Entomology

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Gas Chromatography/Mass Spectroscopy of Contaminated Fire Ant Baits

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Index Words: Red imported fire ant, *Solenopsis invicta,* bait contamination, control, gas chromatography/mass spectroscopy

Nature of Work: The red imported fire ant, *Solenopsis invicta* Buren (RIFA), was introduced into the United States in Mobile, Alabama nearly 50 years ago (2). This species has made its way into nine states and continues to spread into new unrecorded territories. The pest status of the RIFA is based on its ability to inflict a painful sting, deter wildlife, interfere with livestock grazing, and hamper farm machinery moving through infested fields (1). Beyond traditional agriculture, plant nurseries and turf farms are concerned about selling infested materials and increasing the range of the RIFA (1).

Chemical control of RIFA has involved the use of 1) residual control, broadcast as granular formulations of insecticides, 2) individual mound treatments using numerous insecticides as drenches mixed with water, and 3) toxic baits such as Amdro®, Maxforce®, and Ascend® which consist of a food attractant, a chemical toxicant and a granular carrier (3). Toxic baits are the most economically feasible and environmentally safe materials for control of RIFA but they are sometimes ineffective. Several factors may impact the effectiveness of baits such as competition with other food sources, bait age, timing of application and environmental conditions during application (3). Bait palatability is a complex of many different factors and the effect of contaminants on RIFA has not been investigated. The purpose of this research was to determine if toxic baits can become contaminated when exposed to cigarette smoke, other insecticides, fertilizers and gasoline during storage.

Three fire ant baits, Amdro® (a.i.: hydramethylnon; American Cyanmid Company), Ascend® (a.i.: abarnectins, Whitmire Research Laboratories Incorporated) and Maxforce® (a.i.: hydramethylnon; Maxforce Insect Control Systems) were exposed to potential contaminants. The contaminants included the insecticides Orthene (a.i.: acephate powder; Chevron Chemical Company), Cyren (a.i.: chlorpyrifos liquid; Cheminova) and Tempo 2 (a.i.: cyfluthrin liquid, Bayer Corporation); cigarette smoke

(Marlboro Lights, Philip Morris Incorporated); gasoline (unleaded, 89 octane, Hess Corporation) and fertilizer (10- 10- 10, Wetsel Company). Fire ant baits were contaminated by placing 5 0 g of bait in a covered foil-lined, plastic box (3 4 x 20 x 10 cm). Bait granules were spread evenly in the bottom of the box and 2 g of the contaminant were placed in a container in the center of the box for 48 h. Cigarette contamination was achieved by placing five lit cigarettes on an aluminum dish in the center of the box with holes drilled in the lid and sides to create air flow. The box was then placed in an operating fume hood until the cigarettes were completely burned. The holes were then covered with tape.

After the contamination was completed, 15-ml vials were filled with the treatment baits and stored in a standard freezer until analyzed. Three samples of each treatment in each trial were collected. Only two samples of each treatment were analyzed with the third held in reserve if sample analyses were inconsistent. For analysis, one gram of sample was placed in a sealed vial with an open cap and teflon septum. Sealed vials were then placed in a water bath at 80°C for five minutes allowing compounds within the baits to volatilize. A I -ml syringe was inserted through the teflon septum and a I -ml gas sample was extracted, and then manually injected into the gas chromatograph/mass spectrometer (GC/MS). GC/MS analysis conditions were as follow: The column was a DB-5MS (30m x 0.25mm 1. D., 0.25 :m film) run from 50 to 150°C at 10°/min and held 5 minutes. The injector was 270°C and transfer line was 245°C. The mass spectrometer was set to monitor from 35-400 mass/charge with 0.5 sec/scan. After the GC/MS analysis was completed the total ion chromatograms of uncontaminated baits were compared with contaminated baits and spectra of peaks associated with the contaminated baits were compared to the Wiley5 spectral library for identification of components. Compounds identified in the contaminated baits were compared with compounds associated with the specific contaminant.

Results and Discussion: In the comparison of the total ion chromatograms for the contaminants compared to the contaminated baits all the chromatograms for the contaminated baits appeared similar to the contaminants except for the bait exposed to the fertilizer. These results indicated that the baits readily absorbed volatile compounds from the contaminants. In comparing the spectra of specific peaks associated with the contaminants with peaks of the same retention time in the contaminated bait samples the spectra were identical indicating the same compound was present. This demonstrates that the tested compounds were transferred and absorbed by the baits. These compounds have the potential of rendering the baits ineffective.

Significance to Industry: Results of this study have proven that baits commonly used for the control of red imported fire ants can be easily contaminated by compounds present during storage and application. It is extremely important that care be taken to assure proper storage of fire ant baits since the use of contaminated baits can result in poor control and economic loss to the lawn care professional and nursery operator.

Literature Cited:

1. Lofgren, C. S. 1986. The economic importance and control of imported fire ants in the United States, pp. 227-256. In S. B. Vinson [ed.], Economic impact and control of social insects. Praeger, New York.

2. Williams, D.F. 1983. The development of toxic baits for the control of the imported fire ant. Fla. Entomol. 66(l):162-170.

3. Williams, DR, W. A. Banks, R. K. Vander Meer, and C.F. Lofgren. 1991. Red imported fire ant (Hymenoptera: Formicidae) control with a corn Grit Bait of Fenoxycarb with out soybean oil. J. Econ. Entomol. 84(30):814-817.

Effects of Contaminants on Bait Palatability to the Red Imported Fire Ant

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Index Words: Red imported fire ant, *Solenopsis invicta,* bait acceptance, bait contamination, control

Nature of Work: One of the most common control measures for *Solenopsis invicta* Buren, the red imported fire ant (RIFA), in urban, nursery and lawn environments is the use of bait products either broadcasted or applied directly to individual mounds. Several factors impact the effectiveness of bait products for RIFA control including competition with other food sources, age of the bait, timing and environmental conditions when bait is applied (5). Palatability is also an important complex factor, which can influence bait acceptance and its effectiveness (1, 3, 6). One aspect of bait palatability that has not been thoroughly investigated is the effect of contaminants on RIFA bait acceptance. Baits may become contaminated when they are stored or used in areas where they are exposed to volatile substances such as gasoline, fertilizers, insecticides or cigarette smoke.

In this study, three commonly used fire ant baits, Amdro (a.i.: hydramethylnon; American Cyanmid Company), Ascend (a.i.: abamectins, Whitmire Research Laboratories Incorporated) and Maxforce (a.i.: hydramethylnon; Maxforce Insect Control Systems) were exposed to potential contaminants. The contaminants included the insecticides Orthene (a.i.: acephate powder; Chevron Chemical Company), Cyren (a.i.: chlorpyrifos liquid; Cheminova) and Tempo 2 (a.i.: cyfluthrin liquid, Bayer Corporation); cigarette smoke (Marlboro Lights, Philip Morris Incorporated); gasoline (unleaded, 89 octane, Hess Corporation) and fertilizer (10- 10- 10, Wetsel Company). Fifty grams of each bait were placed in foil-lined, plastic boxes (34 x 20 x 10 cm) covered with lids. The bait granules were spread evenly across the floor of the boxes. For most treatments, an aluminum pan containing 2 g of a contaminant was placed in the center of each box for 48 hrs. Cigarette contamination was achieved by placing five lit cigarettes on an aluminum pan in the center of the boxes. Four holes were drilled in the lid and six holes were drilled in the sides of each box to create air flow. These boxes were held in an active fume hood until the cigarettes burned completely. The holes were then covered with tape. Gas

chromatography/mass spectroscopy was used to determine contamination. Baits were contaminated at detectable levels. Gas chromatograph/mass spectroscopy results are presented in Sparks et al. (SNA Research Conference, Vol. 45: 2000).

Bait products (Amdro, Ascend, Maxforce) were exposed to Orthene, Tempo 2, Cyren, cigarette smoke and gasoline. To eliminate bias associated with bait preference, only one bait product was tested on any given RIFA mound. Treatments consisted of one uncontaminated bait and that same bait product contaminated with each of the five contaminates. Along with control samples, nine replicates for each bait and contaminant were conducted to evaluate bait acceptance by RIFA around active mounds in a randomized complete block design. All mounds were inspected one to two days before treatment. Mounds were blocked by size and activity. Trials were initiated within one hour after sunrise on sunny days. Each treatment consisted of a small plastic petri dish (60 x 15 mm) containing four to five g of bait. The treatments were placed around selected RIFA mounds. Thus each mound had a circle of six petri-dishes of bait randomly placed around it. Petri dishes were placed within 5 to 10 cm from the edge of the mound. Petri dishes remained in place for 1 hr.

After 1 hr., petri dishes were covered with lids, and left for 2 hrs in the sun to kill any ants remaining in the dishes. Dead ants were removed and bait was weighed. The difference between pre- and post-feeding weight was calculated and used for analysis. Data were analyzed using analysis of variance and means were separated using Tukey's studentized range test (4).

Results and Discussion: For Amdro, untreated baits were preferred by fire ants over smoke, Cyren, Tempo 2 and gasoline contaminated baits (Table 1). For Maxforce, untreated baits were preferred over Tempo 2, Cyren, and gasoline contaminated baits, but for Ascend, the untreated baits were preferred over Cyren and Tempo 2 contaminated baits. Orthene exposed Amdro, Maxforce and Ascend baits and smoke exposed Maxforce and Ascend baits were not significantly different from the control.

Table 1. Mean removal of contaminated baits (g) by red imported fire ants after one hour (n=9)

Treatment	Amdro* ($P \leq 0.001$)	Maxforce* ($P \leq 0.001$)	Ascend* ($P = 0.013$)
Control	0.274^{a}	1.833^{a}	0.286^{a}
Orthene	0.201^{ab}	1.692^{a}	0.226^{ab}
Smoke	0.119^{bc}	1.494^{ab}	0.194^{ab}
Tempo2	0.055^{bc}	0.224^{c}	0.039^{b}
Cyren	0.041^{c}	0.715^{bc}	0.049^{b}
Gasoline	0.040^{c}	0.442^{c}	0.121^{ab}

*Means followed by the same letter within colomns are not significantly different

These results indicate that other insecticides and products such as gasoline can contaminate baits and significantly affect bait palatability. Volatile, odorous products such as Orthene and smoke may contaminate baits, but may not significantly affect bait selection. However, while removal of Orthene and smoke contaminated bait was not significantly different than the uncontaminated control for two of the baits, a trend was observed in which contaminated bait removal was reduced compared to control treatments. Our results indicate that storage of baits around other materials should be carefully considered to maintain bait effectiveness.

