Entomology

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Effects of plant age and cultivar on western flower thrips damage threshold for *Impatiens wallerana*

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Index Words: bedding plant, pest susceptibility, vegetative growth, reproductive growth, economic threshold

Significance to Industry: Western flower thrips is one of the most challenging insect pests for bedding plant production. Impatiens 'Dazzler Violet' and 'Super Elfin Red' are relatively susceptible and resistant to thrips feeding damage, respectively. Plants at 3, 6, or 9 weeks into production were inoculated with 0, 25, 50, or 75 female adult thrips and evaluated for thrips damage for four weeks. Number of leaves showing damage and visual damage ratings increased with increasing numbers of thrips inoculated. Plant age at the time of thrips infestation significantly affected the severity of damage and the ability of plants to recover from the damage. These results suggest that thrips infestation levels and plant age are important factors to consider when developing action thresholds.

Nature of Work: Western flower thrips (*Frankliniella occidentalis*) has become a significant pest problem in bedding plant production. Alternative strategies are needed to manage this pest because of the limited number of effective insecticides currently available (1, 2). Impatiens cultivars that are relatively resistant to thrips have been reported (3). It has also been reported that level of thrips damage to impatiens is affected by the growing stages. Plants with flowers sustain much less visual damage to the foliage than plants at vegetative stage (4). However, information on interactions between cultivar, plant age, and thrips infestation level is lacking. Therefore, the objective of this study was to assess thrips damage on susceptible and resistant cultivars at three growing stages to help develop action thresholds.
'Dazzler Violet' and 'Super Elfin Red' were chosen for this study because the former is more susceptible to thrips damage and both cultivars are popularly grown by the industry (3).

Seeds were sown and transplanted at different dates to obtain plants of different ages (3-, 6-, and 9-week old) and for four replications overtime. A total of 24 plants were used for each treatment replication (2 cultivars x 3 ages x 4 subsamples). Single-plant cages were constructed using 5-gal plastic buckets purchased from The HomeDepot. Four windows, each 6 x 12 inches were cut on the sidewall of a bucket and covered with no-thrips screen (GreenTek, Janesville, WI). The top of bucket was covered by a muslin cloth and held in place by rubber bands. Plants were placed inside the buckets and watered by drip irrigation via a tube snuggly fit through a hole drilled on the sidewall. Plants were inoculated with 0, 25, 50, or 75 on 4 different inoculation dates as four treatment replications. Female adult thrips were selected from a colony reared on green beans under laboratory conditions at the research station and placed into a 2-ml petit tube with cap closure. Tubes were then taken to the greenhouse, opened, and placed on the plant inside each bucket. Thrips were allowed to feed and develop for 7 days and were removed by an insecticide spray. Plants were taken out of cages and grown on benches for evaluation during a 4-week period. Thrips damage was assessed by counting the number of damaged leaves and a visual damage rating using a scale from 1 to 10, where 0 = no damage, 1 to 3 = minor damage, 4 to 6 = moderate damage, 7 to 9 = severe damage, and 10 = complete dead. At week 4 of the evaluation, plants were cut and placed into an oven for dry weight measurements. These treatments were replicated 4 times over time.

Results and discussions: Significant interactions were found between cultivar and plant age for all variables, therefore, data are presented by cultivar. ‘Dazzler Violet’, the cultivar more susceptible to thrips feeding damage had more damaged leaves and fewer flowers than ‘Super Elfin Red’ (Fig. 1, flower data not shown). However, damage ratings of the two cultivars were similar throughout the evaluation (Fig. 2). This suggests that visual damage ratings may be less effective than counting damaged leaves in detecting differences among cultivars. Both number of damaged leaves and visual damage ratings increased with increased thrips densities (Fig. 1 and 2). Overall, damage ratings decreased from week 1 to week 3 because of new growth and new leaves that replaced damaged leaves (Fig. 2). This recovery (decrease in damage ratings) was negatively correlated with thrips inoculation density ($r = 0.49$, $p = 0.0352$) and plants inoculated with 25 thrips generally recovered more quickly than those inoculated with 75 thrips.

Plant age at the time of thrips infestation significantly affected both number of damaged leaves and damage ratings (Fig. 1 and 2). Younger plants (3-week old at inoculation) had fewer damaged leaves than older plants. This is most likely due to the fact that smaller plants have fewer leaves (Fig. 1). Three-week old ‘Super Elfin Red’ had higher damage ratings than six- and 9-week old plants when infested with 75 thrips and rated at 2 or 3 weeks after thrips removal, and three-week old ‘Dazzler Violet’ had higher damage rating than six- or nine-week old when infested with 75 thrips at 3 weeks after thrips removal (Fig. 2). Infestation with 75 thrips per plant reduced dry weight for plants that were three- or six-week old at inoculation 4 weeks after thrips removal compared to plants infested with 25 or 50 thrips (Data not shown). Dry weight of plants that were 9-week old at the inoculation was not affected.

These results suggest that thrips infestation levels and plant age are important factors to consider when developing action thresholds. The number of damaged leaves, as has been used in developing action threshold for bedding plants, may not be an accurate action threshold indicator for young plants. Instead, percentage of damaged leaves may serve as a better indicator.

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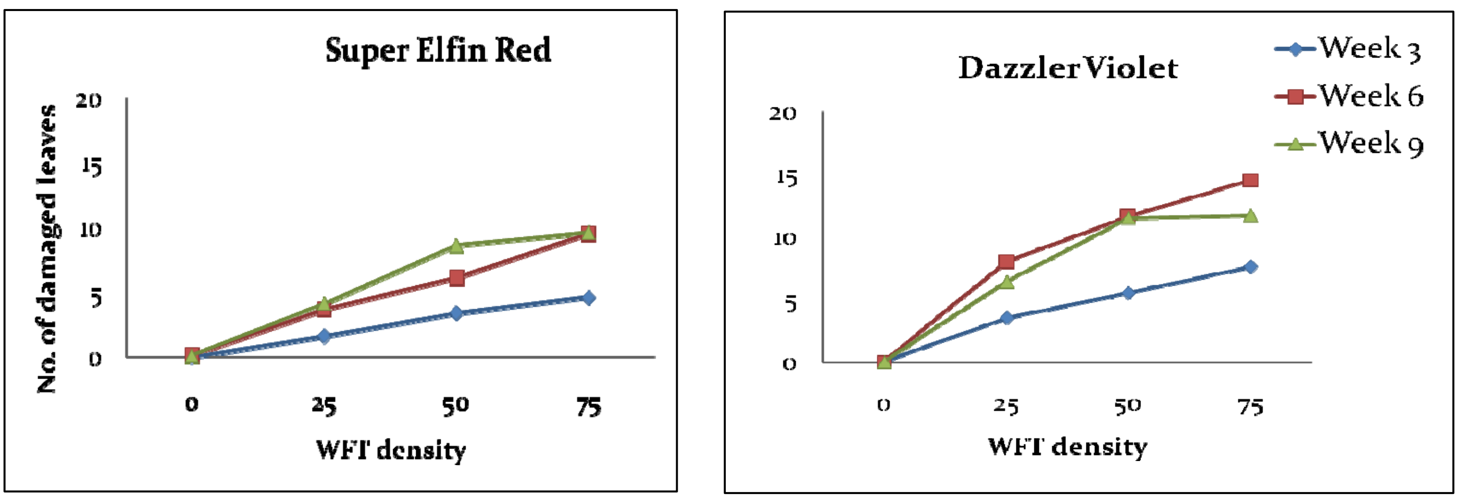

Figure 1. Number of damaged leaves on ‘Dazzler Violet’ and ‘Super Elfin Red’ impatiens 3 weeks after thrips were removed by insecticide spray. Plants were 3-, 6-, or 9-week old at the time of thrips inoculation, and 7, 10, and 12 weeks old at the time of this evaluation

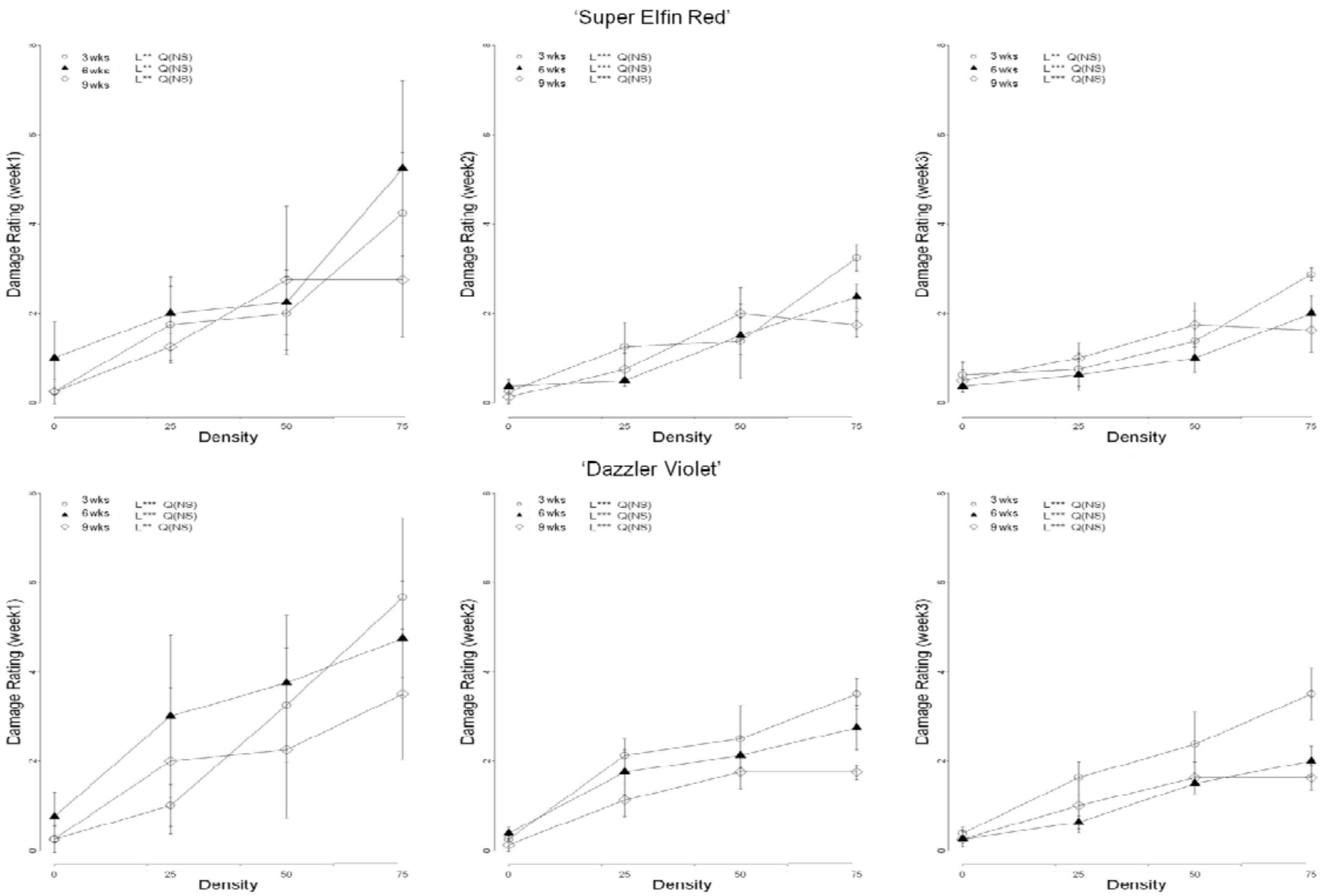

Figure 2. Visual damage ratings of 'Super Elfin Red' and 'Dazzler Violet' impatiens at weeks 1, 2 and 3 after thrips had been removed from plants. Plants were inoculated with 0, 25, 50, and 75 western flower thrips prior to evaluation and thrips were allowed to feed for 7 days.

