Ohio State
Integrated Pest Management Grants Program Reports, 2005-2006

Ohio Integrated Pest Management

THE OHIO STATE UNIVERSITY
OARDC

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Special Circular 199
Ohio Agricultural Research and Development Center

In Partnership With Ohio State University Extension

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Contents

Introduction

The Ohio State University Integrated Pest Management (IPM) program is a comprehensive program that is designed to encourage collaboration and innovation among Ohio Agricultural Research and Development Center (OARDC) scientists and Ohio State University Extension (OSUE) personnel to better address the pest-management needs of the citizens of Ohio. The goal of the Ohio State IPM program is to reduce the environmental, economic, and social risk associated with managing pests — insects, diseases, or weeds. One way that we accomplish this goal is to provide funding to Ohio State University collaborators through an internal IPM grants program to evaluate and disseminate new IPM information. This OARDC Special Circular is a collection of reports from those projects that were funded during 2005 and 2006.

The Ohio State University IPM grants program funded 21 projects from USDA Smith-Lever 3d funds during 2005 and 2006. These projects ranged in size from $1,500 to $10,000 and totaled nearly $114,000. Some 20 reports were submitted that encompassed all of the basic areas of IPM — monitoring, forecasting, and cultural, biological, and chemical control — on many agriculturally important crops as well as on urban pests.

In this special circular you can find reports on monitoring methods of oriental fruit moth in tree fruit, surveys on the distribution of weeds and aphids in soybeans, bee pollinators in fruit, and phenology calendars to improve soil pest forecasting. Reports that addressed alternative or organic pest control methods in tree fruit, vegetables, and soybeans are also presented. In addition, reports that addressed pests of concern to urban citizens such as lawn IPM, ornamental gardens, and bed bugs can also be found in this special circular.

Some projects reported here are early in their research, such as finding natural herbicides and measuring the impact of CO_2 and light on floriculture pests, while other projects are ready for implementation. Throughout this publication research-based IPM information is provided that can be used by all Ohio citizens, whether they are conventional or organic farmers or urban residents. It is our feeling that by having access to these innovative IPM reports, the vast majority of Ohioans will find pest management methods that are economically efficient, environmentally responsible, and socially acceptable.

Evaluation of Bio-rational and Natural Products for Vegetable Crop Management in Commercial Market Gardens and Home Gardens, 2005

Investigators:

Celeste Welty (entomologist), Sally Miller (plant pathologist), Doug Doohan (weed scientist); and Mark Bennett, Matt Kleinhenz, and Bob Precheur (horticulturists)

Background

The insect pests and diseases that affect vegetable crops are the same whether the crops are grown on large farms for commercial production or on small diversified farms or home gardens, but the management tactics preferred by growers are often different for the different scale operations. Many market gardeners prefer to avoid using conventional pesticides because of concern about human safety and environmental contamination.

During the past few years, many bio-rational crop protection products have become available. Bio-rational protection products are derived from a variety of biological sources, including bacteria, viruses, fungi, and protozoa, as well as chemical analogues of naturally occurring biochemicals such as pheromones and insect growth regulators. While it is known that bio-rational products are safer to humans than conventional pesticides, it is not known whether they are effective in controlling the target pests that they claim to control.

In addition to products for insect and disease control, many products promote plant growth, such as microbial soil inoculants. There is little to no unbiased data available on the efficacy of these products. This deficit is a limiting factor in formulating up-to-date Extension recommendations for market gardens and home gardens.

This project was an important first step in the development of a set of recommended garden IPM tactics that will include cultural controls to prevent or delay pest problems, along with biological controls and selective chemical controls.

Objective

The objective of this project was to evaluate the efficacy of bio-rational products that are available for vegetable crop management in comparison with standard conventional materials.

Methods

Laboratory bioassays were conducted to evaluate the toxicity of 17 insecticides to 10 arthropod pests and two natural enemies. Whole leaves or leaf pieces were treated on both sides and air dried. Target arthropods and treated leaves were placed in plastic

8-ounce deli dishes and held at constant temperature. Bioassays for beetles, bugs, leafhoppers, and natural enemies were residual tests, in which the leaf substrate was treated but the insects themselves were not directly treated. Bioassays for aphids and mites were direct plus residual tests, in which the pest plus the leaf substrate were treated. Mortality was evaluated after 24 hours in all tests and also after 48 hours for most tests. Damage was rated for chewing pests. Arthropod species tested and details on size of trials are given in Table 1 for pests and in Table 2 for natural enemies.

Eight field trials were conducted — four on insecticides, two on foliar fungicides, and two on soil inoculants. Details about the scope of the trials are summarized in Table 3.

Results

In bioassays, differences among insecticide treatments were significant ($P < 0.05$) for all species tested. Products that were most and least effective for each species are shown in Table 1. A product was considered effective if it prevented damage and/or caused high mortality. Products most and least harmful to natural enemies are listed in Table 2.

The late-season snap bean trial, which included daily sprays during the seedling stage, showed significant differences among insecticides for bean leaf beetle control. Rotenone, pyrethrins, and carbaryl were most effective; permethrin, azadirachtin, capsaicin, and neem seed oil were intermediate; and endosulfan, spinosad, and garlic were least effective.

The broccoli insecticide trial showed significant differences in damage from caterpillars and flea beetles. Permethrin, spinosad, and carbaryl were most effective; pyrethrins, BT, and azadirachtin were intermediate; and capsaicin and neem seed oil were least effective.

Results of the squash vine borer trial were inconclusive. All treatments produced similar results. Results of fungicide efficacy trials are not yet available but will be summarized in a complete report to be posted at the Extension Entomology web site.

Conclusion

Valuable information on pesticide efficacy was obtained, information that will be presented at upcoming Extension programs and in a new bulletin on vegetable pest management.

Table 1. Bioassays Conducted to Evaluate Toxicity of Insecticides Against Common Vegetable Pests, 2005.							
Species	**Crop and Date Tested**	**Treat-ments**	**Rep-licates**	**Arthro-pods per Replicate**	**Most Effective Products**	**Intermediate Effective Products**	**Least Effective Products**
Bean leaf beetle	Snap bean 6/9/05	7	5	5	Rotenone Permethrin Carbaryl	Pyrethrins Capsaicin	Garlic
Striped flea beetle	Cabbage 6/30/05	4	3	4	Carbaryl	Pyrethrins	Capsaicin
Striped cucumber beetle	Pumpkin 7/5/05	10	4	5	Rotenone Permethrin Endosulfan Carbaryl	Pyrethrins	Capsaicin Neem oil Garlic Azadirachtin
Potato leafhopper, nymph	Snap bean 7/28/05	9	3	5	Endosulfan Pyrethrins Carbaryl	Permethrin Garlic	Azadirachtin Capsaicin Neem oil
Spotted cucumber beetle	Pumpkin 8/22/05	10	5	5	Carbaryl Pyrethrins Endosulfan	Permethrin Rotenone	Garlic Azadirachtin Neem oil Capsaicin
Spotted cucumber beetle	Pumpkin 9/22/05	9	5	5	Esfenvalerate L-cyhalothrin Carbaryl Cyfluthrin Pyrethrins	Endosulfan	Spinosad Permethrin
Squash bug, young nymphs	Zucchini 8/27/05	11	5	5	Spinosad	Carbaryl Endosulfan Pyrethrins Permethrin	Capsaicin Azadirachtin Garlic Neem oil Rotenone
Squash bug, old nymphs	Zucchini 8/31/05	7	5	3	Spinosad	Endosulfan Permethrin	Pyrethrins Rotenone Carbaryl
Squash bug, adults	Zucchini 9/19/05	9	5	3	L-cyhalothrin Cyfluthrin Pyrethrins	Esfenvalerate Endosulfan	Spinosad Permethrin Carbaryl
Blister beetle	Swiss chard 9/6/05	8	5	2	Pyrethrins Rotenone Permethrin	Carbaryl Endosulfan Spinosad	Neem oil
Melon aphid	Pumpkin 10/5/05	13	3	10	Pyrethrins Endosulfan Oil Esfenvalerate Carbaryl	Soap Permethrin	Azadirachtin Spinosad Capsaicin Garlic Neem oil
Potato aphid	Tomato 10/18/05	9	3	10	Esfenvalerate Pyrethrins Oil	Endosulfan Soap Permethrin	Neem oil Carbaryl
Two-spotted spider mite	Snap bean 10/26/05	6	3	30	Dicofol Soap, Oil	Pyrethrins	Permethrin

Table 2. Bioassays Conducted to Evaluate Toxicity of Insecticides to Common Natural Enemies, 2005.							
Species	**Crop and Date Tested**	**Treat-ments**	**Rep-licates**	**Arthro-pods per Repli-cate**	**Most Harmful Products**	**Intermediate Harmful Products**	**Least Harmful Products**
Parasitoid wasp of imported cabbage-worm	Broccoli 10/24/05	11	3	3	Rotenone Spinosad Endosulfan Carbaryl	L-cyhalothriin Pyrethrins Neem oil Esfenvalerate	Permethrin BT
Multi-colored Asian lady beetle	Broccoli 11/1/05	18	3	4	Pyrethrins L-cyhalothrin Carbaryl Rotenone	Permethrin Esfenvalerate Oil Cyfluthrin	Azadirachtin BT Capsaicin Dicofol Endosulfan Garlic Neem oil Soap Spinosad

Table 3. Summary of Vegetable Pesticide Efficacy Field Trials Completed, 2005.					
Crop	**Target**	**Number of Treatments**	**Number of Blocked Reps**	**Treatment Timing**	**Evaluations**
Zucchini (early; transplant 6/1)	Insecticides for squash vine borer	10	10	Spray 7 times (every 5 days), 6/22 to 7/20, or spray 5 times (every 7 days).	Harvest yield (18 times; 6/27 to 8/2); pheromone trap for SVB, June to August; scout 3 times for insects; stem dissection after final harvest.
Zucchini (late; transplant 6/24)	Fungicides for powdery mildew	9	5	Spray 5 times (every 10 days), 7/22 to 8/29.	Harvest yield (22 times; 7/20 to 9/7); foliar disease symptoms 3 times (8/16, 8/29, 9/7); scout 3 times for insects.
Tomato (main season; transplant 6/6)	Fungicides for anthracnose and early blight	9	5	Spray 6 times (every 10 days), 7/21 to 9/8.	Harvest yield and quality (7 times; 8/19 to 9/30); foliar disease symptoms 3 times (8/16, 8/29, 9/7); scout 5 times for insects.
Broccoli (late; transplant 7/8)	Insecticides for cabbage-worms	9	5	Spray 5 times, 7/28 to 9/2.	Scout 8 times: 2 pre-spray and 6 post-spray; harvest quality (9/23).
Beans (mid-season; plant 6/21)	Insecticides for bean leaf beetle and potato leafhopper	9	5	Spray 4 times: 7/23, 7/29, 8/13, 8/21.	Scout 7 times: 3 times pre- spray and 4 times post- spray.
Beans (late; plant 8/24)	Insecticides for bean leaf beetle and spotted cucumber beetle	10	6	Spray 4 to 10 times (every 1 to 10 days); different timing for each of 3 groups of products	Scout 6 times, all post-spray.
Beans (early; plant 6/7)	Soil fungicides for pythium et al.	3	5	Treat once at seeding	Stand count 3 times in first 6 days after emergence.
Beans (late; plant 9/30)	Soil fungicides for pythium, etc.	6	6	Treat once at seeding	Stand count 3 times in first 10 days after emergence.

Organic Thinning Techniques for Apples

Investigator:

Diane Doud Miller

Department of Horticulture and Crop Sciences

Introduction

Efficiently adjusting apple crop load has proved to be one of the most difficult aspects of organic production of apples. In normal bloom years, a final set of one flower per four flower clusters *(i.e.*, 20 flowers, as each cluster contains five flowers) ensures good fruit size and adequate return bloom. Hormonal thinners, used by commercial growers, are not allowed in organic production and hand thinning is a time consuming, difficult, boring, and discouraging job (If in doubt just try it!).

While bloom time thinning is somewhat dangerous in Ohio where nighttime temperatures during bloom will often result in frost killing of blossoms, it seems that blossom thinning is the only way to reduce cropping by spraying approved organic compounds. Frost killing of blossoms is an unreliable way to reduce cropping. The first blossoms to open (king blossoms) are most susceptible to frost, and these blossoms result in the highest quality fruit and need to be conserved in any blossom-thinning strategy.

Methods

In this first trial of potential organic thinning compounds in Ohio, compounds were selected to test based on the following criteria — approved organic, available to homeowners, easily accessible, and inexpensive. Crisco pure soybean vegetable oil and Heinz apple-cider vinegar (5 percent acid) were tested. Five treatments were applied:

1. No thinning treatment (control) — lime flagging.
2. Full-strength vegetable oil — pink flagging.
3. Tank mix 1:1 full-strength vinegar: full-strength vegetable oil — orange flagging.
4. Full-strength vinegar — pink/black flagging.
5. Full-strength vinegar followed by full-strength vegetable oil — orange/white flagging.

Treatments were applied at the beginning of petal fall. This was considered to be the time when (from a homeowner’s standpoint) the enjoyment of the bloom was declining as the petals were beginning to brown and fall. Many petals fell off when the trees were sprayed. During the 2005 season, full bloom was May 5, and treatments were applied May 11.

Two high value, disease-resistant apple varieties were treated — ‘Goldrush’ and ‘Honeycrisp’. ‘Goldrush’ was at late full bloom-petal fall stage when sprayed, and ‘Honeycrisp’ was at late full bloom (roughly two days behind ‘Goldrush’). Sprays were applied from 10:30 a.m. to 12:30 p.m. on a clear day with 80ºF temperatures and no wind. A backpack sprayer was used with an application rate of approximately 2 gallons of oil per 10 trees and 2 to 3 gallons of vinegar per 10 trees (to drip). The oil was difficult to apply in a fine spray. The vinegar was applied in a fine mist.

The trees used were located at Horticulture Unit 2 of The Ohio State University’s Ohio Agricultural Research and Development Center (OARDC) in Wooster, Ohio. Trees were six-years-old on B9 rootstock. Experimental trees were selected at bloom time, utilizing trees displaying uniform bloom volume.

The experiment was arranged as a randomized complete block with five trees per block and five replications (25 trees total per variety). Roughly 100 flowers per tree were counted and fruit set recorded by counting apples on tagged branches at harvest.

For ‘Goldrush’, at harvest, fruit set was determined, total number of fruit per tree were counted, total fruit weight was determined, and fruit finish was assessed. For ‘Honeycrisp’, only fruit set was determined as these trees were greatly over-thinned by each treatment.

Results with Goldrush

Data are presented in Table 1.

Here are the responses by treatment:

No Thinning

Un-thinned trees over-fruited with small, poor-quality fruit. It is unlikely these trees will flower next year.

Full-Strength Vegetable Oil

This basically removed all fruit and routinely killed the fruiting spurs.

Tank Mix 1:1 Full-Strength Vinegar: Full-Strength Vegetable Oil

This treatment was variable but gives the hint that reduced concentrations of both oil and vinegar may moderate the harsh thinning/tree damage seen by the oil at full strength and the probable over-thinning seen with the vinegar. This treatment suggests reduced rates will result in reduced thinning and should be followed up with future research.

Full Strength Vinegar

This treatment gave very interesting results. It thinned too much BUT really improved the size and the appearance of the ‘Goldrush’ (excluding the russeting response! Russeting is a skin roughening.). Definitely this preliminary experiment should be followed by a rate-and-timing experiment. The backyard and organic aspect of this is very exciting.

Full-Strength Vinegar Followed By Full-Strength Oil

Don’t do it. This researcher almost killed these trees.

Table 1. Response of 'Goldrush' Apple Trees to Various Organic Thinning Treatments.					
	% Set				
Treatment	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**	**Rep 5**
No thinning	64	30	63	71	46
Full strength vegetable oil	0	18	0	1	1
Tank mix 1;1 vinegar, vegetable oil	52	8	9	51	29
Vinegar	42	29	65	9	44
Vinegar followed by oil	0	1	2	2	1
	Mean Fruit Weight (g)				
No thinning	130	130	150	130	130
Full strength vegetable oil	200	160	180	160	220
Tank mix 1;1 vinegar, vegetable oil	220	170	170	100	190
Vinegar	220	220	240	190	210
Vinegar followed by oil	100	200	100	150	200
	Yield/Tree (kg)				
No thinning	32	43.9	57.7	36.4	42.5
Full strength vegetable oil	0.2	8.3	5.3	2.9	4.6
Tank mix 1;1 vinegar, vegetable oil	33	39	20	16.6	7.9
Vinegar	31.6	20	25.1	7.7	34.9
Vinegar followed by oil	0.5	0.2	0.3	0.3	3.4

Discussion

Goldrush

'Goldrush' is a variety that is difficult to thin; it over-fruits and stunts tree growth. 'Goldrush' has great potential as a Midwest organically grown variety, however, due to genetic scab-resistance and overall fitness. Untended fruit do tend to show sooty blotch, a fungal disease caused by *Gloeodes pomigena.*

Vinegar over-thinned this variety and is definitely worth investigating in lower concentrations in future years! Whether lower vinegar concentrations will give a response or not needs to be determined.

There was some russeting of 'Goldrush' probably due to the caustic acidic nature of the vinegar, but this was at an acceptable level (less than 10%) from a homeowner's standpoint. The increase in fruit size and overall fruit appearance was remarkable. 'Goldrush' is a variety that probably needs to be over-thinned to achieve better appearance and size.

One aspect of this research that may be valuable is that in many sidewalk, homeowner situations, it is desirable to remove all fruit — but there are no commercial hormonal compounds labeled. This research suggests modifying either oil or vinegar concentrations may give complete (or almost complete) fruit removal with minimal tree damage or environmental impact. Certainly this aspect should be followed up with further research.

Subsequent to selecting vinegar as a treatment this researcher learned of research evaluating vinegar as an organic herbicide (Rafiq Islam, Ohio State University South Centers at Piketon). The immediate effect that was seen with vinegar was a browning of the leaves — a herbicide effect. There was no immediate visible effect of the oil treatment beyond shining up the leaves.

However, four weeks later the effects were quite different with black, dead, fruiting spurs on any oil-treated trees and basically complete removal of fruit. The vinegar-treated trees had either re-greened or completely re-leafed with considerable fruit thinning response.

Any further experimentation with oil needs to be at a greatly reduced concentration. Pure vegetable oil at various concentrations also needs to be compared to Crocker's fish oil for effectiveness. Certainly, Crisco vegetable oil smells a whole lot better than Crocker's fish oil!

Honeycrisp

Honeycrisp is easily over thinned on young trees and in this particular year, on these trees, no thinning was required. All treatments greatly over thinned Honeycrisp and made further evaluation of yield and quality irrelevant. As these trees age, a thinning protocol will be required, however.

Soybean Aphid

Investigator:

Alan Sundermeier, Wood County Extension Educator

Introduction

This project focused on quantifying the distribution of soybean aphid in northwestern Ohio during the 2005 growing season. A better understanding of soybean aphid reproduction ability and spread will improve pesticide application timing. Also, a speed sampling technique was tested for accuracy.

Methods

Scouting was conducted in the following counties — Wood, Henry, Fulton, VanWert, Crawford, and Allen. Several fields in each county were scouted weekly from the first signs of aphids until pesticide spraying. A total of 49 fields were used to collect data. Up to 20 sites were selected in each field, and these sites were GPS located whenever possible. Observations were gathered from that specific site each week. In this way, field variation was overcome by tracking an exact site's aphid changes over time.

Results

As predicted, soybean aphids were a widespread problem in the summer of 2005, with every participating county reporting above-threshold levels by August.

Movement spread from the northern counties of Wood, Fulton, and Henry reporting initial soybean aphid counts during the week of June 27. Crawford and Van Wert Counties did not report initial counts until the week of July 18 or later. It took about three weeks for a site to increase from just a handful of aphids per plant to an over-threshold level of 250 aphids per plant. The period of July 25 to August 7 saw a majority of northwestern Ohio fields applying pesticide control for soybean aphids.

Distribution of soybean aphids within an individual field site did not vary significantly. The speed sampling technique developed by the University of Minnesota was tested and proved to be a good model. More details on this sampling technique are available from the University of Minnesota web site at: http://www.soybeans.umn.edu/crop/insects/aphid/aphid_sampling.htm.

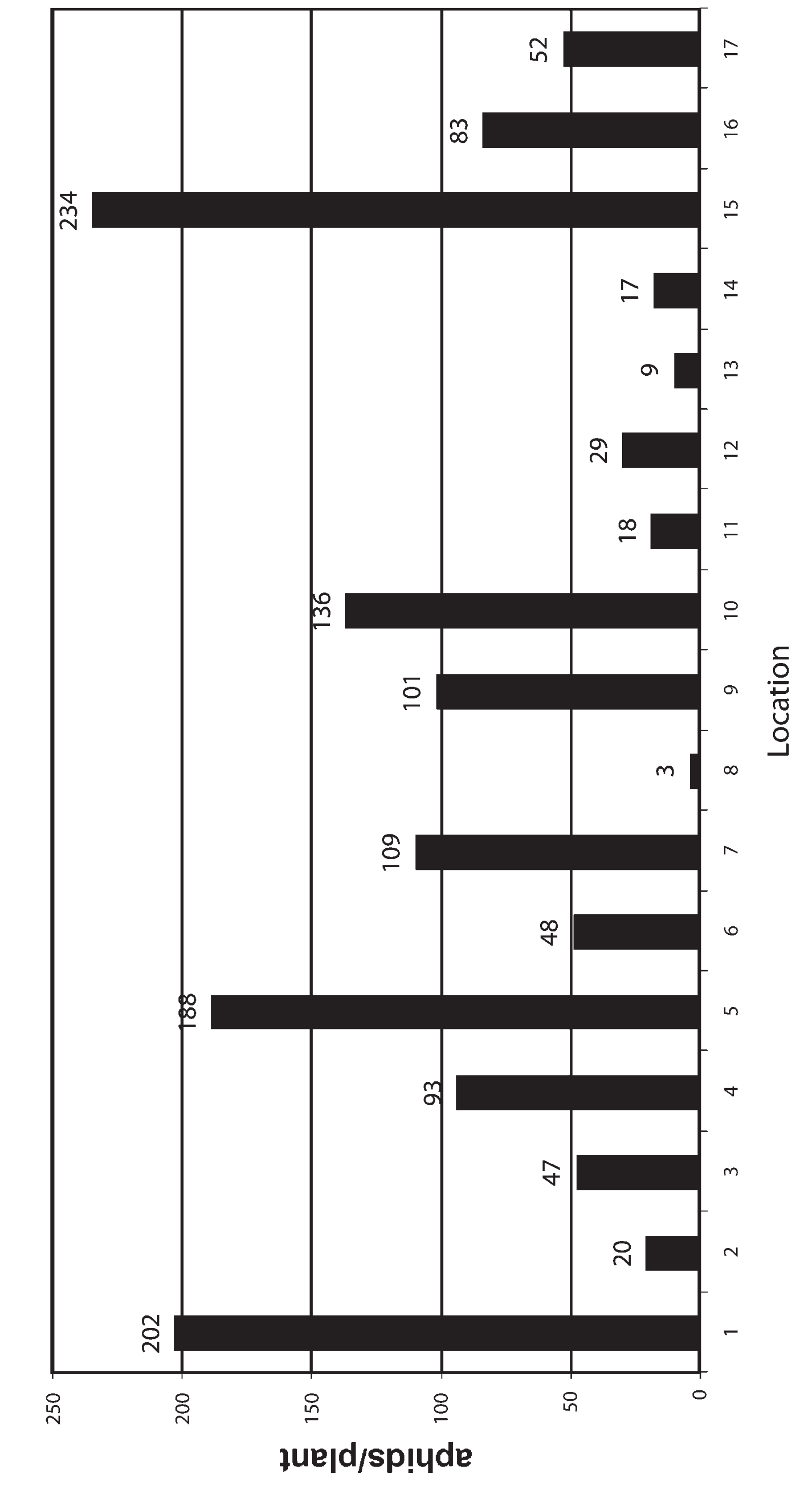
When every soybean plant counted had at least 40 or more aphids per plant, threshold levels were reached, and a pesticide application was needed. This technique will save time for scouting and still accurately predict treatment needs.

Conclusion

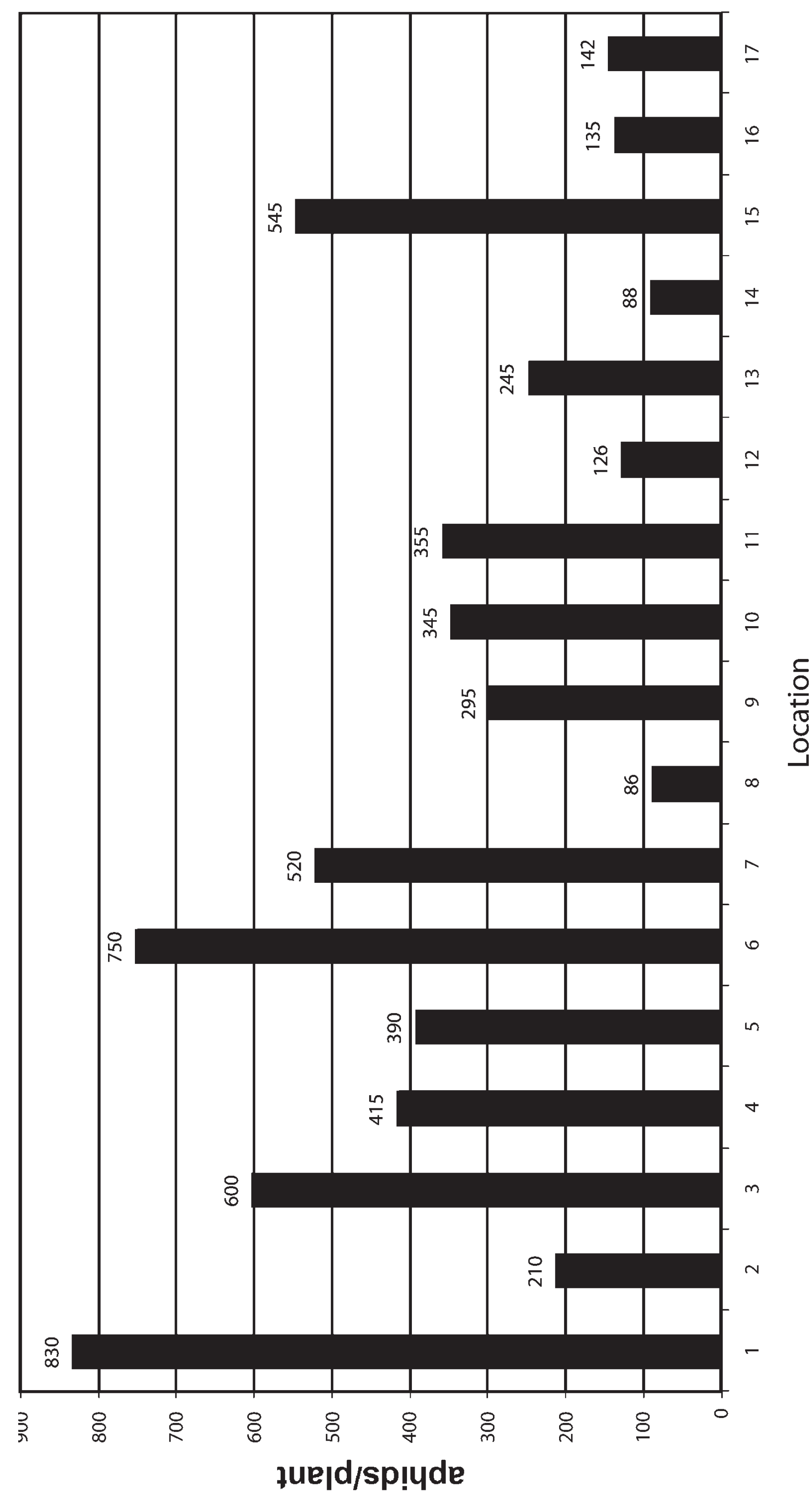
Because of the variation of infestation timing in the area, there will continue to be a need to gather localized aphid population data to accurately determine if a pesticide application is needed. Weekly observations are needed once an initial infestation has been detected. Speed sampling scouting may be used to allow a rapid assessment of a site to determine threshold levels.