Significance to Industry: The red imported fire ant has been identified as a key pest of both commercial and private property owners (2). The data from this study indicate that it is possible to contaminate and decrease the palatability of fire ant bait. Use of contaminated bait can result in poor control and economic loss to the lawn care professional and nursery operators.

Literature Cited:

1. Banks, W.A., A.S. Las, C.T. Adams, and C.S. Lofgren. 1992. Comparison of several sulfluramid bait formulations for control of the red imported fire ant (Hymenoptera: Formicidae). J. Entomol. Sci. 27: 50-55.

2. Klotz, J.H., J.R. Mangold, K.M. Vail, and L.R. Davis, Jr. 1995.A survey of the urban pest ants (Hymenoptera: Formicidae) of Peninsular Florida. Fla. Entomol. 78: 109-118.

3. Klotz, J.H., K.M. Vail, and D.F. Williams. 1997. Toxicity of a boric acid-sucrose water bait to *Solenopsis invicta* (Hymenoptera: Formicidae). J Econ. Entomol. 90: 488-491.

4. Ott, L. 1988 An Introduction to Statistical Methods and Data Analysis. Third Edtion. PWS-Kent Publishing Company. Boston, MA. 835 pp.

5. Stein, M.B., H.G. Thorvilson, and J.W. Johnson. 1990. Seasonal changes in bait preference by red imported fire ant *Solenopsis invicta* (Hymenoptera: Formicidae). Fla. Entomol. 73: 117-123.

6. Stringer, C. E., C. S. Lofgren, and F. J. Barlett. 1964. Imported fire ant toxic bait studies: evaluation of toxicants. J. Econ. Entomol. 57: 941-945

Can Atmospheric Gases Disinfest Greenhouse Propagules of Arthropod Pests?

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Index Words: Anoxia, Controlled atmosphere, Greenhouse, Floriculture
Nature of Work

Most greenhouse production takes place in tightly sealed structures, which limits pest immigration. Arthropod pests can only enter greenhouses on unrestricted airflow through vents, fan louvers, open doors; the clothes of workers entering the greenhouse or on infested plant material. Propagules or whole plants are frequently moved in and out of greenhouses during production, thus allowing periods where plants and pests are concentrated. Control tactics that target these points could eliminate arthropod pests before they become distributed throughout the greenhouse. However, the palette of available chemical control measures is being reduced by resistance issues, as well as environmental and worker safety legislation. Therefore, a tactic that would eliminate pests while adequately addressing these issues would be an asset to growers.

Anoxia, the use of inert gases such as CO_2 or N_2 to produce a low 0_2 atmosphere, has been successfully used to control arthropod pests and pathogens on fruits, vegetables, and grains in storage (Fleurat-Lessard 1990, Reid 1997). Anoxia could potentially be used to eliminate greenhouse pests by treating plant propagules during, or just before shipping. For example, a grower might treat plants overnight prior to shipment or plants could be treated in transit. Development of such an approach is presently limited by lack of knowledge of how different pests and plants respond to short-term, anoxic treatments at moderate temperatures. We recently completed an investigation of the effects of anoxia on arthropod pests and common greenhouse plants (Held et al. 2000). This paper presents a summary of that research.

All experiments were conducted at 68°F (20°C) in a prototype system of 12 treatment chambers constructed from 10-liter vacuum dessicators modified for airflow. In-line flow meters and indicating moisture traps were used to standardize and regulate flow within each treatment. Arthropod species used were confined on bean leaf discs (50 mm) on moistened absorbent cotton within vented, 50-mm diameter plastic petri dishes. In most experiments, oxygen levels within selected chambers were simultaneously monitored with an electronic oxygen analyzer.

Our first experiment evaluated the comparative susceptibility of fungus gnat larvae, twospotted spider mites, thrips, whiteflies, and aphids to anoxia by determining the time required to kill the pest with either CO_2, N_2 or air as a control. All gases were tested for 6, 12, or 18 h of exposure. Following treatment, containers with pests were moved to ambient laboratory conditions and survival was assessed 0, 6 and 12 h after treatment.

Another series of experiments evaluated the relative susceptibility of adult mites versus eggs. In all tests, a single life stage was prepared on a leaf disc as previously described. We first compared the survival of adults and eggs exposed for 24 h to $C0_2$ vs. air or N_2 vs. air. Next, survival of adults and eggs was compared following exposure to N_2 for 12 and 24 h. Finally, survival of adults and eggs was determined after exposure to either air, $C0_2$, or N_2 for 12 h. Survival of eggs was determined by observing the percentage of eggs hatched. Egg hatch was evaluated over 7 d by daily counting the number of mites that hatched from treated eggs. We also studied whether or not those anoxic conditions that are required to kill pests would adversely affect commonly grown greenhouse taxa. Plants used in these tests were obtained from commercial producers as seedlings or rooted cuttings. Cocktail series begonia seedlings were exposed for 6, 12, or 24 h to either N_2 or air atmospheres. A second experiment was conducted by exposing different sets of seedlings to either air, N_2, or CO_2 for 6 or 18 h. We also tested the compatibility of rooted cuttings of different cultivars of geranium *(Pelargonium x hortorum* 'Melody Red' and 'Everglow') and chrysanthemum *(Dendranthema grandiflora* 'Pomona', 'Charm', and 'Red Remarkable') exposed to either air, N_2, or $C0_2$ for 6 or 18 h. Following exposure, the plants were rated for aesthetic quality.

A more detailed experiment was conducted with impatiens seedlings *(Impatiens wallerana,* Super Elfin series). Plants were exposed to 6- and 12-h exposures of either N_2 or air. After treatment, plants were transplanted and grown in the greenhouse. After 4 wk, shoot and root mass was measured as well as the number of branches for each plant. The percentage of plants that flowered was determined once daily throughout the 4-wk period after treatment.

Since a grower utilizing anoxia for pest control would be treating living plants, we hypothesized that 0_2 production or increased relative humidity from plants might increase pest survival. To test this hypothesis, we did two separate experiments using western flower thrips and twospotted spider mites. In the first test, we evaluated the effect of humidified (85% relative humidity) and de-humidified N_2 atmospheres on pest survival.

The second test determined the effect of living plants, and light or dark, on anoxia (N_2 atmosphere) efficacy. In this test, half of the treatment chambers were wrapped completely with aluminum foil. Across both light treatments, half of the chambers received 40 impatiens seedlings each and the others were without plants. Thrips and mites (about ≈ 20 each) were placed inside each chamber and exposed to N_2 for 12 h.

Results and Discussion: In the comparative threshold experiment, no insect species survived 18 h exposure to either $C0_2$ or N_2 except fungus gnat larvae which had < 42% survival in all treatments including air controls. No whiteflies survived even 6 h exposures to either anoxic gas. Aphid survival was 28 and 20% for CO_2 and N_2 respectively at 6-h and 0% thereafter. No mites survived 12 h of exposure to $C0_2$ whereas survival in N_2 for the same exposure time was 20%. For thrips, survival after 12 h was 4.2 and 10% for $C0_2$ and N_2 respectively and 0% thereafter in both treatments. Large numbers of fungus gnat larvae were killed in both anoxia treatments, as well as in air controls, suggesting they are as sensitive to desiccation as to anoxia.

In trials with adult mites versus eggs, exposures that were lethal to adults also killed eggs. In one trial, however, measured 0_2 levels were higher than expected (>1.5 %). This level of O_2 was enough to sustain adults (86 % survival), although no eggs survived.

Across all the plant studies, there was variability among species, cultivar, and anoxic gas used. Tolerance of begonias varied from trial to trial. For example, in one trial, all plants exposed to N_2 for 12 or 24 h were killed by the treatment. In another trial, N_2 exposures as long as 18 h caused no noticeable damage. However, both 6- and 18-h exposures to CO_2 caused significant damage to treated plants. For chrysanthemum and geranium cultivars, there was significantly more damage from CO_2 than from N_2 after 12 h of exposure. There were no differences between geranium cultivars; however, 'Red Remarkable' was the most damaged by all treatments among chrysanthemum cultivars. Aesthetic quality of N_2-treated plants did not differ from that of control plants.

In the experiment with impatiens, vegetative characteristics, including number of branches, root mass, and shoot mass, were not affected by the treatments. Plants exposed to N_2 for 12 h required significantly longer to flower, and fewer plants produced flowers.

Humidified and de-humidified N_2 were equally effective in killing thrips and mites. In the factorial experiment which incorporated presence or absence of plants or light, mite survival under N_2 treatment was significantly higher in chambers without plants than in chambers with living

impatiens plants, and higher in darkness than in light. However, survival of thrips was unaffected by either presence of living plants or light.

Significance to Industry: This study demonstrates the potential application of short-term anoxic treatments at moderate temperatures for controlling greenhouse pests while they are concentrated on propagules before, during, or after shipment. Potential advantages of this approach include reduced environmental and worker exposure to pesticides, and resistance management. This study indicates, however, that pests, and especially plants, may vary in their tolerance of anoxic conditions. Interactions between treatment variables such as anoxic gas, 0_2 concentration, or relative humidity and the plants and pests being treated may modify the effects of anoxia. Greater understanding of these interactions will be needed to determine if anoxia can be used for controlling pests on an increasing diversity of plant species and cultivars being produced in commercial greenhouses.

Literature Cited:

1. Fleurat-Lessard, F. 1990. Effects of modified atmospheres on insects and mites infesting stored products, pp. 21-38. *In. M.* Calderon and R. Barakai-Golan [eds.], Food preservation by modified atmospheres. CRC, Boca Raton, FL.