Fall and spring insecticide drenches to manage azalea lacebugs

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Index words: *Stephanitis pyrioides*, Acelepryn, Merit, DPX-HGW86, azalea

Significance to Industry: We investigated the efficacy of fall versus spring drenches of Merit (imidacloprid), Acelepryn (chlorantraniliprole), and DPX-HGW86 (Cyantraniliprole)against azalea lacebug in ornamental landscapes. This is significant to the nursery industry because imidacloprid provided good control when applied in the fall. Fall insecticide applications would reduce the amount of work in the busy spring season. In addition, if applications are made in the fall there is no chance that growers will miss the onset of lacebug activity and incur damage that will be sustained for years on evergreen azaleas. Fall applications of imidacloprid and other systemic insecticides could provide good protection of other in-ground and container grown crops.

Nature of Work: Azalea lacebug, *Stephanitis pyrioides*, is an important pest of azaleas in production nurseries and ornamental landscapes. Azalea lacebugs damage plants by piercing leaf tissue and sucking out leaf contents. This results in stippling damage that reduces the aesthetic and monetary value of plants. A number of insecticides are available to reduce azalea lacebug abundance and damage. Chemical applications are generally timed to lacebug activity in the spring. However, if applications are made after lacebugs become active plants will incur injury. Since evergreen azaleas retain their leaves, damage also persists for many years. Therefore, we investigated the use of fall drench applications of imidacloprid, Acelepryn, and DPX-HGW86 to prevent lacebug damage in spring.

This experiment was conducted using azaleas planted in ornamental landscapes on the campus of North Carolina State University in Raleigh, NC. Plants were assigned to treatments within a randomized complete block design with 5 replicates of 17 treatments. All plants were 2 feet high. Applications were made on 14 October 2009 or 5 March 2010 using a soil basal drench. A shallow trench was made around each Azalea prior to treatment to ensure the solution stayed near the root flare.

Data was collected 26 May 2010 by beating 2 samples of foliage from each plant 10 times each into an 8 x 12 inch white plastic tray. The number of lace bugs in the tray was counted. Since this was conducted at the end of the first generation of lace bugs all insects sampled were adults. In addition, ten leaves from the current years' growth were randomly selected from each plant and returned to the laboratory. The percent of the leaf surface with lace bug damage was estimated visually. This is an estimate of the accumulated feeding by lace bugs since they emerged in spring and a measure of aesthetic damage. Under a dissecting scope the number of fecal spots on each leaf was counted. This is also a measure of accumulated lace bug activity on leaves and fecal spots compromise plant aesthetics. The mean value of the ten leaves per plant was the data point for each plant.

Data were log(x+1) transformed prior to analysis to meet assumptions of ANOVA. In addition, block 5 was removed from analysis because only one insect was captured on these plants and so they provided no data.

Results and Discussion: There was no significant difference in number of lacebugs per plant (Table 1). Merit was the only product applied in fall that significantly reduced feeding damage compared to the untreated check (Table 1). Spring applications of Merit or DPX-HGW86 reduced lacebug feeding damage in spring. Using fecal spots as another measure of lacebug activity, spring applications of Merit or the experimental reduced the number of fecal spots that accumulate on leaves. Plants treated with Acelepryn tended to have more damage and fecal spots than other treatments (Table 1). Although some treatments were effective, statistical power is limited by the number of treatments and replicates so further work may be needed to refine recommendations.

An interesting result of this study is that lacebug abundance was quite variable between treatments but feeding damage and fecal spots differed between treatments. This suggests movement of lacebugs between plants. Lacebugs move from plants in response to competition or predators (1). However, it appears if they land on plants treated with Merit they feed very little and do not remain long enough to deposit much fecal material. Merit applied in the fall or spring generally reduced lacebug activity on landscape azalea plants.

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Table 1. The number of lacebugs, fecal spots, and percent feeding damage on azaleas after fall and spring drench applications of systemic insecticides. Treatments with different letters within a column are significantly (*P*<0.05) different.

No.	Treatment	Rate	Rate Unit	# Lacebugs	# Fecal Spots	% Damage
Fall Applications						
1	Acelepryn	0.0625	fl oz/ plant ft.	1.9 a	5.8 a-d	10.25 a-d
2	Acelepryn	0.125	fl oz/ plant ft.	7.3 a	3.0 a-d	6.25 bcd
3	Acelepryn	0.25	fl oz/ plant	4.0 a	4.8 a-d	10.63 a-d
4	DPX-HGW86	0.0625	fl oz/plant ft.	2.0 a	3.5 a-d	6.00 bcd
5	DPX-HGW86	0.125	fl oz/ plant ft.	2.5 a	4.0 a-d	14.00 a-d
6	DPX-HGW86	0.25	fl oz/ plant ft.	2.0 a	6.8 a-d	13.38 a-d
7	Merit	0.0345	oz / plant ft.	4.3 a	2.3 a-d	3.50 cd
8	Merit	0.069	oz / plant ft.	0.8 a	0.0 d	0.13 d
Spring Applications						
9	Acelepryn	0.0625	fl oz/ plant ft.	7.8 a	24.5 a	32.50 ab
10	Acelrpryn	0.125	fl oz/ plant ft.	2.0 a	21.0 ab	36.38 a
11	Acelepryn	0.25	fl oz/ plant ft.	3.0 a	18.8 abc	22.75 abc
12	DPX-HGW86	0.0625	fl oz/ plant ft.	0.0 a	0.5 cd	1.53 cd
13	DPX-HGW86	0.125	fl oz/ plant ft.	0.0 a	0.0 d	3.50 cd
14	DPX-HGW86	0.25	fl oz/ plant ft.	1.0 a	1.3 bcd	3.00 cd
15	Merit	0.0345	oz / plant ft.	0.8 a	0.0 d	0.13 d
16	Merit	0.069	oz / plant ft.	6.0 a	4.5 a-d	10.75 cd
17	Untreated Check			4.5 a	7.3 a-d	19.13 abc
Treatment F				1.294	1.870	2.680
Treatment Prob(F)				0.2405	0.0484	0.0043

Gleanings from a Five State Pest Management Strategic Plan and Crop Profile

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Significance to the Industry Pest problems can cause substantial lost revenue (dead and unhealthy/unmarketable plants) and increased inputs (labor, fuel, and pesticide) for ornamental plant producers. A focus group composed of industry and academic members identified and prioritized Extension, research, and regulatory issues for the nursery crop industry. This information will help growers, land grant professionals and administrators, and government officials focus resources on the most relevant pests. Additionally, this information will allow regional comparisons of serious nursery crop pests and will allow for temporal comparisons of pertinent nursery crop pests.

Nature of Work Growers face many challenges to growing a healthy, profitable nursery crop. Pests can cause substantial losses to the nursery industry. For example, In North Carolina, the green industry reported annual losses of $91,000,000 due to insects and diseases (2). A regional group of Extension professionals formed in October 2008 to address nursery crop production needs through integrated pest management (IPM) programming. The group, the Southern Nursery IPM Working Group (SNIPM), represented five states: Georgia, Kentucky, North Carolina, South Carolina, and Tennessee. The initial goal of the working group was to acquire funding to develop a five state nursery crop pest management strategic plan (PMSP) and crop profile (CP) and to subsequently create these two documents that could be used to define research and Extension objectives.

So that the PMSP and CP would accurately reflect current needs of the nursery crop industry, growers (two per state) were invited to form a focus group with the Extension professionals. Growers were selected to broadly represent the respective state's nursery industry. In advance of the meeting, growers identified their top insect, weed and disease problems.

A two-day facilitated sharing session and needs assessment took place with the focus group on July 30-31, 2009 in Mills River, NC. At the meeting, Extension professionals provided overviews of the production characteristics and metrics for each respective state. Growers provided an overview of their nursery followed by common pest problems and challenges to managing those problems. Growers again prioritized pests within each pest category (insect, disease, weed) as follows:

Insect pests - For insect pests, growers ranked the previously identified pests using a ballot system. Specifically, each focus group member was issued 10 votes and was permitted to use them at his or her discretion to vote for insect pests based on difficulty to control and prevalence. All votes could be used on one pest or divided among several insect pests. Not all votes had to be cast.

Disease pests - In order to rank diseases, the facilitator guided the focus group in a consensus-building process to rank the pests, greatest to least.

Weed pests - To rank weeds, the facilitator guided the focus group in a process to review and modify, as needed, the pre-meeting weed rankings to reflect the current group consensus.

Growers also identified specific emerging pests as well as issues influencing insect, disease, and weed control such as contaminated irrigation water, and non pest issues, (e.g. water availability, water rights, etc). Finally, growers were asked to identify Extension, research, and regulatory priorities for each pest category and overall priorities through facilitation and a consensus-building process. These data were assimilated into a five state pest management strategic plan and crop profile (1).

Results and Discussion Focus groups developed final pest rankings for insects, diseases, and weeds (both container and field production)(Tables 1-4).

Insect pests - Insects were ranked for both difficulty to control and prevelence. Borers (flatheaded and clearwing), granulate ambrosia beetle, mites and scales accounted for 91% and 73% of the difficult to control and prevelence pest votes, respectively (Table 1).

Disease pests - Diseases ranged from leaf spots and mildew, bacterial and fungal blights, root rots, and cankers (Table 2). Root rots (*Phytophthora* and *Pythium*) were the most highly ranked disease problem.

Weed pests - Ten weed species were identified as major nursery pests (Table 3). More weed species were listed for container production than for field production. Marestail [horseweed; *Conyza canadensis* (L.) Cronquist] was listed in field production specifically because of concern regarding glyphosate-resistant plants. An additional 12 weed, algae and liverwort species were identified as emerging or potential pests for nursery producers in the southeast (Table 4).

Based on the focus group discussion, 34 Extension and research priorities were developed for insect, disease, and weed pests (Tables 5-10). Overall Extension, research, and regulatory priorities were often very specific, but spanned a broader range of concepts than previously discussed by the focus group, sometimes including issues outside of pest management (Tables 11-13).

A focus group of field and container nursery crop producers and Extension professionals identified and prioritized major nursery pests. The focus group was also able to develop priorities for Extension programming and applied research for five southeastern U.S. states. These priorities can be used to develop state-wide or multi-state strategic plans, define research and Extension objectives, and support grant proposals.

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Table 1. SNIPM focus group identification of arthropod pests in the southeast based on grower-perceived difficulty to control and prevelance in field and container nursery production.

Arthropod	Difficulty to Control (votes)	Prevalence (votes)
Scales	26[1]	20[2]
Borers	17	17
Granulate ambrosia beetle	15	12
Mites	14	16
Root grubs/weevils	5	3
Caterpillars	1	1
Leafhoppers	1	7
Aphids	0	6
Japanese beetle	0	5
Flea/leaf beetles	0	2

[1] Number of votes cast by insect, greater number of votes indicates more focus group members identified this as a problem insect.
[2] Number of votes cast indicating how frequently focus group members encounter the pest.

Table 2. SNIPM focus group ranking of diseases in the southeast by grower-perceived importance.