This project was the first attempt to gather widespread, accurate soybean aphid population data in northwestern Ohio. The project should be repeated for several years to determine if weather, natural predator levels, or other factors have any effect on soybean aphid reproduction and distribution.

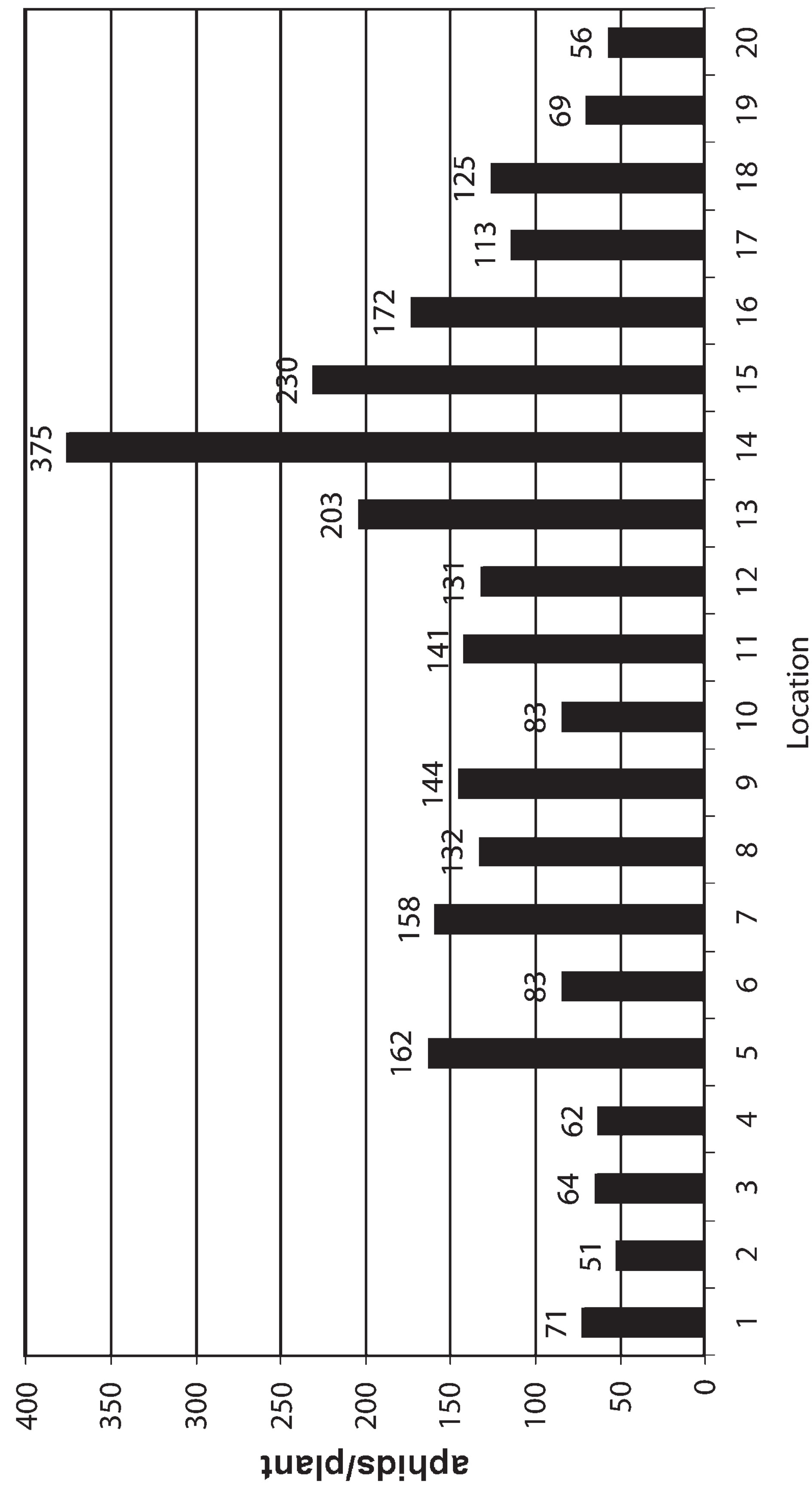
Number of soybean aphids/plant at 17 locations on the Swartz Farm, Wood County, OH on 13 July 2005



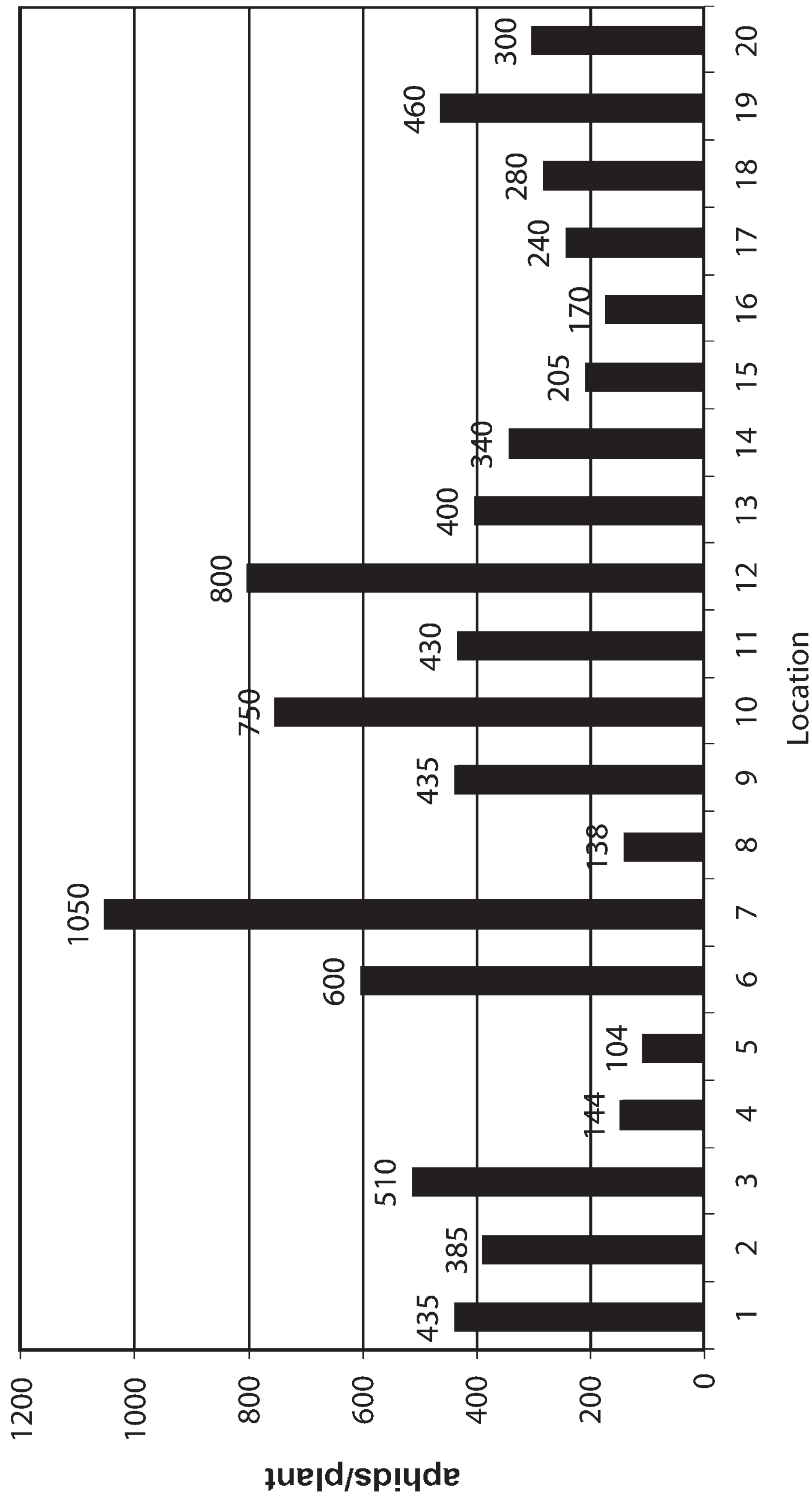
Number of soybean aphids/plant from 17 locations on the Swartz Farm, Wood County, OH on 21 July 2005



Number of soybean aphids/plant from 20 locations on the Sunweb Farm, Wood County, OH on 21 July 2005



Number of soybean aphids/plant from 20 locations on the Sunweb farm, Wood County OH on 26 July 2005



Tolerance of Strawberry Cultivars to Herbicides

Investigator:

Douglas Doohan, Assistant Professor

Ohio Agricultural Research and Development Center, Horticulture and Crop Science

Introduction

Strawberry is sensitive to most herbicides, and certain varieties may even be injured by labeled rates of herbicides registered for the crop. Certain older varieties, like 'Kent' and 'Honeoye,' were considered to be very sensitive to Sinbar, commonly used to control weeds in strawberry, while others such as 'Veestar' were considered relatively tolerant.

Sinbar is the principal herbicide used in strawberry grown in matted rows; thus, as new varieties become available, there is a great interest in their respective tolerance to this herbicide. The objective of this research was to characterize the response of strawberry cultivars to the herbicide Sinbar and also to the very recently registered herbicide Spartan.

Methods

Four field studies were established in 2005 — three trials at The Ohio State University's Ohio Agricultural Research and Development Center (OARDC) in Wooster, Ohio, and a fourth on Polter Berry Farms in Fremont, Ohio. The trial at Polter Berry Farms was abandoned in summer 2005 when it became clear that the impact of the residual effect of herbicides used on a previous crop was confounded with effects of Sinbar. An additional study site was established at the OARDC Research Station at Fremont in May 2006 (data will be provided to the Ohio State University Extension IPM program in 2007).

Two of the Wooster trials and both Fremont trials were intended to evaluate varietal response to Sinbar. The third Wooster trial was to evaluate variety tolerance to Spartan. Multiple sites were required for the Sinbar trials because of a suspected interaction with soil particle size and organic matter (OM) (see Table 1).

Strawberry tolerance to Spartan herbicide is known to decrease when soil pH is greater than 6.5 (Figueroa *et al.*, 2005); therefore, the Spartan trial was established on a site where soil pH had been elevated to pH 7 by liming in 2003 and 2004.

Dormant strawberry plants were transplanted in each site in early May 2005 (2006 at Fremont) and were maintained following practices recommended by Ohio State University Extension (OSUE). Weeds were controlled by cultivation and hand-weeding as needed to control those that tolerated herbicide applications. The experimental design was a randomized complete block with a split-plot treatment design in which main plots were herbicide treatments and sub-plots were strawberry cultivars. Each treatment was replicated four times and a plot was a single row of strawberry.

Sinbar was applied either immediately after planting (Wooster Trial No. 1 and Fremont Trial) or four weeks after planting (Wooster Trial No. 2). Spartan was applied to the designated plots in late November after onset of crop dormancy. Sinbar treatments were evaluated visually for crop injury at one, three, and six weeks after treatment. Spartan treatments were evaluated in April/May 2006, and fruit yield from all Wooster plots was recorded in June 2006.

Results and Discussion

Strawberry cultivars varied in response to Sinbar treatment rate and timing of application. Cultivar sensitivity, as indicated by leaf chlorosis at one week after treatment (WAT), was greatest in 'Honeoye', 'Evangeline', 'Darselect', 'Jewel', 'Brunswick', and 'Cabot' (Table 2). Chlorosis increased with increasing rates of Sinbar and was maximum with the 6 oz. per acre (2X) rate applied to 'Honeoye' the same day as transplanting.

Three WAT more injury was apparent at given rates when strawberry was treated at planting in comparison to treatments applied four weeks after planting (WAP). At the recommended rate of 3 oz. per acre applied the same day as transplanting, 'Brunswick', 'Cabot', and 'Darselect' were not injured relative to an untreated control.

Regardless of initial injury, chlorosis of all varieties declined rapidly as new leaves developed and at six WAT was almost impossible to detect. Injury could not be detected in either Wooster Sinbar trial in May 2006. Significantly lower yield was detected in 'Honeoye' and 'Evangeline' treated at planting (0 WAP in Table 3), corresponding with the observed ranking of cultivar sensitivity the previous spring. Yield reductions were only noted at the highest rates (3 and 6 oz. per acre). However, no effect on yield was noted when Sinbar application was delayed until four weeks after planting.

Strawberry cultivars responded differentially when treated with Spartan (Table 4). 'Cabot', 'Evangeline', and 'Jewel' were the most sensitive varieties. 'Brunswick' and 'Honeoye' were not affected even at the 2X rate (16 oz. per acre). However, yield of fruit was not affected by Spartan rate in any variety.

Conclusions

Results indicate that Sinbar should be delayed until strawberry plants are well established. 'Evangeline' and 'Honeoye' yield were affected by 3 and 6 oz. per acre applied at the time of planting, even though visual effects on the crop were not apparent at harvest time. Delaying Sinbar until four weeks after planting completely eliminated a yield effect even at the 2X rate (6 oz. per acre).

Even though 'Evangeline', 'Cabot', and 'Jewel' were slightly injured when Spartan was used in a high pH soil (>7), yield was not affected.

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Figueroa, R. 2003. Biology and management of common groundsel (*Senecio vulgaris* L.) in strawberry. Ph.D. Dissertation. The Ohio State University.

Polter, S. B., D. Doohan, and J. C. Scheerens. 2005. The effect of irrigation on terbacil tolerance in field-grown strawberry. *HortTechnology.* 15(3): 560-564.

Table 1: Soil Characteristics at Wooster and Fremont, Ohio, Trial Locations.		
	Wooster (all trials)	**Fremont**
Soil Name	**Wooster Silt Loam**	**Colwood Fine Sandy Loam**
Fertility	**Moderate**	**Moderate**
% OM	3.11	2.90
CEC	14	11.3
PH	6.86	5.90
% Sand	11	70
% Silt	75	20
% Clay	14	10

Table 2: Strawberry Variety Injury at Wooster in Response to Sinbar Rate and Timing of Application.						
	% Strawberry Plant Stunting					
	0 WAP[1]	**4 WAP**	**0 WAP**	**4 WAP**	**0 WAP**	**4 WAP**
SINBAR (oz/A)	**1.5**	**1.5**	**3.0**	**3.0**	**6.0**	**6.0**
Brunswick	0	2	0	2	0	3
Cabot[2]	7		7		22	
Darselect	3	0	5	0	7	3
Evangeline	10	0	10	2	33	7
Honeoye	3	2	25	2	23	3
Jewel	5	3	10	7	10	12
LSD (0.05)	15	6	15	6	15	6

[1] WAP = Sinbar application 0 Weeks After Planting, or 4 Weeks After Planting.
[2] Cabot was planted only in Trial 1 (treated 0 WAP).

Table 3: Strawberry Yield in Response to Sinbar Rate Applied Either at Planting (0 WAP) or 4 Weeks After Planting (4 WAP).								
	Strawberry Yield (lbs/plot)							
	0 WAP[1]				**4 WAP**			
Rate (oz/A)	**0**	**1.5**	**3.0**	**6.0**	**0**	**1.5**	**3.0**	**6.0**
Brunswick	14.5	14.8	12.5	14.6	14.7	13.4	15.4	15.3
Cabot[2]	3.6	4.5	2.6	5.5				
Darselect	9.8	8.7	7.5	7.8	10.5	10.4	9.6	12.0
Evangeline	13.8	11.7	10.8	11.0	12.0	14.5	12.6	11.8
Honeoye	15.5	16.9	12.7	13.5	15	15.3	13.1	14.0
Jewel	6	8.5	8.3	6.9	7.8	9.1	9.1	9.6
LSD (0.05)	2.8				3.3			

[1] WAP = Sinbar application 0 Weeks After Planting, or 4 Weeks After Planting.
[2] Cabot was planted only in Trial 1 (treated 0 WAP).

Table 4: Strawberry Cultivar Tolerance and Yield in Response to Spartan Rate (oz/A) Applied the Previous Autumn (November).							
	0 oz/A	**4 oz/A**		**8 oz/A**		**16 oz/A**	
Variety	**Yield (lbs/plot)**	**Injury 3 WAE**	**Yield (lbs/plot)**	**Injury 3 WAE**	**Yield (lbs/plot)**	**Injury 3 WAE**	**Yield (lbs/plot)**
Brunswick	11.2	0	10	0	11.1	0	15.5
Cabot[2]	6.92	0	6.9	10	4.7	15	6.7
Darselect	12.4	0	12.7	0	10.8	10	12.2
Evangeline	10.1	7	9.8	8	10.5	17	11.3
Honeoye	13.9	0	15.7	0	15.9	0	12.8
Jewel	7.8	0	7.6	5	8.1	8	7.4
LSD (0.05)	3.0	9	3.0	9	3.0	9	3.0

[1] WAE = Weeks after foliage emergence/ removal of winter mulch.
[2] Cabot was planted only in Trial 1 (treated 0 WAP).

Use of Trap Crops and Companion Planting to Manage Common Cabbage Pests in Truck Patch Plantings, 2005

Investigator:

Ron Becker, Program Assistant

Ohio State University Extension, Wayne County

Background

As traditional livestock and grain growers seek to improve the profit on their farms, many have turned to high-value crops, such as vegetables, as a portion of their farming enterprise. Cole crops, especially cabbage, are among the more popular vegetables to grow. However, when considering insect control, they are also among the more intensively sprayed crops.

Research into the use of perimeter trap crops as a means of reducing the application of pesticides directly to a crop has been carried out in Ohio in the past in large-scale cabbage fields where the crop was intended for processing purposes. Results of this research have shown that the use of collards as a perimeter trap crop reduced the infestation of flea beetles and diamond back moth larvae (DBM) in the cabbage crop. However, because of the quality requirements of the processors, growers have felt that the reduction was not enough to continue the use of the perimeter trap crop system and have therefore returned to the use of pesticides applied directly to the cabbage crop.

Much of the cabbage grown in the Wayne and Holmes County areas of Ohio is sold through a local Amish produce auction and as such is intended for fresh market use with the sizes of the fields being much smaller than the fields where the cabbage is grown for processing (generally five acres or less). Researchers who were involved with the previous research in Ohio felt that the use of perimeter trap crops might be of even more benefit in smaller plots due to the ratio of collard plants to cabbage plants being increased.

To further aid in pest suppression within the plantings, the use of companion crops was considered. Other studies[1,2] had suggested tomatoes as having a repellent effect, specifically on DBM. Thus, when the growers' enterprises included tomatoes, tomatoes were inter-planted with the cabbage as well.

Objective

The objectives of this project were to determine the effectiveness of perimeter trap crops and companion plants in an attempt to reliably provide enough insect control to reduce or eliminate the need for pesticide applications directly to the cabbage crop.

Method

To determine the effects of the collards as a trap crop as well as the effect of tomatoes in deterring the DBM, three plots were to be planted on each farm. These would include one plot of cabbage with a double row of collards planted completely around it; a second plot of cabbage inter-planted with tomatoes and a double row of collards around it; and a check plot consisting entirely of cabbage with no collards planted around it.

Three Amish farms agreed to be part of this project. Of these, only one farm (Plot 2) had tomatoes as a normal part of the farming enterprise and was therefore the only farm to plant all three types of plots. The variety of collards used was Vates, and the variety of tomato was at the discretion of the grower. Plots were scouted on a weekly basis for DBM and imported cabbage worm (ICW) larvae, which is also considered a major pest in the local cabbage fields. A spray threshold of 0.5 larvae per plant was used. Whenever possible, spraying of the collards was avoided to encourage beneficial insects.

Observations

Plot 1 was located in northern Holmes County and was an early-season planting. The plot consisted of two sections, each approximately 1/4-acre in size (54 ft. by 200 ft.). One section had eight double rows of cabbage surrounded on all sides by a double row of collards; the second section consisted of 10 double rows of cabbage.

The plants were set out on May 9 and harvested July 28. During this period of time, DBM and ICW activity was generally low. Only once during this period did the number of larvae go over the spray threshold. This occurred on June 30. Larval counts on 15 plants in each section showed the highest numbers of larvae being found on the collards surrounding the cabbage, followed by the cabbage in the check, followed by the cabbage surrounded by collards. This was most notable for the DBM. Even though the numbers were lowest in the cabbage surrounded by collards, the level of infestation was still high enough to warrant a rescue treatment. At this point only the cabbage plants in both plots were sprayed with permethrin (Pounce 3.2EC) in an effort to preserve any beneficial insects that might be present on the collards.

Seasonal Counts of Diamond Back Moth (DBM) and Imported Cabbage Worm (ICW) Larvae Found on Cabbage Without a Trap Crop of Collards (Cabbage-Check), on Collards, and on Cabbage Surrounded by Collards on a Farm in Northern Holmes County, Ohio.							
Plot 1							
	DBM/15 Plants				**ICW/15 Plants**		
Date	**Cabbage/ Check**	**Collard/Ca-Co**	**Cabbage/ Ca-Co**		**Cabbage/ Check**	**Collard/Ca-Co**	**Cabbage/ Ca-Co**
05/18/05	0	0	0		0	0	0
05/26/05	0	0	0		0	0	0
06/02/05	1	1	1		0	0	1
06/10/05	4	2	5		0	0	0
06/16/05	1	2	1		0	0	0
06/23/05	1	5	1		6	2	6
06/30/05	16	32	8		19	37	18
07/07/05	0	11	0		0	8	0
07/14/05	0	1	0		0	10	0
07/21/05	0	2	0		0	6	0

Plot 2 was located in southern Wayne County and was a mid-season planting. This plot consisted of three sections. The first section consisted of two rows of tomatoes with two double rows of cabbage on both sides, and the entire section was surrounded by a double row of collards. The second section consisted of eight double rows of cabbage with no collards, and the third section had six double rows of cabbage surrounded by a double row of collards. Each section was approximately 1/4-acre (42 ft. by 250 ft.).

The plot was planted June 13. From June 23 through July 11, counts were consistently higher on collard plants than on the cabbage plants. However, after this point, counts tended to be higher on the cabbage plants. The cabbage in the cabbage-collard-tomato section had the lowest population of larvae for the June 23-July 11 period. And while the cabbage in the check and cabbage-collard sections needed four rescue treatments (permethrin [Pounce 3.2EC] sprayed only on the cabbage plants) during the eight-week period, the cabbage-collard-tomato section went over threshold only three times.

Seasonal Counts of Diamond Back Moth (DBM) and Imported Cabbage Worm (ICW) Larvae on a Mid-Season Planting of Cabbage and Collards on a Farm in Southern Wayne County, Ohio. (See text for more details.)					
Plot 2					
	DBM				
Date	Cabbage/Check	Collard/Ca-Co	Cabbage/Ca-Co	Collard/ Ca-Co-To	Cabbage/ Ca-Co-To
6/23	0	4	0	1	0
6/30	0	4	1	0	0
7/07	1	2	0	8	0
7/11	4	8	9	11	0
7/18	0	1	0	0	0
7/25	0	5	0	1	1
8/01	4	1	8	1	0
8/08	0	0	0	0	0

	ICW				
Date	Cabbage/Check	Collard/Ca-Co	Cabbage/Ca-Co	Collard/ Ca-Co-To	Cabbage/ Ca-Co-To
06/23	1	0	1	1	2
06/30	17	32	13	23	9
07/07	8	18	3	15	0
07/11	2	31	0	21	0
07/18	2	5	5	12	6
07/25	18	5	54	4	23
08/01	5	3	12	1	8
08/08	4	11	1	7	5

Plot 3, a late-season planting, was also located in southern Wayne County. Though this grower did not raise tomatoes, he did include broccoli as part of this trial. This plot consisted of three sections. The first section consisted of 10 double rows of cabbage completely surrounded by a double row of collards. The second section consisted of 10 double rows of broccoli completely surrounded by a double row of collards. The third section, used as the check, was broccoli with no collards. This third section was not scouted the first week of the trial.

Each section was approximately 1/2-acre in size (66 ft. by 300 ft.). In this plot there was no consistency at any time as to which crop the DBM and ICW seemed to prefer.

However, possibly due to the time that this plot was planted, it was similar to Plot 2 in that the counts after July 25 seemed to indicate that collards were no longer the preferred crop. Rescue treatments (Spinosad [SpinTor 2SC] applied to the entire planting) were applied twice to this plot as a whole, with the check section also needing an additional rescue treatment after the final scouting.

Seasonal Counts of Diamond Back Moth (DBM) and Imported Cabbage Worm (ICW) Larvae on a Late-Season Planting of Broccoli and Cabbage Either Surrounded by Collards or Not on a Farm in Southern Wayne County, Ohio.

Plot 3

	DBM				
Date	**Broccoli/Check**	**Collard/Ca-Co**	**Cabbage/Ca-Co**	**Collard/Br-Co**	**Broccoli/Br-Co**
08/03		6	1	2	8
08/11	0	0	0	0	0
08/18	0	0	0	0	1
08/25	6	0	0	0	0
09/01	0	0	1	1	0
09/08	5	0	0	0	0
	ICW				
Date	**Broccoli/Check**	**Collard/Ca-Co**	**Cabbage/Ca-Co**	**Collard/Br-Co**	**Broccoli/Br-Co**
08/03		3	19	7	15
08/11	0	0	0	0	0
08/18	0	3	1	1	3
08/25	3	0	0	2	2
09/01	0	1	2	0	0
09/08	3	1	0	0	0

Conclusion and Discussion

Though it was originally thought that the effect of using collards as a trap crop in smaller fields would be even greater than in larger fields, this trial failed to prove that. Even though there was a portion of the season when both DBM and ICW seemed to prefer the collards, the larval infestation levels in cabbage plots with collards were not decreased enough that any sprays could be dropped as compared to check plots.

If a grower were to use collards as a trap crop, they should be used only in early season plantings when the preference for collards seems to be more pronounced. The presence of tomato plants in Plot 2 did seem to act as a deterrent, especially to the DBM.

This effect was also demonstrated on another farm that was not part of this trial, but did, in fact, plant a portion of the cabbage side-by-side with tomato plants. Though there were several times that the plants had to be sprayed for flea beetles, at no time was there a problem with DBM or ICW. Further research may be in order to substantiate this observation.

The cost of using the trap crop was also of concern to the growers. When considering the cost of the collard transplants as well as the loss in yield from the space taken up by the collards (which were not marketed), the cost of spraying was less than the cost of the trap crop. This effect would be even more pronounced in these smaller plantings than in larger fields due to the ratio of collard to cabbage plants.

I would like to express my gratitude to the Ohio State University Integrated Pest Management Block Grant Program for funding this project.

Footnotes

[1] Talekar N. S., Lee S. T., and Huang, S. W. 1986. Intercropping and modification of irrigation method for the control of diamondback moth. p. 145 - 152. In: Talekar, N. S. and Griggs, T. D., Eds. *Proceedings, First International Workshop, Diamondback Moth Management.* Shanhua, Taiwan: AVRDC, 1985.

[2] Sivapragasam, A., Tees, S. P., and Ruwaida, M. 1982. Effects of intercropping cabbage with tomato on the incidence of *Plutella xylostella. MAPPS Newsletter* 6 (2): 6 -7.

Using Gender Sensitivity in Trapping Oriental Fruit Moth in Peach and Apple Orchards, 2005

Project Leader:

Ted W. Gastier, Huron County Extension Educator

Producer and Location of Cooperating Farm:
Rich Eshleman, 781 E. Maple Avenue, Clyde, Ohio 43410
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Executive Summary

This project provided an alternative method and procedure for monitoring the movement of female Oriental fruit moths into north-central Ohio peach orchards. Pheromone traps, by nature of the female pheromone lures used, only attract and capture male adult Oriental fruit moths. Historically, these male catches have been used to gauge pressure from this pest in peach orchards. However, the use of mating disruption during the previous two seasons has resulted in trap shutdown, i.e., no catches, but with larvae still being found not only in peach fruit but also in apple fruit.

The purpose of this project was to better monitor the movement of mated female Oriental fruit moths into peach and apple orchards. This could allow for better timing of control measures.

Objective

The objective of this project was to reduce the economic damage caused by internal feeding of the Oriental fruit moth (OFM) larva in peaches by providing an indicator of female moth activity before tree flagging and fruit feeding appeared.