2. Held, D. W., D. A. Potter, R. S. Gates, and R. G. Anderson. 2000. Controlled atmosphere anoxia treatments as a potential disinfestation technique for arthropod pests in greenhouses. J. Econ. Entomol. *In press.*

3. Reid, M. 1997. A summary of CA and MA requirements and recommendations for ornamentals and cutflowers, pp. 129-136. In M. E. Saltveit [ed.] Proceedings, 7th International Controlled Atmosphere Research Conference, vol. 4. Davis, CA.

Assessment of Japanese Beetles and Their Natural Enemies in Eastern Tennessee

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Index Words: Japanese Beetle, *Popilhajaponica,* Biological Control

Nature of Work: First recorded in 1916 near Riverton, New Jersey, the Japanese beetle, *Popillia japonica* Newman, is now established in 22 states east of the Mississippi River; isolated infestations have been reported in states west of the Mississippi (1). The Japanese beetle is established in eastern and middle Tennessee and has recently been recovered in western Tennessee. In North America, Japanese beetle grubs and adults cause tremendous economic losses exceeding $234 million annually (2). Although grubs primarily feed on grass roots and can cause extensive turf damage, adults are polyphagous, feeding on more than 300 species of plants - many of these being agriculturally and ornamentally important (3, 4). To reduce damage and economic losses by the Japanese beetle, several management strategies have been initiated in eastern Tennessee. The impact of one of these strategies, biological control, on populations of Japanese beetles is poorly understood. The goal of this research project is to assess populations of Japanese beetles and their natural enemies in eastern Tennessee. Ultimately, this information will be used to assess the role of biological control as a component of integrated pest management programs to reduce populations of Japanese beetles. Specific objectives of this research are to: 1) monitor population levels of Japanese beetle adults and grubs in eastern Tennessee, 2) assess incidence and seasonality of biological control agents of Japanese beetle in eastern Tennessee, and 3) determine parasitism and infection levels of Japanese beetles by biological control agents (parasitoids and pathogens).

During 1999 and 2000, populations of Japanese beetles and biological control agents were sampled in two plots in each of five counties (Campbell, Greene, Johnson, Knox, and Monroe County) in eastern Tennessee. In each county, one plot had been inoculated within the last 20 to 25 years with milky spore *(Bacillus popilliae* Dutky), a Japanese beetle pathogen, and the other had not. Plots (30ft x 30ft) were divided into nine 10ft x 10ft subplots. Biweekly sampling was conducted from April to November 1999, and will be conducted from April to November 2000. On each sampling date, one soil sample (1ft x 1ft) was chosen randomly from each subplot, and soil was removed to a depth of 8in.

Each soil sample was examined for Japanese beetle eggs, grubs, and pupae, as well as miscellaneous coleopterans. All coleopterans were collected, taken to the laboratory, catalogued, and identified. Grubs were placed in small containers, fed grass roots, and monitored to determine the incidence of infection or parasitism. Three Japanese beetle traps, containing pheromone and floral lure, were positioned around each plot, monitored weekly, and emptied as needed. Adults were counted to obtain population estimates and examined to assess levels of parasitism.

Sampling for parasitoids of Japanese beetle larvae also was initiated in April 1999 and again in April 2000. Soil samples, as described above, were examined for various life stages (e.g., pupae) of parasitoids (e.g., *Tiphia* spp.), which were taken to the laboratory, identified, and catalogued. Adult trapping of *Tiphia* spp. was conducted from late April to August 1999, and from mid-April to August 2000. When sampling for Japanese beetle grubs, the foliage of trees around each plot was sprayed with a 10% sugar water solution and monitored for the presence of adult *Tiphia* using a sweep net. Captured *Tiphia* were taken to the laboratory, identified, and catalogued. One gallon of soil also was collected from each plot and sent to the University of Tennessee Plant and Pest Diagnostic Lab in Nashville, Tennessee. Each soil sample was subjected to soil filtration, and entomopathic nematodes were extracted and identified. Finally, collected grubs were examined for symptoms and/or signs of infection by a pathogen; any grubs believed to be infected were biopsied, and the pathogen was cultured and identified.

Results and Discussion: In 1999, the density of Japanese beetle grubs, averaged across all sampling dates, ranged from <1 to 3.0 grubs/1 ft^2. The greatest number of Japanese beetle grubs were collected from Knox County, with as many as 7 grubs/1 ft^2 collected on several sampling dates. Adult Japanese beetles were first collected in early May 1999 and 2000 in Campbell, Knox, and Monroe counties, with Greene and Johnson counties experiencing adult emergence several weeks later. Adult populations were roughly equal across counties, with >10,000 adults collected/trap/week in each county from mid-June to early October 1999. Few natural enemies were identified from samples collected in 1999. One *Tiphia vernalis* Rohwer, a parasitic wasp of Japanese beetle grubs (5), was found in only one county (Campbell) in 1999, but thus far has been found in three counties (Campbell, Knox, and Monroe) in 2000. The fungus *Metarhizium anisopliae* (Metsch.) Sorokin was recovered from one Japanese beetle grub collected in Campbell County on July 9, 1999, and the fungus *Paecilomyces lilacinus* Bainier was recovered from an unidentified grub in Greene County on July 21, 1999. No entomopathic nematodes or milky spore were recovered from any of the soil samples and/or insects collected from any of the counties in 1999.

Significance to industry: Due to its wide host range, relative abundance, and voracious appetite, the Japanese beetle is an important pest for homeowners and nursery growers in Tennessee. The Japanese beetle quarantine has greatly impacted the shipment of plant products from infested to non-infested areas. With the closing of some markets to nursery growers, this quarantine has led to losses in market opportunities. A strategy aimed at reducing populations of Japanese beetle to tolerable levels would be an important step in enhancing profits for nursery growers. Unfortunately, thus far, our results show that the levels of biological control agents of Japanese beetles in eastern Tennessee are very low. Perhaps, through better understanding, augmentation and enhancement of existing natural enemies, and continued investigation into and release of new biological control agents, biological control can play an important role in long-term reduction of Japanese beetle populations. A multi-faceted control program, incorporating biological control, may provide reductions in Japanese beetles, allowing growers to economically manage populations of this destructive pest.

Literature Cited:

1. U.S.D.A. 1997. Managing the Japanese beetle: A homeowner's handbook. U.S.D.A. Program Aid No. 1599.

2. Garland, J. A, F. Meloche, E. J. Dobesburger, and R. S. Dickhout. 1992. Special project on Japanese beetle. Plant Res. Centre, Ottawa, Res. Contrib. No. 1425.

3. Hawley, I. M. and F. W. Metzger. 1940. The feeding habits of the adult Japanese beetle. U.S.D.A. Circ. No. 547.

4. Tashiro, H. 1987. Turfgrass insects of the United States and Canada. 389p. Cornell University Press, Ithaca and London.

5. King, J. L. and L. B. Parker. 1950. The spring Tiphia, an imported enemy of the Japanese beetle. USDA, Bur. Entomol. Plant Quar. E-799. 8p.

Viburnum Beetle: A Serious Threat to the Landscape

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Index Words: Viburnum, *Pyrrhalta viburni*, leaf beetle

Nature of Work: The genus *Viburnum* is represented regularly in landscapes from the Canadian border to the Gulf Coast in the Eastern United States. Diverse flowering, fruit, leaf and form characteristics lead to a variety of landscape uses. The diversity in this group of shrubs is botanically described by Krüssman (1984). Table 1 lists his nine sections within *Viburnum*.

Viburnum leaf beetle (*Pyrrhalta viburni*) is a pest of *Viburnum* and the insect is now established in the United States. Viburnum leaf beetle, a European native which is established from Great Britain to Italy, was first detected in North America in Ontario, Canada. Since then it is believed to have migrated over land into Maine and across the Niagara Isthmus into New York. In New York it was first detected in 1996 along the shores of Lake Ontario. This work was initiated to learn more about the insect and the extent of damage it caused to viburnums.

Results and Discussion: Viburnum leaf beetle larvae hatch in the spring from eggs laid the previous year. This happens in Rochester, NY in early to mid May, or after 80 to 100 growing degree-days have accumulated. Larvae feed on newly expanded leaves, completing their development by mid June. The full-grown larvae drop to the soil where they pupate and emerge as adults in late June or early July. The adults feed on the same shrubs on which they developed or fly to adjacent favorable plants. This insect is capable of flying some distance and the population is believed to be spreading from 15-20 miles per year in New York. The adults also feed gregariously and are commonly clustered on their favored host(Viburnum). The females lay eggs during the remainder of the summer and into the fall. Eggs are deposited on the underside of young stems. Small pits are chewed into the stem and the female will lay the eggs in small clusters (5-6 eggs). The eggs are capped with a mixture of chewed foliage and feces. These are visible as a row of bumps on the underside of the stem.

Viburnum is the only known host for the insect. As there is a wide range of variability to the genus *Viburnum*, there is a wide range of susceptibility to Viburnum leaf beetle. We have classified the susceptibility of viburnums to the beetle based on the degree to which larvae and adults are capable of defoliating the plant. This classification is based on plants

grown in full sun sites. Plants grown in shade have been observed to be more heavily fed upon than their counterparts in full sun.

Susceptible species are extensively defoliated by the larvae or beetle. Plants have little or no living leaves after having been fed upon for two or more years in succession. Plant death usually occurs after two-three years of infestation. *Moderately susceptible* species are fed on only slightly. Feeding sites will perforate the leaf, but the foliage appears healthy otherwise. Only a small percentage of the foliage mass on a given plant will show signs of feeding damage. Plants viewed from a distance may appear normal, but close observation in a landscape may show unacceptable visual damage. *Resistant* species may show signs of feeding attempts, but these rarely penetrate the leaf.

In New York, the most susceptible viburnums (the ones which would require an annual control program) are cranberry, arrowwood, Rafinesque, and Sargent (Table 2). Contributing to the spread of this pest is the fact that the susceptible group contains native understory plants throughout the forests of the Eastern United States. The native population of susceptible species may very well be completely eliminated.