Disease	Rank[1]
Root rots (*Phytophthora* and *Pythium* spp.)	1
Fungal leaf spots	2
Powdery mildew	3
Downy mildew	4
Phomopsis	5
Black root rot	6
Botryosphaeria	7
Cedar rusts	8
Passalora needle blight, *Cercosporidium* needle blight or *Cercospora* blight)	9
Fire blight	10

[1] Rank = 1 greatest importance, 10 lowest importance.

Table 3. SNIPM focus group ranking of container and field production weeds in the southeast by grower-perceived importance.

Container Production		Field Production	
Weed Species	Level of Importance (votes)	Weed Species	Priority (votes)
Spurge	9[1]	Yellow Nutsedge	12
Oxalis/woodsorrel	7	Crabgrass	7
Bittercress	6	Marestail/horseweed	7
Liverwort	5		
Groundsel	5		
Eclipta	4		
Annual bluegrass	2		

[1]Greater numbers of votes indicates more focus group members found this to be a problem weed.

Table 4. Emerging weeds, algae and liverworts of concern in the southeast U.S

Common name	Scientific name
Algae[1]	*Nostoc* spp.
American Burnweed	*Erechtites hieraciifolia*
Asiatic Hawksbeard	*Youngia japonica*
Benghal Dayflower	*Commelina benghalensis*
Cogongrass	*Imperata cynlindrica*
Dogfennel	*Eupatorium capillifolium*
Doveweed	*Murdannia nudiflora*
Liverwort	*Marchantia polymorpha*
Mulberryweed	*Fatoua villosa*
Longstalked phyllanthus, chamberbitter, gripeweed	*Phyllanthus tenellus* (longstalked phyllanthus *P. urinaria*, (chamberbitter, gripeweed)
Ragweed Parthenium	*Parthenium hysterophorus*

[1]Species are listed alphabetically, not in order of priority or importance.

Table 5. Entomology Extension priorities (unranked)

Priorities
• Monitor the presence and populations of insects and establish action thresholds
• Group scale insects and develop management guidelines for each group
• Emphasize scouting and early detection to be able to act on thresholds
• Use oils early when thresholds are reached to avoid using products that might be more expensive, more toxic or both
• Emphasize the importance of decreasing stress on plants and using appropriate production practices to do so

Table 6. Entomology research priorities (unranked)

Priorities
• Improve mite management
• Develop thresholds and what products to use to avoid secondary pest outbreaks *i.e.*, potato leafhopper applications increasing mite populations
• Use of water conditioner for pH
• Develop understanding of production practices relationship with pest outbreaks—focus on insect complexes, not on an individual but rather focus on a plant to allow the consolidation of sprays
• Determine if improved nutrition in the fall will reduce attacks by the flatheaded apple tree borer in field and container-grown plants. (Some growers use 25 ppm K or Mg nitrate late in summer to gradually slow the plants down
• Timing in pruning
• Increase chemical efficacy by determining correct surfactants and their rate
• Improve borer identification technique, distinguish between various borers
• Determine insect biology, host preference and overwintering host preference and how production practices might affect both
• Products that control pests with minimal negative effects on natural enemies and pollinators
• Determine possibilities for management of granulate ambrosia beetle after they enter trees
• Investigate pesticide efficacy, life history, timing of sprays, trials to show using life history and timing of sprays for Japanese maple scale, white peach scale.
• Develop thresholds for Japanese beetles

Table 7. Plant pathology Extension priorities (unranked)

Priority
• Develop resources that provide information regarding cultural practices as well as chemical controls with efficacy tables that also include other details such as curative/preventative activity and certain state label restrictions

Table 8. Plant pathology research priorities (unranked)

Priority
• Evaluate the efficacy of products applied via chemigation

Table 9. Weed Extension priorities (unranked)

Priorities
• Improved management guidelines for “hard to control” weeds such as; seasonal timing for postemergent (POST) weed control to manage perennial weed pests in nursery borders, field rows and new (e.g., container and pot-in-pot) production areas
• Improved monitoring tools, protocols, and educational programs (e.g., improved guides for identifying “emerging weeds of concern”)
• Improved decision-aids for selecting the most appropriate weed management options – (e.g., economic thresholds, efficacy tables, resistance management protocols)
• Training leading to development of an overall integrated weed management plan, tailored to each specific production operation, for controlling weeds
• Education on avoiding crop damage from herbicides

Table 10. Weed research priorities (unranked).

Priorities
• Biology and ecology of weeds in these unique nursery ecosystems (e.g., environmental and climatic modeling for predicting certain weed seed germination; development and reproduction of common and newly introduced species)
• A systematic survey of the current state of weeds in nursery production systems across the southeastern United States
• Greater understanding of herbicide persistence and longevity of control relative to the need for re-applications or other supplemental management (e.g., pairing environmental/climatic models with knowledge of herbicide persistence and efficacy to better time both deployment and re-application of preemergent (PRE) herbicides)
• Effectiveness and utility of cultural, physical and mechanical controls such as cover crops and living mulches, physical barriers (e.g., landscape fabric, geotextile, woolpack, hair and coir disks and large bark chip topdressings)
• Accurate cost accounting of weed management systems including labor for hand-weeding and strategies for efficient resource utilization through use of IPM to decrease weed management costs
• Opportunities to achieve efficient weed control with reduced PRE and POST emergence herbicide use, particularly in crops nearing sale date
• Understanding and avoiding crop injury from herbicide use in nurseries (e.g.: long-term consequences of POST emergence herbicide use such as glyphosate applications via “Enviromist” sprayer technology, or environmental persistence such as herbicide residue effects on seedling germination and liner growth
• Phytotoxicity of both PRE- and POST emergence chemistries on the diverse ornamental crops, with emphasis on new and expanding crop categories (e.g., perennials, ornamental grasses, tropical plants) being grown in the southeastern United States
• Development of new weed control technologies and herbicide formulations

Table 11. Overall Extension priorities (unranked) of nursery producers and Extension professionals in the southeast U.S.

Priorities
• Encourage the support and use of county Extension personnel (serving the green industry) in the dissemination of information
• Utilize multi state collaboration of university/industry personnel to develop a regional web site/clearing house for compiling and disseminating pest/pest management information
• Emphasize use of digital diagnosis through county offices
• Develop training and certification for scouting (expand to on-line and through distance education)
• Develop and make available efficacy tables to include re-entry intervals and mode of action group
• Create awareness regarding timing of pesticide application to increase worker protection and effectiveness of chemicals

Table 12. Overall research priorities identified by nursery producers and Extension professionals in the southeast U.S.

Priorities
• Make IPM profitable and viable for nursery crop production
• Identify effective treatments for foliar nematodes
• Identify plant phenological indicators of arthropod pest activity
• Investigate how to manage arthropod pest complexes rather than individual species
• Whole systems approaches to pest management
• Determine cause and treatment of *Cryptomeria* tip disorder
• Develop more cost effective management of fire ants
• Understand glyphosate damage in nursery crops, symptoms, application technology
• Determine physiological differences between container and field grown plants with regard to pest susceptibility and pesticide treatments
• Develop systemic controls of borer and scale insects
• Identify surfactant and penetrate use for insect control in trees
• Conduct efficacy and cost analysis of generic pesticides
• Develop a controlled release preemergence herbicide
• Determine appropriate timing of pest monitoring, scouting, and pesticide applications for weeds, arthropods, and diseases
• Test efficacy of chemigation techniques- test efficacy of chemicals
• Investigate biology of black root rot

Table 13. Overall regulatory priorities identified by nursery producers and Extension professionals in the southeast U.S.

Priorities
• Evaluate the sustainability of oak production regarding Sudden Oak Death
• Resolve questions on required quarantined treatments for fire ants and Japanese beetles
• Address use of hydrogen peroxide for water filters
• Address chlorine concerns (Homeland Security)
• Numerous water issues (availability, quality, runoff, regulations, etc.)
• Identification of ornamental production as an agriculture industry

Approaches in the Southern Region to Research and Extension for Sustainable Landscape Plant Production, Use and Pest Management

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Index Words: green industry, nursery, IPM.

Significance to Industry: Attempts to develop sustainable production, maintenance and integrated pest management (IPM) strategies for the Green Industry have been challenged by the number of plant species, growing methods, climatic zones and site conditions across the U.S. Nevertheless, current market and governmental emphases on sustainability necessitate innovation in developing integrated approaches to make landscape plant production and consumption more environmentally compatible. More than 45 stakeholders from eight states convened at two meetings and developed a series of strategies for southern U.S. regional approaches to create sustainable landscape plant production, use and pest management.

Nature of Work: The Green Industry consists of various component industries linking landscape plant production and consumer use in the landscape. Current pest management efforts that operate independently of plant culture and management practices are ineffective, inefficient and unsustainable. Previous approaches for Green Industry sustainability by research and extension have been piecemeal and have not effectively exploited the interactions between the ecological components of the production systems from a holistic perspective. Changes in research and extension are necessary to provide new breakthroughs to enable growers to progress toward higher sustainability. The time is ripe for innovation in the Green Industry in all sectors to make production more sustainable and consumption more environmentally efficient.

A Planning Grant from the USDA Specialty Crops Research Initiative allowed us to convene two regional planning meetings to develop transdisciplinary, multistate extension/research grant proposals and other activities. We used the regional pest management centers as a model for this effort, with the objective of changing the way landscape plant research, extension and ultimately production and consumption of landscape plants are conducted in the southern United States.

Results and Discussion: Meetings were held 4-5 November 2009 at the University of Florida/IFAS North Florida Research and Education Center in Quincy, FL, and 13-14 May 2010 at the University of Florida/IFAS Mid-Florida Research and Education Center in Apopka, FL, both regional centers of nursery production. Each meeting convened more than 45 scientists, producers, and others from associated industries connected with landscape plant production and use in the Southern region. In addition, participants included members of regulatory organizations as well as representatives of the chemical and other allied industries. Attendees represented the states of AL, FL, GA, LA, MS, SC, TN, and TX and the academic disciplines of entomology, plant pathology, weed science and horticulture. The first meeting was organized with the objective of developing a document that builds on available industry data contained in a crop timeline and two pest management strategic plans (Knight 2005; Knox et al. 2003; Mizell et al. 2009) to conceptualize methods to achieve a regional systems approach to sustainable landscape plant production, use and pest management.

In facilitated sessions, the participants determined research, extension and regulatory priorities for the Green Industry. Group participants found commonalities in strategies and tactics that delineate interactions between disciplines to facilitate future transactional outreach and other activities. Common themes and unifying concepts were explored in areas such as:

- Plant and pest phenology
- Water use as an ongoing factor in production and use of landscape plants
- Plant stress as it interacts with pest management
- Emerging pests
- Key pests and production barriers to their management
- Lack of management tools for certain pests, especially "soft" pesticides
- Need for pest prediction tools integrating weather, biological and chemical information
- Extension:
    - Output that can be taught, i.e. BMPs.
    - Linking research more directly to outreach.

Participants then outlined a schedule of attack to move the Green Industry toward more rapid change. The second, follow-up meeting further refined the themes explored.