Background

Apple and peach are important tree fruit crops in Ohio. Combined, these crops contributed more than $25 million to family farm income in 2004. Ohio fruit growers have a long tradition of providing quality fruit to consumers through the use of IPM. Some growers had utilized mating disruption of OFM for two seasons previous in peach orchards as an integral portion of those accepted IPM procedures. However, some blocks of peaches continued to show economically unacceptable levels of internal feeding damage. In addition, OFM larva had been confirmed in apples.

Procedures

This project introduced the use of terpenyl acetate traps for OFM. This old-time homemade mix of terpenyl, sugar, and water had been suggested as an attractant for both female and male OFM adults. The Multipher III was modified with the insertion of a clean one-pound cottage-cheese container covered with window screening. The screening allowed removal of specimens without dumping the liquid mix.

The recommended trap — the Efekto fly trap, manufactured in Australia — was not available for this project. Standard OFM pheromone lures in Multipher III traps were used for comparison.

Harvest evaluations were conducted to determine fruit quality based on freedom from pest damage. Random samples from peach baskets were selected during twice-weekly orchard visits throughout the harvest seasons, and cull peaches were examined for evidence of internal feeding damage.

Control recommendations from Celeste Welty and Don Thomson of Pacific Biocontrol were utilized for OFM management by the Eshleman family.

Relevancy

The use of both mating disruption and pheromone traps has not been an accurate indicator for the presence of mated OFM females. We believe the mating was occurring in nearby areas of abandoned unsprayed trees with the moths moving into commercial blocks.

Results

Some description of the location and history of these seven peach blocks is necessary for interpretation of the results. The Dagg block is isolated by several miles from other peaches and is a young planting in its third year of production. The Burkholder block is contained within the large, home operation with middle-aged trees. The Center block, also in the home operation, is just in its first year of heavy production. The Cherry block, also at home, is representative of older trees on the property.

The City block is isolated from other peaches and contains trees of early to very late production ages. The traps were in an older portion of this block. The Gerhardstein block is several miles from other peaches. It suffered a complete production loss this year due to fruit bud kill last December. It was not sprayed beyond early spring.

The Packing House block has been problematic in recent years due to extensive internal feeding due to OFM confirmed by examination of many collected larva. The estimated loss in 2003 was 60 percent in this block and 20 percent in 2004. Mid-to-late-season spray applications have been nearly impossible due to the mix of many different maturity peaches and nectarines. This block is also popular for pick-your-own (PYO) — another challenge in later season pest management.

Twist-ties for mating disruption were first tried in this block for the 2003 season. The trap counts with the regular OFM pheromone lures **dropped from 60 per day! to zero immediately** and never indicated any potential problems. However, by mid-season, tree flagging was very apparent, and by harvest completion, the loss was as noted earlier.

Mating disruption was again used in 2004; OP sprays were alternated with pyrethrins, but fruit damage was still excessive. The Eshlemans did feel that mating disruption was at least partly reasonable for the reduction in fruit damage. Therefore, twist ties were applied in all peach blocks for 2005.

Conclusions

As indicated by the table, in blocks where OFM were trapped, the catches with the terpenyl acetate (TA) baited traps had higher counts than the conventional pheromone traps. No attempt was made to determine the gender of the TA specimens. Chapman and Lienk, in their book *Tortricid Fauna of Apple,* reported "the male is of essentially identical appearance." If a 50-50 ratio of male to female is assumed, then 50 percent of the additional catch could be females.

Most of the catches occurred in the later part of the season. In the case of the conventional pheromone trap, this could be an indication that the twist ties were beginning to lose their effectiveness earlier than expected due to warmer than normal summertime temperatures. Another factor could be the dropping of any spray applications once harvest started. The result of this late season buildup of adults could increase the number of over-wintering individuals.

The terpenyl acetate mixture is quite sticky by nature and caused considerable consternation for those working with it. It will dissolve certain types of plastics — No. 6, for example. Any dried splashes on the traps provided a food source for black mold.

On a more positive note, this method of monitoring female OFM could be useful in managing this pest where mating disruption is used, at least until better alternatives are developed.

One suggestion was made for the manufacturers of the twist-ties. Once the twist ties are used in one season, they remain on the trees. This can be confusing to workers installing ties in subsequent seasons. Could each season's production be a different color or somehow marked to distinguish old from new?

Thank you for the funding that made this project possible. Additional years' experiences would be useful in verifying these limited results.

Seasonal Adult Oriental Fruit Moth Catches, Fruit Damage, and Tree Flagging — 2005.						
Block	**Average Weekly Conventional Pheromone Trap OFM catches**	**Average Weekly Terpenyl Acetate Baited Trap OFM Catches**	**Total Season OFM Catches**		**Fruit Damage at Harvest**	**Tree Flagging on September 5**
			Conv	**T A**		
Dagg	0.1	3.7	3	93	> 2 %	None noted
Burkholder	0.4	0.8	11	20	> 2 %	None noted
Center	0.0	0.0	0	1	> 2 %	None noted
Cherry	0.0	0.0	0	0	> 2 %	None noted
City	0.0	0.7	0	17	> 2 %	None noted
Gerhardstein	1.6	3.0	38	69	No production due to winter kill	Apparent
Packing house	0.0	0.1	0	2	> 2 %	None noted

Western Corn Rootworm Sampling in Soybeans in Ohio, 2005

Investigators:

Curtis Young, Ron Hammond, Bruce Eisley, and Greg LaBarge

Personnel from Ohio State University Extension continued to sample for western corn rootworm adults (WCR) in soybean fields for the ninth year. Data from the 2005 rootworm trapping program have been assembled. This is an overview of the results from that survey.

Sampling was done using Pherocon® AM yellow sticky traps placed in 94 fields located in 26 counties. Six traps were placed in the soybeans on metal posts at canopy height and located at least 100 feet from the field edge and evenly spaced in the field. The traps were initially placed in fields in late July and removed in late August or early September. Traps were serviced once a week throughout the sampling period with a new, clean trap.

After each trapping week, the numbers of beetles collected were summed and divided by the number of traps (6) and the number of days the traps were in the field, resulting in the average number of beetles collected per trap per day.

A summary of the weekly catches of WCR adults per trap per day from the 2005 growing season is presented in Table 1.

Research indicates that catches in soybean of five or more beetles per trap per day during any trapping week indicates a potential problem with rootworm in the field the following year.

The trapping data from 2005 had the following results from the 94 fields:

- Only a single field with an average of more than five beetles per trap per day.
- Five fields with an average between four and less than five beetles per trap per day
- Most fields were less than three beetles per trap per day.

The field that had more than five beetles per trap per day was in Williams County. Those fields with between four and five beetles per trap per day were in Champaign (2), Shelby, Van Wert, and Williams Counties.

We should mention that many fields, especially those in northwestern Ohio, had also been sprayed for soybean aphid. It is not clear exactly how that might have affected the collection of first-year western corn rootworm (FYWCR); however, we believe that if there were high numbers of the WCR, they would have been collected in higher numbers on the yellow sticky traps at least one time during the sampling survey.

Additionally, we did not hear of many problems with FYWCR in first-year corn this past summer.

So What Does This Mean?

Based on the potential treatment level of five beetles per trap per day during any trapping week, if the single field with more than five beetles per trap per day is planted to corn in 2006, a treatment of either a soil insecticide, Poncho 1250 or Cruiser CRW seed treatments (the highest rate of each), or a transgenic rootworm corn (YieldGard Rootworm or Herculex RW, or perhaps YieldGard Plus or Herculex Xtra) should be considered for control of rootworm.

As we have stated previously, these data do not mean that other fields in a county that were not sampled do not need treatment. But we feel that the data do give good information about the fields that were sampled and about the overall abundance of the beetles this year. Rootworm populations continue to be relatively low.

We do NOT recommend widespread treatment for rootworms unless you have scouted your field and know that you have a population in the field. However, there might be those very few soybean fields that do have populations sufficient to warrant treatment next spring. Because of this continued concern with this insect, we urge growers to develop a sampling plan next year in their soybean fields and to sample roots for feeding injury in their first-year corn for the presence of FYWCR.

Funds for traps were provided by Monsanto, Pioneer Hi-Bred International, and a grant from the Ohio State University Integrated Pest Management (IPM) Program to the OSU Extension Agronomic Crops Team.

Counties and Personnel

Counties and personnel involved with the first-year corn rootworm trapping in 2005.

County	*Extension Educator*
Allen	C. Young
Auglaize	J. Smith
Champaign	H. Watters
Crawford	S. Prochaska
Darke	S. Foster
Defiance	B. Clevenger
Fulton	G. Lebarge
Henry	D. Sonnenberg
Hancock	G. Wilson
Mercer	T. Mangen
Miami	H. Watters
Morrow	S. Ruhl
Paulding	J. Lopshire
Putnam	G. Arnold
Sandusky	M. Koenig
Seneca	E. Lentz
Shelby	R. Bender
Van Wert	A. Kleinschmidt
Williams	F. Chirra
Wood	A. Sundermeier

Table 1. Average Western Corn Rootworm Beetle per Trap per Day, 2005.								
Average WCR/Trap/Day During Weekly Period								
Approximate Date Traps Changed								
County	**Township**	**July 29**	**Aug 5**	**Aug 12**	**Aug 19**	**Aug 26**	**Sept 2**	**Sept 9**
Allen		0.45	2.97	1.02	0.17	0.06	0.05	na
Allen		2.50	2.81	1.96	1.36	0.56	0.71	na
Allen		1.21	0.95	0.63	0.08	0.12	0.04	na
Allen		0.38	1.42	0.63	0.29	0.28	0.35	na
Allen		0.65	1.08	0.54	0.17	0.03	0.19	na
Allen		1.38	1.78	0.75	0.97	0.55	0.75	na
Allen		2.50	2.88	2.33	0.55	0.14	0.05	na
Auglaize	Pusheta	0.31	0.26	0.36	0.31	0.17	0.10	na
Auglaize	Logan	0.63	0.57	0.36	0.12	0.07	0.07	na
Butler	Morgan	0.53	0.33	0.31	0.57	0.74	0.17	na
Butler	Wayne	0.33	0.13	0.22	0.17	0.07	0.14	na
Butler	Ross	0.06	0.19	0.08	0.04	0.10	0.10	na
Butler	Ross	0.17	0.08	0.11	0.15	0.17	0.00	na
Clark			1.10	1.88	1.19	0.57	0.30	na
Clinton	Clark	0.02	0.03	0.00	0.00	0.00	0.00	na
Champaign	Miami	4.79	0.53	1.08	0.25	0.17	0.65	na
Champaign		4.46	1.11	0.94	0.78	0.55	0.23	na
Champaign		1.75	0.42	1.06	1.30	0.40	0.50	na
Champaign		1.75	0.44	0.29	0.40	1.43	0.94	na
Crawford		0.40	1.43	1.50	1.50	0.44	0.33	na
Crawford		0.50	2.71	1.83	2.10	1.65	2.03	na
Darke	Twin	0.86	1.45	1.05	1.19	0.88	2.72	na
Darke	Greenville	0.24	0.75	0.45	0.25	0.20	0.17	na
Darke	Monroe	1.31	1.88	2.05	2.19	1.43	3.39	na
Defiance	Adams	1.06	0.94	0.74	0.79	1.76	1.79	na
Defiance	Hicksville	2.50	0.78	0.90	0.98	1.76	0.64	na
Defiance	Milford	1.56	1.28	0.83	2.45	1.50	0.29	na
Defiance	Delaware	0.11	0.19	0.07	0.12	0.07	0.02	na
Fulton	Dover	0.25	0.18	0.39	0.14	0.03	0.04	na
Fulton	Fulton	0.59	0.17	0.94	0.33	0.14	0.29	na
Fulton	York	0.35	0.40	2.61	0.67	0.11	0.38	na
Fulton	Gorham	na	0.04	0.94	0.52	0.33	0.71	na
Fulton	German	0.83	0.05	0.44	0.02	0.10	0.06	na
Hancock		1.95		1.57	0.31	0.21	0.09	na
Hancock	Union	1.38	3.62	1.21	2.62	0.90	0.44	na
Hancock		0.55	2.38	1.10	1.64	0.45	0.46	na

Table 1 (continued). Average Western Corn Rootworm Beetle per Trap per Day, 2005.								
Average WCR/Trap/Day During Weekly Period								
Approximate Date Traps Changed								
County	**Township**	**July 29**	**Aug 5**	**Aug 12**	**Aug 19**	**Aug 26**	**Sept 2**	**Sept 9**
Hardin		0.89	2.57	2.45	0.90	0.36	0.05	na
Hardin		1.67	1.31	1.90	0.50	0.43	0.36	na
Henry	Bartlow	0.33	0.19	0.08	0.00	0.00	0.00	na
Henry		0.18	0.56	0.42	0.19	0.03	0.06	na
Henry		0.47	1.57	0.55	1.00	0.42	0.30	na
Henry	Flatrock	0.32	1.05	0.79	0.95	0.56	0.80	na
Henry	Ridgeville	0.45	1.52	1.31	1.50	0.86	0.72	na
Henry	Pleasant	0.43	0.52	0.28	0.29	0.33	0.19	na
Henry	Liberty	0.43	0.58	0.31	0.52	1.39	1.22	na
Henry	Liberty	0.17	1.23	1.93	1.10	1.39	1.44	na
Madison			0.19	0.92	0.31	0.21	0.00	na
Mercer	Center	0.29	0.43	0.40	0.21	0.24	0.17	na
Mercer	Granville	0.21	0.45	0.36	0.07	0.07	0.05	na
Miami	Concord	1.33	1.57	2.79	2.94	3.02	1.77	na
Miami		1.02	2.10	0.35	0.14	0.71	0.52	na
Miami	Bethel	0.67	1.64	2.27	2.67	2.67	1.71	na
Miami		1.50	1.93	1.52	0.61	0.76	1.69	na
Morrow	Congress	0.07	0.75	na	0.10	0.07	0.23	na
Morrow	Harmony	0.00	0.08	na	0.03	0.02	0.00	na
Ottawa	Clay	0.02	0.10	0.37	0.19	0.07	0.12	na
Ottawa	Harris	0.04	0.07	0.20	0.12	0.05	0.12	na
Paulding	Paulding	1.69	0.98	0.90	0.86	2.07	0.63	na
Paulding	Benton	na	na	1.67	0.00	0.10	0.10	na
Paulding	Benton	1.93	2.71	1.38	1.79	2.52	1.21	na
Paulding	Benton	2.57	1.95	1.50	0.10	0.12	0.02	na
Paulding	Carryall	2.52	1.83	2.33	1.19	0.21	0.06	na
Putnam	Ottawa	0.60	0.79	0.55	0.21	0.31	0.19	na
Putnam	Pleasant	0.74	0.96	0.50	0.31	0.14	na	na
Putnam	Blanchard	0.48	0.71	0.86	0.43	0.21	0.17	na
Putnam	Greens-burg	0.83	0.95	0.29	0.19	0.14	0.24	na
Putnam	Jennings	1.79	1.76	0.81	0.31	0.33	0.21	na
Putnam	Perry	2.24	2.21	2.14	2.02	1.60	1.67	na
Sandusky	Jackson	0.04	0.29	0.23	0.19	0.07	0.07	na
Sandusky	Madison	0.04	0.40	0.37	0.33	0.20	0.33	na
Seneca	Eden	2.23	1.83	2.14	0.14	0.13	na	na

Table 1 (continued). Average Western Corn Rootworm Beetle per Trap per Day, 2005.								
Average WCR/Trap/Day During Weekly Period								
Approximate Date Traps Changed								
County	**Township**	**July 29**	**Aug 5**	**Aug 12**	**Aug 19**	**Aug 26**	**Sept 2**	**Sept 9**
Seneca	Seneca	1.28	0.40	0.43	0.31	0.07	na	na
Shelby	Cynthian	0.14	0.33	0.50	0.23	0.36	0.52	0.26
Shelby	Salem	1.81	4.79	0.98	0.43	1.50	0.57	na
Shelby	McLean	na	0.27	1.36	0.39	na	0.20	na
Shelby	Turtle	0.00	0.02	0.00	0.17	0.10	0.05	na
Van Wert		1.14	3.50	na	0.00	0.00	na	na
Van Wert		0.43	1.86	na	0.00	0.00	na	na
Van Wert		0.90	0.89	0.76	0.52	2.10	na	na
Van Wert		0.81	1.03	0.95	0.44	1.40	na	na
Van Wert		0.90	1.56	1.24	1.03	3.58	na	na
Van Wert		1.33	1.33	1.48	1.53	3.72	na	na
Van Wert		0.52	1.88	na	0.13	0.12	na	na
Van Wert		4.72	1.97	0.44	0.45	1.07	na	na
Williams	Bridge	0.33	0.76	0.36	0.10	0.02	0.00	na
Williams	Florance	2.31	3.31	5.21	4.36	2.33	na	na
Williams	Florance	na	1.71	1.60	3.71	4.40	2.69	na
Williams	Jefferson	na	1.90	2.38	1.17	1.81	1.06	na
Wood	Milton	0.19	0.30	0.14	0.04	0.24	0.03	na
Wood	Henry	0.11	0.87	0.43	0.02	0.10	0.00	na
Wood	Webster	0.07	0.15	0.06	0.04	0.05	0.05	na
Wood	Bloom	0.27	0.90	0.83	0.17	0.52	0.27	na
na = Traps were not in the fields during this trapping period.								

Bioassays of Novel Bio-Control Agents for the Control of Economically Important Tomato Diseases

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Studies of diacetylphoroglucinol (DAPG)-producing pseudomonads isolated from different soils have revealed that strains differentiated by phlD-RFLP display distinct phenotypes, including their capacity to colonize host tissues (Landa *et al.*, 2002, 2003) and inhibit the growth of different pathogens (McSpadden Gardener *et al.*, 2005). However, the amount of pathogen inhibition can be expected to differ by crop and growing conditions. Therefore, a systematic screening of phlD+ *Pseudomonas* spp. under different conditions was undertaken to develop options for the biological control of tomato diseases.

STUDY 1: Characterize pathogen sensitivity to diverse genotypes of phlD+ pseudomonads and their fermentation products in vitro.

Antibiotic activities of 22 phlD+ pseudomonads over nine tomato pathogens were screened *in vitro* in three different agar media by using the overlay technique. Solutions containing pathogen propagules (*i.e.*, of *X. campestris*, *A. solani*, *C. coccodes*, and *Fusarium* sp. EDG1-05) were applied to the media [1/3 King's Media B (KMB), 1/5 V8 Agar, or Tomato Leaf Agar (TLA)] and then overlayed with washed pseudomonads cells and sterile distilled water (dH_2O) using the multichannel pipettor. After 48 hours incubation, the size and clarity of the inhibition zone was rated from 0 to 2, where 0 represented no inhibition, and 2 represented high inhibition. This experiment was run twice to confirm the results.

In vitro responses varied by strain and media (Annex 1). Of the 22 isolates tested, strains Wayne1, PF5, Wayne2, and Clinto1 demonstrated the most significant ($P < 0.000$ in the three media) inhibition potential over *X. campestris* pv. *vesicatoria*, *A. solani* (Mg23), *C. coccodes* (Sa3), and *Fusarium* sp. in all media (Table 1). Therefore, these four isolates were selected to be used in the assays testing the inhibitory capacity of the bacterial fermentation products. Additionally, the pathogens differed in sensitivity ($P < 0.000$) to DAPG-producers, with the *Fusarium* sp.

(EDG1-05 being the most inhibited in all media (Table 1).

The second stage of the *In vitro* screen was to assay the fermentation products of the four selected DAPG-producing strains over four selected pathogens. The DAPG-producers were grown on four different basal media — 1/3X KMB, 1/10X tryptic soy agar (TSA), 1/10X V8, and 1X tomato leaf infusion (TLE) media. These media were amended with and without 1 ppt glucose (glu), 10 ppm zinc (Zn), and/or 10 ppm autoclaved pathogen biomass (Patho).

The bacteria were incubated at room temperature (24ºC) under stationary conditions for 72 hours in 100 µl volumes. Prior to overlaying, the solutions were passed through a syringe filter. However,

Table 1: Results of the Inhibition Rates of Tomato Pathogens by phlD+ pseudomonads with Evidence of Inhibition Potential in 1/3 King Media B, 1/5x V8 and Tomato Leaf Agar (Mean Values).1

DAPG-producing pseudomonads Strain (genotype)	Pathogen	1/3 KMB		1/5 V8		TLA	
Wayne1 (A1)	*A. solani*	1.333	bc	1.250	c	1.500	abc
	C. coccodes	1.000	cd	2.000	a	2.000	a
	Fusarium sp.	2.000	a	2.000	a	1.500	abc
	X. campestris	1.500	b	0.250		1.750	ab
PF-5 (A2)	*A. solani*	2.000	a	2.000	a	2.000	a
	C. coccodes	1.000	cd	2.000	a	1.667	ab
	Fusarium sp.	1.000	cd	1.000	c	1.000	cd
	X. campestris	2.000	a	0.000	d	0.333	ef
Wayne 2 (R)	*A. solani*	0.750	d	1.333	bc	1.333	bc
	C. coccodes	1.000	cd	1.667	ab	2.000	a
	Fusarium sp.	2.000	a	2.000	a	2.000	a
	X. campestris	2.000	a	0.000	d	0.667	de
Clinto (S2)	*A. solani*	0.000	e	0.000	d	0.000	f
	C. coccodes	2.000	a	1.750	a	0.500	def
	Fusarium sp.	0.000	e	0.250	d	0.000	f
	X. campestris	2.000	a	1.750	a	2.000	a
dH2O (negative control)	*A. solani*	0.000	e	0.000	d	0.000	f
	C. coccodes	0.000	e	0.000	d	0.000	f
	Fusarium sp.	0.000	e	0.000	d	0.000	f
	X. campestris	0.000	e	0.000	d	0.000	f
P value		0.000		0.000		0.000	

[1] The data shown includes only the significantly ($P < 0.01$) more inhibitory strains chosen for future studies. LSD mean separation test at $P < 0.10$.

one of the extracts resulted in significant pathogen inhibition (Annex 2); therefore, subsequent studies were only conducted with live strains.

STUDY 2: Characterization of the efficacy of different formulations containing phlD+ pseudomonads.

Two *in-situ* bioassays were performed to determine the sensitivity of three tomato pathogens to DAPG-producing pseudomonads inoculated onto two different tomato cultivars, Tiny Tim and Moskvich.

For the first assay, *C. coccodes, A. solani,* and *X. campestris* were challenged separately by spray applications of the genotypes A1, A2, and S2 and water (control) on cv. 'Tiny Tim'. For each treatment, five pots containing four V2 plants were inoculated until run-off, first with the biocontrol (106 cells/ml) and 24 hours later with the pathogens (104 conidias/ml for fungi and 106 cells/ ml for xanthomonads). The plants were incubated under high humidity conditions for 48 hours to promote infection and disease development.

Then they were placed in a greenhouse to be grown under regular conditions. The plants were evaluated for disease development 7, 14, 22, and 40 days post-inoculation by counting lesions present on the second youngest leaf and also by rating the whole plant with the Horsfall and Barratt (HB) rating system.

Significant differences were observed in the number of lesions of the second youngest only on day 22 ($P < 0.078$) where *X. campestris* in combination with genotype S2 demonstrated the greatest amount of lesions (annex 3).

Nonetheless, when evaluated with the HB rating system, all DAPG-producing pseudomonads strains demonstrated a significant decrease in disease on days 22 and 40 ($P < 0.090$ and 0.101) compared to the control for *X. campestris* (Table 2), indicating that overall, the disease was diminished with the presence of DAPG-producing pseudomonads. However, disease rating did not vary among plants treated with A. solani. These results indicate that DAPG-producing pseudomonads have an antagonistic effect over *X. campestris* pv *vesicatoria* in tomato plants.

The second *in-situ* trial was done using the varieties 'Tiny Tim' and 'Moskvich' which at V2 growth stage were exposed to different treatments. First, *Fusarium* sp. was drenched in the soil at a dose of 104 conidias/ml. Twenty-four hours later, overnight cultures

Table 2: Horsfall and Barrat Disease Rating for *X. Campestris* pv. *Vesicatoria* in the Presence of DAPG-Producing Pseudomonads.[1]

	HB rating						
Pathogen	**Genotype**	**Day 7**	**Day 14**	**Day 22**		**Day 40**	
X. campestris	A1	0.460	0.928	1.200	ab	1.800	b
	A2	0.566	1.024	1.125	ab	1.500	b
	S2	1.460	0.740	0.300	b	0.900	b
	dH_2O	4.560	1.118	2.400	a	12.000	a
P value		0.378	0.774	0.090		0.101	

[1] LSD mean separation test at $P < 0.10$

of DAPG-producing pseudomonads [Genotypes A1, A2, R, and S2 (106 cells/ml)], Bravo® (chlorothalonil), Kocide® (copper hydroxide), tomato leaf extract (TLE) or dH_2O were applied to soil and foliage.

And 24 hours later, foliar pathogens were sprayed in a mixed broth that contained *X. campestris* (106 cells/ml) and *A. solani* (104 conidias/ml); this broth was sprayed on plants with and without *Fusarium* sp. Each treatment was done in five 4”pots (one plant per pot) having a total of 80 pots per cultivar. Incubation was done as described in the first greenhouse assay.

Disease development was rated 9, 14, and 21 days post-inoculation. Significant variation (P < 0.097 and 0.011) was observed in the number of lesions on the second youngest leaf on day nine in ‘Tiny Tim’ plants for both pathogen challenges, but the biological controls did not reduce the number relative to the control (data not shown).

Also, HB ratings were significantly different in plants inoculated with *Fusarium* sp. + *X. campestris + A. solani*. However, significant differences were only observed between chemical and biological treatments, with the chemical treatments having significantly lower disease ratings (data not shown). And, plants inoculated with *X. campestris* + *A. solani* and *Fusarium* sp. + *X. campestris* + *A. solani* tended to have lower disease ratings when pretreated with Wayne1R and PF5 respectively (data not shown).

In ‘Moskvich’ plants, the number of lesions on the second youngest leaf demonstrated significant disease reduction (P < 0.1 for both days) on day 14 and day 21 in plants inoculated with *X. campestris + A. solani)* (Table 3). The disease reduction was observed in all biological and chemical treatments with the exception of the strain Wayne1.

In this second trial, assessments of plant height and vigor were also made at 21 days post-inoculation. Overall, cv. ‘Tiny Tim’ inoculated with *Fusarium* sp. and treated with Clinton (S2) and PF5 were taller than the control (Table 4). For shoot weight, PF5 significantly promoted shoot weight in ‘Tiny Tim’ plants inoculated with *Fusarium* sp. (P < 0.10) compared with the control.

Table 3: Disease Development of *Fusarium* sp, *X. Campestris* and *A. Solani* in Presence of DAPG-Producing Pseudomonads in Tomato cvs Moskvich.[4]

		Lesions on the Second Youngest Leaf						Horsfall and Barrat Disease Rating					
Pathogen	**Treatment**	**Day 9**		**Day 14**		**Day 21**		**Day 9**		**Day 14**		**Day 21**	
	Wayne1 (A1)	2.20		1.20		1.20		1.6	*	2.20		2.20	
	PF5 (A2)	0.60		0.20	*	0.20	*	1.2		1.20		1.20	
	Wayne2 (R)	0.80		0.00	*	0.00	*	0.8		1.00		1.00	
X. campestris	Clinton (S2)	1.00		0.80	*	0.80	*	0.8		1.00		1.00	
+	Bravo	0.40		0.60	*	0.60	*	0.8		0.80		0.80	
A. solani	Kocide	0.20		0.00	*	0.00	*	0.6		1.00		1.00	
	TLE	0.40		0.20	*	0.20	*	0.2		0.60		0.60	
	dH20	1.00		3.40		3.40		0.6		2.00		2.00	
P value		0.418		0.017		0.017		0.041		0.105		0.105	
	Wayne1 (A1)	0.60		0.20		0.20		0.80		0.80		0.80	
Fusarium sp.	PF5 (A2)	0.40		0.00		0.00		0.60		0.60		0.60	
+	Wayne2 (R)	0.40		0.00		0.00		0.40		0.80		0.80	
	Clinton (S2)	2.20		0.00		0.00		1.80		1.20		1.20	
X. campestris	Bravo	0.60		2.00		2.00		1.00		2.00		2.00	
+	Kocide	3.00	*	0.80		0.80		2.00		1.80		1.80	
A. solani	TLE	0.00		0.00		0.00		0.20		0.20	*	0.20	
	dH20	0.80		0.80		0.80		1.20		2.00		2.00	
P value		0.001		0.048		0.048		0.002		0.066		0.066	

[4] Dunnett's mean separation test at P < 0.10 are indicated by asterisks (*) after the tabulated values.