The most resistant species include those species with thicker leaves. Exactly what makes these species resistant is not completely understood. Feeding will occur on leaves, but with no leaf blade penetration. Most of these species are in the Lantana Section (Krüssman1984). This Section is noted for very thick or very pubescent leaves and includes the leatherleaf and Koreanspice types. Additional resistant viburnums include doublefile, tea, and Siebold. In between is the moderately susceptible group. The Lentago Section is included here as well as species related to either susceptible or resistant species (Table 2).

Significance to Industry: *Pyrrhalta viburni* is now establish in the United States. If it establishes on this continent like it has in Europe, it should be a pest throughout the Eastern United States if not even further west. Nurseries and landscape maintenance firms should be prepared to change their plant palate or develop a pest management program for the susceptible species. Sustainable management methods such as biological control are being investigated.

Literature Cited:

1. Krüssman, Gerd.1984. Manual of Cultivated Broad-Leaved Trees and Shrubs. Timber Press, Portland, OR. 1923 p.

Table 1. Sections of *Viburnum* as described by Gerd Krüssman in "Manual of Cultivated Broad-Leaved Trees and Shrubs".

Section 1.	Thyrsoma
Section 2.	Lantana
Section 3.	Pseudotinus
Section 4.	Pseudopulus
Section 5.	Lentago
Section 6.	Tinus
Section 7.	Megalotinus
Section 8.	Odontotinus
Section 9.	Opulus

Table 2. Susceptibility of *Viburnum* species to colonization by *Pyrrhalta viburni* [a]

Most susceptible
V. dentatum, Arrowwood viburnum (8)
V. opulus, European cranberrybush viburnum (9)
V. rafinesquianum, Rafinesque viburnum(or downy-leaved arrowwood)(8)
V. sargentii, Sargent viburnum (9)
V. trilobum, American cranberrybush viburnum (9)

Moderately susceptible
V. acerifolium, Mapleleaf viburnum (8)
V. dilatatum, Linden viburnum (8)
V. lantana, Wayfaringtree viburnum (or wayfaring tree) (2)
V. lentago, Nannyberry viburnum (or sheepberry) (5)
V. ´pragense, Prague viburnum (2)
V. prunifolium, Blackhaw viburnum (5)

Particularly resistant
V. burkwoodii, Burkwood viburnum (2)
V. carlcephalum, Carlcephalum (or fragrant) viburnum (2)
V. carlesii, Koreanspice viburnum (2)
V. ´juddii, Judd viburnum (2)
V. plicatum, Doublefile viburnum (4)
V. ´rhytidiophylloides, Lantanaphyllum viburnum (2)
V. rhytidiophyllum, Leatherleaf viburnum (2)
V. setigerum, Tea viburnum (8)
V. sieboldii, Siebold viburnum (1)

[a] Numbers following each accession refers to the sections of *Viburnum* in "Manual of Cultivated Broad-Leaved Trees and Shrubs" by Gerd Krüssman

Insecticide Efficacy For Adult Root Weevil Control

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Index Words: *Otiorhynchus sulcatus*, *Otiorhynchus ovatus*, *Otiorhynchus rugostriatus*, *Rhododendron*, container production, lambda cyhalothrin, bifenthrin, deltamethrin, acephate, bendiocarb

Nature of Work: Sometimes called the "trojan horse" of the nursery industry (Cowles et al., 1997), root weevil species are pests in nurseries world-wide (Bogatko and Labanowski, 1993; Horne, 1997). In a recent survey of *Rhododendron* growers in Oregon, 54% of respondents were not satisfied with the level of root weevil control when pesticides were used (Rosetta and Svenson, unpublished data). This dissatisfaction persisted even when there were no out-of-state *Rhododendron* shipments rejected due to root weevil infestations (Reusche, 1999). The objective of this study was to determine the efficacy of selected pesticides for control of adult root weevils.

The study was conducted on *Rhododendron* 'PJM' in 1-gallon (2.7-liter) containers at the North Willamette Research and Extension Center in July of 1999. Adult stages of black vine root weevil (*Otiorhynchus sulcatus*), strawberry root weevil (*Otiorhynchus ovatus*) and rough strawberry root weevil (*Otiorhynchus rugostriatus*) were established in each pot. Weevils had been collected from an infested strawberry field. Pesticide applications were made as foliar sprays using a CO_2-sprayer on July 12 from 9 to 11 PM. Insecticides studied included: bifenthrin (Talstar flowable); lambda cyhalothrin (Topcide); deltamethrin (Alta); bendiocarb (Closure); and acephate (Orthene). Treatments were evaluated for percent adult mortality and Effective Kill Ratio (EKR) at 7 and 14 DAT (July 19 and July 26, respectively). The EKR adjusts the data to account for the natural death of the root weevils as indicated by mortality of untreated controls. Since adult root weevils can "play dead," prolonged observation is often required before the status of a particular weevil can be determined. The randomized complete block experiment used 5 blocks with two pots for each treatment. Data was checked for normality and homogeneity, and then analysis proceeded with SAS ANOVA using the LSD procedure for mean comparisons.

Results and Discussion: At seven days after treatment (DAT), lamda cyhalothrin, bifenthrin, deltamethrin and acephate killed a greater fraction of strawberry root weevil, and had a greater Effective Kill Ratio (EKR) compared to untreated controls, but the bendiocarb application was not

different from the control (Table 1). Only lambda cyahalothrin had an EKR different from untreated controls after 14 days.

At 7 DAT, response to treatments for black vine weevil (Table 2) was similar to the response for strawberry root weevil, with only bendiocarb not different from the control. Because of natural death of black vine root weevils in the control treatment, none of the treatments had a fraction of dead black vine root weevils or an EKR significantly different from untreated controls after 14 days. All black vine weevils in all treatments, and 60% of untreated black vine weevils, were dead after 14 days.

For rough strawberry root weevil at 7 DAT, only lambda cyhalothrin killed a fraction of the root weevils significantly greater than the untreated controls (Table 3), but all treatments except bifenthrin had significantly greater EKR compared to controls. Similar to black vine root weevils, the natural death of rough strawberry root weevils in the untreated control treatment led to no significant difference in the fraction dead or EKR of rough strawberry root weevil at 14 DAT. Only acephate and lambda cyhalothrin killed 100% of the rough strawberry root weevils.

Black vine root weevils were more sensitive to the insecticides studied compared to either strawberry root weevil or rough strawberry root weevil. Black vine root weevil and strawberry root weevil are both common in nursery stock in the Pacific Northwest compared to rough strawberry root weevil. It is interesting to note that bifenthrin was not as effective at killing rough strawberry root weevil compared to strawberry or black vine root weevil.

As there was considerable mortality of the black vine weevils and rough strawberry root weevils in the untreated plots by the second evaluation date, it may be more useful to look at the results from 7 DAT for product comparisons. Mortality of the strawberry root weevils in the untreated plots by 14 DAT remained relatively low and both evaluation dates should be useful.

Significance to Industry: Available pesticides for adult root weevil control are effective, but the selection of a particular active ingredient may be important based on the species of root weevils infesting the crop. The efficacy of pesticides indicated by this study may be different if pesticides are applied during daylight hours. Repeated use of the same active ingredient may create localized populations of root weevils that are resistant to specific pesticides. Black vine root weevils appear to be more susceptible to the active ingredients we tested compared to strawberry or rough strawberry root weevils.

Literature Cited:

1. Bogatko, W. and G. Labanowski. 1993. Chemical control of the black vine weevil (*Otiorhynchus sulcatus* F.) on ornamental crops. J. Fruit and Orn. Plant Res. 1(3):93-101.

2. Cowles, R.S., D.O. Gilrein and S.R. Alm. 1997. The trojan horse of the nursery industry. Amer. Nurs.186(3):51-57.

3. Horne, P.A. 1997. Grubs in your pots? Are they weevils and what can you do about it? The Nursery Papers 11:1-7.

4. Reusche, E. 1999. Summary of rejections of Oregon nursery stock in 1999. Nursery News 1(4):3.

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Table 1. Influence of insecticides on mortality of strawberry root weevil in *Rhododendron* 'PJM'.

Insecticide	Application rate	Fraction Dead[2]		EKR[3]	
		7 DAT	14 DAT	7 DAT	14 DAT
lambda cyhalothrin	0.48 oz ai/100 gal	90 ab[1]	90 a	88 ab	87 a
bifenthrin	0.19 oz ai/100 gal	60 bc	76 ab	54 abc	68 ab
deltamethrin	0.19 oz ai/100 gal	58 bc	68 abc	52 abc	67 ab
acephate	12.0 oz ai/100 gal	54 bc	65 abcd	47 bcd	53 abc
bendiocarb	6.08 oz ai/100 gal	25 cde	60 abcd	21 cde	47 abc
untreated control	0	13 de	25 cde	0 de	0 bc

[1] Means in columns for the same days after treatment and followed by the same letter are not significantly different; mean separation using LSD (5%).
[2] Fraction of all weevils found per treatment that were dead (DAT=days after treatment).
[3] Effective Kill Ratio; values may be lower on 14 DAT compared to 7 DAT due to sampling errors or missing weevils.

Table 2. Influence of insecticides on mortality of black vine root weevil in *Rhododendron* 'PJM'.

Insecticide	Application rate	Fraction Dead[2]		EKR[3]	
		7 DAT	14 DAT	7 DAT	14 DAT
lambda cyhalothrin	0.48 oz ai/100 gal	75 ab[1]	100 a	63 abc	100 a
acephate	12.0 oz ai/100 gal	80 ab	100 a	70 ab	100 a
bifenthrin	0.19 oz ai/100 gal	100 a	100 a	100 a	100 a
deltamethrin	0.19 oz ai/100 gal	100 a	100 a	100 a	100 a
bendiocarb	6.08 oz ai/100 gal	75 ab	100 a	3 abc	100 a
untreated control	0	33 bc	60 ab	0 bc	0 ab

[1] Means in columns for the same days after treatment and followed by the same letter are not significantly different; mean separation using LSD (5%).
[2] Fraction of all weevils found per treatment that were dead (DAT=days after treatment).
[3] Effective Kill Ratio; values may be lower on 14 DAT compared to 7 DAT due to sampling errors or missing weevils.