Final research and extension themes for future projects include:

- Regional phenology projects for predictive purposes
    - Regional research on key pests
        - Study phenology, ecology, biocontrol, detection and monitoring, degree day models, biology, host plant resistance and chemical control of selected model pests such as scale, mites, borers and selected weeds
        - Perform research on a latitudinal basis in-depth to determine requisite understanding of population dynamics and the driving variables to implement habitat management strategies for suppression
    - Regional phenology gardens as predictive tools
        - Sentinel plots of key plant species across the region for predicting pathogen and pest population phenology based on plant phenology (budding, bloom, etc.; Orton and Green 1989)
        - ipmPIPE (Integrated Pest Management Pest Information Platform for Extension and Education) to deliver pest information

        - May not be applicable to the lower South due to lack of distinct seasons
- Nursery diversity: defining and exploiting the systems ecology of the nursery to enhance IPM and integrated crop management:
    - Landscape level structure and function, biological control augmentation, banker plants, multifunctional ecological services (augmentation of beneficials, pollinators, wildlife, nutrient capture, water filtration, erosion control), pathogen epidemiology
    - Landscape level with geospatial components (varying levels of resolution)
    - Weeds (contribution to pest problems negative or positive), scales, mites, pathogens
        - Mite IPM – biological control (mycopathogens, predatory mites), habitat manipulations to augment, production practices to suppress outbreaks, determine key habitat factors (moisture, host plant, leaf density, leaf characteristics (hairs, wax, etc.), host plant resistance and environmental interactions.
    - Ecosystem services – systems structure and function, emergent properties, habitat manipulation, landscape level processes (pollination, salt tolerance, biological control), market groups (colors, pest free, sustainably grown, native, wildlife friendly, drought tolerant, low input landscape plant (little or no irrigation, fertilizer, pesticide, pruning, etc.)
    - Host plant resistance and its uses in plant production, landscape design, installation and maintenance
- Plant stress as it relates to pest susceptibility using borers as model organisms:
    - Ambrosia beetles: plant stress-insect interactions, regional phenology and monitoring using degree day models; stress factors as they relate to host susceptibility and semiochemistry, host plant resistance, insect behavior
    - Other wood borers: host quality relationships, monitoring methods, biological controls using nematodes and mycopathogens
- Marketing, landscape use, culture and management:
    - Specialty plants: developing and marketing plants for specific uses or purposes, i.e.:
        - Augmentation of pollinators, natural enemies or wildlife
        - Nutrient capture, water filtration, erosion control
    - Interactions of cultural factors with pest management: irrigation methods and frequencies, fertilizer, species, cultivars, spacing, arrangement of plant species according to function (ex. nectar through blooms for parasitoids) or practices (similar production requirements), input use and pest occurrence (water, fertilizer, stress), regulatory issues
- Extension outreach:
    - IPM PIPE as a delivery platform for:
        - Regional pest phenology to predict pest occurrence
        - Real-time delivery of pest occurrences in regional sentinel plots
        - Presence and distribution of invasive species
    - Landscape architect training on designs for pest suppressive landscapes

- o Software updating and integration (e.g., WoodyBug, http://entnemdept.ifas.ufl.edu/fasulo/woodypest/)
- o Economics: determining cost:benefit ratios of IPM strategies and tactics, pest impacts, measurement
- o Other topic areas: regulatory issues as related to pests.

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Chemical Control of Armored Scales

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Key Words: *Euonymus,* Euonymus scale, *Laurus nobilis*, California red scale

Significance to Industry: Armored scales can be one of hardest to control pests on nursery grown plants. In two trials, systemic insecticides, contract insecticides, and insect growth regulators provided excellent control of California red scale and euonymus scale. In these trials each plant was individually sprayed. This resulted in thorough spray coverage. Growers often have plants spaced pot tight. As a result it can be difficult to get contact insecticide to all the scales on a plant. When using non-systemic insecticides it is essential to completely cover the plant when applying the insecticide.

Nature of Work: Armored scales are one of the hardest to manage nursery pests. This is due to, plant being placed pot tight, scales located under leaves, and the cryptic nature of many species makes them difficult to detect at low levels. Results are presented from trials conducted evaluating the efficacy of commercially available insecticides against euonymus scales and California red scales on container grown plants.

Euonymus Scales: The efficacy of Aloft SC, Distance, Flagship 25WG, Safari 20SG, Talus 40SC, Safari 2G, TriStar 30SG and Triact 70 was evaluated against euonymus scale (*Unaspis euonymi*) on euonymus plants (*Euonymus japonica*, 'Microphylla') grown in one-gallon pots. The trial was conducted on plants obtained from a commercial nursery with a natural infestation of euonymus scale. The trial was conducted on an overhead irrigated nursery pad at the Texas AgriLife Research and Extension Center at Overton, TX. Plants were set up in a randomized complete block design with six replicates. Foliar treatments (Table 1) were applied on 23 Aug and 21 Sep 2009 using an R & D® CO2 backpack sprayer with an 8002VS tee-jet flat spray nozzle at 60 psi. Capsil (6 oz / 100 g) was included in all foliar treatments. The Safari applications were only applied on 23 Aug. To monitor the scale population, branch terminals were collected and 25 scales per plant were evaluated under a microscope to determine if they were dead. Samples were collected on 23 Aug, 21 Sep, and 19 Oct. Percent mortality for each treatment was calculated by dividing the number of dead scales by the total number of scales evaluated. Data were transformed (arcsine$\sqrt{x}$) prior to analysis. Data were analyzed with ANOVA and means separation was accomplished using the Tukey's HSD test at $P \leq 0.05$.

<u>*California Red Scale*</u>: The efficacy of Distance, Flagship 25WG, Marathon II, Safari 20SG, Safari 2G, SuffOil-X, Talstar Flowable, Talus 40SC, and Triact 70 was evaluated against California red scale (*Aonidiella aurantii*) on bay laurel (*Laurus nobilis*) plants grown in three-gallon pots in an unheated hoop house. The trial was conducted at a commercial nursery in Wills Point, TX. Plants were set up in a RCB block design with six replicates. Foliar treatments (Table 2) were applied on 5 Feb and 4 Mar 2010. The foliar treatment was applied using an R & D® CO2 backpack sprayer with an 8002VS tee-jet flat spray nozzle at 35psi. Capsil (6 oz / 100 gal) was included in all foliar treatments. The Safari applications were only applied on 5 Feb. To monitor the scale population, five leaves were randomly collected from each pot on 5 Feb and 21 April. Twenty-five adult scales per replicated treatment were randomly selected, flipped over, and recorded as dead or alive by microscopic inspection. Percent mortality for each treatment was calculated by dividing the number of dead scales by the total number of scales evaluated. Data were transformed (arcsine√x) prior to analysis. Data were analyzed with ANOVA and means separation was accomplished using the Tukey's HSD test at the $P \leq 0.05$ level.

Results and Discussion:

<u>*Euonymus Scales*</u>: Fifty-seven days after the first treatment all the insecticide treatments results in significantly higher euonymus scale mortality rates compared to scales on the untreated plants. Both Safari treatments resulted in a mortality rate of over 99%. This is significantly higher than the scale mortality on the TriStar treated plants. This research was supported by the Texas IPM Program and IR-4 Project.

<u>*California Red Scale*</u>: At the initiation of the trial the plants were infested with all scale life stages. Although the plants were covered with scales, many of them were dead and had not fallen off the plants. This is typical with many scale species. Mortality ranged in the treatments from 47.3% to 68.7%. The scale mortality rate on the untreated plants was 66.7% at the start of the trial and 75 days after the first treatment. The mortality rate increased on the plants that received an insecticide treatment. The Triact 70 treatment was the only treatment that was not significantly different than the untreated control. However, the Triact 70 treatment was statistically similar to the Safari 20SC, Marathon II, Distance IGR, and Talus treatment. The mortality rates were over 93% for the SuffOil-X, Safari 2G, Safari 20SC, Flagship 25WG, Marathon II, Talstar Flowable, Distance, and Talus 40SC treatments. This research was supported by the Texas IPM Program.

These results indicate that with proper application techniques armored scales can be managed with a number of different insecticides. It is important to note that in these trials each plant was individually sprayed. This resulted the pesticides making contact with the scales. Growers often have these plants spaced pot tight. As a result it is difficult for them to get the insecticide to all the leaves and stems.

Table 1. Mean euonymus scale mortality after insecticide applications.

Product	Rate / 100 gal	Application method	Days after treatment 0	29	57
Safari 20SG	24 fl oz	4 oz drech / pot	18.7a	66.4abcd	99.3a
Safari 2G	2.6 g / pot	Top Dress	34.7a	96.0a	99.2a
Aloft SC	10 fl oz	Foliar	32.7a	82.7abc	97.3ab
Distance	12 fl oz	Foliar	38.7a	46.7cde	92.8ab
Triact 70	2 gallons	Foliar	29.6a	91.3ab	90.0ab
Talus 40SC	21. 5 fl oz	Foliar	21.3a	29.3de	82.7ab
Flagship 25 WG	8 oz	Foliar	26.7a	68.0abcd	80.1ab
Aloft SC	5 fl oz	Foliar	23.3a	94.0a	77.3ab
TriStar 30SG	8 oz	Foliar	30.0a	57.3bcde	62.0b
UTC	6 oz		25.3a	17.3e	12.0c

Means within a column followed by the same letter are not significantly different (Tukey's HSD; P> 0.05).

Table 2. Mean California red scale mortality after insecticide applications.

Product	Rate /100 gal	Application method	Days after treatment 0	75
SuffOil-X	2 gal	Foliar spray	62.0	100 c
Safari 2G	2.6 g / pot	Top dress	68.7	99.3c
Flagship 25WG	8 oz	Foliar spray	56.7	99.3c
Talstar Flowable	28.5 fl oz	Foliar spray	52.0	98.7c
Safari 20SG	18 oz	Foliar spray	52.0	98.0bc
Marathon II	50 ml	Foliar spray	47.3	98.0bc
Distance	12 oz	Foliar spray	61.3	96.7bc
Talus 40SC	21.5 fl oz	Foliar spray	58.0	94.0bc
Triact 70	2 gal	Foliar spray	51.3	83.3ab
Untreated Check			66.7	66.7a

Means within a column followed by different letters are not significantly different (Tukey's HSD; P< 0.05).

A New Method for Monitoring Strawberry Rootworm Populations in Nurseries

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Index words: leaf beetle, *Paria fragariae*, IPM, scouting

Significance to Industry: The strawberry rootworm, *Paria fragariae* Wilcox (Coleoptera: Chrysomelidae), is a primary pest of azaleas and other containerized ornamental crops at production nurseries throughout the southeast. The cryptic nature of all life stages of this pest can make detection and subsequently control a challenge. The intent of this project was to improve strawberry rootworm monitoring in nurseries. Proper timing of insecticide applications, when aided by a monitoring program, can be critical to reducing potentially devastating late-season pest outbreaks. This can have the added benefit of increased savings in pest control expenses. Here we discuss a new and effective method for monitoring cryptic pest insect populations in areas of intense overhead irrigation.

Nature of Work: The standard method of sampling for *P. fragariae* is to manually shake or beat a plant until insects drop onto a beat sheet or into a shallow sweep net (2). This is an effective method when practiced by an experienced scout, but due to the nocturnal and cryptic nature of our target pest, it can prove challenging and time-consuming, and may even be damaging to plants over time. In addition, manual sweeps only represent a snapshot of the insect community while the scout is actively surveying. The nocturnal *P. fragariae* can take cover under leaf litter during the day, and even when it is collected in a sweep net, it will stubbornly adhere to the underside of bits of debris, playing dead when exposed. These tiny, dark-brown beetles can be easily overlooked by less experienced scouts, or even mistaken for mulch debris.