Table 4: Effect of Different Formulations Containing phlD+ Pseudomonads on Two Tomato Cultivars (Mean Values)[5].

		Tiny Tim				Moskvich			
Pathogen	**Treatment**	**Plant Height**		**Shoot Fresh Weight**		**Plant Height**		**Shoot Fresh Weight**	
Fusarium sp.	Bravo	6.60		0.61		13.30		1.74	
	Clinton (S2)	12.14		1.34		9.82	*	0.89	*
	Kocide	5.90	*	0.49		11.50		1.30	
	PF5 (A2)	12.40		1.90	*	11.34		1.03	*
	Wayne1 (A1)	8.94		0.88		10.04	*	1.18	*
	Wayne2 (R)	11.30		1.11		12.98		2.03	
	TLE	10.64		1.01		9.50	*	0.85	*
	dH2O	9.80		0.85		14.10		2.25	
P value		0.0001		0.0001		0.007		0.005	
X. campestris + *A. solani*	Bravo	11.26		1.45		11.08		1.13	
	Clinton (S2)	13.42		2.43		11.18		1.15	
	Kocide	9.10		1.24		12.90		1.70	
	PF5 (A2)	11.00		1.48		16.18		2.43	
	Wayne1 (A1)	11.04		1.88		12.54		1.37	
	Wayne2 (R)	12.94		1.88		14.52		1.89	
	TLE	12.22		1.64		13.90		1.70	
	dH2O	11.40		1.57		12.90		1.52	
P value		0.516		0.55		0.159		0.305	
Fusarium + *X. campestris* + *A. solani*	Bravo	10.60		1.21		14.32		1.74	
	Clinton (S2)	13.70		2.57		11.62		0.96	
	Kocide	11.80		2.45		12.70		1.30	
	PF5 (A2)	14.46		2.23		14.54		1.81	
	Wayne1 (A1)	13.30		2.11		15.42		2.05	
	Wayne2 (R)	11.40		2.02		12.68		1.24	
	TLE	11.00		1.64		17.30		2.73	
	dH2O	10.94		1.48		15.76		1.50	
P value		0.478		0.334		0.211		0.112	

[5] Dunnett's mean separation test at P < 0.10 are indicated by asterisks (*) after the tabulated values.

Study 3: Characterization of plant growth in tomato mediated by DAPG.

Plant health promotion may be mediated by mechanisms other than direct inhibition of pathogens; thus, *In vitro* studies of the effects of DAPG on tomato roots were carried out. Surface-sterilized seeds were set on 0.8 percent water-agar media plates followed by the addition of 50 µl of DAPG at 10-4, 10-5 M and water. The plates were incubated in the dark for 48 hours at room temperature.

Afterward pictures of the seedlings were taken, and root length was measured using the APS Access Program (AAP). This experiment was conducted three times. No significant differences were detected among the treatments in any individual experiment (Table 5), suggesting that direct inhibition might be the source of disease suppression; nonetheless, alternative doses of DAPG should be tested. Consequently, further studies were carried out.

Table 5: Effect of Two Doses of DAPG Concentrations on Tomato Root Length Among Three Experiments (Mean Values).

Treatment	Replicate 1	Replicate 2	Replicate 3
10-4 DAPG	4.10	1.40	3.34
10-5 DAPG	3.10	1.63	3.73
Control	3.16	1.50	3.10
P values	0.589	0.864	0.588

Study 4: Tomato root growth responses to selected strains with and without added *Pythium ultimum.*

We expanded upon the proposed work to further examine the effects of DAPG-producing pseudomonads in comparison to *Bacillus* sp. with proven capacities to promote tomato growth when applied to the roots. Two *In vitro* trials were conducted to evaluate the response of root growth of tomato to selected strains of *P. fluorescens*, *B. pumilus*, and *B. amyloquefaciens* in the presence or absence of *P. ultimum.*

Four surface-sterilized seeds set on 0.8 percent water-agarose media were soaked in 50 µl of *B. pumilus* (GB34), *B. subtilis* (MB1600, IN937a, IN937b), *B. amyloquefaciens* (FZBYZ, AK1), and *P. fluorescens* strains (PF5, F113, Clinton, Wayne1R, and Wood) at 105 cell per µl and dH_2O. The plates were incubated in the dark at room temperature, and measurements were taken four and eight days post-treatment. In the first assay cv. Peto 696 was used, while in the second trial cv. 'Moskvich' was used. Moreover, on the second experiment, mycelial plugs of *Pythium ultimum* were added at 1 cm from the growing roots.

Overall, there were significant differences between treatments in the first assay. But only on day 8 post-inoculation, MB1600 and F113 stimulated a significant ($P < 0.1$) increase in root length compared to the control by Dunnett's test. Strains GB34, PF5, IN937b, and AK1 also appeared to stimulate tomato root growth, but the changes were not significantly greater than the control (Table 6).

Table 6: *In vitro* Tomato cv Peto in Root Length as a Response to Pseudomonas and Bacillus Strains (Mean Values).				
Bacterial Treatments		Root length (cm)		
		4d PI	8d PI	
Bacillus amyloquefaciens	FZBYZ	1.20	2.40	
Bacillus amyloquefaciens (mutant)	AK1	2.29	5.90	
Bacillus pumilus	GB34	1.98	6.20	
	IN937a	3.33	7.20	
Bacillus subtilis	IN937b	2.65	5.90	
	MB1600	3.54	7.70	*
	Clinton	1.84	2.40	
	F113	1.24	7.50	*
Pseudomonas fluorescens	PF5	1.33	6.00	
	Wayne 1R	1.22	1.70	
	Wood	0.93	2.20	
Control	dH2O	1.90	3.70	

In the second assay, a smaller subset of strains was tested on two different tomato cultivars in the presence and absence of *Pythium ultimum.* While there were no significant differences observed in root lengths, some similar trends appeared. For example, IN937a increased root length but only in the absence of *P. ultimum.* And, in the presence of *P. ultimum,* PF5 also seemed to increase root growth.

Table 7: Effect of *Pseudomonas* and *Bacillus* Strains in Tomato Root Length (cm) with and Without Adding *Pythium Ultimum* (Mean Values) at 8 Days Post-Inoculation.					
Bacterial Treatment		Peto		Moskvich	
		No Pythium	Pythium	No Pythium	Pythium
Bacillus amyloquefaciens	FZBYZ	0.23	0.40	0.76	1.60
Bacillus amyloquefaciens (mutant)	AK1	0.40	0.50	1.29	2.10
Bacillus subtilis	IN937a	0.83	0.70	1.42	1.70
Pseudomonas fluorescens	Clinton	0.84	0.60	1.26	1.70
	PF5	0.34	1.00	1.12	1.80
	Wayne1R	0.33	0.40	1.10	1.60
	Wayne2R	0.32	0.30	1.20	1.40
Control	dH2O	0.70	0.70	1.35	1.70

Conclusions

In vitro and *in vivo* studies indicated significant biocontrol potential of DAPG-producing pseudomonads targeting different tomato pathogens and the damage they cause. In vitro, only a small subset of the diverse strains screened displayed clear antagonism against multiple tomato pathogens. When these strains were tested in pot trials, spray inoculation helped to reduce disease severity, especially when plants were challenged with *Fusarium*. Furthermore, some inoculated strains could enhance root growth and plant height. As is typical with biocontrol screens, efficacy varied by strain, pathogen, and cultivar, indication that additional studies will be required to identify useful combinations for field applications.

Annex 1: Inhibition Rates of the DAPG-Producing Pseudomonads Strains Over Nine Tomato Pathogens in Culture (Mean Values).[1]

DAPG-Producing Pseudomonads		Media					
Genotype	Strain	1/3 KMB		1/5 V8		TLA	
A1	WAYNE 1	1.290	ab	0.936	ab	1.452	a
A2	PF5	1.292	abc	0.833	abc	0.958	b
B	Q2-87	0.667	cd	0.542	cdef	0.042	de
C	STAD384-97	0.875	bc	0.208	fgh	0.500	c
D1	WOOD 1	0.958	bc	0.625	abcde	0.292	cde
D2	Q8r1-96	1.083	bc	0.583	bcdef	0.333	cde
E	QT1-6	0.917	bc	0.250	efgh	0.500	c
F	JMP-6	1.000	abcd	0.500	cdef	0.292	cde
G	FFL1R18	0.840	abcd	0.360	defgh	0.480	c
H	CV1-1	1.156	ab	0.688	abcd	0.313	cde
I	FATD1R36	0.871	abcd	0.581	bcdef	0.290	cde
J	FFL1R22	1.083	abc	0.625	abcde	0.417	cd
K	F113	1.250	abc	0.417	defgh	0.250	cde
L	W4-4	0.160	e	0.080	gh	0.000	e
M	D27B1	0.742	abcd	0.419	defg	0.355	cd
N	HT5-1	0.125	e	0.583	bcdef	0.208	cde
O	7MA-12	1.000	abc	0.520	cdef	0.440	c
P	MVP1-4	0.844	bcd	0.469	cdef	0.438	c
Q	MVW4-2	0.742	bcd	0.387	defgh	0.290	cde
R	WAYNE 2	1.520	a	1.000	a	1.480	a
S1	WOOD 3	1.000	bc	0.600	abcdef	0.280	cde
S2	CLINTO	0.906	abc	0.625	abcde	0.438	c
Control	dH20	0.033	e	0.033	h	0.000	e

[1] Results combined for all the nine pathogens tested. (Significant differences between pathogens were observed. Data not shown.)

Annex 2: Rates of Pathogen Inhibition by Fermentation Products of DAPG-Producing Pseudomonads (Mean Values).[2]

		Media			
Strain	**Fermentation media**	**1/3 KMB**		**TLA**	
CLINTO	1/3KMB	0.000	b	0.167	abc
	1/3KMB+Patho	0.000	b	0.000	c
	dH2O	0.083	b	0.000	c
	Soy	0.083	b	0.000	c
	TLE	0.000	b	0.000	c
	TLE+glu+Zn	0.500	a	0.333	a
	TLE+Patho	0.000	b	0.000	c
PF5	1/3KMB	0.000	b	0.000	c
	1/3KMB+Patho	0.000	b	0.000	c
	dH2O	0.000	b	0.000	c
	Soy	0.000	b	0.083	bc
	TLE	0.000	b	0.000	c
	TLE+glu+Zn	0.500	a	0.250	ab
	TLE+Patho	0.000	b	0.000	c
Wayne1	1/3KMB	0.000	b	0.000	c
	1/3KMB+Patho	0.000	b	0.000	c
	dH2O	0.000	b	0.000	c
	Soy	0.000	b	0.000	c
	TLE	0.000	b	0.000	c
	TLE+glu+Zn	0.500	a	0.250	ab
	TLE+Patho	0.083	b	0.000	c
Wayne2	1/3KMB	0.083	b	0.000	c
	1/3KMB+Patho	0.000	b	0.000	c
	dH2O	0.000	b	0.000	c
	Soy	0.000	b	0.000	c
	TLE	0.000	b	0.000	c
	TLE+glu+Zn	0.500	a	0.333	a
	TLE+Patho	0.000	b	0.000	c
Control	dH2O	0.000	b	0.000	c
	dH2O+Soy	0.000	b	0.000	c

[2] The pathogens used for fermentation product experiment were *X. campestris* pv. *vesicatoria, A. solani* (Mg23), *C. coccodes* (Sa3), and *Fusarium* sp.

Annex 3: Disease Development in the Presence of DAPG-Producing Pseudomonads in Tomato vv 'Tiny Tim'.									
		HB Rating							
Pathogen	**Genotype**	**Day 7**		**Day 14**		**Day 22**		**Day 40**	
X. campestris	A1	0.460		0.928	a	1.200		1.800	b
	A2	0.566		1.024	a	1.125		1.500	b
	S2	1.460		0.740	a	0.300		0.900	b
	dH2O	4.560		1.118	a	2.400		12.000	a
A. solani	A1	0.000		0.000	b	0.600		0.900	b
	A2	0.800		0.000	b	1.500		2.700	b
	S2	0.000		0.000	b	0.600		0.600	b
	dH2O	0.134		0.040	b	1.500		1.125	b
P value		0.224		0.000		0.159		0.044	
		Number of Lesions on the Second Youngest Leaf							
Pathogen	**Genotype**	**Day 7**		**Day 14**		**Day 22**		**Day 40**	
X. campestris	A1	1.000		0.000		0.000	b	0.000	
	A2	2.600		0.000		0.134	b	0.000	
	S2	1.750		0.000		1.084	a	0.000	
	dH2O	1.434		0.000		0.050	b	0.000	
A. solani	A1	0.000		1.000		0.000	b	0.000	
	A2	0.000		1.200		0.000	b	0.000	
	S2	0.000		0.800		0.000	b	0.000	
	dH2O	0.000		1.250		0.000	b	0.000	
P value		0.671		0.756		0.078			

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Bloom Time Apple Crop Optimization, 2006

Investigator:

Diane Miller

Department of Horticulture and Crop Sciences

Introduction

Apple trees produce far more blossoms than the tree has the resources to mature into apples. Where apples are wild in nature (Kazakhstan and Kyrgyzstan in Central Asia), trees are (in general) very biennial-bearing with a large crop of small apples one year followed by a small crop of large apples the next year. A short shoot (spur) that produces an apple one year will not produce an apple the following year. As apple has become a domesticated crop, this "wild" trait of biennial bearing has become a problem for growers desiring to have a reliable annual year in order to supply markets.

In the chemical age, hormonal thinners have been applied to trick the tree into shedding set fruit, normally at 10 to 12 mm fruit size. As cell division determining fruit size occurs in the first 30 days after bloom, competition among fruits before chemical thinning results in reduced size potential of remaining fruits. With some genetically small-fruit-prone varieties such as 'Gala' and 'Goldrush', this will limit fruit size achieved even if chemical thinning is successful.

Dave Ferree at The Ohio State University, over many years of chemical thinning, recorded quite variable success due to undetermined genetic and environmental factors but did provide growers with chemical application guidelines that are standard for the industry today. In other words, there are trends that can be found and that are fairly reliable across many studies, but that, in individual studies, do not always produce expected results.

As the apple industry moves toward more sustainable production practices and even into organic growing, chemical thinners will be limited or unacceptable, and alternatives must be found. While hand thinning of blossoms is the most reliable way to achieve an optimum crop of large fruit, this task is overwhelming in labor and concentration. Consequently, there is a need to creatively determine reliable and socially acceptable alternatives.

In 2005, using IPM block grant funding, we showed that full-strength vinegar applied to apple trees at bloom successfully reduced fruit set and increased fruit size while russeting fruit to probably a more than commercially acceptable level. This 2006 project followed up on 2005 results with a diversity of thinning strategies, including pollen exclusion (competition with Surround kaolin clay), blossom thinning by burning (lime sulfur/oil combinations; vinegar concentrations), and compared this with standard commercial practice (MaxCel + Sevin at 10 to 12 mm fruit size), looking at ‘Goldrush’, ‘Fuji’, and ‘Golden Delicious’ apple varieties.

Extenuating Circumstance

A severe spring frost occurred on April 26, 2006, at Horticultural Unit II of The Ohio State University’s Ohio Agricultural Research and Development Center (OARDC), in Wooster, Ohio, an event that impacted this research extensively.

The temperature fell to 24ºF while the blossoms were at pink, balloon, or open stage (variability within trees and among varieties). This caused blossom kill which looked complete, and we considered jettisoning the research, but over the following few days, it became apparent that lots of blossoms remained.

We decided to proceed with the treatment applications, just for the experience but bearing in mind that we had already lost the desirable king blooms and were working in an undesirable scenario.

Ideally, blossom thinners are applied after king blooms are open and pollinated (set) and are purposed to kill side and lateral blossoms. In our case, most king blossoms were killed along with some second or third side blossoms, so we had already lost what we wanted to keep. Nevertheless, this is Ohio, and spring frost happens sometimes, so we decided to apply treatments and monitor results and see what happens in a frost year.

Materials and Methods

Three studies were conducted.

Experiment 1: Use of Surround to reduce fruit set.

The kaolin clay formulation (trade name Surround) has been shown to inhibit insect damage to fruit trees, probably due to both a coating and an annoyance factor, when it is sprayed onto foliage and fruit. We investigated to see if Surround could also coat stigmatic surfaces and therefore exclude pollen.

Surround was suspended in water at the recommended concentration (30 cups per 10 gallons) and sprayed onto trees every other day (from April 28 through May 6) for a total of five applications. Controls were unsprayed, un-thinned. The variety used was ‘Goldrush’. Treatments were:

- Sprayed with Surround as king blooms are opening (April 28) and every spray after (April 30, May 2, May 4).
- Sprayed with Surround when king + one side blossom were open (April 30) and every spray after (May 2 and May 4).
- Sprayed with Surround when the tree was at full bloom (May 2) and every spray after(May 4).
- Sprayed at the beginning of petal fall (May 6).
- Unsprayed control (no thinning).

No other thinning treatments were applied. There were five repetitions of five trees. Data collected included total fruit per tree plus weight of 25 fruit per tree.

Experiment 2: Vinegar as an organic blossom thinner.

This experiment was a follow-up to interesting preliminary results from 2005. ‘Goldrush’ was the variety, chosen because the potential exists to grow it organically due to its genetic disease resistances and because it is inherently small fruited. Treatments were:

- Sprayed with full-strength apple-cider vinegar May 3 (slightly after full bloom).
- Sprayed with 1/2-strength apple-cider vinegar May 3 (slightly after full bloom).
- Sprayed with vegetable oil + lime sulfur (0.2 gal Crisco vegetable oil + 0.2 gal liquid lime sulfur per 10 gallons water) May 3.
- Sprayed with petroleum-based DAM oil + lime sulfur (0.2 gal DAM oil + 0.2 gal liquid lime sulfur per 10 gal water) May 3.
- Sprayed with petroleum-based DAM oil + lime sulfur (0.2 gal DAM oil + 0.2 gal liquid lime sulfur per 10 gal water) May 1 and May 5.

Data collected included fruit set, total fruit per tree plus weight of 25 fruit per tree. This experiment also tested the efficacy of lime sulfur/vegetable oil as an organic alternative to lime sulfur/DAM oil (petroleum based).

Experiment 3: Use of alternative thinners on other varieties.

It's necessary for treatments to be effective across varieties in the new paradigm which emphasizes diversity of varieties in Midwest local marketing. To test efficacy, we used two additional varieties, 'Golden Delicious' and 'Fuji' (as well as 'Gala' — in studies funded by the Ohio Fruit Growers Society and not reported here, we also tested these methods on four grower's blocks [Sages, Grims, Simmons, and Eshleman's]). Treatments were:

- Vinegar full strength slightly after full bloom (May 3).
- Vinegar 1/2 strength slightly after full bloom (May 3).
- Lime sulfur + DAM oil (0.2 gal DAM oil + 0.2 gal liquid lime sulfur per 10 gal water - May 3).
- Maxcel + Sevin May 23 (conventional thinning treatment).
- No thinning.

Results

Experiment 1: Surround.

Surround sprays proved not effective at all in preventing pollination and fertilization (Table 1: Goldrush Surround). While coating the leaves of the trees with the liquid suspension was relatively easy, it was difficult to spray at all the angles to coat the blossoms. This was a nice idea that proved ineffective.

An additional nice idea to try would be to spray a dark coating that would reduce photosynthesis of the leaves without physically damaging the leaves. I put some thought into a possible treatment during spring 2006 but couldn't come up with a leaf-friendly spray.

Experiment 2 and Experiment 3: Non-conventional thinning treatments.

Vinegar was excitingly effective in 2005 but not so in 2006 (see Tables 2 and 3, Golden Delicious organic thinning and Fuji organic thinning). Two key factors appear to be involved.

Temperature at application appears very important. In 2005, it was around 80ºF at and after vinegar application, and there was a lot of leaf burning; this appeared to contribute to the thinning effect. Also, in 2005 there was no frost event.

In 2006, it was 60ºF and overcast at the time of application, and the leaf burning effect was almost non-existent. In 2006, the trees

Table 1. Response of 'Goldrush' Apple Trees to Different Timing of Application of Kaolin Clay (Surround).			
Treatment	**Total Fruit Wt (kg)**	**Wt 25 Fruit (kg)**	**Mean Fruit Wt (g)**
King bloom	4.2	169	18.4
kb + 1 side	4.6	157	20.9
Full bloom	4.6	184	12.6
Petal fall	4.8	190	15.8
No spray	4.5	180	16.1

Table 2. Response of 'Goldrush' Apple Trees to Various Thinning Treatments.				
Treatment	**% Set**	**Total Fruit Wt (kg)**	**Wt 25 Fruit (kg)**	**Mean Fruit Wt (g)**
Veg oil + LS 5/3	171	4.8	165	13.8
DAM oil + LS 5/3	114	4.3	171	17
DAM oil + LS 5/1 + 5/5	124	4	160	17
Vinegar FS 5/3	158	4.1	161	28.4
Vinegar 1/2 strength 5/3	123	4.2	168	17.1

Table 3. Response of 'Fuji' Apple Trees to Various Thinning Treatments.				
Treatment	**% Set**	**Total Fruit Wt (kg)**	**Wt 25 Fruit (kg)**	**Mean Fruit Wt (g)**
Vinegar FS 5/23	147	9.7	4.2	184
Vinegar 1/2 strength 5/3	164	10	4.2	167
LS + Dam oil 5/3	133	16.8	3.8	152
Maxcel/Sevin 5/23	161	14.5	4.1	163
No thinner	180	12.4	4.2	168

had already suffered a lot of blossom loss due to the April 26 frost event. Fruit set in 2006 was roughly three times higher than in 2005 based upon this frost and subsequent lack of competition among fruit sets. This is probably the most profound finding of these studies. Under frost damaged conditions, blossoms that normally wouldn't set, do set.

Vinegar at 1/2 strength was ineffective in thinning, as was the DAM oil/ lime sulfur treatments (singly or in combination), as was the conventional Maxcel/Sevin thinning treatment. These trees were thinned by the frost, and no additional thinning treatments were needed OR were effective OR caused additional thinning in 2006. Treatments had no effect on set, crop load, or on individual fruit size. These are disappointing results from a research standpoint — basically a lost year of work.

Summary

From a grower standpoint, on the bright side, it appears difficult to over-thin trees that have been frost-thinned. Fruit size in 2006 was larger than 2005 based upon reduced crop load. These trees were under-cropped, some more severely than others.

We will need to repeat all of these studies in spring 2007 and hope for a mild spring to thoroughly test the treatments. Vinegar only appears effective in hot conditions, and we will test this more thoroughly in spring 2007 by selecting the time of application based on ambient temperature and sunlight. All growers involved in collaboration suffered frost damage also and are interested in trying treatments in a non-frost spring.

Development and Evaluation of Natural Product Herbicides

Investigator:

John Cardina

Horticulture and Crop Science

Introduction

There is considerable interest in the use of natural products for weed control. Many studies show that dried, ground plant material can inhibit growth of various weeds. But results vary with growth stage and environmental conditions, and as a result, no practical field application has been developed. We have tried a different approach, using seeds as the natural product source. Unlike other plant materials, seeds provide a product that is relatively consistent in chemical composition. Moreover, seeds are readily available to farmers in the marketplace, or they can grow their own.

In preliminary studies, we evaluated weed seed germination and post-emergence seedling growth suppression by crude extracts from seeds of many crop, wild-flower, and weed species that could be grown in a farmscape as a nectar source, windbreak, shelter, border, interplant, cover crop, companion crop, green manure, or harvested as a crop. Among the species that have demonstrated bioactivity are several crop plants, such as caraway *(Carum carvi* L.), coriander *(Coriandrum sativum* L.), anise *(Pimpinella anisum* L.), parsley (*Petroselinium crispum* (Mill.) NYM.), fennel *(Foeniculum vulgare* Mill.), red clover *(Trifolium pratense* L.), parsnip *(Pastinaca satriva* L.), and rye *(Hordeum vulgare).*

Our objectives in this project were to evaluate weed suppression in more crop species, determine activity levels in those that show promise, and evaluate the potential for post-emergence activity in the seed extracts.

Materials and Methods

Water and ethanol extracts were prepared from ground seeds (15 g) and filtered. Ethanol extracts were evaporated to dryness and reconstituted with 50 mL dH_2O. Standard germination bioassays were conducted using smooth pigweed *(Amaranthus hybridus* L.) and large crabgrass *(Digitaria sanguinalis* (L.) Scop.).

In follow-up studies, we estimated the LC_{50} (lethal concentration), evaluated chemical stability, and compared extraction techniques, focusing on species known to accumulate a large diversity of biologically active chemical compounds. Because we detected significant weed suppression from these extracts, and because others have reported bioactivity of interest for pest management, we focused initially on these species.

Extracts of Ground Seeds

Seeds (15 g) were ground in a coffee grinder and placed into a flask with 50 mL of either EtOH (100%) or dH_2O. Flasks were placed on a rotary shaker (200 rpm) for 1 hr (EtOH) or 24 hr (dH_2O) at room temperature. Seed particulates were filtered out by pouring the extracts through layers of Kim wipes. EtOH extracts were concentrated to dryness by heating (~78ºC) on a hotplate and reconstituted with 50 mL dH_2O.

Germination Experiments

We used petri dishes containing Wooster silt loam soil. We planted 50 seeds (1 spp/dish) of four weed species. Four grams of ground seeds were spread uniformly, followed by 15 ml H_2O. For extracts, 15 ml of extract (plus a water control) were applied per dish. The dishes were covered, sealed in Ziplock bags, and incubated at 30/25ºC (12-hr light/12-hr dark). Germinated seeds were counted and removed daily for 14 days.

Post-Emergence Studies

Weed seedlings were grown in flats containing a mix of Wooster silt loam and commercial potting mix. Two concentrations of each seed extract, plus a water control, with 0.05% surfactant (Tween-20) were applied to two-leaf seedlings. Visible injury symptoms (necrosis, discoloration, stunting, and mortality) were recorded daily for 14 days.

Field Plot Studies

Sites with known high weed seed populations were prepared. The seed extracts were applied to soil in June, when weed seed germination was expected to be high. Ground seeds were applied at rates equivalent to 0, 1, 10, 100, and 1,000 lb per acre. Six concentrations of extract (0, 10, 25, 50, 75, 100%), prepared by dilution in water, were applied through a backpack sprayer delivering 20 GPA. Weed seedling emergence was counted in two 0.5 to m^2 quadrats per plot, and visual evaluation of weed control by species was made weekly for four weeks after treatment.

We used SAS to conduct analysis of variance on data following transformations if needed to meet normality assumptions. Regression analysis was used to evaluate rate responses.

Results and Discussion

The test of preemergence activity showed significant germination inhibition from extracts of several crop seeds. Similar results were found for crabgrass and pigweed seed germination. About 50% inhibition was found for some extracts, but other extracts did not reduce germination sufficiently to pursue use of those species in subsequent tests.

We tested these extracts in soil media as well as in petri dishes with filter paper to determine if the active compounds would be bound to soil and lose activity. Results showed that activity was not lost in soil.

We focused on wild carrot seed extracts since this was the species that showed activity, and it is one that is easily cultured and readily available. It also represents a case of making a potentially useful product from a species that is considered a weed. It is also considered a useful species for providing habitat for beneficials, and so would fit in well with farmscapes that leave borders for such habitat.

The LD_{50} (lethal dose that kills 50% of the population) represents a value that can be used for comparison among products and formulations. The LD_{50} for pigweed seed germination was a 19.2% dilution, and for crabgrass seed germination, the LD_{50} was a 4.2% dilution when seeds were treated with wild carrot extract (Figure 1). This LC_{50} is for the crude extract, and fractionation is not yet complete to determine the LC_{50} for the active fractions.

Pigweed, a dicotyledonous species, is very sensitive to the compounds in the extract, whereas crabgrass, a monocotyledon, was slightly more tolerant. Bioactivity at low LC_{50} levels is a favorable aspect for soil-applied bioherbicides. Inhibition at low concentrations is environmentally and economically friendly. Low concentrations of bioactive compounds reduce the chances of leaching into the surrounding environment and groundwater. It is also economically favorable since lower amounts of these compounds would be needed for effective weed control.