Table 3. Influence of insecticides on mortality of rough strawberry root weevil in *Rhododendron* 'PJM'.

Insecticide	Application rate	Fraction Dead[2]		EKR[3]	
		7 DAT	14 DAT	7 DAT	14 DAT
acephate	12.0 oz ai/100 gal	80 ab	100 a	100 a	100 a
lambda cyhalothrin	0.48 oz ai/100 gal	93 a	100 a	100 a	100 a
bendiocarb	6.08 oz ai/100 gal	71 abc	93 ab	70 a	71 ab
untreated control	0	44 bcde	77 abc	0 b	0 abc
bifenthrin	0.19 oz ai/100 gal	33 cdef	75 abc	0 bc	0 abc
deltamethrin	0.19 oz ai/100 gal	56 bcd	67 abc	100 a	5 abc

[1] Means in columns for the same days after treatment and followed by the same letter are not significantly different; mean separation using LSD (5%).
[2] Fraction of all weevils found per treatment that were dead (DAT=days after treatment).
[3] Effective Kill Ratio; values may be lower on 14 DAT compared to 7 DAT due to sampling errors or missing weevils.

Flatheaded AppleTree Borer Infestations on Newly Planted Maple Liners

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Index words: *Acer rubrum* 'Northwood', red maple, *Chrysobothris femorata*, flatheaded appletree borer, nursery liners

Nature of Work: Nursery producers in the south central United States are often plagued with infestations of flatheaded appletree borer, *Chrysobothris femorata* (Oliver) (Coleoptera: Buprestidae) on newly planted field liners, especially during the first growing season (4,5). The flatheaded appletree borer is a common and destructive pest of many species of shade and fruit trees (1, 3). The damage caused by this borer has been increasing for several years and can seriously damage or kill a tree.

Adult beetles emerge in the late spring and early summer, mate, and oviposit beneath bark scales and in cracks, crevices, and wounded areas. They often invade trees at the graft junction, trees that were bruised during transplanting or pruning, or trees damaged by environmental factors like sun scald (1). The larvae feed beneath the bark making irregular tunnels in the phloem and outer sapwood that can girdle and sometimes kill the tree. The mature larvae overwinter in the sapwood and pupate the following spring. Sap flow on the bark surface, sunken areas under the bark, and patches of missing bark are commonly seen with this pest.
Presence of the flatheaded appletree borer and other buprestid borers has been correlated to plant stress such as drought, wounding, and defoliation (4). Root pruning liners prior to planting is a common cultural practice that allows the root system of the liner to easily be placed through the opening shoot of a mechanical transplanter. Approximately 50% of the root system is commonly removed. Root pruning prior to transplanting may increase plant stress and therefore, increase the likelihood of attack by borers.

The objectives of this project are 1) to evaluate chemical control of borers with preventative trunk applications and systemic soil applications, and 2) to examine the effects of stress on the growth of the plant and how this relates to borer attack.

On 12 March 1999, uniform 122-152 cm (4-5 feet) tall bare root liners of *Acer rubrum* 'Northwood', red maple, were either subjected to severe root pruning (about 50% of the roots were removed with a final length about 23 cm [9 inches] long) or minimal pruning (only to remove broken or damaged roots). Maple liners were field planted 107 cm (42 inches) apart in 213 cm (84 inches) wide nursery rows using a mechanical transplanter with a 45.7 cm (18 inches) opening.

One-half of the liners were planted in irrigated plots that received one inch of water applied through in-line emitter drip lines weekly from 1 August and through 30 September. The experimental design was a split plot with ten single plant replications completely randomized. The main plots were irrigation verses no irrigation and the subplots were root pruning versus no root pruning. The treatments within each subplot included the removal of the root stock stump at planting; removal of the root stock stump on 12 May; two bark spray applications, Dursban 4E (chlorpyrifos,) applied at 2.5 ml/liter (about 75 ml of solution per tree) and Dimilin 25W (diflubenzuron) applied at 0.6 g/liter (about 75 ml of solution per tree) each starting on 6 May and applied five times at two week intervals; and two soil drenches, Marathon 60 WSP (imidacloprid) applied at 2.4 g/liter and CGA-293343 25WG (thiomethaoxam) (Novartis Crop Protection, Inc.) applied at 1.3 g/liter. A 250-ml solution of each soil drench was applied within a 15.2 cm (6 inches) radius around the tree.

The field site was soil tested the previous fall and a recommended broadcast of phosphorus and lime was applied to adjust the soil (Waynesboro silt loam) to optimal levels. On 5 April and 24 June 1999, sidedress applications of 34-0-0 were applied at 50 lbs. N/A with a Vaughn fertilizer spreader. Weed control was accomplished with two tank-mixed applications of Factor at 1.0 lb. ai/A, Gallery at 0.5 lbs. ai/A and Finale at 1% solution on 8 April and 23 July applied in a 30.5 cm (12 inches) band on both sides of the trees. In September 1999 the trees were evaluated for borer damage and in November, height and caliper measurements were recorded. Tree mortality was documented during the spring of 2000.

Results and Discussion: After one growing season, the Northwood red maples treated with insecticides were minimally affected by flatheaded appletree borer (Table 1). Borer infestation was less among the repetitive bark treatments (i.e. Dursban or Dimilin) and the single drench treatment (i.e. Marathon or CGA-293343) than untreated trees. Borer incidence was 7.5% on trees treated with Dimilin in both irrigated and non-irrigated plots. Marathon, a systemic insecticide, is labeled for use as a soil drench to control insects on ornamental plants in nurseries and greenhouses. These data lead the authors to believe that a single soil

application would reduce the amount of insecticide used and ensure less pesticide exposure to the applicator. Current Tennessee recommendations are frequent insecticide (dursban or lindane) treatments to the trunk from mid-May through late June (2).

About 20% of the untreated liners were attack by the borer regardless of root pruning, irrigation, or root stump removal. Eighty-two percent of the maple liners that were attacked by the borer had died by the following spring.

Previous research has demonstrated that many insects selectively choose unhealthy or stressed plants for feeding or oviposition. This project was designed to observe the effect of plant stress (lack of water, root pruning, and root stump removal) on plant growth and the incidence of borer attack. During the growing season, there was adequate rainfall from planting through early August which likely negated the irrigation treatments. The effect of root pruning was initially considered an important stress factor on the incidence of borer attack; however, these preliminary results indicate that it is not.

Many ornamental tree liners are cut back near the ground after the first growing season to force a bud to develop into a strong straight trunk during the following growing season. This practice leaves a small stump with a crevice in the trunk near the soil line that is similar to the junction of a grafted plant. Borers often invade and oviposit in these crevices. Removal of the stump at planting or in early May did not affect borer presence in this study.

Plant height and caliper growth was similar among maple liners in the experiment (Table 1). During this experiment, plant processes that weaken plant vigor, such as root pruning and water stress, were not key factors in the incidence of borer attacks.

Significance to Nursery: This research demonstrates that red maples treated with timely applications of insecticide, regardless of application method, should control flatheaded appletree borer attack on newly transplanted liners. Future research is needed for better understanding of the borer life cycle to predict the optimal timing of pesticide applications, alternative pesticide control measures, and a better understanding of plant stress factors that determine borer preference.

Literature Cited

1 Brooks, Fred E. 1919. The Flat-headed Apple-Tree Borer. 1919. U.S. Dep. Agric. Farmer's Bulletin 1065, 15 pp.

2 Hale, Frank A. 2000. Commercial Insect and Mite Control for Trees, Shrubs, and Flowers. Univ. Tenn. Agric. Ext. Serv. Pub 1589, 59 pp.

3 Neilsen, D.G. Studying Biology and Control of Borers Attacking Woody Plants. 1981. Ann. Entomol. Soc. Am. 27(4):251-259.

4 Potter, Daniel A., G. Mark Timmons, and F. Carter Gordon. 1988. Flatheaded Apple Tree Borer (Coleoptera: *Buprestidae*) in Nursery-Grown Red Maples; Phenology of Emergence, Treatment Timing, and Response to Stressed Trees. J. Environ. Hort. 6(1):18-22.

5 Wohlers, Vicki. 1990. Bored to Death. American Nurserymen 172(6):76-89.

Table 1. Influence of soil and bark insecticide treatments, irrigation, and root pruning on the presence of flatheaded apple borer on newly planted red maple liners.

Treatments	Insecticide rate	Height (cm)	Caliper (mm)[Z]	Borer presence (%)[Y]
Irrigated plots				
Root pruning prior to planting				
Root stump removed at planting	-	162.3	15.8	0
Root stump removed early-May	-	159.2	15.6	15
Dursban 4E, bark spray	2.5 ml/liter	161.9	16.6	0
Dimilin 25W, bark spray	0.60 g/liter	156.9	15.9	5
Marathon 60WSP, soil drench	2.4 g/liter	160.6	15.8	0
CGA-293343, soil drench	1.3 g/liter	158.4	16.0	0
No root pruning				0
Root stump removed at planting	-	158.1	15.5	20
Root stump removed early-May	-	163.8	16.6	20
Dursban 4E, bark spray	2.5 ml/liter	164.2	16.1	0
Dimilin 25W, bark spray	0.60 g/liter	164.5	15.0	10
Marathon 60WSP, soil drench	2.4 g/liter	157.7	15.8	0
CGA-293343, soil drench	1.3 g/liter	153.9	15.9	0
Non-irrigated plots				
Roots pruned prior to planting				
Root stump removed at planting	-	159.4	15.1	20
Root stump removed early-May	-	167.3	16.8	5
Dursban 4E, bark spray	2.5 ml/liter	165.9	15.8	0
Dimilin 25W, bark spray	0.60 g/liter	160.4	14.5	5
Marathon 60WSP, soil drench	2.4 g/liter	164.7	15.8	0
CGA-293343, soil drench	1.3 g/liter	157.8	15.7	0
No root pruning				
Root stump removed at planting		172.1	16.9	0
Root stump removed early-May	-	163.9	16.5	20
Dursban 4E, bark spray	2.5 ml/liter	174.8	17.2	0
Dimilin 25W, bark spray	0.6 g/liter	162.1	16.7	10
Marathon 60WSP, soil drench	2.4 g/liter	155.1	15.4	5
CGA-293343, soil drench	90 g ai/A	165.9	16.1	0
Significant contrasts[X]:				
Irrigated vs. non-irrigated		NS	NS	NS
Root pruning vs. no root pruning		NS	NS	NS
Root stump removal at planting vs. in May		NS	NS	NS
Soil insecticide application vs. untreated controls		NS	NS	***
Bark insecticide applications vs. untreated controls		NS	NS	*

[Z]Caliper was measured 15.2 cm (6 inches) above the soil line.
[Y]Percentage of borer presence was based on a total of ten trees in each treatment.
[X]Significance at $p \leq 0.05$, NS = not significant.

