal to move it to another location to release. The concern is that there is a chance of releasing an animal with the chance of spreading diseased animals to a new location.

Winter Vegetable & Fruit Meetings

Mark your calendars now
and plan to be
a part of the winter meetings.

Central Maryland
Fruit and Vegetable Meeting
January 24th, 8am to 4pm
Friendly Farms Restaurant
Upperco, Maryland.
Contact Dave Martin dmarti@umd.edu for more information.

Southern Maryland
Fruit and Vegetable Meeting
February 5th, 8am to 4pm
Bowie Elks Lodge
Gambrills, MD.
Contact Dave Myers myersrd@umd.edu for more information.

Eastern Shore
Fruit and Vegetable Meeting
February 18th, 8am to 4pm
Cambridge, MD.
Contact Sudeep Mathews samathew@umd.edu for more information.

Bay Area Fruit Meeting
February 26th, 8:30am to 4pm
Wye Research and Education Center
Queenstown, MD
Contact Mike Newell (mnewell@umd.edu) for more information.

Vegetable & Fruit Headline News

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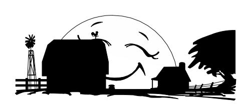
Submit Articles to:



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