In the evaluation of post-emergence activity, most seed extracts did not show any post-emergence herbicidal activity on pigweed or crabgrass plants (data not shown). Only one extract showed some suppression of crabgrass height. This result was somewhat unexpected since the extract showed little

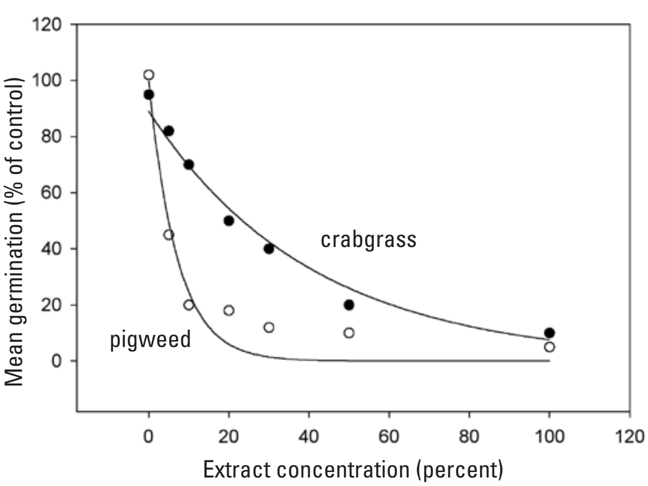

Figure 1. Effect of exact concentration on germination of pigweed and crabgrass seeds.

suppression of germination. The study was repeated with the same result; therefore, further studies are being conducted to explore the possible mode of action of this extract.

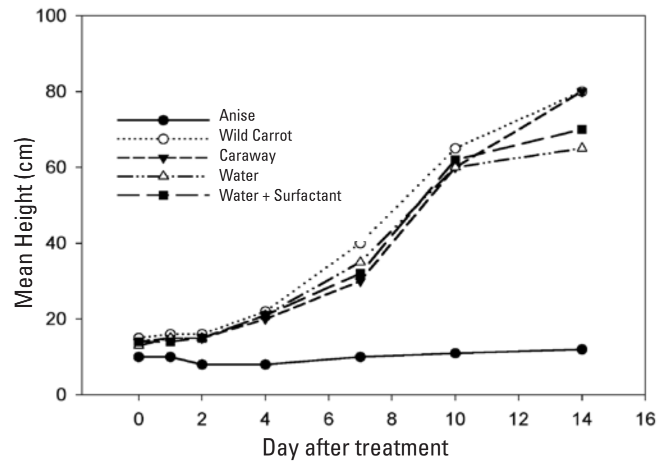

Figure 2. Effect of selected extracts on growth (height) of crabgrass.

Results suggest that seed extracts may be a source of an effective 'natural' soil-applied herbicide. Extracts inhibited pigweed and crabgrass germination in soil, at low concentrations. The activity of the extracts was stable over time and not affected by temperature. Some seed extracts exhibited selectivity by significantly reducing crabgrass germination without significant impact on pigweed, a broadleaf weed.

These results are significant because they demonstrate efficacy of pre-emergence weed control based on a plant product that growers could harvest and store. This kind of product development could help reduce potential human health risks and adverse environmental effects from management strategies in production agriculture and residential and public areas. The public interest in 'natural' methods for weed control is very strong, but virtually no such methods have been developed for use in vegetable crops or home gardens where user exposure and environmental impacts could be substantial.

Funds were used to support an undergraduate summer student who conducted his senior independent study research on extraction and identification of biologically active chemicals from seeds of some of the species used in this research. Minimal funds were used for supplies, mostly for chemical analysis and plant culture. A second student is now conducting her project on mode-of-action studies using these seed extracts.

Future research will focus on three areas:

- Increase the number of species tested as extracts and as target plants.
- Use the USDA GRIN system to obtain cultivars for evaluation of germplasm with high levels of activity.
- Continue with separation and identification of bioactive fractions from extracts that show promising pre- or post-emergence weed suppression.

The preliminary results from this project were used in a grant proposal recently submitted to the North Central IPM program in an effort to continue this research.

Don't Let the Bed Bugs Bite: Conveying IPM Strategies for Bed Bugs in Urban Housing

Investigator:

Susan C. Jones, Ph.D., Urban Entomologist,
The Ohio State University, Department of Entomology

Introduction

Bed bugs are blood-feeding parasites that prefer human hosts. They were very common pests in the United States prior to World War II, after which time they virtually disappeared due to a number of factors including the widespread use of synthetic insecticides such as DDT, increased regulation of the used furniture market, and improvements in household and personal cleanliness. However, in the past decade, bed bugs have begun making a comeback in the United States and worldwide (Krueger, 2000; Myles *et al.*, 2003). The bed bug, *Cimex lectularius*, and the tropical bed bug, *Cimex hemipterus*, are the most economically important species.

Even though adult bed bugs are small, approximately 1/5th of an inch, they can be readily seen with the naked eye. However, bed bug infestations are not easily located because these insects hide during the day in dark, protected sites, and their flat shape enables them to readily hide in cracks and crevices (Snetsinger, 1997). They feed primarily at night when their host is asleep. They then crawl away to a hiding place to digest the meal. When hungry, bed bugs again search for a host.

When a bed bug penetrates the skin with its mouthparts to obtain blood, it injects saliva that causes skin irritations and the delayed onset of intense itching, although individuals can differ in their sensitivity. In some cases, painful welts develop and last several days. Scratching may cause the welts to become infected. Rows of three or so welts on exposed skin are characteristic signs of bed bugs. The amount of blood loss due to bed bug feeding typically does not adversely affect the host, although some cases of anemia have been reported. Bed bugs have never been implicated in the transmission of disease to humans (Dolling, 1991), although they are suspected carriers of leprosy, oriental sore, Q-fever, and brucellosis (Krueger, 2000).

The psychological torment associated with bed bugs should justify concern by public health officials and others. Individuals often respond to bed bug infestations with anxiety, worry, stress, and insomnia. The associated costs to families and to society include absenteeism, lost wages, workplace disruptions, lawsuits, and unwarranted ridicule, embarrassment, or blame. The social stigma that surrounds a bed bug infestation also can result in a home-remedy approach to treatment. Uninformed consumers risk unnecessary chemical exposure as they misuse over-the-counter insecticidal products or repeatedly use ineffective home remedies.

Bed bugs most commonly occur in dwellings with a high rate of occupant turnover, such as apartment complexes, shelters, tenements, prisons, hostels, dormitories, hotels, and motels. In multiple-type dwellings, these fast-moving insects travel long distances to infest adjoining units. Furthermore, bed bugs are able hitchhikers that subsequently can be transported to private residences and the workplace. Upscale hotels and private homes have recently noted infestations, suggesting that good sanitation is not sufficient to prevent a bed-bug infestation (Krueger, 2000).

In urban housing, the challenges are to detect a bed bug infestation early and to begin control measures before bed bugs have spread. An important first step is to correctly identify the blood-feeding pest, because itchy bites can be caused by many arthropods, such as mosquitoes, fleas, lice, and mites. Clients also need to recognize the telltale signs of bed bugs and the symptoms of bed bug bites. Recognizable signs of a bed bug infestation include excrement left around points of entry and exit to their hiding places (Dolling, 1991) and reddish brown spots on mattresses and furniture (Frishman, 2000).

An IPM Innovative Grant of $4,500 was awarded in spring 2006 to sponsor the development and dissemination of training materials pertaining to bed-bug management in Ohio. The project was implemented with the assistance of Nicky Gallagher, Research Associate, The Ohio State University Department of Entomology. A PowerPoint presentation was prepared detailing IPM strategies, including preventive measures, sanitation, and chemicals applied to targeted sites. High resolution images of bed bugs were incorporated into the PP presentation. In addition, copies of the Ohio State University Extension fact sheet *Bed Bugs*, HYG-2105-04, were provided to participants at seminars and conferences, and bed-bug specimens (dead) were available for examination. (The fact sheet is available at: **http://ohioline.osu.edu/hyg-fact/2000/2105.html.)**

Results

Project Participants/Partnerships

The Council on Aging of Southwestern Ohio (COA) was among the project participants because this organization serves as a conduit to provide information to senior adults, those with similar needs, and caregivers. COA is a private non-profit agency that is responsible for planning, coordinating, and administrating local, state, and federally funded programs and services for older adults in Butler, Clermont, Clinton, Hamilton, and Warren Counties.

The Service Coordination program is jointly sponsored by COA and Folker's Management Corporation; the programs are funded through the Department of Housing and Urban Development (HUD). HUD is the federal agency that is responsible for national policy and programs that address American's housing and that improve and develop the nation's communities. HUD provides technical assistance to ensure that Section 8 housing is properly maintained by the Housing Authority.

PowerPoint Program

A PowerPoint (PP) program was presented at the following locations:

Ohio Environmental Health Association Southeastern Conference, September 28, 2006. *Sleep Tight, Don't Let the Bed Bugs Bite!* Steve Chordas III, Ph.D., and Susan C. Jones, Ph.D. Participants: ~60 adults.

St. Francis Court Apartments, Cincinnati, Ohio, Senior Center Seminar, November 8, 2006. *IPM Strategies for Bed Bugs.* Susan C. Jones, Ph.D., and Nicky Gallagher, M.S. Participants: ~15 adults.

In addition, copies of the PP presentation were provided on CD for further distribution by:

HUD Service Coordinators, via Jennifer Kelly Mast, HUD Service Coordinator at the St. Francis Court Apartments, Cincinnati, Ohio.

Council on Aging, via Jennifer Kelly Mast, HUD Service Coordinator at the St. Francis Court Apartments, Cincinnati, Ohio.

Community Action, via Porothea Schall, Community Action representative, Cincinnati, Ohio.

Ohio State University Pesticide Applicator Training Program, via Joanne Kick-Raack, Pesticide Applicator Training Coordinator.

Ohio Department of Health, via Dr. Steve W. Chordas III, Zoonotic Disease Control Program, Ohio Department of Health, Columbus, Ohio.

Outcomes

This project has helped meet the need of housing authorities for training materials to educate service providers and housing clientele about bed bugs. It advises that control of bed bugs is best achieved by following an integrated pest management (IPM) approach that involves multiple tactics, such as preventive measures, sanitation, and chemicals applied to targeted sites. This project is consistent with focus areas of the USDA National IPM roadmap in that it will reduce potential human health risks from bed bugs and related management strategies in residential areas. The project also will minimize adverse environmental effects from bed-bug management strategies in residential areas.

The project's long-term goal is to decrease the incidence of bed bugs in urban housing. Successful prevention efforts also will decrease the need to use pesticides for bed bug control. The concomitant decrease in insecticides and their misuse will benefit society's children, families, and communities. Attendees at the two seminars indicated that they came away with an increased knowledge of bed bugs and management approaches.

Effect of CO_2 Enrichment, Light, and Nutrients on Plant-Herbivore Performance and Impact on Pest Management Practices

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Introduction

The state of Ohio is the fifth largest producer of floriculture crops in the United States, representing an industry with annual sales of $186 million dollars (USDA NASS, 2006). The successful production and maintenance of high-quality plants require the development and implementation of appropriate plant and pest management programs. While effective plant management techniques have been developed, and some of their effects on herbivores have been quantified, less is known about their impact on pest-management tactics *(e.g.,* biological control, chemical control).

Few studies have explored the integration of various environmental components *(e.g.,* CO_2, light, and nutrition) on plant-herbivore relations. For instance, Sudderth *et al.* (2005), when evaluating the response of aphids to varying CO_2 and N regimes, found increased aphid populations with high CO_2 levels and low N. Giertych *et al.* (2005) studied the influence of fertilization on food quality of oak leaves for Gypsy Moth and found fertilization can increase herbivore food utilization efficiency, resulting in increased insect performance. Evidence from greenhouse and field studies suggests that excess nutrients and other inputs that promote plant growth often result in favorable conditions for pest population growth, making pest management more difficult (Facknath and Lalljee, 2005; Borowicz *et al.*, 2005). However, none of these studies assessed the impact on pest-management alternatives to control these pests.

Understanding how various environmental factors, such as CO_2, light, and nutrient uptake affect plants, the herbivores that feed on them, and the natural enemies that attack them will lead to an effective use of resources, ultimately resulting in reduced pest pressure and more effective controls.

The objective of this study was to evaluate plant parameters from Petunia *(Petunia hybrida)* grown in different CO_2, light, and nutrient regimes and their impact on herbivores — silverleaf whitefly *(Bemisia tabaci* Gennadius biotype B) and its natural enemies *(Encarsia formosa* Beltsville and *Eretmocerus mundus* Mercet.). Our hypothesis is that plants that receive higher nutrition, higher light levels, and higher CO_2 levels will be able to grow faster but this would compromise their response to insect attack. Thus, we expect the insects to develop better *(i.e.,* higher) fecundity, making overall pest management difficult.

Materials and Methods

Location

The study was conducted at the Biosystem Phytotron from the Department of Food, Agricultural, and Biological Engineering at The Ohio State University/Ohio Agricultural Research and Development Center (OARDC) (Figure 1).

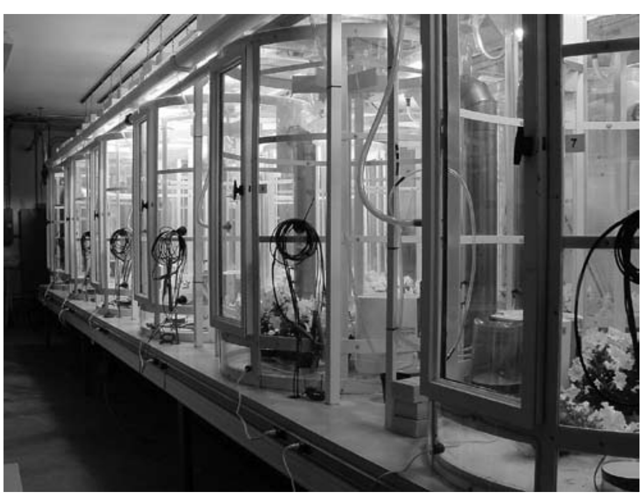

Figure 1. Biosystem Phytotron.

The Biosystem Phytotron is equipped with 12 reach-in, fully sealed, Plexiglas cylindrical chambers with the capability to provide up to 600 µmole/m^2·s quantum intensity light for the plant canopy. CO_2 was injected into six of the chambers while the others received ambient CO_2 level (~ 380 mg/L). A computer-based data acquisition and control system monitored temperature and humidity and controlled gas composition.

Plants

Petunia *(Petunia* x *hybrida)* plants were grown from seeds in 288-unit trays in a greenhouse and were transplanted after three to four weeks into larger 12.7-cm pots. The pots were placed within the 12-chamber facility and after a week of acclimation, environmental and nutritional treatments were begun.

Plants were grown under the following conditions: two fertilizer rates (based on nitrogen at either 100 to 300 mg/L from a general 20-10-20 fertilizer supply), two light levels (200 µmole/m^2·s and 600 µmole/m^2·s) and two CO_2 levels (380 mg/L and 800 mg/L). A total of six replicates were used.

Basic growth measurements were taken including stem, leaf, and flower partitioning. After periodic harvests (every two weeks), elemental analysis of the three plant tissues (leaf, stem, and flowers) was performed for essential micro- and macro-nutrients.

Insects

During the first set of experiments, six pairs (male, female) of three-day-old whiteflies *(B. tabaci* biotype B) were collected from colonies maintained at the Department of Entomology and were placed in a clip cage (Figure 2). One clip cage was placed in each of three leaves per plant on all plants and the whiteflies were allowed to oviposit for four to seven days. The total number of eggs produced by females during initial oviposition was counted. After egg hatching, 10 recently settled first instars were marked and followed throughout their life at three- to four-day intervals. Nymph mortality and whitefly emergence were recorded.

During the second set of experiments, the same procedure as previously noted was followed, but after egg hatching, the parasitoids *Eretmocerus mundus* and *Encarsia formosa* were released using a 50:50 ratio based on commercial recommendations for use of these parasitoids. All parasitoids were obtained from commercial insectaries and were collected previous to release to ensure good quality. Whitefly nymphs were followed through time, and their mortality by these two parasitoids was assessed.

Plant and insect data were transformed using the function Ln (X+1) and were analyzed using a nested ANOVA (light level nested under CO_2 and fertilization nested within light) with an alpha = 0.05.

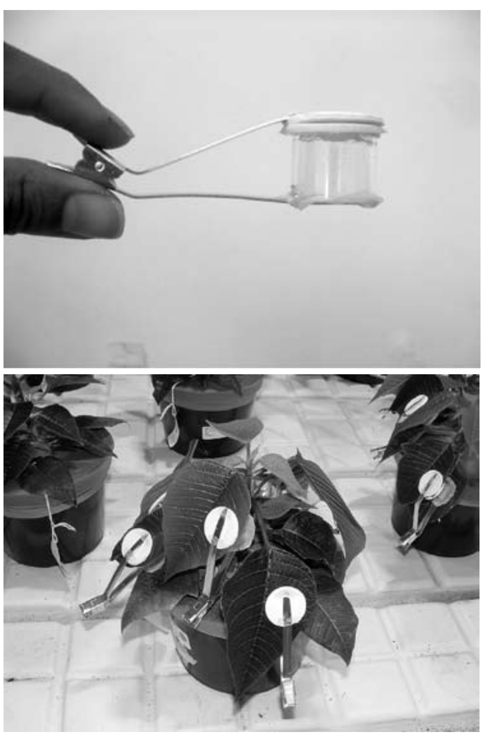

Figure 2. Clip cages for whiteflies.

Results and Discussion

The results of our study indicate elevated CO_2 decreased the concentration of nearly all essential elements in the stem but had no consistent effect on leaf nutrient content (Figure 3).

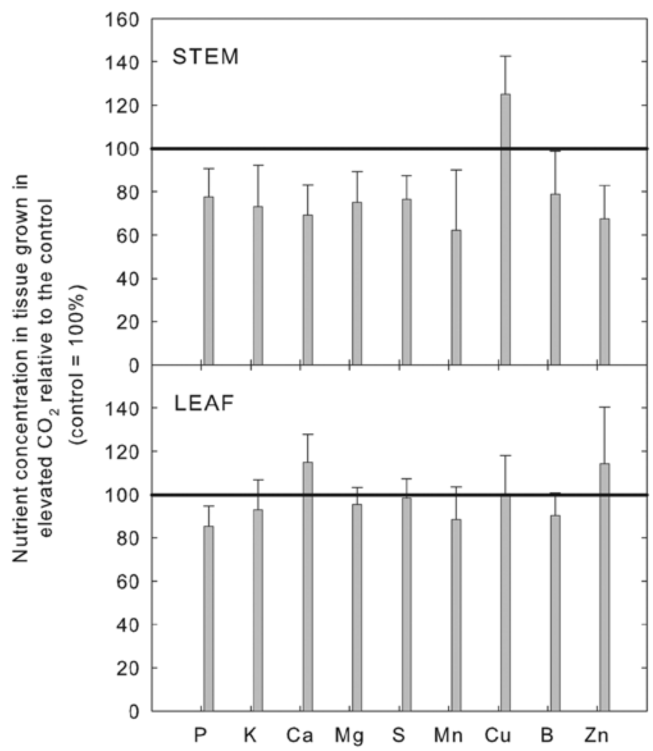

Figure 3. Effect of elevated CO_2 on nutrient partition of Petunia. Nutrient content in the stem and leaf expressed as a percent of the control values (100%). In stem tissue, nearly all essential elements decreased in concentration, but there was no clear pattern in the leaf tissue.

Previous studies have demonstrated that elevated CO_2 levels stimulate plant growth in the short term (Flynn *et al.*, 2006). In addition, CO_2 can modify plant C:N ratio, protein, phenolics, and tannin levels (Zvereva and Kozlov, 2006; Mattson *et al.*, 2005), making plants more vulnerable to herbivore attack (Chen *et al.*, 2005).

In our study, petunia plants grown under elevated CO_2 shifted resources from leaves to flowers, as indicated by the decreased biomass on the leaves and increased flower biomass under elevated CO_2 conditions (Figure 4). Leaf stem nutrient content changed between the two CO_2 environments, but CO_2 had little effect on the flower nutrient status. While a shift in resources favoring flowers over leaves could result in better flowers, this shift might make leaves more susceptible to insect attack.

Insect responses were affected by fertilization and CO_2 levels but not light levels (Figure 5). Whitefly fecundity increased on plants receiving higher nutrient levels ($F = 7.07$; df = 2, 45; $P = 0.0023$). And this increase was more marked when the plants were grown at high CO_2 levels ($F = 4.35$; df = 1, 45; $P = 0.0434$; Figure 5). Other studies have shown significant insect responses under elevated CO_2 conditions. Peltonen *et al.* (2006) and, in a separate study, Sudderth *et al.* (2005) showed that aphids fecundity and their populations can increase under elevated CO_2 conditions. Sudderth *et al.* (2005) also showed that CO_2 levels can interact with the plant nutrients, especially N, ultimately favoring the aphids.

During our study, whitefly mortality was not affected by either of the factors being evaluated. However, there was a tendency for lower mortality when CO_2 levels were higher (Figure 6).

Mortality caused by the parasitoids *Encarsia formosa* and *Eretmocerus mundus* showed a tendency to be lower under elevated CO_2 (Figure 6). Higher whitefly survival coupled with increased fecundity under elevated CO_2 levels would result in higher populations. Therefore, management programs for whiteflies would need to be adjusted to maintain populations below damaging levels. As our study shows, elevated

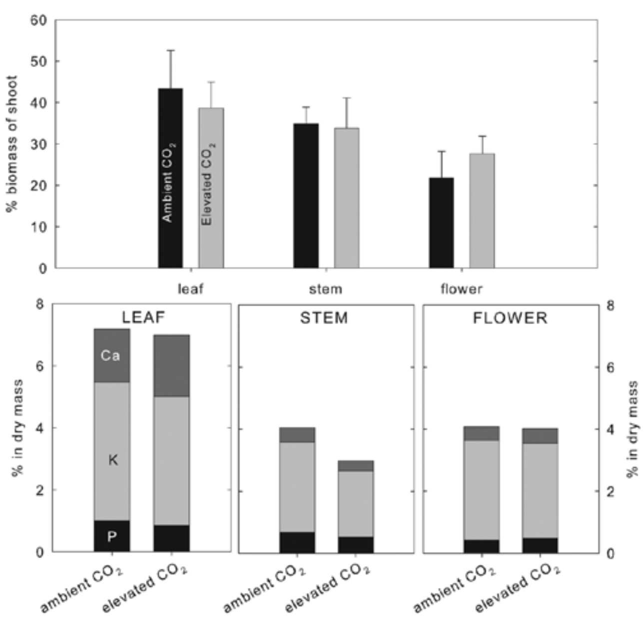

Figure 4. Biomass partitioning in petunia exposed to ambient or elevated CO_2 concentrations (top figure) and the P, K, and Ca content of each fraction (bottom figures).

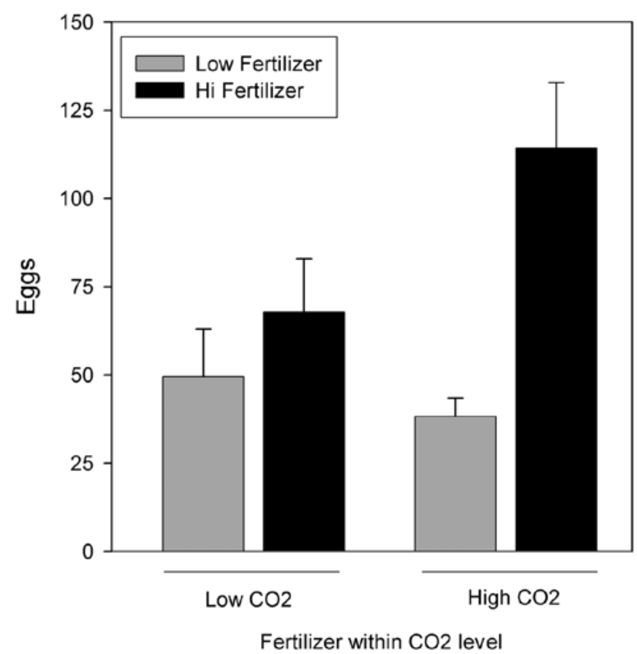

Figure 5. Whitefly fecundity on petunia plants grown under different levels of CO_2, light, and fertilizer (light level is not included).

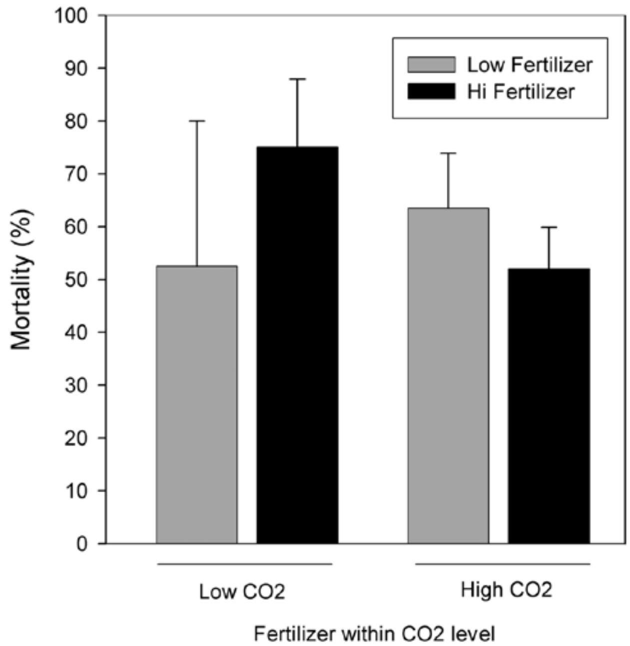

Figure 6. Whitefly nymph mortality on petunia plants grown under different levels of CO_2, light, and fertilizer (light level is not included).

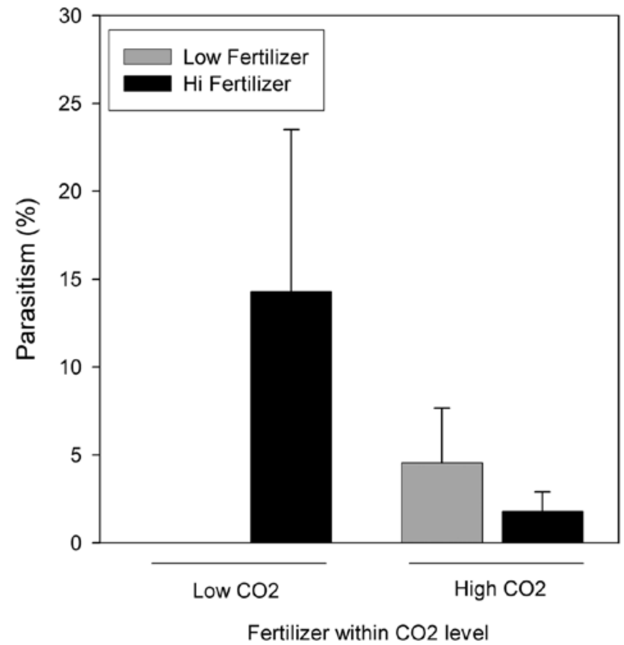

Figure 7. Parasitism by Encarsia formosa and Eretmocerus mundus on whitefly nymphs on petunia plants grown under different levels of CO_2, light, and fertilizer (light level is not included).

CO_2 levels coupled with higher nutrition can change plant growth and chemical composition, which in turn will have consequences for herbivore performance, ultimately affecting management outcomes.

Significant Outcomes

Because the data look very promising, the authors will use these data to seek extramural funding to test further hypotheses about the effect of environment manipulation on pest-management methods.

Since some floriculture growers have the ability to inject CO_2 to increase plant growth, this information will be very useful for developing appropriate management methods. Thus, the information gathered from this study will be shared in trade magazines and other media outlets.

Acknowledgments

The authors thank Henry Paz, Eliana Rosales, and Christian Cruz for their technical support. Funding was provided by a grant from the OH-IPM program.