Sticky cards are commonly used by pest control professionals for monitoring insect populations in greenhouses, where cards are not exposed to adverse weather conditions. In 2009, we conducted an area-wide survey for *P. fragariae* at 26 azalea production nurseries using sticky cards. It was our hope that this could save time and effort during our monthly tri-state (LA, MS, AL) survey, and that it would permit quick on-site diagnosis of insect pest species. We quickly discovered that sticky cards are rendered useless by the constant barrage of sunlight and water from overhead irrigation risers. Insects that were collected in melting glue would often drift to the bottom of the card where they would be washed away, while the cardboard became waterlogged and the trap either molded or was torn from its twist-tie anchor. Only 68 specimens of *P. fragariae* were identified from over 900 sticky cards placed at the 26 nurseries, as opposed to 174 specimens collected from manual sweeps.

For our 2010 *P. fragariae* survey, we have designed a trap station that incorporates a sticky card with a protective roof. Painted pine boards (1x6) were cut to lengths of 12" for the trap station backing and 10" for the roof, which were screwed together and fitted with U-bolts so that trap stations could be affixed to irrigation risers. Sticky cards were easily stapled and removed from the trap stations. In addition, we incorporated a light trap design for half of the stations using solar-charged garden lanterns (Hampton Bay) with the anticipation of attracting the nocturnally active *P. fragariae*. Round holes 5" in diameter were cut into roof sections for lanterns to rest in, and sealed with all-weather silicone caulk (Fig. 4). The solar lights charge during the day and power a small LED for 8-9 hours at night.

Two large production nurseries were surveyed with three blocks at each nursery, and an additional block was located at the Southern Horticultural Laboratory for a total of seven research blocks. Each block had one light and one non-light trap installed on separate irrigation risers, with the sticky card roughly level with plant canopy height. Beginning in March, sticky cards were changed out every two weeks. In addition, two plants proximal to each trap station were manually sweep-sampled (ten sweeps per plant) for comparison. Sticky cards were enclosed in protective plastic kitchen wrap and returned to the lab for microscopic analysis. Data from the three collection methods (light traps, non-light traps and sweeps) were analyzed using Tukey's Test for Multiple Comparisons.

Results and Discussion: Light trap stations collected significantly more *P. fragariae* compared with non-light trap stations or sweep samples (Fig. 1). Differences between light and non-light trap captures were astonishing at times, with a maximum disparity of 63 *P. fragariae* collected from a light trap to only 3 at the non-light trap from the same block in early September. The only exception was at site 1, where the non-light traps outperformed the light traps, but this was probably due to one of the light traps malfunctioning for several weeks. Trap captures, with or without a light, were higher at two of our three sites when compared with sweep captures (Fig. 2). The exception was at site three, where non-light captures were slightly lower than sweep captures.

Site differences were observed, with site two largely responsible for the significance (Fig. 2). *P. fragariae* populations were higher at site two throughout the collection period, as evidenced by higher captures from all three methods.

While light trap captures were significantly higher than sweep captures, using four sweep samples from each block may not be an accurate comparison for these monitoring methods. When considering time, a sweep sample of four plants may take as little as four minutes. Each light trap station operated for 8-9 hours each night for two weeks, and an additional 15-16 hours each day as a non-light trap when the LED was not powered. This comes out to 112-126 hours of light trapping and 210-224 hours of non-light trapping, or 336 hours total for each two-week sample period.

Seasonal effects were apparent from our data (Fig. 3). As *P. fragariae* became increasingly active in warmer weather, they were more likely to be captured by our trap stations. In contrast, as the weather cooled, they may have ceased flying, preferring to crawl up plant stems instead. Overwintering populations of *P. fragariae* take refuge in leaf litter, but will venture out to feed on foliage. This behavior may make sweep sampling more effective in cooler months, and trap stations more effective in warmer months. This hypothesis is corroborated by the increased effectiveness of sweeps that we found during the cooler months of 2010, and also by comparing our data to that presented by Boyd and Hesselein (1). In examining *P. fragariae* biology, they found four distinct population peaks in April, June, July and the zenith in August/September, suggesting four separate generations. Interestingly, our research corresponds very similarly to that of Boyd and Hesselein in terms of the timing and severity of outbreaks, though we encountered only three population peaks in April, July and August/September.

In addition to this success with *P. fragariae* captures, light traps easily outperformed other monitoring methods with more than double the total insect capture. This would suggest that our light trap station may prove useful as a monitoring tool for a range of insect pests at container nurseries. Midges and flower thrips in particular were captured in large numbers from our trap stations.

We recommend monitoring for emerging overwintering populations and early season sprays to disrupt the lifecycle of *P. fragariae*, and monitoring throughout the summer for subsequent population spikes. Also, practicing good sanitation can greatly reduce refuge for overwintering populations and may significantly reduce pest control costs.

Acknowledgments: We would like to thank Chazz Hesselein of the Alabama Cooperative Extension Service for his invaluable advice and assistance, and Grant Kirker of the USFS Forest Products Lab for initiating this research.

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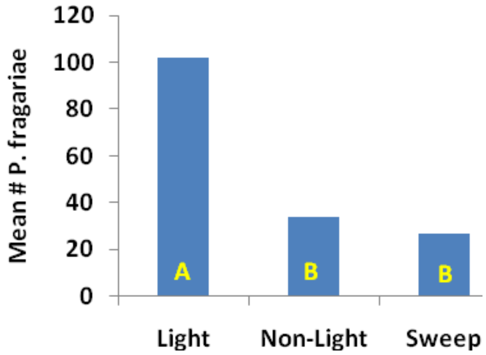

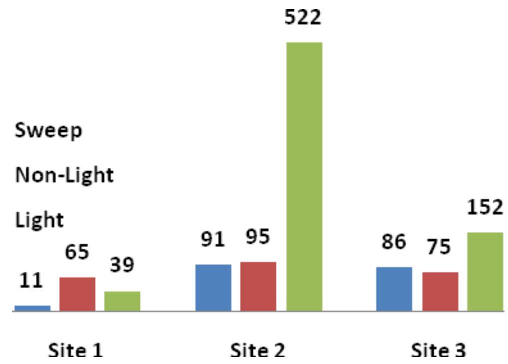

Figure 1. Mean number of *P. fragariae* collected from seven research blocks in 2010, using three different collection methods. Bars with the same letter are not significantly different, according to Tukey's Test for Multiple Comparisons.

Figure 2. Total number of *P. fragariae* collected in 2010 from three sites using three different collection methods: sweeps (blue), non-light traps (red) and light traps (green).

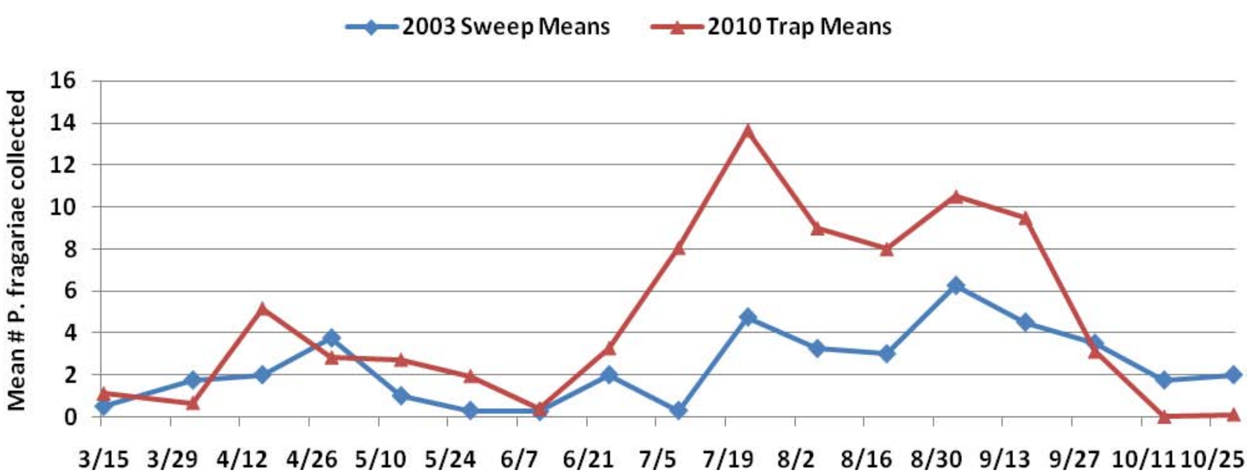

Figure 3. Mean *P. fragariae* captured bi-weekly with light and non-light traps in 2010 compared with mean bi-weekly sweep collections in 2003 (Boyd and Hesselein 2004).

Figure 4. Insect monitoring station with solar lantern fixture.

The black pearl pepper banker plant for biological control of thrips in greenhouses

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Index words: banker plant, biological control, minute pirate bug, *Orius insidiosus*, Western Flower Thrips, *Frankliniella occidentalis*

Significance to Industry: Sustainable pest management methods are becoming increasingly popular among growers around the world. In the United States, ornamental plants are the second most valuable crop worth $14.7 billion (4). Due to the value of ornamental crops, effective and sustainable thrips management is a priority for ornamental growers (2). Biological control is a form of sustainable pest management that most often involves the release of natural enemies of a targeted pest to either consume or parasitize the pest and decrease its abundance and damage to a crop. Biological control can reduce pest abundance and damage to acceptable levels (5). However, efficacy is unpredictable because natural enemies starve, emigrate from greenhouses, or cannot suppress rapidly increasing pest populations. Growers are hesitant to implement biological control because current implementation practices, in which growers have to repeatedly purchase and release natural enemies, make efficacy inconsistent and often expensive.

This study sheds light on a possible solution to the current problems in biological control by using a banker plant system for sustainable thrips management. A 'banker plant' is defined as, "A plant that directly or indirectly provides resources, such as food, prey, or hosts, to natural enemies that are deliberately released within a cropping system" (1). In this study's particular banker plant system, the 'Black Pearl' pepper plant, an ornamental pepper that flowers continuously throughout the year, is placed among crop plants to provide pollen for *Orius insidiosus,* an omnivorous predator of thrips. Banker plant systems are also compatible with popular pesticide tactics required to manage thrips. The banker plant can be removed from the greenhouse if an insecticide application becomes necessary and replaced after a safe interval to resume thrips suppression by *O. insidiosus*. The Black Pearl pepper banker plant has the potential to increase and sustain *O. insidiosus* populations and in doing so would provide preventative and long-term thrips suppression. The following experiment investigates the ability of the Black Pearl pepper to serve as a banker plant by sustaining populations of *O. insidiosus*.

Nature of Work: Western Flower Thrips (*Frankliniella occidentalis*) are one of the most economically important greenhouse pest of ornamental and vegetable crops. Thrips feeding and oviposition cause aesthetic damage to leaves and fruit tissue in the form of deformed leaves and buds. Thrips also transmit tospoviruses such as Tomato Spotted Wilt Virus and Impatiens Necrotic Spot virus which are lethal to many crops and result in significant economic loss. To prevent economic loss, growers rely on frequent insecticide applications to reduce thrips abundance and damage. However, thrips are especially hard to control using insecticides because eggs are protected in leaf tissue, pupae are protected in soil, and larvae and adults feed in curled leaves and buds. In addition, rapid development of resistance has made many insecticides less effective (3).

O. insidiosus is often purchased for the biological control of thrips and is most often used in augmentative biological control. In augmentative biological control, natural enemies are released and pest suppression is expected to occur only from the released individuals, not successive generations. By providing pollen to sustain and retain populations of *O. insidiosus* throughout a growing season, banker plant systems could make biological control of thrips more effective and affordable. For example, sustaining *O. insidiosus* in greenhouses before thrips colonize will make biological control more reliable since *O. insidiosus* will be present when the initial thrips infestation occurs rather than trying to cure an outbreak. Banker plants will also save time and money by decreasing the number of augmentative releases necessary to suppress pests.