Insecticide Evaluation for Control of Nantucket Pine Tip Moth, *Rhyacionia frustrana* (Comstock) using Pheromone Traps to Time Sprays

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Index Words: Insecticide evaluation, Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), Virginia pine, *Pinus virginiana* Mill., Christmas trees, Mimic, Dimilin, pheromone traps.

Nature of Work: Insecticides were evaluated for control of the Nantucket pine tip moth (NPTM) on Virginia pine Christmas trees. Pheromone trap catches were used to better time the spray applications.

The NPTM is the most serious insect pest of Christmas trees in Tennessee, Georgia (1) and possibly the southeastern U.S. This pest attacks Virginia, loblolly, shortleaf and other pines with the exception of white pine (1). The adult moths are small (0.36-0.6 inch wingspread) gray moths mottled with tiny brownish to brick-red patches on their wings (1). NPTM pupae over-winter in NPTM injured buds or shoots of infested pines (1). Adult moths usually begin to emerge in early April in Tennessee (2). Within a few days of emerging, moths mate and begin laying eggs on needles, developing shoot tips, or on buds (1). There are three generations per year in Tennessee (2) and north Georgia (1).

After hatching, the larvae feed on the new shoots under small tent-like webs. Larvae are brown to orange and up to 3/8 inch long. Larvae feed on elongating shoots and will tunnel into buds and eventually bore down the center of the stem. The whorl of needles at the end of the infested stem will initially turn pale orange, darkening over time to burnt orange. In three to four weeks, larvae construct a webbed cell in the dying shoot where they pupate (2). The pupal stage lasts one to two weeks (1).

Pheromone traps are commercially available to catch the adult male moths. Trap catches coincide with mating and egg laying. Expected first egg hatch is 25-30 days after the first moth emergence for generation one, 10-20 days for generation two, and 5-10 days for generation three (1). When pheromone traps are used to detect moth flights, insecticide sprays should be applied 14 days after peak adult emergence for first-generation moths in early spring. In the warmer months, spray 5-10 days after peak emergence for both the second and third generations (2). This study was conducted at a Middle Tennessee (Wilson County)

commercial Christmas tree farm. The Virginia pines were transplanted 3.25 years prior to the study in a 6 ft by 6 ft spacing. A NPTM pheromone trap was put out on May 23, 2000 to detect the second-generation flight. An initial peak trap catch occurred on June 4 followed by a more sustained peak from June 8-12 (Table 1). The timing of the spray test was planned to fit into the 5-10 day after peak trap catch parameters. On June 13, a water check versus the following commercial insecticide formulations were tested: Mimic 2LV (8 oz/acre), Mimic 2LV (4oz/acre) and Dimilin 25W (4 oz/acre). The two insecticides were chosen because of their long residual efficacy. This residual efficacy allowed the test to be conducted with only one spray application. The sprays were made at a 50 gal/acre rate using a CO_2 compression sprayer operating at 40 psi, equipped with two TXVS-18 hollow cone nozzles. Each treatment plot consisted of 6 trees (36 row ft). Each treatment was replicated 4 times. On July 7, whole tree inspections were made on all trees in the test. In each treatment, the number of trees with NPTM damage, the number of damaged shoots, the number of damaged terminal leader shoots, and the presence of larvae and pupae was recorded. The data were subjected to analysis of variance.

Results and Discussion: For percentage of trees with damage, number of damaged shoots per tree, number of damaged terminal leader shoots per tree and number of larvae per tree, insecticide treatments were significantly more effective than the water check ($P \leq 0.05$)(Table 2). The percent of water check trees with damage was 100 percent, versus no damage in the Mimic LV (8 oz/acre), 12.8 percent in the Mimic LV (4 oz/acre) and 20.8 percent in the Dimilin 25W. The 8 oz/acre Mimic LV was significantly more effective than the 4 oz/acre Mimic LV or the Dimilin 25W treatments. There was an average of 3.3 damaged shoots per tree in the water check versus none in the Mimic 2 LV (8oz/acre), 0.1 in the Mimic 2LV (4 oz/acre), and 0.2 in the Dimilin 25W. The average number of damaged terminal leader shoots per tree was 0.9 in the water check, none in the Mimic 2LV (8oz/acre), 0.1 in the Mimic (4 oz/acre), and 0.2 in the Dimilin 25W. There was an average of 2.8 larvae in the water check, none in the Mimic 2LV (8 oz/acre), and 0.1 larvae in both the Mimic 2LV (4 oz/acre) and the Dimilin 25W treatments. There were no significant differences for the average number of pupae (0.2 pupae per tree in the water check, and no pupae for any of the insecticide treatments). No phytotoxicity was observed during the study. While alternative spray timing was not tested in this study, the use of the recommended spray timing worked well with the insecticides tested.

Significance to the Industry: Both the insecticides tested exhibited excellent residual control of second generation NPTM larvae when applied 9 days after the initial peak pheromone trap catch.

Literature Cited:

1. Ellis, H. C. 1992. Insect Pests of Christmas Trees. Cooperative extension Service, The University of Georgia College of Agriculture and Environmental Sciences, Athens.

2. Hale, F. A., Formerly by J. Yanes Jr., R. E. Caron and H. Williams. 1998. Nantucket Pine Tip Moth. SP290-U. The University of Tennessee Agricultural Extension Service.

Table 1. Nantucket Pine Tip Moth Pheromone Trap Catches in Virginia Pine Christmas Trees (Wilson County, TN)

Date	Moths
May 23	Put out trap
May 26	2
May 28	0
May 30	0
June 3	12
June 4	46
June 5	12
June 6	11
June 7	12
June 8	26
June 9	27
June 10	36
June 11	30
June 12	27

Table 2. Efficacy of Insecticide Treatments for Nantucket Pine Tip Moth Control on Virginia Pine Christmas Trees (Wilson County, Tennessee).

Treatment	Rate/Acre	Percent Damaged Trees	Damaged Shoots/ Tree	Damaged Terminals/ Tree	Larvae/ Tree	Pupae/ Tree
Mimic 2LV	8 fl oz	0.0 c	0.0 b	0.0 b	0.0 b	0.0 a
Mimic 2LV	4 fl oz	12.8 b	0.1 b	0.1 b	0.1 b	0.0 a
Dimilin 25W	4 oz	20.8 b	0.2 b	0.2 b	0.1 b	0.0 a
Water Check		100.0 a	3.3 a	0.9 a	2.8 a	0.2 a

Means followed by the same letter do not significantly differ (P=0.05, Duncan's MRT)

Management of the Mealybug *Phenacoccus madeirensis*

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Index Words: *Phenacoccus madeirensis*, Insect Growth Regulators (IGR), Insect Management

Nature of Work: *Phenacoccus madeirensis* has become the most difficult species of mealybugs to manage on Georgia ornamentals. Adult females were described by Green (1923) and Williams (1958, 1987) as greenish and oval-shaped, dusted with white waxy secretions. *Phenacoccus madeirensis* was included in with the Mexican mealybug but is now a separate species. There are four instars in the female's life cycle. The first instar is a mobile crawler, 2nd and 3rd instars have a waxy coating on the body with legs but are not as mobile, and 4th instar is the reproductive adult. Male mealybugs have five instars, with the first and second indistinguishable from females, and the 3rd and 4th instars enclosed within a filamentous wax cocoon. Upon completing development, the 5th instar male emerges as a winged, non-feeding adult. The purpose of these experiments was to evaluate the efficacy of several insecticides for control of *P. madeirensis*. Initial screening trials determined the activity of selected compounds currently used against mealybugs. These insecticides represented a wide array of modes of action including the insect growth regulators (IGRs) [azadiractin,(Azatin XL 0.26EC), kinoprene (Enstar II 5EC), pyriproxyfen (Distance 0.86EC), fenoxycarb (Precision 25WP)], the carbamates [bendiocarb (Turcam 76WP), methiocarb (Mesurol 75WP), carbaryl (Sevin 50W)], the pyrethroids [bifenthrin, (Talstar T&O 10WP), fenpropathrin, (Tame 2.4EC), fluvalinate (Mavrik 2EC), cyfluthrin (Decathlon 20WP)], the organophosphates (OP) [acephate, (Orthene 75S), chlorpyrifos (Dursban 50WP), diazinon, (Diazinon 25EC)], soap (M-Pede), and oil (Sunspray Ultra-Fine, Triact 80). Insecticides that performed best in the initial screening were used in the second set of experiments.

In the second group of experiments, coleus 'Volcano' seeds were planted and placed on a greenhouse mist bench at the University of Georgia, Georgia Station, Griffin, GA. After germination, the seeds were transplanted into 6" ultra azalea pots and placed on raised benches in the greenhouses at the Georgia Mountain Station, Blairsville, GA. Coleus were infested by placing one female and 3-5 small nymphs per plant; the insects were allowed to establish for two weeks prior to treatment. In the preliminary trials: Enstar, Precision, Distance, Talstar, Orthene, Dursban and Turcam showed the best activity. Each insecticide was applied twice, at a two-week interval. Weekly observations were made to

evaluate mealybug populations. For both experiments, population levels were evaluated based on a rating scale from 0-100 where 0 equaled no mealybugs and 100 equaled a plant completely covered with mealybugs. Data were analyzed using Henderson's Corrected Mortality (percent effectiveness). (Henderson's Corrected Mortality is inversely related to the evaluation rating scale, which was based on percent infestation). A randomized compete block design was used with five replications, two plants per replication.