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End-of-Season Weed Control Survey in Soybeans

Investigators:

Greg LaBarge, Mark Loux, Jeff Stachler, Harold Watters, John Yost, Jonah Johnson, Alan Sundermeier, John Hixson, Woody Joslin, Roger Bender, Andy Kleinschmidt, Gary Prill, and Ed Lentz

Project Goal

The goal of this project was to quantify summer annual weeds present in soybean fields that were near maturity. Monoculture weed control methods have caused an increasing concern about weed population shifts and the potential for resistance development. This study establishes a baseline for quantifying these weed control shifts and identifying troublesome species.

Method

Ohio State University Extension educators drove a route through their county that was representative of soils, tillage, and cropping patterns. The route included systematic stops every one to one-and-one-half miles, stopping at soybean fields and noting the types of summer annual weeds that were present in the soybean canopy. Eighty soybean fields (the minimum) were targeted for the survey to be representative of the county.

A record was made for each field where stops occurred. The following information was recorded:

1. Field location by road name and crossroads or GPS point. (Enough information so the field could be located in future years or to visit with the operator for herbicide program information.)

   Note: If there were soybean fields on both sides of the road, both fields were recorded, and the side of the road was noted by direction.

2. Estimated acres in the observation field.

3. Each plant species and the infestation level based on this scale:

   a. Mark a 1 in the spreadsheet for a named species, if present.

   b. Write in the common name of the first weed for other species in the other weed area; record up to three weeds.

   c. Use the key shown here to indicate infestation level.

   1 = Occasional:
   A plant of the species as an occasional individual plant.

   2 = Large patch(es):
   A patch or two of five or more plants of individual species in a couple areas of field.

   3 = Wide Spread:
   Numerous patches or individual plants of the species across the field.

An Excel spreadsheet was developed to provide a standardized record used to summarize observations. The spreadsheet was set up so that it could be taken to the field on a laptop and data recorded using the laptop, or the spreadsheet could be printed on legal paper, taken to the field, and then the information transferred to the computer later. Routes were driven between September 21 and October 1, 2006.

Results

Results were obtained from nine Ohio counties primarily in the western part of the state. Participating counties were Fulton, Champaign, Wood, Clark, Fayette, Union, Shelby, Van Wert, and Seneca Counties. A total of 959 fields representing 59,137 acres of soybean ground were visited in the survey. An average of 105 fields per county were observed, with a range of 80 to 237 fields.

Table 1 shows the statewide summary of observations. Of 959 total fields visited, 612 fields or 64 percent had observable levels of weeds in the field rating at least a 1 on the rating scale. The most observed species was Giant Ragweed followed by Marestail, Common Lambsquarter, Common Ragweed, and Giant Foxtail. Of the fields observed with weeds present and receiving a field rating of 3, Common Cocklebur was the most observed species followed by Common Lambsquarter, Common Ragweed, Giant Ragweed, and Marestail. From a raw numbers standpoint, Giant Ragweed had the greatest presence with 100 of the 403 fields observed rating a 3 on the weed presence rating.

Table 1. Summary of Statewide Observations (Nine Counties) of Weed Species Growing in Soybean Fields, Autumn 2006.

Bayer Code	Common Name	Total Fields	% of Fields Recorded with Weed	% Rated 1	% Rated 2	% Rated 3
AMBTR	Giant Ragweed	959	42	57	19	25
ERICA	Marestail	959	19	62	15	22
CHEAL	Common Lambsquarter	959	15	55	14	31
AMBEL	Common Ragweed	959	9	58	13	29
SEFTA	Giant Foxtail	959	9	59	30	11
ABUTH	Velvetleaf	959	8	78	4	18
AMARE	Redroot Pigweed	959	4	72	21	7
ZEAMX	Volunteer Corn	959	3	76	15	9
PHTAM	Pokeweed	959	2	80	15	5
XANST	Common Cocklebur	959	1	40	0	60
DATST	Jimsonweed	959	0	67	0	33
PANDI	Fall Panicum	959	0	25	75	0

Tables 2 through 7 show the ratings by county of the top six species observed. The range of field observation of these top species was 8 to 42 percent of the fields surveyed. Weed species levels do vary by county. Giant Ragweed was found in more than 50 percent of the total number of fields in Champaign, Fayette, and Seneca Counties. The highest percentages of Giant Ragweed infestation rating a 3 were found in Seneca, Fayette, Fulton, and Shelby Counties, respectively, with a range of 52 down to 15 percent.

Table 2. Summary by County of Giant Ragweed Infestations.

AMBTR	Giant Ragweed					
County Number	County Name	Total Fields	% Recorded with Weed	% Rated 1	% Rated 2	% Rated 3
26	Fulton	83	34	75	7	18
11	Champaign	85	54	83	17	0
87	Wood	100	17	65	35	0
12	Clark	80	25	35	55	10
24	Fayette	80	54	60	14	26
80	Union	120	36	74	26	0
75	Shelby	84	48	40	45	15
81	VanWert	90	24	77	18	5
74	Seneca	237	61	42	6	52
		959				

Table 3. Summary by County of Marestail Infestations.

ERICA	Marestail					
County Number	County Name	Total Fields	% Recorded with Weed	% Rated 1	% Rated 2	% Rated 3
26	Fulton	83	1	100	0	0
11	Champaign	85	15	85	15	0
87	Wood	100	5	60	40	0
12	Clark	80	39	68	23	10
24	Fayette	80	50	70	18	13
80	Union	120	9	55	27	18
75	Shelby	84	13	64	18	18
81	VanWert	90	16	64	21	14
74	Seneca	237	17	35	5	60
		959				

Table 4. Summary by County of Common Lambsquarter Infestations.						
CHEAL	**Common Lambsquarter**					
County Number	**County Name**	**Total Fields**	**% Recorded with Weed**	**% Rated 1**	**% Rated 2**	**% Rated 3**
26	Fulton	83	8	71	14	14
11	Champaign	85	14	83	0	17
87	Wood	100	1	100	0	0
12	Clark	80	1	100	0	0
24	Fayette	80	15	58	8	33
80	Union	120	9	55	27	18
75	Shelby	84	31	65	31	4
81	VanWert	90	18	88	6	6
74	Seneca	237	23	29	11	60
		959				

Table 5. Summary by County of Common Ragweed infestations.						
AMBEL	**Common Ragweed**					
County Number	**County Name**	**Total Fields**	**% Recorded with Weed**	**% Rated 1**	**% Rated 2**	**% Rated 3**
26	Fulton	83	5	100	0	0
11	Champaign	85	0	0	0	0
87	Wood	100	6	100	0	0
12	Clark	80	8	33	50	17
24	Fayette	80	3	100	0	0
80	Union	120	7	38	50	13
75	Shelby	84	6	100	0	0
81	VanWert	90	32	83	10	7
74	Seneca	237	11	12	4	84
		959				

Table 6. Summary by County of Giant Foxtail Infestations.						
SEFTA	Giant Foxtail					
County Number	County Name	Total Fields	% Recorded with Weed	% Rated 1	% Rated 2	% Rated 3
26	Fulton	83	8	29	71	0
11	Champaign	85	5	50	25	25
87	Wood	100	6	83	17	0
12	Clark	80	1	0	100	0
24	Fayette	80	3	50	0	50
80	Union	120	33	50	38	13
75	Shelby	84	18	73	13	13
81	VanWert	90	8	100	0	0
74	Seneca	237	0	0	0	0
		959				

Table 7. Summary by County of Giant Foxtail Infestations.						
ABUTH	Veltvetleaf					
County Number	County Name	Total Fields	% Recorded with Weed	% Rated 1	% Rated 2	% Rated 3
26	Fulton	83	7	100	0	0
11	Champaign	85	2	100	0	0
87	Wood	100	2	100	0	0
12	Clark	80	0	0	0	0
24	Fayette	80	0	0	0	0
80	Union	120	4	100	0	0
75	Shelby	84	0	0	0	0
81	VanWert	90	28	92	8	0
74	Seneca	237	16	0	0	0
		959				

Horticulture High Tunnel Workshop, November 14, 2006

Co-Principal Investigators:

Matt Kleinhenz, Brad Bergefurd, and Ron Becker

Introduction

The Horticulture High Tunnel Workshop was partially funded by the Ohio IPM Program through its approval of the proposal *Optimizing High Tunnel-Based Vegetable Production Systems* submitted April 2006 by the co-PIs on behalf of the Ohio State University Vegetable Team. High tunnels (HT) are unheated greenhouses that extend the growing season. The Workshop was developed with input from farmers, research-Extension professionals, and many others. Six points guided the Workshop's development:

1. High tunnels are relatively inexpensive, simple structures lacking supplemental lighting, a permanent floor, and an automated temperature-control system.
2. High tunnels allow horticultural crop producers to dramatically but inexpensively lengthen production-marketing periods and protect crops from undesirable natural phenomena (e.g., excessive rain, wind, temperature fluctuations).
3. High-tunnel use is increasing rapidly in Ohio and other parts of the Midwest.
4. Increases in soilborne disease, declines in soil quality, the need for small specialized equipment and/or hand labor, and abiotic and biotic conditions resembling a blend of those of open fields and enclosed spaces are characteristic of high tunnels.
5. High-tunnel design is highly variable but must conform to conditions of a region and farm.
6. Reliable recommendations — from many sources, especially farmers — on high-tunnel construction and integrated crop management are needed.

Therefore, based on suggestions from farmers and university personnel, we set out to:

1. Assess the current level of knowledge and adoption of Integrated Crop Management (ICM) practices within industry and university communities currently using or planning to use high tunnels. (ICM is IPM with nutrient management.)
2. Complete an interactive Workshop on ICM within high tunnels.

3. Assess the level of knowledge gained regarding the use of ICM practices in high tunnels through the Workshop.

4. Establish a multi-state and university-, industry-, and public-member high-tunnel ICM learning community through which the information needs of high-tunnel users and their use of ICM techniques can be assessed.

Methods

Program Development

- Discussed program with farmers (range of demographics), academic, industry advisors.
- Completed weekly-biweekly (August - November) program committee planning meetings. Additional communication by phone, e-mail.
- Prepared for audio and paper product creation with CFAES/OARDC/OSUE Communications and Technology and Print Shop.
- Identified and recruited speakers, sponsors, exhibitors, vendors, partners.
- Collected high-tunnel and organic production-related educational products.
- Established program-day logistics, roles, and responsibilities and recruited volunteers.

Activities and Products

Before Workshop (publicity)

- Web sites, list-serves, trade publications, OSU news release, newsletters, direct mailing, paper announcements, phone consultations, farm and produce auction visits, field days, and farm tours

During Workshop - Program Execution

- Integrated farmers, academics, others as teachers in interactive, moderated panel discussion format.
- Took written, spoken questions from audience.
- Provided an Information Packet that contained high-tunnel reference information and copies of speaker-panelist visual aids.
- Obtained audio recording of program.
- Provided high-tunnel and organic production-related resources for sale and at no charge.
- As much as possible, restricted all food and beverages to Ohio products or ingredients.

After Workshop

- Information Packet.
  Contains 71 black-and-white and color pages of high-tunnel reference materials and visuals used by Workshop panelists and speakers.
- Audio CD.
  Contains the recording of six hours of discussion (in 16 searchable segments) involving speakers, panelists, and audience members. Offers insights often unavailable in other formats.
- Web sites.
- Growers' meetings, trade publications (to date, two articles printed in *Farm and Dairy Magazine* and one in *The Columbus Dispatch),* newsletters, direct mailing, phone consultations, farm and produce auction visits, field days, and farm tours.
- Enter, analyze, and summarize evaluation form data and prepare report.

Inputs and Investments

Personnel and Number of Hours Worked on Program

Matt Kleinhenz, 220
Brad Bergefurd, 125
Ron Becker, 80
Leah Miller, 135
Gerald Payn, 4
Sonia Walker, 14
Michelle Sutter, 14
Sasha Bogdan, 14
Bob Napier, 4
Jerome Rigot, 4
Kathy Bielek, 12
Registration Helper 1, 12
Registration Helper 2, 12

Revenue Generation

Registration, sponsorship, exhibitor fee, in-kind/donation, Information Packet, Audio CD.

Materials and Equipment

- Fisher Auditorium, OARDC, Wooster. North Exhibit Area and seating, South Exhibit Area and seating, Kitchen.
- Kleinhenz/Peri-Urban project. High Tunnel No. 1 at Horticulture and Crop Science's Horticulture Unit No. 1, OARDC, Wooster.
- Print Shop, OARDC, Wooster.
- Communications and Technology (various).
- Contracted Audio CD Duplication Service.
- Williams, Edgington, and Thorne Halls, office facilities and equipment, OARDC, Wooster (various).
- Ohio State University South Centers at Piketon, office facilities and equipment (various).
- Ohio State University Extension, Wayne County, office facilities and equipment (various).
- Small Farm Institute, office facilities and equipment (various).
- OARDC Motor Pool, 15-passenger van (2).
- OARDC, OSUE, Small Farm Institute, employee personal vehicles.
- Sprenger Retirement Center Transport Van.
- Catered lunch.
- Snack foods, beverages, and dry goods.

Partners

- Ohio Agricultural Research and Development Center (OARDC), The Ohio State University.
- Ohio State University Extension.
- Ohio State University South Centers at Piketon
- Ohio Integrated Pest Management (IPM) Program (personnel).
- Small Farm Institute (personnel).
- U.S. Department of Agriculture — Cooperative State Research, Education, and Extension Service (CSREES).
- U.S. Department of Agriculture — Sustainable Agriculture Research and Education (SARE) — (personnel, high tunnel for tour)
- Ohio Vegetable and Potato Growers Assocation (OVPGA) — Ohio Vegetable and Small Fruit Research and Development Program (personnel).

Results

Workshop Participants

Speakers

Primary OSUE appointment (3), primary OARDC appointment (2), Extension-research appointment with other universities (2), farmers (9), produce industry members (e.g., buyers, input suppliers, consultants) (7).

Audience (ca. 150 attendees)

	No	Yes
Are you a...		
Farmer	8	62
Conventional Farmer	46	17
Professional Produce Buyer	68	2
Transitional-Organic	43	20
Resource Person for Farmers	56	14
Certified-Organic	51	12
Do you...		
Farm in open fields only	48	15
Grow vegetables	17	46
Farm in high tunnels only	62	1
Grow small fruit	39	24
Farm in open fields and Hts.	35	28
Grow other crops*	48	15

* Evidence suggests that those who responded with "Yes" to "other" grow flowers.

States and locations represented (from registration list):
Ohio (40 zip codes), Michigan, Illinois, Indiana, West Virginia, New York.

Those who heard about and/or participated in the Workshop included farmers and market gardeners; OSU Extension; OARDC; Michigan State University Extension (MSUE); grower associations — Ohio Vegetable and Potato Growers Assocation (OVPGA), Ohio Ecological Food and Farming Association (OEFFA), Innovative Farmers of Ohio (IFO), Non-Profit Organizations (NPO), and Non Governmental Organizations (NGO) personnel; consultants; bankers; farm input suppliers; representatives of multiple types of markets *(e.g.,* grocery store, produce auction, farmers market, restaurant); trade publication authors; technical working group *(e.g.,* Great Lakes Vegetable [GLV]) members.

Program Evaluation — Change in Knowledge, Attitude, Skills, and Awareness

Summary statements regarding the outcomes of the Workshop — based on data collected with the Program Evaluation form — are presented here:

1. The overall satisfaction with the Workshop was rated as 88.5 ± 9.9% on a scale of 1 to 100 (100 = totally satisfied).
2. The response to the question "the information presented in today's program was useful to me (1 = strongly agree, 4 = strongly disagree)" was 1.6 ± 0.71.
3. The response to the question "after today's program, my confidence in the use of high tunnels is (1 = higher, 2 = lower, 3 = same, 4 = not sure)" was 1.4 ± 0.87.
4. Ninety-seven percent of the respondents indicated that the Workshop topics were important to them.
5. Ninety percent of the respondents indicated that they would attend another program like the Workshop.
6. Ninety-two percent of the evaluators indicated that they would do something

different in their operation because of something they learned at the Workshop.

7. Eighty-six percent of the evaluators participated in the tour of OARDC high tunnels.

Evaluators were asked to rate their knowledge and understanding in six areas of high-tunnel production (1 to 5 scale, low-high) before and after the Workshop. Their self-assessments are summarized in the table on this page.

Most Beneficial

In their own words, evaluators indicated that the following part(s) of the program were most beneficial:

General management; high-tunnel design and construction; disease and pest management; farmers' experiences, marketing, use of compost as a fertilizer and its overall effect on crops. The benefits of high tunnels on disease control; marketing potential for season extension and any info pertinent to organic production; networking with others, learning the basic construction of high tunnels, and hearing about why/how you use them; segments 1, 2, 3, 4 HT design; hearing experiences from other growers; hearing about successes and failures of the farmers.

The insights from research were good too; Hay Grove tunnels; Panel No. 6. It was beneficial to hear about the personal experiences of local growers; integrated crop and pest management; construction, practical experience; soil, fertility, and irrigation management, disease management; segment 7.

Case studies in successful high-tunnel production; actual high-tunnel construction and use, use of beneficials and timing in swing crops; mostly design, set-up, crops, pests, and motivation/advice-buyer; all.

We were happy that there was a good blend of conventional as well as organic information; integrated crop management.

I'm starting from the beginning so most everything was beneficial; well-rounded; listening to and exchanging ideas with other people with the same ideas and goals; pest and disease management; produce managers; high-tunnel design and construction; integrated crop management; design and construction; integrated management (nutrients, irrigation, diseases, and insects); pest disease; all the way through; disease management.

Sum and Number of Responses				
	Before (N)		After (N)	
			Pre-to-Post Gain *	
A. HT Design and Construction	225 (72)	272 (69)		
			47	
B. Limits on HT Production	201 (73)	259 (68)		
				58
C. HT Water and Fertility Management	198 (73)	251 (67)		53
D. HT Disease Management	189 (73)	246 (67)		57
E. HT Insect Pest Management	186 (72)	250 (67)		64
F. Season Extension in Local Markets	216 (69)	244 (62)		28

* Average gain per category = 52. Average gain from before to after in each category (A-F) per respondent = 0.8 - 1.1 (ca. 20%, data not shown). Overall, the largest self-reported gains in knowledge and understanding were in the Insect Pest, Limits on HT Production, and Disease Management categories.

Great topics, too hard to just pick two; case studies, pictures and explanations of specific high tunnel operations and set-ups; importance of seasonal extension in local market; everything was exceptional; case studies in successful high-tunnel production; insect problem; all very interesting and helpful; speakers; all; contacts; producers spotlight; water and fertilizer management, disease management; panel discussion, everything, moderator was great!!!

High-tunnel production; disease management; tour, local food markets; construction; 5.2, 5.6a and b; water and fertility management; the basics of where and how to use high-tunnels; all new to us, so all really good; all good, usable info; high-tunnel design and tour tunnel; all; basic set-up, costs; scare tactics/industrial attitude not my cup of tea.

This "farmer input" program simply could not have happened 20 years ago. Wendell Berry would be proud to see this. Kamyar, also. Amish farmers on panel discussions!! Tapping genius! Reasonably non-arrogant researchers sharing data and LISTENING!! Extension agents who — well, there's always room for improvement, eh? At any rate, this is the way we were meant to learn — from each other — thanks!!

Tunnel design and construction; good description of different designs, features, and uses; hoop house operation and use; markets for extended season; panel format; crop management; high-tunnel design; hearing of possible disease/pest issues related to HT; all topics were of interest — my first experience with high tunnels; integrated crop management — insects and disease.

Least Beneficial

In their own words, evaluators indicated that the following part(s) of the program were least beneficial:

Design and construction — I would like to see more specific info in this area. Pest control (discussion of conventional methods was of no benefit); I'd like to hear more pest, disease management discussed in terms of getting away from monoculture crops and going beyond even companion planting into the idea of polyculture; more info presented on research data. More visual pictures to illustrate presentations; conventional fertilizer and insecticides. Too much sitting. Five-minute breaks too short; 10 better.

High-tunnel construction. We are not organic. We were also looking more to high tunnels we could work with equipment; everything was beneficial to various levels; segment No. 3; limits on production (but it was still useful); organic; really none; composting; very well balanced; increase info on soil balance — handouts with specific information; hot-house building — already have several; insect problems and control.

References to "organic;" not everyone is interested, nor is it universally thought to be better or positive; need more on compost, more on bramble fruit; construction; nothing; green house brambles; beneficial insects — already in use; insect pest management; limits on HT production; exhibitors — too much talk and not enough pictures — could have been better to us as newbies/part timers.

At beekeeping workshops, we are inundated with catalogs; none; specific disease discussion; disease management; non-hoop house specific straying; organic.

Use of Audio Recording

Responses to the statement "I plan to use the audio recording of this Workshop" were yes (42), no (18), and not sure (11).

Future Needs/Direction Changes Because of This IPM Project

Future Topics

In their own words, evaluators indicated that they would like to have the following topic(s) covered in future high-tunnel programs:

Fruit crops, brambles, blueberries, cherries; bramble production; raspberries; growing brambles in high tunnels; detailed scheduling info; provide actual parts lists and suppliers for materials used in building high tunnels.

More detail about low-budget high tunnels; polyculture, a permaculture concept in high tunnels, especially as it offers solutions to disease and peat management; high tunnel construction (Penn State boys: Mike Orzolek and Bill Lamont); plastic cover options, poly installation; repair and maintenance of high tunnels; more about marketing to restaurants and stores.

How about a lecture on cost/maintenance/style of various brands and homemade; more on marketing; winter production; berries in hoop house; construction, more about other crops, less tomatoes; fertility, varieties; growing and transplanting new starts, drip irrigation/fertilization schedules, marketing strategies, nutrient usage; crop varieties, beginner high-tunnel basics: size, planting, managing; growing summer lettuce in tunnels and what type plastic may work with that.

Which shade cloths work for which crops in tunnels; more on growing — and how to grow in the 21st century specialty crop market; disease management, use of compost/mulch; more info on crops planted in what time frame from seed to harvest; bramble fruit culture in high tunnels; bramble production in high tunnels, experience with different crops and varieties; more specific information about irrigation, how to measure moisture.

More specific resource info regarding high tunnel and related vendors; strawberries, watermelon; importance of compost for soil/fertility and disease management, brambles and small fruit production under high tunnels; growing brambles in high tunnels, using thermal-mass components to improve cold-season temp. regulation; brambles; case study examples on cost analysis — specific dollars; more case studies, more examples of varieties, spacing of plants, etc.; more handouts with specific data.

Soil samples, how to read soil test, how to apply organic fertilizers in stages to meet need; specific crops that work well in the high tunnel and how to grow it; specific fertilization programs and schedules, compost timing; construction details!!

Organic pest control, tree fruits in high tunnels (peaches, cherries, etc.)?; organic production and end wall construction; variety lists that are successful, in-depth schedule of planning, PowerPoint presentation on ID and treatment of disease; marketing strategies; brambles; photos of various tunnels in production so can better understand specific crop — grass, brambles, profits, marketing; amending soils, plastic layer — planting — row size, how far apart, etc.; organic production, diversified production; fruit — strawberries; strawberries; more on brambles and strawberries; possibly fruit trees; crops other than tomatoes, esp. brambles and herbs.

Design/arrangement of beds — more pictures/examples; brambles; different kits, manufacturers; movable tunnel structures, supplemental heating of tunnels, irrigation practices (drip and micro sprinklers); construction types, mechanical — uses of hoop houses, examples of year-long schedules; fruits/rotation from field to tunnel.

Can a high-tunnel design exist that the whole cover can be removed and reapplied? Would that type of design be a benefit?; segment 6c and 8; more of intensive/intercropping in high tunnel; rotation of crops in high tunnels; more case studies in detail; use of cover crops; durability of structures; some research on a wider crop range; would like a wider discussion on plants, brambles, herbs, etc. (tomatoes were the main discussion).

Needed Research

In their own words, evaluators indicated that research is needed in these area(s) in order to help high tunnel farmers:

Polyculture, a permaculture concept in high tunnels, especially as it offers solutions to disease and peat management; automation of high tunnels, temperature control; other crops; cover cropping in high tunnels; fertilization and building organic matter. Effects of crop rotation on fertility, diseases, and insects; drip irrigation specialist: equipment and rates, design.

Use of plastic mulches and drip irrigation. Understanding labor management in high tunnels; use of organic compost in high tunnels, best crop rotations for northern Ohio. Competition among local farmers — what are good prices to expect by crop?; long-term management seems unexplored. Figuring out a better ventilation system. How about solar heating and attaching gutters to collect water?

Best ways to maintain fertility in high tunnels (organically); soil fertility (organic); construction on high tunnels; crops in high tunnels other than tomatoes; what can be used in high tunnel (e.g., pesticides); herbicides, insecticides; crop varieties; more on specialized crops — berries, etc.; insect control; how to control soil diseases; use of plant breeding, organic systems.

How to price the product you grow; more specifics on benefits of different high-tunnel plastics; varieties that excel in high tunnels; approximate yields we can possibly expect; brambles and small fruit production under high tunnels; organic soil and organic matters management; microbial populations and effect on disease occurrence; more variety trials specifically for high tunnels; the possibility of using animals in an integrated system; fungicide labels.

Was great to have so much on organic, always good to have more on organic/local research; effect of temp fluctuations (35 degrees to 85 degrees daytime) on tomatoes (fruit); cultural tomato info — varieties for high tunnel, etc.; organic with compost; seed variety performance; organic methodologies (fertility); types of compost, application type, heat performance.

Which is best irrigation, types of soil penetration rates, absorption for crops — by crop temp, rate of compost/organic dissipation rate; cut flowers; crop timing; tomato grafting; small fruit and specific vegetable success/failure; homemade construction vs. purchased kits; berries; actual effects of pesticide, herbicide, insecticide in high tunnels; soil fumigation like steam; fruits; micro greens.

Planning and scheduling for diversified production within the same high tunnel; types of heat for high tunnels; not sure, we're too new at this to answer; mulches; homemade tunnels at low cost that really are sturdy, etc.; snow load or weight capacity of HayGroves and other common tunnels; soil nutrient levels (micro and macro) and how they correlate to insect and disease outbreaks in tunnels; supplemental heating. Foils — heat and energy costs; synthetic input residues/pollination.

Important Identifying Characteristics

To our knowledge, the Horticulture High Tunnel Workshop was the first of its type offered in Ohio. Important identifying characteristics of the Workshop include:

- Its development at the urging and with the assistance of farmers.
- Its interactive format, integrating academics and non-academics as teachers, along with a tour of a working high tunnel; availability of reference material and digital audio capture.
- Timely scheduling.
- Broad support from and attendance by a wide range of individuals and groups involved in local-regional food systems.
- Apparent success (based on evaluation form data and informal feedback) at achieving its objectives and establishing a foundation for future related programming.

We have accomplished the first three objectives of the project and are well-positioned to achieve the fourth, longer-term objective.

Implementation of Integrated Pest Management in Commercial Lawn Care

Investigators:

Parwinder Grewal, John Cardina, Joseph Kovach, David Shetlar, and Joseph Rimelspach

The Ohio State University

Introduction

Lawns are a major component of urban landscapes and are highly valued for aesthetic, environmental, and recreational purposes. Lawn care carried out directly by homeowners or professional lawn-care companies is estimated at more than $25 billion in services and products in the United States. Unfortunately, the desire of many homeowners to achieve a perfect lawn has resulted in the establishment of a lawn-care system that heavily relies on routine, often calendar-based, applications of fertilizers, petrochemicals, and other pesticides, which are perceived as significant sources of environmental contamination, ambient ecosystem disruption, and human health risks.

As a result, the U.S. Environmental Protection Agency (EPA) has banned or imposed stringent restrictions on the use of some pesticides in urban settings, leading to fewer products available for use around homes. Therefore, other approaches to lawn pest management that reduce the overuse of these inputs are needed. One such approach is the integrated pest management (IPM) concept, which promotes the integration of multiple tactics including cultural practices and biological control agents. Pesticides and fertilizers are applied only when justified through adequate sampling. Thus, lawn care IPM relies primarily on judicious use of fertilizers, biological control agents, and synthetic pesticides.

Adoption of alternative management approaches in commercial lawn care has not been widespread due to several factors. First, studies designed to develop alternative approaches often deal with insects, weeds, or diseases independently and most often focus on specific pest problems within one of these major pest categories. While such studies provide important biological and pest management information, they do little to elucidate a coherent and conceptually broad approach to managing the entire turf grass system.