The objective of our research was to determine if ‘Black Pearl’ pepper flowers increase *O. insidiosus* abundance compared to plants with no flowers. We evaluated the ability of flowering and non flowering pepper plants to sustain *O. insidiosus* populations for three weeks. In January 2010, individual pepper plants were placed in organdy bags in a hoop house that was completely enclosed by plastic covering. The first treatment, hereafter referred to as “flower,” consisted of pepper plants that were allowed and encouraged to flower continuously by picking off the peppers every week. The second treatment, hereafter referred to as “no flower,” consisted of pepper plants that were not allowed to flower and had buds and any opening flowers picked off weekly. The treatments were replicated ten times. The *O. insidiosus* used in this experiment were purchased from Koppert Biological. At the beginning of the trial, 30 *O. insidiosus* were placed on each plant with a 2:1 male to female ratio. After 3 weeks plants were beaten over a large white tray and any *O. insidiosus* adults and nymphs were counted. Alcohol was poured over the remaining contents in the tray, placed into glass jars, and returned to the laboratory. The number of thrips and other prey items was counted under a dissecting scope. Given that the black pearl pepper plant readily and quickly flowers, occasionally a bud would successfully open before the inspection day. To avoid this, plants were inspected daily by looking through the organdy material at the plants and if a mature bud or opening flower was spotted, the bags were opened briefly to remove them. T-tests were used to compare the effect of flower removal on the abundance of *O. insidiosus* adults and nymphs, flowers, and thrips.

Results and Discussion: There were 85% fewer flowers on plants in the no flower treatment than in the flower treatment (Figure 1). The presence of flowers on the Black Pearl pepper plants had a positive effect on the abundance of *O. insidiosus* adults and nymphs. Initially, 30 *O. insidiosus* were released on each plant. As of week three, the total number of adults decreased in both treatments, however, the number of adults in the flowers treatment was 10 times higher than in the no flowers treatment (Figure 2). The initial number of nymphs for either treatment was zero. As of week three there were significantly more *O. insidiosus* nymphs in the flowers treatment than the no flowers treatment (Figure 3). The results support our hypothesis that pollen from the Black Pearl pepper can sustain populations of *O. insidiosus*.

Due to the development time of *O. insidiosus*, the adults that were present in either treatment as of the third week may have been either the same adults from the initial inoculation or second generation adults that had been initially laid as eggs on the Black Pearl pepper plant. Surviving adults were likely feeding on pollen and other plant resources as well as thrips (Figure 4) and pests such as aphids and white flies (data not shown). Since the abundance of these prey was equal in both treatments, the importance of pollen from the Black Pearl pepper plant in the development and survival of *O. insidiosus* becomes apparent. In many commercial greenhouses, pollen for natural enemies is scarce and unable to sustain natural enemy populations when pests are not abundant. As a result, natural enemies either die for lack of food or leave the greenhouse in search of food and suitable mates or oviposition sites. This study shows the Black Pearl pepper's ability to provide adequate amounts of pollen to sustain *O. insidiosus* abundance and reproduction. Proposed future studies with the Black Pearl pepper banker plant system include full greenhouse experiments to determine the optimum frequency of and distance between banker plants for effective thrips suppression.

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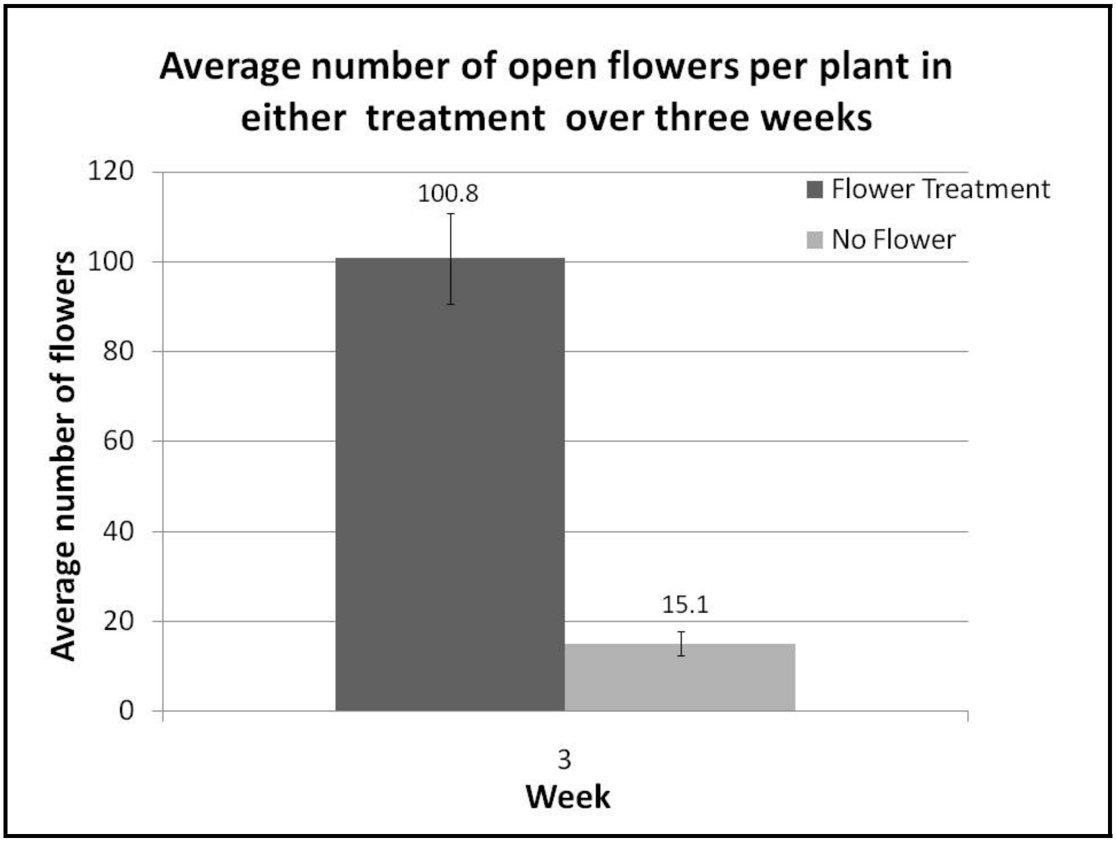

Figure 1. The average number of open flowers on 'Black Pearl' pepper plants after three weeks of flower removal.

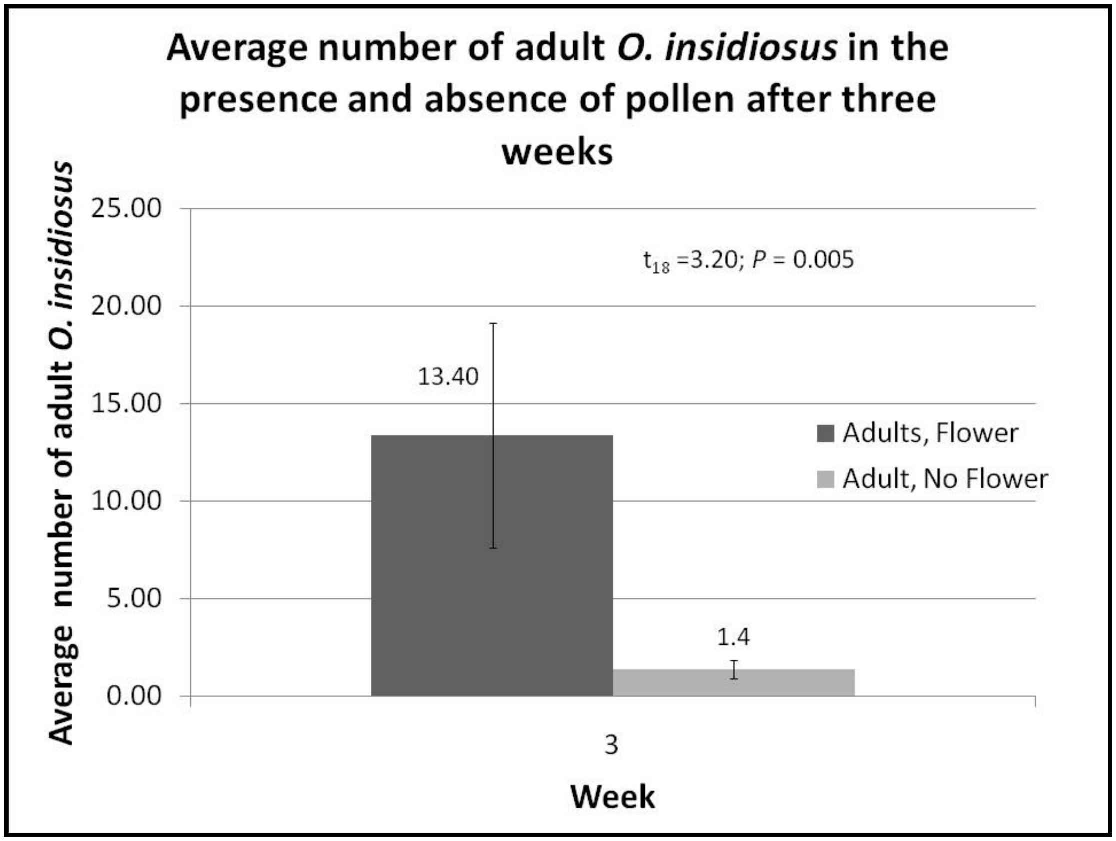

Figure 2. The average number of adult *O. insidiosus* on ‘Black Pearl’ pepper plants with and without flowers three weeks after releasing 30 adult *O. insidiosus*.

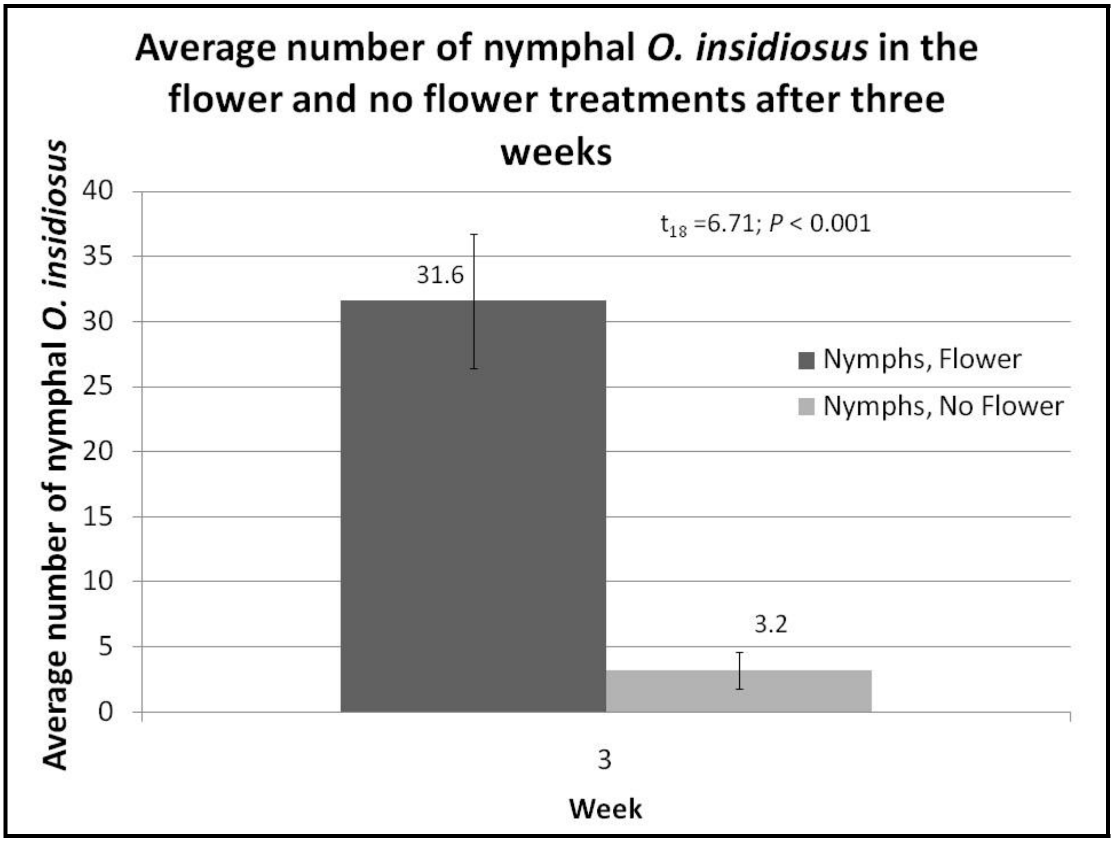

Figure 3. The average number of nymphal *O. insidiosus* on 'Black Pearl' pepper plants with and without flowers three weeks after releasing 30 adult *O. insidiosus*.