In the second experiment the spreader sticker, Triton 80, and Sunspray Ultra-Fine oil were added to one insecticide from different chemical classes (i.e., pyrethroid, IGR, and OP) to determine if efficacy could be enhanced (Table 2). A spray schedule of two sprays two weeks apart was used.

Results and Discussion: In the first experiment the IGRs Precision and Distance did not reduce the population in the first week (Table 1). IGRs are only active against immature insects and may take longer to kill target insects. The IGR, Enstar, did reduce the population by 48% indicating activity on immature mealybugs. Talstar did not reduce the population in the first week, untypical for a pyrethroid. However, by the fourth week, Talstar had reduced the population by 100%. There was good reduction in the population of mealybugs treated with Orthene, Turcam and Dursban in the first week. There was a reduction in the population of all treatments after four weeks. The greatest reduction were in the Enstar, Talstar, Orthene, Turcam and Dursban treatments (Table 1) with over 90% population reduction.

In the second experiment, the additives did not enhance activity of the insecticides (Table 2). The three treatments of Talstar resulted in 100% mortality and Orthene with over 93% reduction. This was excellent control. There was a difference among the three Distance treatments; the addition of oil unexpectantly greatly reduced efficacy of Distance. The percent reduction was greater in the oil and Distance treatments than in the combination. This treatment needs to be tested again to determine if there is an antagonism between Distance and oil. This reduction in efficacy was consistent over the eight weeks of the study; data for only the first and fourth weeks are reported in this paper.

Significance to the Industry: Enstar, Orthene, Turcam, Talstar, and Dursban were most efficacious against the mealybug *P. madeirensis* if applied early in population establishment. Distance and Sunspray Ultra-Fine oil provided approximately 80% reduction and would also fit well in an IPM program. To obtain the best reduction in mealybug populations, at least two applications are necessary.

Literature Cited:

1. Green, E.E. 1923. Observations on the Coccidae of the Maderia Islands. Bulletin of Entomological Research 14: 87-97.

2. Williams, D.J. 1958. The mealybugs (Pseudococcidae: Homoptera) described by W.H. Maskell, R. Newstead, T. D. Cockerell and E. E. Green from the Ethiopian Region. Bulletin of the British Museum of Natural History (Entomology) 6: 203-236.

3. Williams D. J. 1987. *Phenacoccus gossypii* Townsend & Cockerell, *P. madeirensis* Green and some related mealybugs species (Homoptera: Pseudococcidae). Bulletin of Entomological Research 77: 335-356.

Table 1: Percent effectiveness of insecticides against *P. madeirensis* when two sprays are applied.*

Treatment	Rate oz/100 gal	Week 1	Week 4
Enstar II	16 fl oz	48%	95%
Distance	12 fl oz	0%	68%
Precision	4 oz	0%	53%
Talstar	32 oz	0%	100%
Orthene TT&O	11 oz	74%	93%
Turcam	20 oz	80%	100%
Dursban	16 oz	100%	100%

* Mean ratings were corrected using Henderson's Corrected Mortality.

Table 2: Percent effectiveness of insecticides against P. madeirensis with the addition of spreader sticker and oil with two applications.*

Treatment	Rate oz/100 gal	Week 1	Week 4
Triton 80	0.26 fl oz	0%	0%
Sunpray Ultra-Fine oil	1.28 fl oz	69%	78%
Distance	12 fl oz	0%	82%
Distance+Triton	12 fl oz+0.13 fl oz	60%	82%
Distance+Sunspray	12 fl oz+0.64 fl oz	16%	34%
Talstar T&O	32 oz	82%	100%
Talstar+Triton	32 oz+0.13 fl oz	84%	100%
Talstar+Sunspray	32 oz+0.64 fl oz	94%	100%
Orthene TT&O	11 oz	100%	99%
Orthene+Triton	11 oz+0.13 fl oz	98%	98%
Orthene+Sunspray	11 oz+0.64 fl oz	64%	93%

* Mean ratings were corrected using Henderson's Corrected Mortality.

Integrating Chemistry with Natural Enemies for Control of Aphids and Whiteflies

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Index Words: aphids, *Aphis gossypii*, biological control, insecticide, compatibility, *Aphidius colemani*, parasitic wasp, beneficial insect

Nature of Work: There currently exists an increasing interest in the incorporation of biological control into existing insect management practices among greenhouse and nursery production professionals (King and Greene 2000). However, due to the low tolerances for pest damage in the ornamental plant industry, insecticides remain an important and often indispensable part of most greenhouse pest management programs. The potential for integration of biological control into traditional pest management has generated an interest in using chemicals that are more compatible with natural enemies. Insecticides with novel chemistries are currently marketed that are more selective than traditional neuro-active insecticides (Pietrantonio and Benedict 1999, Liu and Chen 2000). However, there is still a need for sound, scientifically validated information on the compatibility of these new insecticides with biological control agents. Endeavor™ 50WG (Pymetrozine) is one such novel insecticide. Endeavor™ 50WG is a systemic, translaminar compound in the novel pyridine azomethine class that stops feeding in aphids and whiteflies. Endeavor™ 50WG is currently marketed for use in greenhouses and nurseries. Before pymetrozine-based insecticides can legitimately be marketed as benign to natural enemies, statistically sound specificity research needs to be documented. The goals of this research were to 1) determine the efficacy of Endeavor™ 50WG on *Aphis gossypii* Glover infesting chrysanthemum and 2) assess the impact of Endeavor™ 50WG on a representative aphid natural enemy, *Aphidius colemani* (Viereck). The choice of *A. colemani* was based on a number of factors including its high rate of efficacy and selectivity on aphids, the natural occurrence of this species in aphid infestations and its commercial availability.

Materials and Methods: *Greenhouse Trial.* The activity of Endeavor™ 50WG was tested on potted chrysanthemums infested with *A. gossypii*. Each treatment (a 3-by-8 array of 24 pots spaced 1 foot apart) was composed of a mixture of three cultivars; 'Charm', 'Pomona', and 'Miramar'. Four treatments (water, Endeavor™ 50WG at 0.025 oz/gal (0.185 g/l) (low rate), Endeavor™ 50WG at 0.05 oz/gal (0.37 g/l) (high

rate) and Orthene™ at 1.0 oz/gal (8 ml/l) applied according to label recommendations) were replicated 4 times in a completely randomized design. Each of the 16 experimental units were treated weekly using a Solo® 15 liter capacity backpack sprayer (Model #475, Solo Inc., Newport News, VA) equipped with a standard adjustable hollow cone spray head and calibrated at 60 lb/in^2 (4.2 kg/cm^2). Sprays were applied to maximize contact of material with both the upper and lower leaf surfaces of the plants. Applications were made on days 0, 7 and 14 of the trial. To assess compatibility with an aphid natural enemy, 200, commercially reared, adult *A. colemani* were released into the center of the study greenhouse 24 hours after the first application. Parasitized aphids (mummies) were subsequently monitored on sample plants from each experimental unit simultaneously with aphid density monitoring. The presence of mummies on insecticide-treated plants giving rise to adult wasps, equivalent to the water-treated control plants, was viewed as an indicator of selectivity.

To quantify population suppression by each of the treatments, aphids and mummies were censused at 0, 3, 7, 14 and 21 days after the first application by removing one plant from each of four randomly selected pots per experimental unit (4 pots x 4 reps x 4 treatments = 64 plants per sample date). Aphid and mummy densities were determined for each of the top 10 leaves from the 64 plants (i.e. 640 leaves on each sample date). Upon completion of each aphid census, plants were placed individually into a white paper bag and sealed at the top with staples. Wasps emerged and died within the 2 weeks the bags were kept shut, after which the adult *A. colemani* cadavers were counted. This number represented all developing wasps on the sample date that subsequently completed development.

Significant differences in aphid density and parasitoid densities were sought via a one-way analysis of variance (ANOVA) with treatment as the independent factor (SigmaStat 2.0 1997).

Laboratory, insecticide compatibility bioassays. Two laboratory assays were conducted to assess the impact of Endeavor™ 50WG on the aphid parasitoid, *A. colemani*. In the first assay we investigated the effect of Endeavor™ 50WG exposure on the development and emergence of wasps; and in the second assay we evaluated the repellency of Endeavor™ 50WG to adult *A. colemani*. For the development bioassay we washed 10, 50-ml conical screw cap centrifuge tubes (Continental Laboratory Products Inc., San Diego, CA) with one of three treatments: water, Endeavor™ 50WG at 0.025 oz/gal (0.185 g/l) or Endeavor™ 50WG at 0.05 oz/gal (0.37 g/l). After letting the tubes air dry for approximately 6 hours at room temperature and ambient humidity, we placed five, 1-2 day

old parasitized aphids (mummies) into each tube. The tubes were checked after 2 hours and then at 12-hour intervals, and the numbers of adult wasps counted to assess the development time. The data were analyzed by two-way analysis of variance with time and treatment as independent variables (SigmaStat v.2.0, 1997).

For the repellency bioassay, individual chrysanthemum leaves (cv. 'Pomona') were dipped into beakers containing solutions of either Endeavor™ 50WG at 0.025 oz/gal (0.185 g/l), Endeavor™ 50WG at 0.05 oz/gal (0.37 g/l) or tap water. The leaves were allowed to air dry and placed singly into one side of sterile plastic 9 cm diameter Petri dishes (Becton Dickinson and Co, Lincoln Park, NJ). A single female *A. colemani* wasp was then placed into each dish and observed for 5 minutes. The total time spent on the half of the dish containing the treated leaf was measured using a stopwatch and timer. Thirty replications were performed for each of the three treatments with a separate wasp and leaf for each replication. Among treatment differences were detected using a one-way analysis of variance on ranks (Kruskal-Wallis test, SigmaStat 2.0 1997).