Second, there is almost no information available regarding the cost-benefit relationships between various management programs. Thus, there is no economic basis for comparing or implementing low-input management philosophies.

Third, very few studies have attempted to address homeowner expectations about the aesthetics of lawns and what constitutes an acceptable stand of turf grass on their lawns. This lack of data addressing the more subjective aspects of urban lawn management further complicates and hinders the widespread adoption of alternative approaches in this system. Thus, there is a need for research to evaluate and compare the biological, aesthetic, and economic aspects of the different lawn pest management approaches. There is also a need to identify the social mechanisms underlying why urban homeowners manage their lawns the way they do and their expectations about lawn aesthetics.

To enable the implementation of IPM in commercial lawn care, this study was conducted, in collaboration with Buckeye Ecocare, a private lawn-care company located in Dayton, Ohio, to compare biological, economic, and aesthetic aspects of IPM and conventionally managed lawns. By involving a commercial lawn-care company and its customers, we think successful demonstration of IPM in commercial lawn care will foster realistic homeowner expectations about the aesthetics of lawns and will lead to rapid adoption of IPM in urban lawn care.

Methodology

Customer enrollment for this study was sought through the company, and letters containing information about the study were mailed out to customers. Twelve (12) Buckeye Ecocare customers enrolled in the IPM program and 11 customers from the company's conventional five-step (non-IPM) lawn-care program to facilitate comparison. Data were collected from IPM and conventionally managed lawns during June, August, and September in 2006 by conducting onsite surveys and evaluations. Insect damage, weed coverage, and disease incidence were evaluated and recorded along a single diagonal established across each lawn. The overall aesthetic effectiveness of the lawns was also evaluated.

Results

No significant differences were observed in either insect damage or weed and disease infestation between IPM and conventionally managed lawns. Likewise, no significant differences were observed in the aesthetics of IPM and conventionally managed lawns.

The results indicate that the IPM program did provide an acceptable level of pest control compared to the conventional five-step program in terms of biological and aesthetic evaluations. However, data comparing the cost of services for each of the programs are not yet available. The IPM customer enrollment of 12 is a drop of approximately of 59 percent from the previous enrollment of 29 in 2005. This drop in customer enrollment raises some interesting questions, such as:

- Why did some customers decide to continue with the IPM lawn-care program and why did others opt out?
- How does the proportion of IPM customers (those who re-signed and those who opted out) relate to demographic characteristics, such as income, age, and education level?
- What is the perception of customers toward IPM lawn care?

Therefore, a separate study will be conducted to try to answer these questions. The answers to these questions will help us understand why some homeowners manage their lawns the way they do.

Improved Apple Pest Management by Codling Moth Granulosis Virus and Modified Timing of Insecticides and Miticides

Principal Investigator:

Celeste Welty
Associate Professor of Entomology, The Ohio State University

Introduction

A three-part study on apple pest management was conducted in 2006. A full report for each study is available on the internet at: (http://bugs.osu.edu/welty/). Highlights of the three studies are presented in this report.

PART 1: Codling Moth Management by Insecticides in Ohio Apple Orchards

Summary

A field trial was conducted to evaluate the effects on codling moth control of three insecticide programs including alternatives to organophosphates. The insecticide programs used one product for control of first-generation codling moth and one product for control of second-generation codling moth. The programs were (1) Rimon followed by Assail, (2) Guthion followed by Asana, (3) Guthion followed by Guthion, and (4) no insecticide. Each insecticide program was used with and without one mid-summer insecticide application of Imidan when the codling moth population was between broods. All programs were followed by Assail or Imidan for late-season codling moth control. Fruit were evaluated for insect injury in mid-summer and at harvest.

All insecticide programs provided control of codling moth that was significantly better than the untreated check treatment. There was no difference between Rimon and Guthion for control of first brood codling moth. There was no benefit from applying an insecticide between broods of codling moth in mid-summer. All three insecticide programs (Rimon followed by Assail, Guthion followed by Asana, and Guthion followed by Guthion) provided equally excellent control of codling moth in harvested apples (Table 1).

Table 1. Effect of Insecticide Program on Insect Injury to Delicious Apple Fruit at Harvest, Mean of Three Blocked Replicates, September 2006, at OSU's Waterman Lab, Columbus, Ohio.

Treatment		Percentage of Fruit[a]				Tarn-ished Plant Bug	Plum Cur-culio Ovi-posi-tion	Plum Cur-culio Late Feed-ing	San José Scale	Leaf Roller	Un-identi-fied[c]
Insecticide for Codling Moth (First Generation/ Second Generation	Imi-dan at 3C	Clean	Internal Lepidoptera[b]								
			Entry	Sting	Total						
Rimon/ Assail	yes	91.2A	1.2 B	0.3 B	1.5 B	6.3	1.0	0	0 B	0.2	0
Guthion/ Asana	yes	91.0A	0.4 B	0.2 B	0.5 B	7.2	1.5	0	0 B	0	0
Guthion/ Guthion	yes	91.7A	0.3 B	0.0 B	0.3 B	6.3	1.8	0	0 B	0	0
Rimon/Assail	no	89.8A	0.2 B	0.3 B	0.5 B	7.7	1.8	0	0 B	0.2	0.2
Guthion/ Asana	no	91.5A	0.7 B	0.2 B	0.8 B	6.3	1.4	0	0 B	0	0.3
Guthion/											
Guthion	no	90.2A	0.8 B	0.3 B	1.2 B	7.2	1.7	0	0 B	0	0
None/None	no	66.9B	11.6A	3.3 A	14.9A	2.6	8.0	0.7	1.3 A	1.0	5.6
Probability value for treatment effect from ANOVA		0.001	0.005	0.001	0.002	0.32	0.16	0.47	0.02	0.10	0.20
Rimon/Assail		90.5	0.7	0.3	1.0	7.0	1.4	0	0	0.2	0.1
Guthion/Asana		91.2	0.5	0.2	0.7	6.7	1.4	0	0	0.0	0.2
Guthion/Guthion		90.9	0.6	0.2	0.7	6.7	1.7	0	0	0.0	0.0
Probability for insecticide effect		0.93	0.89	0.23	0.98	0.97	0.65	-	-	0.21	0.63
Imidan at 3C		91.3	0.6	0.2	0.8	6.6	1.4	0	0	0.1	0.2
No Imidan at 3C		90.5	0.6	0.3	0.8	7.1	1.6	0	0	0.1	0.2
Probability for Imidan Effect		0.61	0.96	0.46	0.83	0.87	0.80	-	-	1.00	0.21

[a] Within each column and group, means followed by the same letter are not significantly different (P > 0.05); mean separations by LSD. Values shown are actual percentages but ANOVA-based on transformed values.

[b] The target populations were codling moth and lesser appleworm; Oriental fruit moth was absent.

[c] An undetermined pest, possibly apple curculio larvae, caused internal damage in some plots. At harvest, this damage was clearly different than internal Lepidoptera damage, but at the mid-summer non-destructive evaluation, it was recorded as internal Lepidoptera damage.

PART 2: Granulosis Virus for Codling Moth Management in Ohio Apple Orchards

Summary

A field trial on codling moth management was conducted to evaluate the effects of codling moth granulosis virus used alone and in combination with insecticide. Treatments evaluated were virus alone, insecticide alone, insecticide plus virus, and an untreated check. The virus product Cyd-X was applied 12 times at seven-day intervals, while the insecticide (Asana then Assail) was applied six times at 14-day intervals.

Control of codling moth was equally good from virus only, insecticide only, or a combination of insecticide and virus, and these three treatments were significantly better than the untreated check treatment (Table 2).

Table 2. Effect of Virus and Insecticide on Insect Injury to Liberty Apple Fruit at Harvest, Mean of Four Blocked Replicates, September 2006, at The Ohio State University's Waterman Lab, Columbus, Ohio.

	Percentage of Fruit[a]				Apple Cur-culio	Plum Cur-culio Oviposi-tion	Plum Cur-culio Late	San José Scale	Tar-nished Plant Bug	Leaf Roller
Treatment	Clean	Internal Lepidoptera								
		Entry	Sting	Total						
Insecticide only	91.9 A	1.7 B	1.7	3.5 B	0.5	2.0	0.0	0.5	1.5	0.0
Insecticide + virus	90.8 A	0.2 B	2.2	2.4 B	0.5	2.2	0.0	2.2	2.4	0.0
Virus only	80.2 B	2.0 B	5.1	7.1 B	0.7	3.5	2.5	5.2	2.0	0.2
Untreated	47.7 C	20.6 A	3.5	24.1 A	9.4	12.3	7.7	4.8	1.8	1.1
Probable value treatment effect	<0.0001	<0.0001	0.21	0.0008	0.09	0.11	0.21	0.11	0.38	0.28

[a] Within each column, means followed by same letter are not significantly different (P > 0.05); mean separations by LSD. Values shown are actual percentages but ANOVA-based on transformed values.

PART 3: Integrated Control of European Red Mite in Ohio Apple Orchards

Summary

A field trial was conducted in Red Delicious apple trees to evaluate the effects on pest mites and predatory mites of several insecticide programs used for control of the key fruit pest, codling moth. Each insecticide program was used with and without oil, and with and without miticide (Envidor), with three replicates of each treatment combination.

The insecticide programs used one product for control of first-generation codling moth and one product for control of second-generation codling moth. The programs were: (1) Rimon followed by Assail, (2) Guthion followed by Asana, (3) Guthion followed by Guthion, (4) no insecticide. Mite density was evaluated at two-week intervals.

The density of European red mite showed that there were strong interactions between mite treatments and insecticide treatments. Where insecticides were used without pre-bloom oil or post-bloom miticide, heavy infestations of European red mite resulted, but where a miticide was used, European red mite population was kept at tolerable levels (Table 3).

The miticide Envidor resulted in excellent control of European red mite, but its use was associated with significantly fewer predatory mites. When oil was used pre-bloom and no miticide was used post-bloom, mites were suppressed only until mid-May. Despite this short period of control, use of pre-bloom oil is advocated for its benefit in resistance management.

Among the three insecticide programs evaluated, the cumulative effect of European red mite was more severe where Guthion/Asana and Rimon/Assail were used than where Guthion/Guthion or no insecticides were used. On a mite-susceptible cultivar like Red Delicious, both oil and miticide are recommended with any insecticide program.

Outreach Activities

The results of these studies were presented to Ohio apple growers at the Ohio Fruit and Vegetable Growers Congress on January 17, 2007, and to Illinois apple growers at the Illinois Specialty Crop and Agri-tourism Conference on January 12, 2007.

Table 3. Main Treatment Effects on Number of European Red Mite MOTILES per Leaf (Mean of Three Blocked Replicates) on Delicious Apple Leaves on Eight Sampling Dates in 2006 at The Ohio State University's Waterman Lab, Columbus, Ohio.									
Treatment	**Number of Mites per Leaf[a] on Each of Eight Sampling Dates**								**Cumu-lative Mite Days**
Date	**5/3**	**5/ 16**	**5/30**	**6/14**	**6/26**	**7/10**	**7/31**	**8/14**	
With oil	0.34 B	0.28 B	2.53	2.08	7.8	7.63	3.66	1.34	381
No Oil	1.00 A	0.66 A	6.74	6.00	21.4	9.60	4.61	1.26	736
Probable value for oil effect	0.02	0.03	0.10	0.09	0.21	0.62	0.69	0.92	0.14
With Envidor	0.69	0.44	1.08	0.07 B	1.0 B	0.08 B	0.38 B	0.65	53 B
No Envidor	0.65	0.50	8.18	8.02 A	28.2 A	17.2 A	7.89 A	1.96	1064 A
Probable value for Envidor effect	0.90	0.72	0.01	0.001	0.02	0.0002	0.003	0.11	0.0002
Rimon/ Assail	0.52	0.59	4.96	5.00	13.1	15.04	8.64	1.33	750
Guthion/ Asana	0.80	0.57	8.89	7.46	31.3	9.30	5.12	0.74	915
Guthion/ Guthion	0.76	0.27	2.09	2.17	9.5	5.45	2.30	2.86	350
None/None	0.60	0.45	2.58	1.53	4.4	4.67	0.47	0.28	220
Probable value insecticide effect	0.88	0.50	0.22	0.24	0.32	0.26	0.10	0.13	0.14

[a] Within each column and group, means followed by same letter are not significantly different ($P > 0.05$); mean separations by LSD.

North Central Tree Fruit IPM Program

Principal Investigator:

Zachary Rinkes, Ohio State University Extension, Erie County

Scouts:

Ted Gastier, Ohio State University Extension Program Assistant

James Mutchler, Ohio State University Extension Program Assistant

Resource People:

Dr. Celeste Welty, Ohio State University Extension Entomology

Dr. Michael Ellis, Ohio State University Extension Pathology

Introduction and Methods

The North Central Tree Fruit Integrated Pest Management Program is designed to educate fruit growers on insect identification and proper pesticide use in northern Ohio. This program has now completed 16 successful years and is still providing recommendations to growers in regards to pesticide application timing and insect population levels. This program encompasses and embraces the aspects of being environmentally friendly, economically feasible, and socially aware.

Sixteen apple growers and six peach growers enrolled 23 apple blocks and seven peach blocks (one block is approximately 10 acres) in the 2006 North Central Tree Fruit Integrated Pest Management Program. Counties involved in the program were Erie, Huron, Lorain, Ottawa, Richland, and Sandusky. Inputs into the program included two program scouts, who incurred compensation for travel and wages, traps, equipment, and data collation technical assistance. Scouts monitored orchards from the beginning part of April through mid-September. They worked approximately 25 to 30 total hours per week combined. Growers were charged a fee to help support the program.

Apple pests monitored included red-banded leaf roller, oriental fruit moth, San Jose scale, apple maggot, spotted tentiform leaf miner, and codling moth. Red-banded leaf roller, oriental fruit moth, lesser Peachtree borer, and greater Peachtree borer were monitored in peach orchards. Pheromone traps were purchased and used to monitor most insect populations.

Apple maggot flies were monitored using a red ball trap with a fruit essence attractant.

Leaf-feeding pests such as green apple aphids, European red mite, white apple leafhopper, and two-spotted spider mite were visually observed by sampling several trees within orchards. Beneficial predators, including lacewings, multicolored Asian lady beetles, thrips, and orange maggot, were noted and reported to growers.

Traps were monitored weekly from April through September. Trap report summaries are available online at: **http://erie.osu.edu/north-central-fruit-integrated-pest-management-program.**

Trap reports were delivered weekly to Shawn Wright, who is stationed at the Ohio State University South Centers in Piketon. They were then included in his Ohio Fruit ICM (Integrated Crop Management) Newsletter that is distributed electronically.

Two meetings, one spring and one winter, were held with Ohio State University Extension specialists in order to review data and address grower concerns. Several growers exhibited concerns over codling moth damage in apples and oriental fruit moth populations in peaches.

Results and Discussion

Major weather events that impacted production in 2006 included a late frost, which raised much concern. However, damage was not as severe as initially anticipated, and damage varied by variety and location. A flooding event with severe winds occurred in late July, but caused minimal damage. Hot, dry temperatures followed the flooding event. Overall, 2006 was a very unpredictable yet successful year for most fruit growers.

Trap data were delivered to the Erie County Extension Agriculture and Natural Resources Educator by the end of each week and were subsequently collated. Codling moth in apples was of great concern as damage has been apparent and significant in several orchards in previous years. Trap counts and date of first capture were utilized to help growers manage this insect pest in 2006.

Several growers reported less damage this year, as much as 60 to 70 percent less, than in previous years. However, it still is considered a formidable and damaging pest that warrants further investigation in future years.

Oriental fruit moth is still of concern in the Western portion of the region, but better control has been achieved by early scouting by the program assistant.

On average, most growers reported saving two cover sprays by being involved in the program. Also, the knowledge gained by receiving weekly trap counts helped them adjust their spray materials and schedules based on the averages reported.

Most growers indicated a significant increase in yield this year as compared to last, although some varieties did not yield as well as hoped. Insect damage was minimal and much improvement was noted from the previous year in regards to several of the more troublesome pests.

Several growers commented on the many ways the scouts helped them with pest control from an economical as well as environmental viewpoint. During post-harvest reports, which were conducted with each grower, several positive comments about the program were mentioned. These included scouts helping improve orchard insect control and providing the information needed to adjust spray materials and schedules according to data found in the scouting reports.

The program was also reported to give growers the confidence that they have an appropriate pest management program that is protecting the quality of their apple and peach crop. New producers enrolled in the program this year noted that they learned the importance of scouting for insects and realized how this can help them increase yield and quality in their orchard. The program helped growers manage blocks appropriately with light crops and provided sound pest control techniques to growers in a reasonable time frame.

Organic Soybean Insect Pest Research

Principal Investigator:

Alan Sundermeier

Ohio State University Extension Educator, Wood County
Co-coordinator OSU Extension Sustainable Ag Team

Background

Organic grain producers in Ohio lack information and research on solutions to control of insect pests that reduce the yield and quality of soybeans. These producers depend on substantial income from organic soybeans in their long-term crop rotations. When that soybean income is reduced due to insect damage, an organic producer's financial viability may be at great risk. If organic approved soybean pest control measures can be utilized, organic production in Ohio will remain or expand.

Procedures

Alan Sundermeier and Dr. Ron Hammond, Ohio State University Extension Entomologist, coordinated research and scouting efforts. Organic Materials Review Institute (OMRI)-approved products for soybean insect control were secured for small plot spraying. A hand-held CO^2 pressurized Model GS sprayer was used with a 10-foot boom. Certified organic soybean fields were located to conduct on-farm research. A student intern was trained to scout for soybean insect pests throughout the season.

A total of four plots were scouted in Wood County, Ohio — Sunweb Farm near Luckey, Ohio; Ken Rider Farms near Deshler, Ohio; and two plots at the John Hirzel Sustainable Agriculture Research and Education site near Haskins, Ohio. These soybean fields were all certified organic production. Within these fields, small plots of 10 by 50 feet were flagged for each material that was applied by spraying. Applications were randomized and replicated three times within the plot, which included a control with no application.

OMRI materials used in this research were:

- NEEMIX 4.5 EC — A botanical agricultural insecticide and insect growth regulator. Active ingredient: 4.5% Azadirachtin.
- PYGANIC EC 1.4 — Flushes insects and mites from hiding and provides rapid knockdown and kill of plant pests. Active ingredient: 1.4% Pyrethrins.
- M-PEDE — A commercial grade contact insecticidal soap. Must be sprayed directly on pest to be effective. Active ingredient: 49% potassium salts of fatty acids.

- ENVIREPEL — A pest repellent derived from garlic. Active ingredient: 10% garlic.
- CINNACURE — A cinnamon-based broad-spectrum insecticide, miticide, and fungicide. Active ingredient: 30% cinnamaldehyde.
- HEXACIDE — A broad spectrum insecticide/miticide. Active ingredient: 5% rosemary oil.

Expenses

Student Scout — 480 hrs =	$3,840.00
Travel =	$1,500.00
Supplies =	$1,300.00
Total =	$6,640.00

Results

Weekly soybean pest scouting did not find soybean aphid to be present. This correlates to other soybean production fields in Ohio which did not have soybean aphid in 2006.

Continued scouting did indicate that threshold levels (10 to 15 percent of pods damaged) of second generation bean leaf beetle (BLB) adults were found. Significant yield loss as well as opening up of the pods to entrance for secondary pathogens can occur due to pod damage. Therefore, an organic control experiment was conducted to control damage to soybean pods caused by the bean leaf beetle.

Sweep net data collected prior to spraying had the following results:

Sunweb:	75 BLB per 10 sweeps
Rider:	30 BLB per 10 sweeps
Hirzel early spray:	40 BLB per 10 sweeps
Hirzel late spray:	63 BLB per 10 sweeps

Threshold for rescue treatment is warranted at 30 to 50 BLB per 10 sweeps.

Data collected at soybean leaf yellowing (two to three weeks after spray application) is listed here. Entire soybean plants were inspected by observing all pods on the plant and recording the percentage of pods that showed scaring, cutting, and discoloration due to BLB feeding damage.

Average pod damage of four plot sites:

Control (no spray) — 15.5 percent of total pods show Bean Leaf Beetle feeding injury.

Cinnacure	17.0 %
Envirepel	18.6 %
Hexacide	16.0 %
M-Pede	20.0 %
Pyganic	19.3 %
Neemix	16.0 %

Conclusion

No significant difference was found between the control (no spray) and any of the listed OMRI-approved organic soybean pest control products. Organic farmers need to be aware that pest control products need to be further tested for effectiveness on their specific farm situation.

The Ohio Ecological Food and Farming Association (OEFFA) organic organization will share this report with members. This project should be repeated for several years to determine if weather or other causes may affect product performance.

Percentage of Pods That Showed Scaring, Cutting, and Discoloration Due to BLB Feeding Damage.					
BLB	**Hirzel**	**Sprayed**	**18-Aug**	**Data on**	**9/14/2006**
	Control	**Cinnacure**	**Garlic**	**Hexicide**	**M-pede**
	0.14	0.19	0.33	0.20	0.18
	0.30	0.10	0.22	0.11	0.17
	0.20	0.14	0.12	0.16	0.16
	0.13	0.20	0.15	0.12	0.16
	0.09	0.15	0.08	0.20	0.08
Total	0.85	0.78	0.90	0.79	0.75
Average	0.17	0.16	0.18	0.16	0.15
Pod Damage	17%	16%	18%	16%	15%
BLB	Hirzel	Sprayed	1-Sept	Data on	9/14/2006
	Control	M-pede	Garlic	Pyganic	Neemix
	0.30	0.13	0.16	0.15	0.05
	0.16	0.35	0.20	0.23	0.10
	0.20	0.33	0.18	0.13	0.05
	0.14	0.27	0.20	0.13	0.15
	0.20	0.16	0.35	0.18	0.15
	0.08	1.25	1.09	0.82	0.30
	0.12	0.25	0.22	0.16	0.15
	0.16				0.30
	0.10				0.20
	0.00				0.25
	0.15				1.70
	0.15				0.17
Total	1.76				
Average	0.15				
Pod Damage	15%	25%	22%	16%	17%

Percentage of Pods That Showed Scaring, Cutting, and Discoloration Due to BLB Feeding Damage.					
BLB	**Sunweb**	**Sprayed**	**9/6/06**	**Data on**	**9/14/06**
Pod					
Damage	**Control**	**Cinnacure**	**Neemix**	**Pyganic**	
	0.08	0.14	0.20	0.25	
	0.16	0.22	0.17	0.15	
	0.13	0.14	0.15	0.20	
	0.20	0.16	0.12	0.30	
	0.07	0.23	0.13	0.24	
Total	0.63	0.89	0.76	1.14	
Average	0.13	0.18	0.15	0.23	
Pod Damage	13%	18%	15%	23%	

Percentage of Pods That Showed Scaring, Cutting, and Discoloration Due to BLB Feeding Damage.				
BLB	**Rider**	**Spray 9-6**	**Data on**	**9/26/06**
	Control	**Neemix**	**Garlic**	**Pyganic**
	0.20	0.27	0.19	0.24
	0.23	0.08	0.10	0.21
	0.17	0.21	0.24	0.15
	0.17	0.14	0.16	0.20
	0.13	0.21	0.17	0.15
	0.21	0.18	0.11	0.28
	0.06	0.16	0.14	0.14
	0.18	0.12	0.15	0.18
	0.09	0.13	0.13	0.11
	0.15	0.18	0.23	0.22
	0.15	0.12	0.17	0.19
	0.21	0.09	0.17	0.28
	0.24	0.10	0.19	0.16
	0.27	0.17	0.18	0.13
	0.17	0.21	0.14	0.20
Total	2.62	2.36	2.47	2.81
Average	0.17	0.16	0.16	0.19
Pod Damage	17%	16%	16%	19%

Perennials for Phenology Garden Network Sites

Denise Ellsworth, Ohio State University Extension

Inputs

Perennials for Phenology Garden Network sites:

Bluestone Perennials	$2,396
Klyn Nurseries	$1,832
Metal markers for gardens:	
Collier Metal Spec.	$1,168
Wages for pick-up and care of plants, care of phenology garden in Wooster:	
Wages for OARDC grounds crew (160 hours x $7.25)	$1,160
Wages for OARDC Entomology	$693
Wages for improvements to Phenology web site, addition of perennials to data collection web site:	
OARDC Computing and Statistical Services wages	$496
Salary for Dave Lohnes, OARDC Computing and Statistical Services	$1,250
Total:	$8,995

Outputs

In 2006, Phase II of the Ohio State University Phenology Garden Network began. Nearly 100 volunteers and staff members from across the state attended a day-long educational workshop in the spring of 2006. Perennials and metal label stakes were distributed at this time. Thirty-one of the 36 OSU Phenology Garden Network sites received 15 herbaceous perennial species, all of which are common in home gardens (many are past Perennial Plant of the Year selections). The majority of these perennial plants are native to North America. Three replicates of each species were added to each garden. Thanks to the IPM grant, the flagship phenology garden in Secrest Arboretum was also greatly enhanced with plantings, labels, and summer maintenance.

First- and full-bloom data will be recorded for each of these perennial plants beginning in 2007, in addition to the 17 woody species in each garden. Data will be submitted online throughout the season using the updated web site: **phenology.osu.edu.**

OSU Phenology Garden Network Perennials

- *Anemone* x *hybrida* 'Honorine Jobert,' Japanese Anemone
- *Asclepias tuberosa*, butterfly weed
- *Baptisia australis*, false indigo
- *Dianthus gratianopolitanus* 'Tiny Rubies'
- *Doronicum orientale* 'Magnificum,' Leopardbane
- *Echinacea purpurea* 'Magnus,' Purple coneflower

- *Geranium* 'Nimbus,' Perennial geranium
- *Helleborus* x *hybrida*, Lenten rose
- *Hemerocallis* 'Raspberry Pixie,' Daylily
- *Iris sibirica* 'Anniversary,' Siberian iris
- *Monarda didyma* 'Raspberry Wine,' Bee balm
- *Penstemon digitalis* 'Husker Red,' Beardtongue
- *Phlox paniculata* 'David,' Garden phlox
- *Salvia* x *sylvestris* 'May Night,' Hybrid sage
- *Sedum* 'Autumn Joy'

The addition of herbaceous perennial plants to the gardens will increase the project's usefulness to home gardeners, as these species are more common in residential landscapes than are many of the woody species. Data generated from this study will be used to incorporate herbaceous perennials into the Biological Calendar, which will greatly increase its relevance for hobbyists and professional horticulturists.

Furthermore, cooperators and interested observers can add indicator plants in their own landscapes, gardens, or nurseries; it will be much easier and cheaper to add perennials. Incorporating perennials will make tracking phenology a practical and inexpensive undertaking for in-home gardens, at community gardens, and in other public sites.

Although the flowering sequence of woody plants has proved to an excellent predictor of phenology of insects that have over-wintering stages exposed to ambient air *(e.g.,* gypsy moth eggs and scales), predicting emergence of insects that over winter in the soil *(e.g.,* white pine weevil and birch leafminer) has been more variable, perhaps because of effects of insulating snow cover or soil moisture. This project will test the hypothesis that the phenology of soilborne insects is more accurately predicted by herbaceous perennials, which also survive the winter below ground. These perennials could not have been added without the support of the IPM grant.

OSU Phenology Gardens with Perennials, 2006

1. Ashtabula: OARDC Ashtabula Research Station — Data Last Entered on 5/3/2006 at 11:34:11 a.m.
2. Athens: Ohio University.
3. Boone County Arboretum, Kentucky.
4. Clark: Gateway Learning Gardens, Clark County Extension — Data Last Entered on 4/14/2006 at 5:46:57 p.m.
5. Clark: Northridge Elementary and Middle School — Data Last Entered on 4/23/2006 at 8:36:23 p.m.
6. Clinton: Wilmington Middle School — Data Last Entered on 7/28/2005 at 9:41:15 a.m.
7. Coshocton: Lake Park, Coshocton Park District — Data Last Entered on 5/22/2006 at 6:45:34 p.m.
8. Defiance Regional Medical Center.
9. Erie: Osborn Park — Data Last Entered on 5/24/2006 at 10:20:46 p.m.
10. Erie: Willoway Nurseries, Huron Farm.
11. Fayette: Master Gardener Memorial Garden, Washington Cemetery — Data Last Entered on 5/21/2006 at 8:47:16 a.m.
12. Franklin: Chadwick Arboretum, Ohio State University Columbus Campus —

Data Last Entered on 5/18/2006 at 9:51:34 a.m.