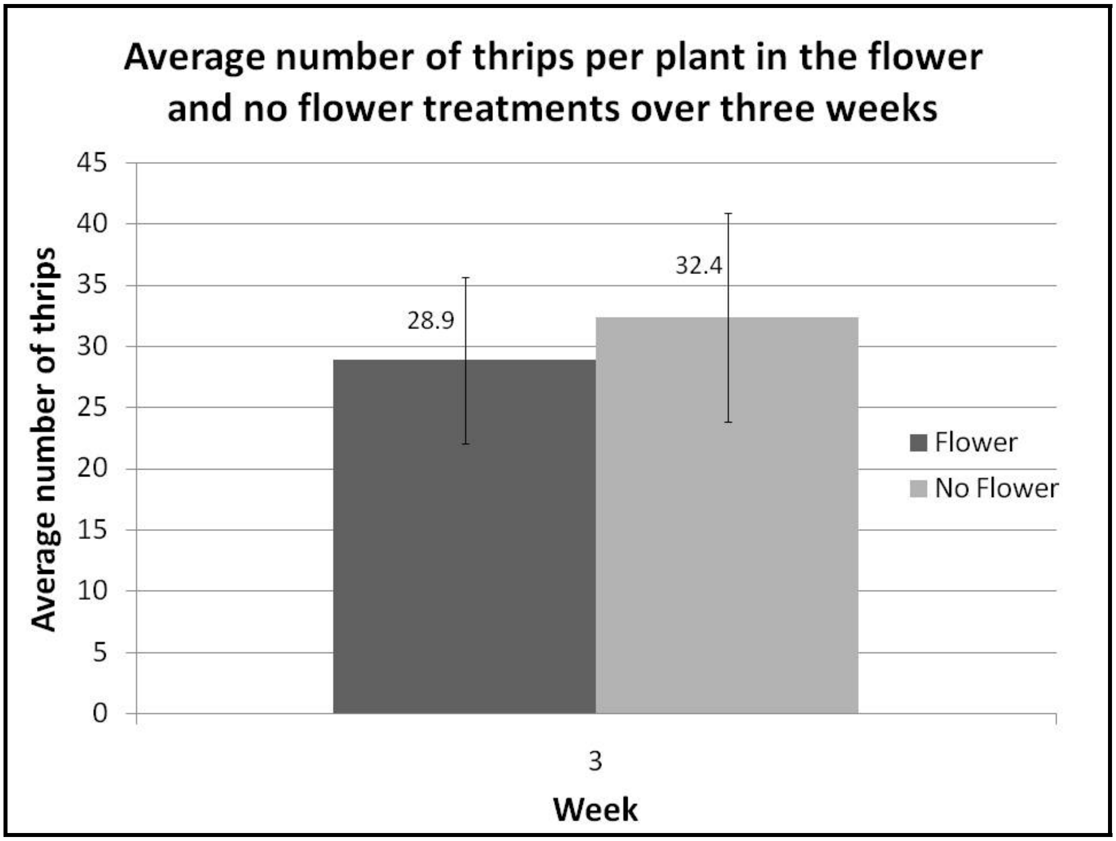

Figure 4. The average number of thrips on 'Black Pearl' pepper plants with and without flowers three weeks after releasing 30 adult *O. insidiosus.*

Usefulness of fire ant genetics in insecticide efficacy trials

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Index Words: SSR, microsatellite, genetic diversity.

Significance to Industry: Red (*Solenopsis invicta* Buren) and black (*Solenopsis richteri* Forel) imported fire ant and their hybrids have spread throughout the southeastern United States after being introduced in Mobile, Alabama in the late 1930's. New infestations can be caused by infested sod and nursery stock that are shipped outside the ant's current range. Nursery items, such as balled nursery stock, that are shipped to areas outside of the quarantine zone must be certified and compliant with USDA-APHIS regulations. Control measures generally include insecticide treatments, which are updated and revised as new research and products are available to improve the management of imported fire ants. Our objective here is to better understand the results of pesticide efficacy trials by analyzing the genetic background of fire ants in colonies being treated.

Nature of Work: Mature fire ant colonies contain an average of 80,000 worker ants. For this study, eight fire ant workers were randomly sampled from each colony. DNA fingerprints for each individual ant were generated using 21 simple sequence repeats (SSR) markers that were developed from fire ant DNA by other laboratories (1, 3, 4). Workers from eight different colonies were tested for a total of 64 individual ants. Samples were labeled with numbers corresponding to the colony and letters for each individual ant (Table 1 and Fig. 1). All colonies were then treated with Onyx Pro Insecticide or Scimitar GC as part of pesticide efficacy trials. Among the eight colonies sampled, colonies that survived from 3 – 8 weeks post treatment included colony numbers 30, 32, 87, 130, and 181 (Table 1). Colonies eliminated during the 1 week after treatment included 7, 160, and 190 (Table 1).
Our objective was to look for evidence of a genetic basis for survival following pesticide treatment by comparing genetic diversity between colonies that survived and those that were eliminated within the first week. DNA fingerprints were compiled for all samples and analyzed for similarities (5). The genetic relationships among ants and colonies were visualized using an unrooted neighbor-joining tree that shows clustering of more closely related ants (Fig. 1).

Results and Discussion: Individual ants from the same colony were closely related to each other (Fig. 1). The only exception was 7A, which did not cluster with the other ants from colony 7. Statistical analysis of the genetic information among ants within a

colony was consistent with a single queen mated to a single male for all colonies (data not shown). Further testing is available using additional genetic markers (e.g. *Gp-9* locus) that would confirm that all ants tested came from single queen colonies (2). Single or multi-queen colony organization has an important role in reproductive and dispersal behavior of fire ants, which may impact eradication efforts. Statistical analyses of the DNA fingerprints also suggest that all ants tested are diploid, or have two copies of each chromosome, which is typical for red and black imported fire ants.
Colonies did not show genetic relationships (i.e., clustering) based on location. For example, colonies located adjacent to each other such as 30 and 32 were no more closely related to each other than to colonies that were more distant (Figs. 1 and 2). Each colony likely represents an independent infestation regardless of location. In terms of pesticide efficacy trials, each colony within a site is as likely as any other to contain a genetic background for pesticide resistance. The potential for resistance at one colony is not likely to influence the occurrence of resistance at another colony unless there is movement of fire ants between colonies.

Genetic testing supports the following conclusions:

1. There is no genetic association between the five colonies that initially survived insecticide treatment.
2. There is no genetic association between colonies that were rapidly eliminated.
3. There are no genetic associations between colonies that are located near each other.
4. Differences in pesticide response are likely due to environmental factors and not genetic background.

In the future, we will test ants collected from colonies before treatment and, if they survive, after treatment. Genetic testing of survivors may uncover evidence of ants moving between colonies or queen replacement. This research is part of a larger program looking at pesticide efficacy in the Tennessee imported fire any quarantine zone.

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Table 1. Post-treatment colony survival for eight mounds sampled in this study.

Colony Code No.	Field Site	Colony Activity (Weeks After Treatment)[a]														
		0	1	2	3	4	6	8	13	20	22	25	27	29	31	34
30	H12	X	X	X	X	X	X	X								
130	H47	X		X	X	X	X	X								
87	H47	X			X	X	X	X								
181	H47	X				X	X	X								
32	H12	X			X											
160	H6	X														
7	SKY	X														
190	SKY	X														

[a] X = Colony was active during sampling week.

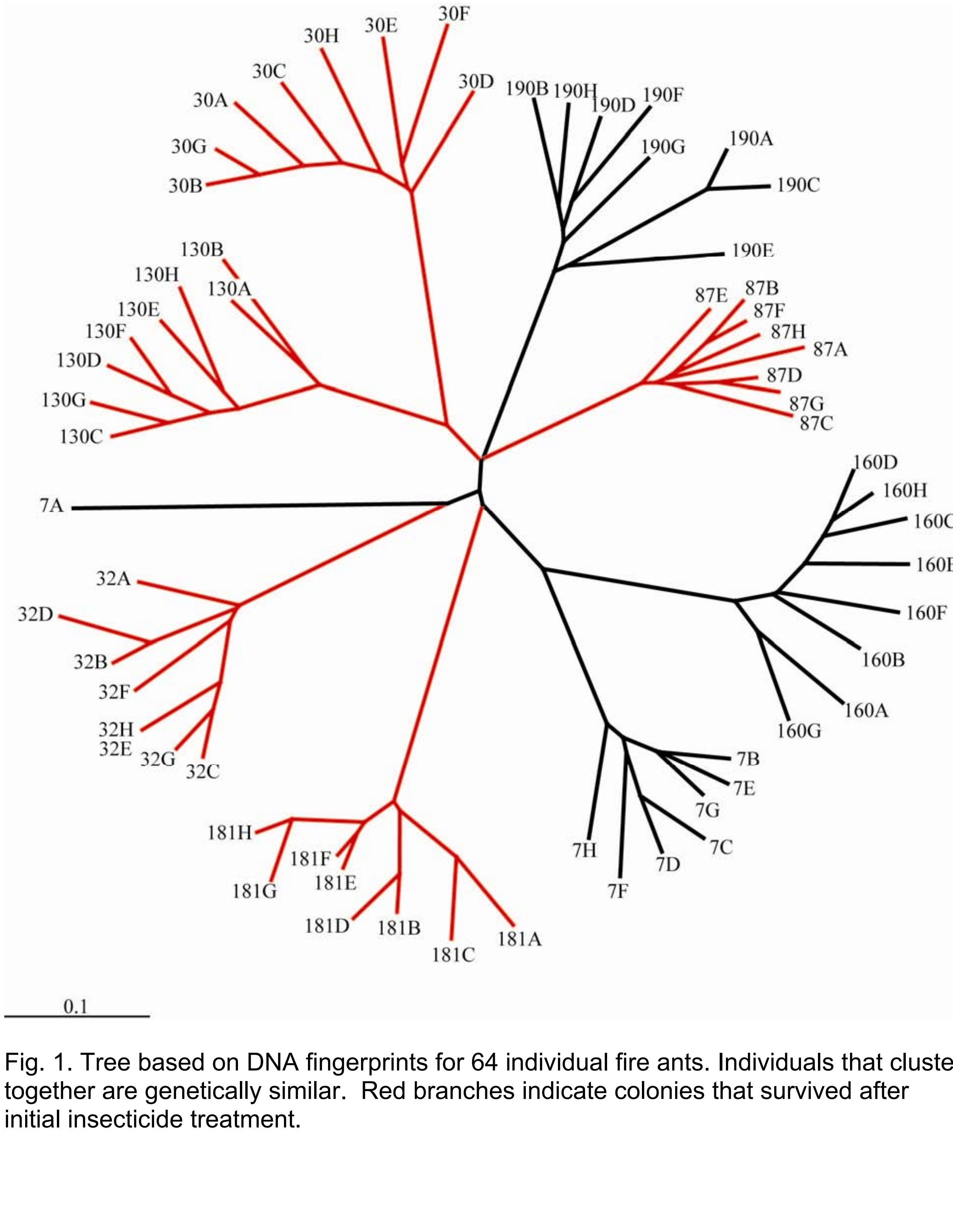

Fig. 1. Tree based on DNA fingerprints for 64 individual fire ants. Individuals that cluster together are genetically similar. Red branches indicate colonies that survived after initial insecticide treatment.