13. Geauga: Berkshire Schools Board of Education Building — Data Last Entered on 5/24/2006 at 12:01:09 p.m.

14. Green: James Ranch Park — Data Last Entered on 5/22/2006 at 8:03:58 p.m.

15. Hancock: Hancock County Demonstration Gardens — Data Last Entered on 5/11/2006 at 8:21:33 p.m.

16. Huron: Shady Lane Park — Data Last Entered on 5/11/2006 at 10:33:56 p.m.

17. Lake: Willoway Nurseries, Long Road Farm.

18. Licking: Licking County Office, Ohio State University Extension — Data Last Entered on 5/12/2006 at 9:15:39 a.m.

19. Lucas: Ohio State University Extension at Toledo Botanical Garden — Data Last Entered on 5/24/2006 at 3:00:53 p.m.

20. Mahoning: Millcreek Metropark — Data Last Entered on 4/25/2005 at 3:09:49 p.m.

21. Pickaway: Monroe Township Community Park, Five Points Pike — Data Last Entered on 5/22/2006 at 11:00:28 p.m.

22. Pike: Ohio State University South Centers — Data Last Entered on 5/22/2006 at 4:28:32 p.m.

23. Portage: Ohio State University Extension, Portage County — Data Last Entered on 5/21/2006 at 7:29:37 a.m.

24. Richland: Ohio State University Extension Richland County — Data Last Entered on 5/20/2006 at 7:19:30 p.m.

25. Ross: Canal Gardens, Camp Sherman — Data Last Entered on 5/12/2006 at 11:31:02 p.m.

26. Stark: Canton Country Day School — Data Last Entered on 5/23/2006 at 8:58:33 p.m.

27. Stark: Ohio State University Extension, Stark County — Data Last Entered on 5/18/2006 at 8:42:45 p.m.

28. Summit: Adell Durbin Arboretum, City of Stow — Data Last Entered on 5/22/2006 at 9:17:11 p.m.

29. Summit: F. A. Seiberling Nature Realm — Data Last Entered on 5/19/2006 at 6:46:57 p.m.

30. Trumbull: Agricultural and Family Center — Data Last Entered on 4/19/2006 at 11:39:13 a.m.

31. Wayne: Secrest Arboretum, OARDC, Wooster Campus — Data Last Entered on 5/17/2006 at 8:18:48 a.m.

For More Information

Visit the Ohio State University Phenology Garden Network web site at **http://phenology.osu.edu/** for Ohio's garden locations, a complete list of plants being studied, and phenology data.

Study the Bioecology of Native Pollinators and their Associated Habitat in Relationship to Commercial Fruit and Vegetable Production

Principle Investigators:

Roger N. Williams, Roger A. Downer, and Dan S. Fickle

Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, Ohio

Introduction

Pollinators play a critical roll in the production and development of fruits and vegetables. In recent years, there has been a decline in cultured and feral honey bee populations, giving rise to interest in alternative pollinators, many of which are native bees. Unfortunately, there is limited data on the types and species of native pollinators and the roll they play in the successful pollination of horticultural crops.

This study was undertaken to try to expand our understanding of the role non-mellifera species play in the successful pollination of fruit and vegetable crops in Ohio. The main objective of this study was to collect voucher specimens of native pollinators that could be used for identification to genus/species and to document their associated host and frequency of pollination visits to available host crops.

The study was conducted at two sites. The first site was a commercial fruit and vegetable farm located near Moreland, Ohio. It borders a natural wildlife preserve, making it an ideal area to study feral bees. Crops grown on this farm included strawberry, raspberries, blackberries, blueberries, apples, cherries, plums, pears, peaches, pumpkins, squash, pickles, tomatoes, sweet corn, and others.

The second site was located on Snyder Farm of The Ohio State University's Ohio Agricultural Research and Development Center (OARDC) research facility at Wooster, Ohio. This site was a smaller operation than Moreland but offered a direct comparison of sites for blueberry, raspberry, and strawberry pollinators. The Snyder Farm site had some wooded areas surrounding the farm similar to a traditional Ohio agricultural setting, whereas Moreland fruit farm borders the Killbuck Wetlands Wildlife Area which consists of 5,500 acres encompassing the Killbuck River Valley in Wayne and Holmes Counties. This reserve consists of a wide range of ecological settings.

Methods

Observations of the pollinators visiting blueberries, strawberries, raspberries, blackberries, pickles, water or musk melons, multi-floral rose, American holly, morning glory, hawkweed, and goldenrod were made from May to September at Moreland Fruit Farm (site 1), Moreland, Ohio, and Snyder Farm (site 2), Wooster, Ohio.

A great deal of our collecting and observation efforts was concentrated on blueberries, strawberries, and raspberries since both sites had these crops in common. Observations of the number and type of pollinators visiting flowers over a 10-minute period were made to determine the type and percentage of different pollinators frequenting the flowers. These observations were conducted at varying times of day from mid-morning to late afternoon. Bee pollinators were noted as *Apis mellifera* (honey bees), *Bombus* (bumble bees), or other (native bees). A representative sample of voucher specimens was determined by Dr. Sam Droege of the U.S. Geological Survey, Beltsville, Maryland.

From the total observations made for each crop or flower type, percentages were calculated to give a relative idea of how much pollination was being contributed by each of the three groups of Hymenoptera — honey bees, bumble bees, or other native bees. It should be noted that cultured honey bee hives were present at both study sites.

Results

Small Fruit Crops

Figure 1 represents the percentage of pollinators frequenting blueberry blossoms at Site 1 and Site 2. Bumble bees were found to be of major importance in blueberry pollination, with more than half the observed visitations made by bumble bees — 51.6 percent at Site 1 and 81.9 percent at Site 2. Honey bee visits were similar at both locations — Site 1, 11.3 percent and Site 2, 10.2 percent. On the other hand, there was quite a difference in the number of visits by other native bees — Moreland, 37.1 percent and Snyder, 7.9 percent. This increase in the number of visits by native bees at Site 1 when compared to Site 2 also held true for strawberries and raspberries (Figure 2 and Figure 3).

For Site 1, strawberries, 79 percent of the visits were by native bees, 20.2 percent honey bees, and 0.8 percent bumble bees, whereas at Site 2 the majority of the flower visits were by honey bees, 76.2 percent; followed by native bees, 22.2 percent; and bumble bees, 1.6 percent. In raspberries, Site 1 pollinator visits were 56.7 percent native bees, 38.6 percent honey bees, and 4.7 percent bumble bees as compared to Site 2 having 7.8 percent native bees, 84.3 percent honey bees, and 7.8 percent bumble bees.

These results demonstrate the importance of non-mellifera pollinators in the production of small fruits. They also show a significant increase in the percentage of flower visits by native bees at Site 1 compared to Site 2. At the onset of this study, we hypothesized that we might see a difference in the native bee population between sites due to the close proximity of Site 1 to the Killbuck Wildlife Area and its greater habitat diversity. The major differences we recorded in native bee visitations when comparing Site 1 with Site 2 seems to support this hypothesis.

Bumble bees were found to be the major contributor to blueberry pollination at both sites but were only marginal pollinators of strawberries and raspberries (Figures 1, 2, and 3).

Bee visitation to flowering blackberries was observed at Site 1 only since they are not currently being cultivated at Site 2. Blackberries are a bramble crop similar to raspberries, but bloom occurs later in the season than early season raspberries. Honey bees were found to be the major pollinator

Continued

Flower Visitation by Pollinators in Blueberries

Moreland, OH 2006

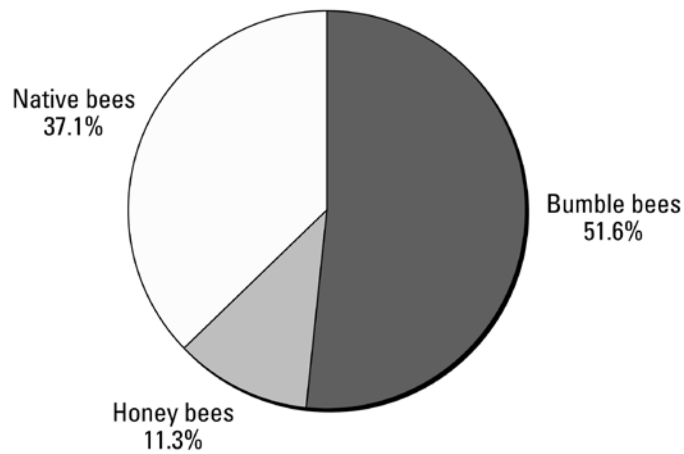


Figure 1. Percent of pollinators visiting blueberry blossoms at the Moreland Fruit Farm, Moreland, Ohio.

Flower Visitation by Pollinators in Blueberries

Snyder Farm, Wooster, OH 2006

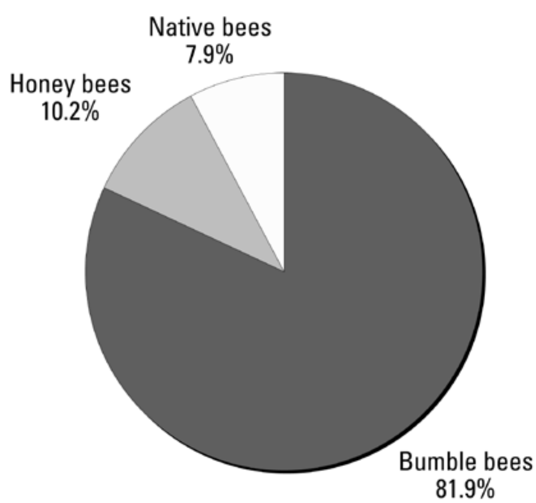
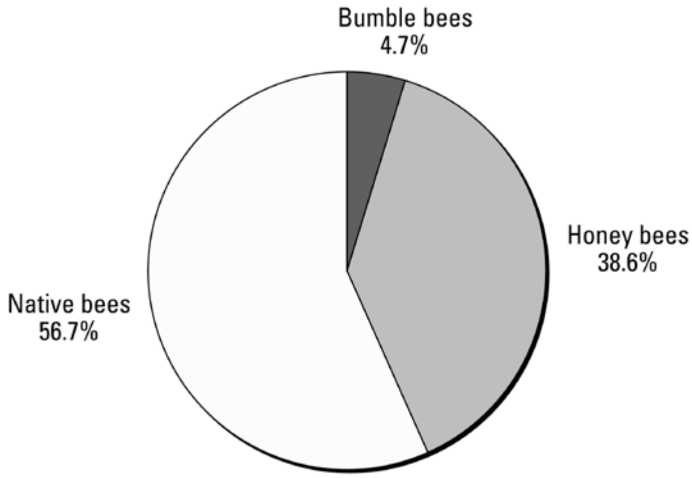


Figure 2. Percent of pollinators visiting blueberry blossoms at the Synder Farm of The Ohio State University's Ohio Agricultural Research and Development Center (OARDC), Wooster, Ohio.

Flower Visitation by Pollinators in Raspberries

Moreland, OH 2006



Flower Visitation by Pollinators in Raspberries

Snyder Farm, Wooster, OH 2006

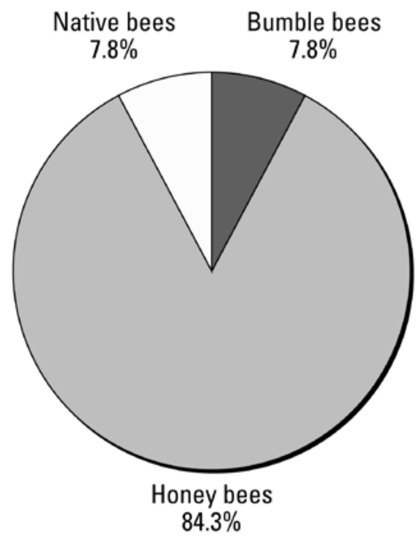


Figure 3. Percent of pollinators visiting raspberry flowers at the Moreland Fruit Farm, Moreland, Ohio, and the Snyder Farm at OSU/OARDC, Wooster, Ohio.

of blackberries with a 68.3 percent visitation rate followed by native bees with 30.1 percent and bumble bees with 1.6 percent (Figure 4).

Cultivated Vine Crops

Site 1 produced the following observations. Flower visitation in pumpkins was 57.1 percent honey bees, 42.9 percent native bees (Figure 5). Pickle flower visits were 96 percent honey bees and 4 percent native bees (Figure 6) and in melons, 100 percent honey bees (Figure 7). The number of observations for pickles and melons were minimal and late in the season, which may account for the lack of other pollinators.

Continued

Flower Visitation by Pollinators in Blackberries

Moreland, OH 2006

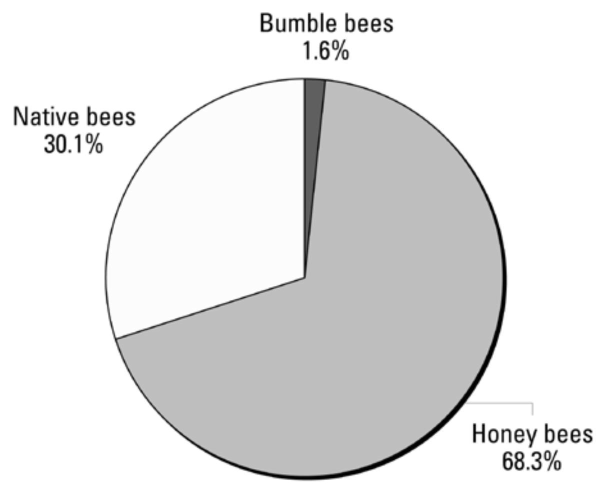


Figure 4. Percent of pollinators visiting blackberry blossoms at the Moreland Fruit Farm, Moreland, Ohio.

Flower Visitation by Pollinators in Pumpkins

Moreland, OH 2006

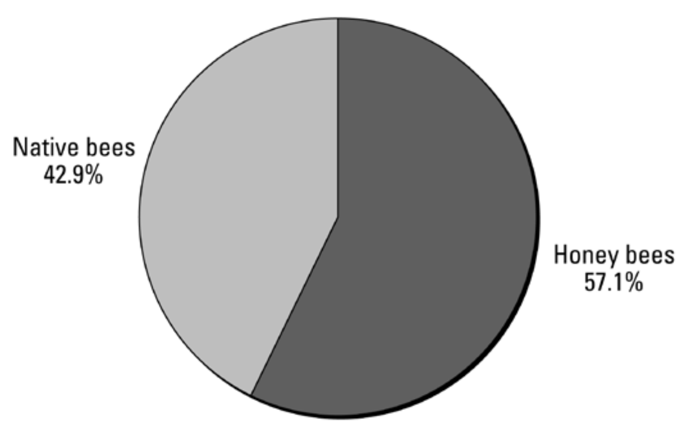


Figure 5. Percent of pollinators visiting pumpkin flowers at the Moreland Fruit Farm, Moreland, Ohio.

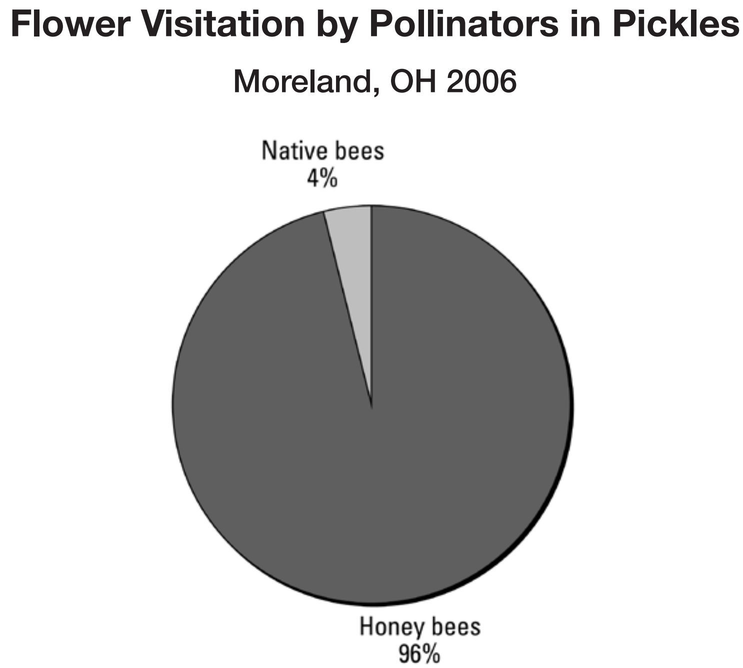


Figure 6. Percent of pollinators visiting pickle flowers at the Moreland Fruit Farm, Moreland, Ohio.

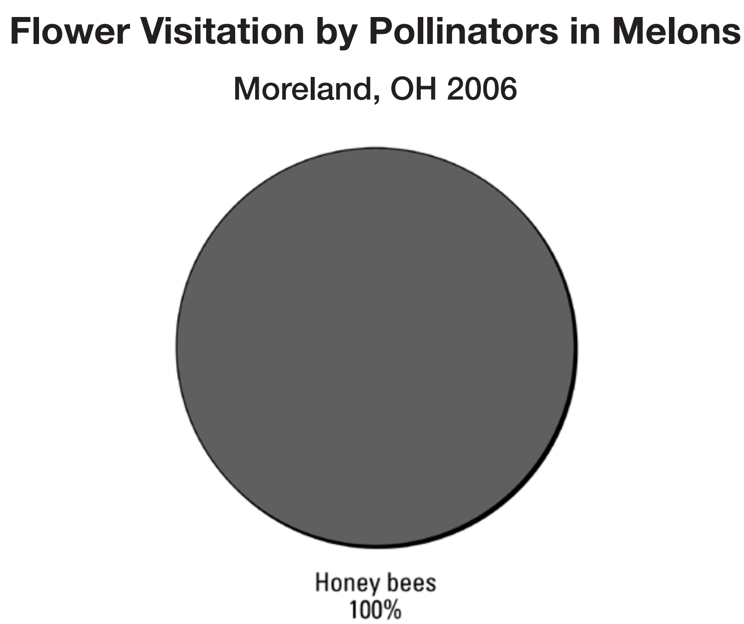


Figure 7. Percent of pollinators visiting melon flowers at the Moreland Fruit Farm, Moreland, Ohio.

In addition to cultivated crops, some observations and collections were made from other flowering plants that were growing in the vicinity of the cultivated crops being studied. Multifloral rose: 76.5 percent native bees and 23.5 percent honey bees (Figure 9). Morning glory: 37.5 percent non-mellifera bees, 37.5 percent bumble bees, and 25 percent honey bees (Figure 10). Goldenrod: 80 percent honey bees, 20 percent native bees (Figure 11). Hawkweed: 100 percent non-mellifera bees (Figure 12).

A couple of additional observations were made at OARDC's Secrest Arboretum at Wooster. One of the curators informed us that the American holly was in full bloom and attracting bees by the thousands. We found that 91.5 percent of the bees visiting the holly blossoms were non-mellifera bees, and 8.5 percent of them were honey bees (Figure 8). No bumble bees were observed going to the holly; however, a variety of mint was blooming within approximately 12 ft. of the holly, and bumble bees were the only pollinators visiting its blue flowers. This proved to be a good example of how different plant varieties attract specific pollinators.

Bee Identification

Voucher specimens were collected throughout the course of this study. From these specimens, representatives were sent to Sam Droege for taxonomic identification. He was able to do a quick turnaround on these specimens, so that we would have some preliminary information to add to this report. He also agreed to look at additional specimens in the near future. From this representative sampling, he was able to identify three families, 12 genera, and 19 species of bees (Table 1). There is no doubt that other species will be added to this list when additional specimens are scrutinized.

Discussion

This study was initiated to learn more about the role non-mellifera bees play in the pollination of crops and to draw attention to the importance of native pollinators in regards to sustainable agriculture practices. The data obtained from this study helps to demonstrate the role non-mellifera species play in the pollination of important agricultural crops and emphasizes the importance of understanding how pollination relates to food production and propagation of plant species. For example, in strawberries and blueberries, the majority of the pollination was attributed to non-mellifera species.

This study also demonstrates the need for growers to examine their pest management practices and assess how they might be affecting non-target organisms like native bees. Many of the pesticides currently being utilized in IPM programs warn against using their products when honey bees are actively foraging. However, many of our native pollinators are foraging when the weather is inclement for honey bees to venture from their hives.

Other agricultural practices such as the clearing of wood lots and fence rows has had a direct affect on localized native bee populations. Many of our native bee species are solitary bees. These species require large areas of land and proper nesting materials in order to produce adequate numbers of offspring. Growers, gardeners, landowners, and developers need to be aware of the importance of habitat preservation when it comes to the survival of our native pollinator species. They are an important part of the food pyramid, and many plant and animal species are reliant on their contributions.

Continued

Flower Visitation by Pollinators in American Holly

Moreland, OH 2006

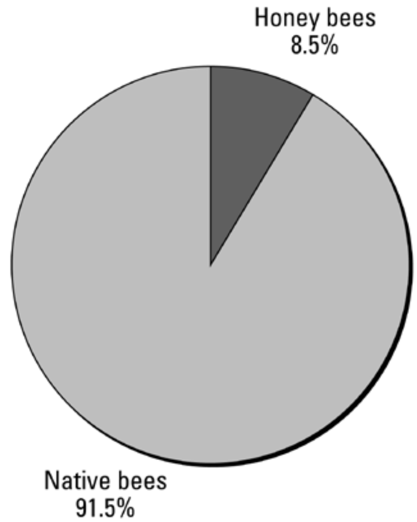


Figure 8. Percent of pollinators visiting holly flowers at Secrest Arboretum, OSU/OARDC, Wooster, Ohio.

Flower Visitation by Pollinators in Multifloral Rose

Snyder Farm, Wooster, OH 2006

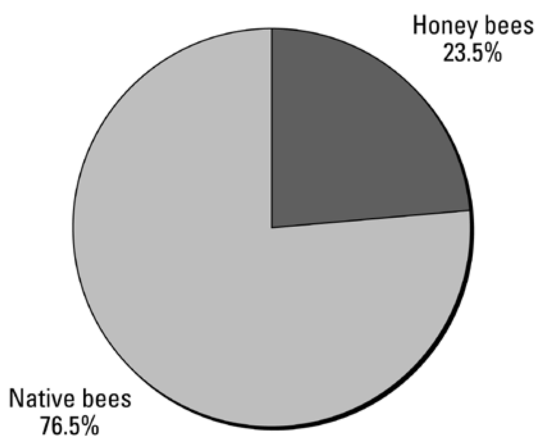


Figure 9. Percent of pollinators visiting multiflora rose flowers at the Snyder Farm, OSU/OARDC, Wooster Ohio.

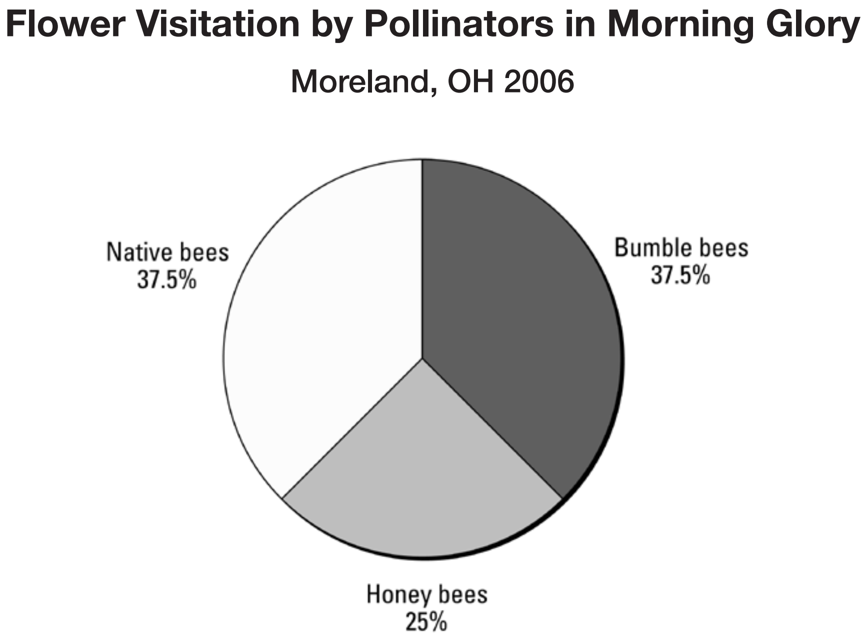


Figure 10. Percent of pollinators visiting morning glory flowers at the Moreland Fruit Farm, Moreland, Ohio.

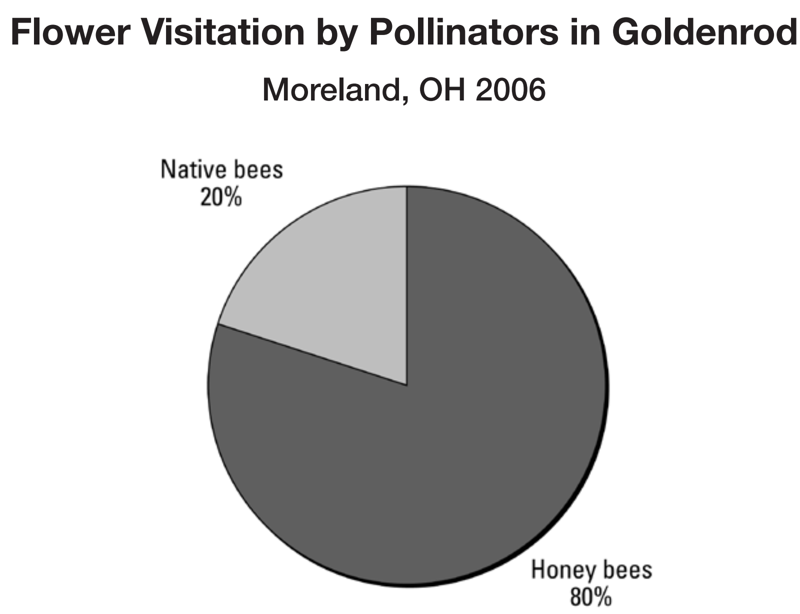


Figure 11. Percent of pollinators visiting goldenrod flowers at the Moreland Fruit Farm, Moreland, Ohio.

Flower Visitation by Pollinators in Yellow and Orange Hawkweed

Moreland, OH 2006

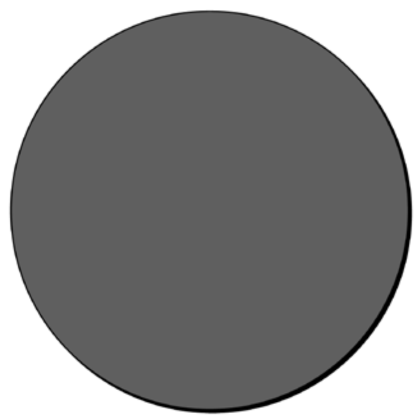


Figure 12. Percent of pollinators visiting yellow and orange hawkweed at Kingsville, Moreland, and Wooster, Ohio.

This study has helped to demonstrate how important native pollinators are in the production of fruits and vegetables, but it is only a beginning. Additional studies are needed to learn more about habitat management in relation to species survival and agricultural production. We also need to learn more about the effects new pesticide chemistry and pest management practices many be having on non-mellifera bee species.

Special thanks to Sam Doege of the U.S. Geological Society, Beltsville, Maryland, for his expertise in bee identification. Also to the Ohio Integrated Pest Management Program for funding this research project.

Table 1. Hymenopterous Pollinators Identified from Fruits and Vegetables, Wooster and Moreland, Ohio, 2006.		
Family	**Genus**	**Species**
Andrenidae	*Adrena*	*vicina*
	Adrena	*nuda*
	Adrena	*imitatrix*
	Adrena	*asonii*
	Adrena	*crataegi*
	Pseudopanurgus	*andrenoides*
	Pseudopanurgus	sp.
Apidae	*Apis*	*mellifera*
	Bombus	*impatiens*
	Bombus	*bimaculatus*
	Ceratina	*calcarata*
	Xylocopa	*virginica*
	Melissodes	sp.
Halictidae	*Agapostemon*	*sericeus*
	Augochlora	*pura*
	Augochlorella	*aurata*
	Halictus	*rubicundus*
	Lasioglossum	*pilosum*
	Lasioglossum	*lineatulum*

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