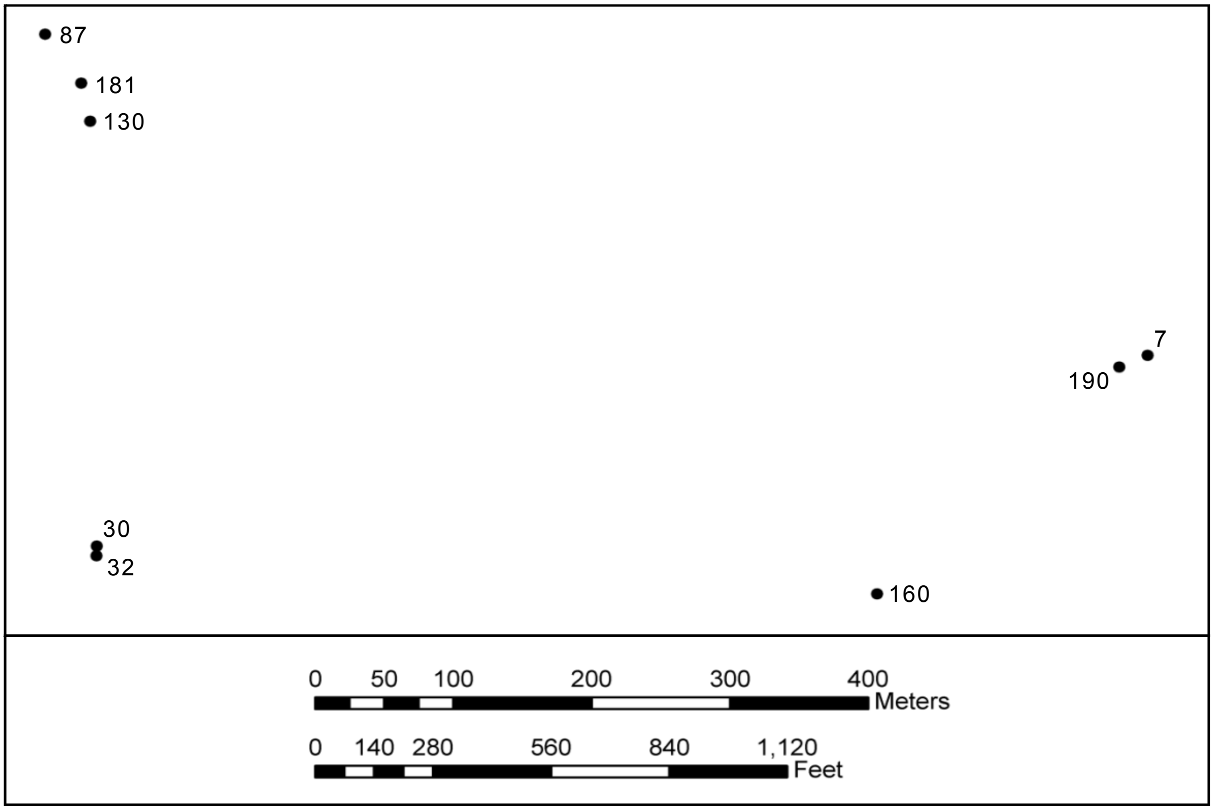

Fig. 2. Map created in ArcGIS showing locations of imported fire ant colonies sampled in this study relative to each other.

Phenology gardens in Alabama: Application of plant phenology to pest management

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Index words: phenology, degree-days, forecasting model, urban integrated pest management

Significance to Industry: The U.S. Green Industry is diverse with an estimated annual economic impact of $148 billion in sales and employs roughly two million people *[1]*. Urbanization increases demand for municipal, commercial, and residential green spaces including lawns and landscapes. As plant diversity increases in the landscape, so do numbers of arthropod pests *[2]*. As a result, significant amounts of pesticides are used for pest control in landscapes. Sparks et al. *[3]* attributed over $229 million worth of damages and costs of control to pests attacking ornamentals in landscapes and nurseries in Georgia.

Monitoring, a practice adapted to landscapes from row crop IPM programs, enables the landscape manager or grounds maintenance professional time to control the pests before significant damage occurs. Use of degree-days or phenological indicators can be useful tools for pest managers *[4,5]*. When made readily available, integration of degree-day information has been shown to decrease pesticide usage and reliance on cover sprays *[5, 6]*.

In these studies, pesticide usage was reduced by ≥85% in landscapes that were actively monitored. These pilot programs relied upon university personnel for scouting, which lacks sustainability once the project is completed. Relating growing degree-days or phenological indicators to vulnerable pest life stages would further focus scouting *[6]* and perhaps make pest managers more apt to monitor for early detection. The objectives of this project were to develop a training program on phenology and its application to landscape pest management and to establish living laboratories where trained personnel could develop these skills under university supervision.

Nature of Work: Dogwood borer (*Synanthedon scitula*): Dogwood borer (DWB), *Synathedon scitula* (Lepidoptera: Sessidae), is a multi-voltine pest of dogwoods but also develops in callus or gall tissue on other plant species including oaks and apples *[7,8]*, affecting plantings in homes and parks. Dogwood borer has a wide host range that includes beech, willow, chestnut, blueberry, hickory, pecan, pine, ash, oak, and elm *[9]*.

Dogwood borer, with a wasp-like body approximately 1.25 cm long, emerges in the spring to lay eggs on the bark. Within 8-9 d, the eggs hatch and first instar larvae enter the plant and form large feeding galleries. It takes approximately a year for larvae to pass through seven instars *[8]*. The following spring, larvae create exit holes close to the exterior of the plant before pupation.

Phenology Gardens Training Program:

Five gardens were established throughout the state containing the same suite of 13 landscape plants (Table 1) selected to provide a continuum of blooms from February to November and have easily recognizable phenological phases (phenophases). Each plot, replicated four times, was approximately 0.16 ha each and mulched. Volunteers began monitoring phenology in the garden and collecting trap data in March 2010. Traps were mailed bi-weekly. Site visits are made monthly to collect data sheets and garden maintenance.

Monitored variables: To test the first hypothesis, we monitor temperature at each of the five gardens using an on-site weather station (HOBO, model # U23-003, Onset Computer Corporation, Bourne, MA). Temperature is a valid tool in predicting insect development rate. Degree days accounts for the accumulation of heat units in a 24-hour period. Ambient temperature will be recorded at each site. Garden sites include Huntsville Botanical Garden, Oak Mountain Middle School (Birmingham), Auburn University Campus, Wiregrass Extension Center (Headland), and Mobile Botanical Garden. In order to test the second hypotheses, we used the flowers as phenological indicators.

Plants were monitored three times per week for phenophases. Data on all four plants in each garden were used to calculate an average date for each phenological event. We recorded first bloom, 50% bloom, and full bloom for plants like camellia and forsythia, similar to *[3]*. On these plants, we will randomly select and flag 4-10 branches (Figure 1) each species in order to count percent of opened flowers. For plants like sunflower and loropetalum, we recorded first bloom and full bloom. For herbaceous perennials such as daylily and daffodil, we have four phenophases 1) bud tight & upright, 2) shepherd's crook, 3) first petal open, and 4) fully open. Plants at other garden sites throughout the state are being monitored by area Master Gardeners, who will be trained via spring training workshops.

Plants established in the landscape may have different phenophases than the newly planted species in the Auburn garden due to acclimatization factors. In order to compare phenophases, I will monitor similar plants on the surrounding campus. I will record phenophases for the spring flowering species (forsythia, daffodil, cherry, and loropetalum) in the first year to compare flower phenology.
We will use pheromones and sticky traps to monitor pest emergence, activity, and peak of two sentinel insect species. At each site, cooperators are provided with sex pheronome lures and wing-type traps for monitoring male dogwood borer flight. Traps will be inspected weekly coincident with monitoring of the plant phenophases and lures replaced monthly. Every 2 weeks, traps will be mailed to Auburn for processing.

At the Auburn site, eight additional pests will be monitored. These additional species represent significant pests of ornamental plants across AL. All traps, pests, and their host plants (e.g., lace bugs) are incorporated into a 'pest block' in the garden (Figure 2). Data compiled for the sentinel species across the state tests whether local PPI and pest data can be reliably extrapolated to different areas of the state. This extrapolation has been made in other states without data for verification. If verified, we can then apply PPI for these additional pests to other areas of the state.
Each site will collect data for sentinel pest species, PPI, and degree days during both years of the project. For each sentinel species, the following response variables will be determined: first and cumulative moth capture of DWB. We also have phenology data for some of the pests in the Auburn garden pest block, including Eastern tent caterpillar, Lesser canna leafroller, and Azalea lacebug.

Results and Discussion: Our training sessions were completed in February and volunteers recorded data in the garden three times per week throughout the growing season. We posted the training manual and some additional training videos on the phenology garden website www.auburn.edu/phenology. Data collected will be posted to the website and published. We have just begun year two of a two year study.

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Figure 1.

Figure 2.

Table 1. Thirteen plant species and cultivars to be established in the phenology gardens

Common Name	Scientific Name	Flowered in 2010
Lynwood Gold Border Forsythia	*Forsythia* x intermedia 'Lynwood Gold'	Mid-March
Ice Follies Daffodil	*Narcissus* 'Ice Follies'	Late-March
Yoshino Cherry	*Prunus* xyedoensis	Late-March
Ruby Loropetalum	*Loropetalum chinense* 'Ruby'	Mid-March
Eleanor Tabor Indian Hawthorn	*Rhaphiolepis indica* Eleanor Tabor tm	Mid-April
Ellen Huff Oakleaf Hydrangea	*Hydrangea quercifolia* 'Ellen Huff'	Early-Mid May
Natchez Crapemyrtle	*Lagerstroemia indica* xfourieri 'Natchez'	May-June
Happy Returns Daylily	*Hemerocallis* 'Happy Returns'	Mid-May
Hummingbird Clethra	*Clethra alnifolia* 'Hummingbird'	Late-June to early-July
Majestic Liriope	*Liriope muscari* 'Majestic'	Late-June
Crown of Rays Goldenrod	*Solidago canadensis* 'Crown of Rays'	June
Little Lemon Swamp Sunflower	*Helianthus* 'Lemon Queen'	Late-June to Mid-July
Daydream Sasanqua Camellia	*Camellia sasanqua* 'Daydream'	Early-October