Results: ***Greenhouse efficacy trial***: Within 3-days after treatment, significant difference in aphid densities were observed (Table 1) ($F= 34.1483$, 3 df, $p< 0.001$). The plants treated with water had significantly higher aphid numbers than those of the other three treatments on days 3, 7 and 14 of the trial (Table 1). No statistically significant differences in aphid density occurred among the insecticide treatments throughout the trial. After day three, aphid densities in the water treated plants declined from the effects of natural enemies, which resulted in aphid densities being statistically indistinguishable from the other treatments by day 21 ($F=1.855$, 3 df, $p=0.191$).

Table 1. Mean number of aphids per leaf averaged across four replicates per treatment in greenhouse efficacy trial.

Treatment	Day 0	Day 3	Day 7	Day 14	Day 21
Water	17.2 a	20.2 a	16.4 a	2.2 a	0.1 a
Endeavor™ 50WG	27.0 a	0.6 b	0.1 b	0.0 b	0.0 a
Endeavor™ 50WG	21.3 a	0.5 b	0.2 b	0.0 b	0.0 a
Orthene	29.8 a	0.0 b	0.1 b	0.0 b	0.0 a

Means within a column followed by the same letter are not significantly different at $p< 0.05$ (Fisher LSD).

Mummy density was also statistically similar among treatments prior to the first application. There was a small naturally occurring aphid parasitism on day 0 that was supplemented by the release of additional wasps on day 1. Mean numbers of mummies underwent an initial increase on all but the acephate treated plants. However, as aphid numbers declined and there were fewer hosts to parasitize, mummy densities also declined until there were no significant differences among treatments and almost no mummies remaining in any treatment by day 21. Significant differences in mummy numbers were found on days 3 and 7 (Table 2).

Table 2. Mean number of mummies per leaf averaged across four replicates per treatment in greenhouse efficacy trial.

Treatment	Day 0	Day 3	Day 7	Day 14	Day 21
Water	0.2 a	1.2 a	1.5 a	0.4 a	0.0 a
Endeavor™ 50WG	0.2 a	0.5 b	0.1 b	0.0 a	0.0 a
Endeavor™ 50WG	0.2 a	0.5 b	0.1 b	0.0 a	0.0 a
Orthene	0.2 a	0.0 c	0.1 b	0.0 a	0.0 a

Means within a column followed by the same letter are not significantly different at $p < 0.05$ (Fisher LSD)

As the number of aphids declined the ratio of mummies-to-mummies plus aphids (%mummies) approached one (Table 3). On those plants with 100% parasitism the number of mummies was very low (0-2 mummies). On day 21 there were no aphids and no mummies found on the plants sampled from the Endeavor treated plots.

Table 3. Mean percent mummies per leaf averaged across 4 reps per treatment in a greenhouse efficacy trial.

Treatment	Day 0	Day 3	Day 7	Day 14	Day 21
Water	1.1 a	5.8 a	10.5 b	12.5 b	71.7 a
Endeavor™ 50WG	1.1 a	45.9 a	76.4 a	100 a	na
Endeavor™ 50WG	1.1 a	54.1 a	39.1 ab	100 a	na
Orthene	0.7 a	52.8 a	29.1 b	100 a	100 a

Means within a column followed by the same letter are not significantly different at $p < 0.05$ (Fisher LSD)

Laboratory compatibility bioassays: Although emergence patterns varied significantly with time ($F=45.45$, df = 6, $P < 0.0001$), no significant among-treatment differences in time to emergence were detected ($F=0.678$, 2 df, $P=0.509$) (Fig. 1). These data suggest that Endeavor™ 50WG residue exposure does not retard the development of *A. colemani*.

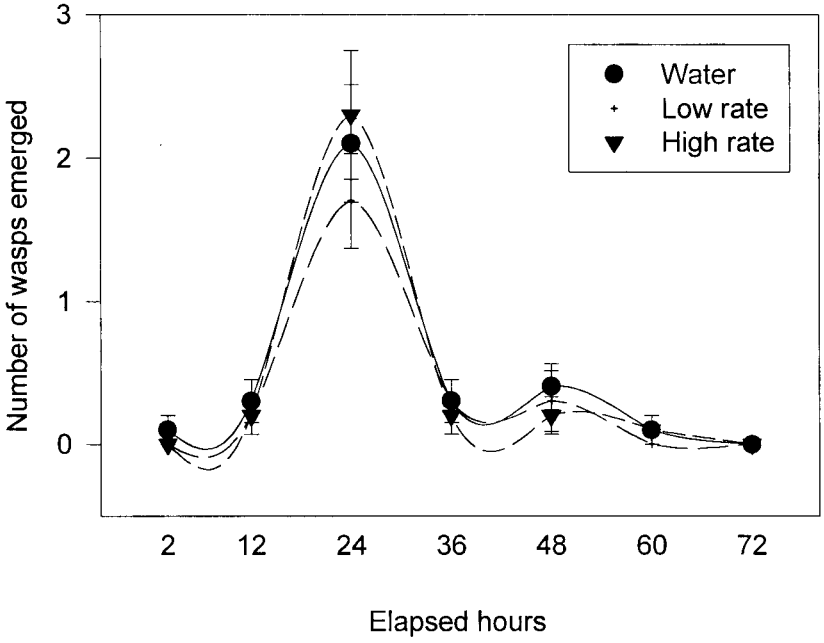

Figure 1

In addition, no significant differences were found between treatments in the repellency bioassay ($H=0.979$, 2 df, $P=0.613$). Wasps spent the same amount of time on the Petri dish half with a treated leaf as the half without a leaf regardless of treatment suggesting that *A. colemani* females are not strongly repelled by Endeavor™ 50WG residues.

Significance to the Industry. Selectivity has been described as the use of a pesticide to kill a phytophagous pest while not affecting natural enemies (Croft 1990); and a selective insecticide as being more toxic to a pest than to beneficial species (Stark et al 1995). Results from our trials indicated Endeavor™ 50WG to be as effective as acephate in controlling aphids. In addition, percent parasitism remained high in the trial for the Endeavor™ 50WG treated plants. Within the context of an IPM program, Endeavor™ 50WG may best be used by: (1) treating only those areas where aphids are problematic and not successfully controlled by the indigenous natural enemies, (2) as a rescue treatment in

cases where biological control is ineffective, (3) as an integrated approach to aphid pest management.

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Literature Cited:

1. Croft, B.A. 1990. Arthropod biological control agents and pesticides. Wiley, New York.

2. King, A.I. and I.D. Greene. 2000. Proceedings for the 16th conference on insect & disease management on ornamentals. Society of American Florists, San Jose, CA.

3. Liu, T.X. and T.Y. Chen. 2000. Effects of the chitin synthesis inhibitor buprofezin on survival and development of immatures of *Chrysoperla rufilabris* (Neuroptera: Chrysopidae). J. Econ. Entomol. 93(2): 234-239.

4. Pietrantonio, P.V., and J. H. Benedict. 1999. Effect of new cotton insecticide chemistries tebufenozide, spinosad,and chlorfenapyr, on *Orius insidiosus* and two *Cotesia* species. Southwest. Entomol. 24:21-29.

5. SigmaStat 2.0. 1997. SPSS Inc. Chicago, IL.

6. Stark, J.D., P.C. Jepson and D.F. Mayer. 1995. Limitations to the use of topical toxicity data for predictions of pesticide side effects in the field. J. Econ. Entomol. 88(5): 1081-1088.

An Emerging Foliar Pest of Canna in Virginia

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Index words: Lesser canna leaf roller, *Geshna cannalis,* Life history

Nature of Work: The lesser canna leafroller, *Geshna cannalis* (Quaintance) together with the larger canna leafroller, *Calpodes ethlius* (Stoll), can be serious pests of canna. The larger canna leaf roller has not been observed in Virginia; however, the lesser canna leafroller has emerged as a serious pest in nurseries and commercial and residential landscapes in Virginia. Very little is known about the latter's distribution. It has been recorded as a pest of canna in Florida, Mississippi, and North Carolina (McAuslane, 2000; Baker 1994, Kimball, 1965). It is likely that this species is present wherever cannas can be grown. It is suspected that the series of mild winters in Virginia has led to increased populations of this insect.

Results and Discussion: The lesser canna leafroller is reported to overwinter as medium to large larvae within rolled, dead leaves (Baker 1994) and in the pupal stage in dead canna leaves (McAuslane, 2000). In Virginia, we observed first, third, and fourth instar larvae in dead foliage in December. Adults reportedly appear in February and March in Florida, March and April in North Carolina (Baker, 1994). We collected the first adult of the season March 30, 2000; however these plants had been placed in a heated greenhouse. Eggs are laid on the foliage, and the new larvae mine into the leaves until they outgrow the tunnels. It frequently feeds within leaves that have not yet expanded, tying the unfurled leaf together with silk, to prevent leaf expansion. They then chew a circular hole to the upper surface and begin to roll the leaves. The larvae which are light green reach one inch in length. Pupation occurs on the foliage in a silken cocoon, and the next generation of adults emerge about 10 days later. Adults are small light-brown pyralid moths with a 1-inch wingspan.

Feeding injury results in foliage that is ragged in appearance, and it often turns brown and dies. In natural landscapes, one can expect this insect in late spring as the foliage begins to appear. However, when cannas are grown in greenhouses or in overwintering structures, the seasonal biology can be greatly altered. An unusual, severe infestation of lesser canna leafroller was reported in January, 2000, in the Hampton Roads area, on cannas being grown in a greenhouse for a winter garden show.

Significance to industry: Cutting dead canna plants to the ground and removing the cut material from the property in late winter is an excellent technique to reduce the overwintering stages and the subsequent spring population. Partial control can be achieved when larvae are first observed by physically pressing the leaves to kill the young larvae. Any contact insecticide treatment should be directed downward to penetrate the open tops of the rolled leaves. Due to their concealed behavior, the best chemical strategy would be the application of a pyrethrin, either natural or synthetic (e.g. Astro, Decathlon, DeltaGard, Scimitar, Talstar). These chemicals act as irritants and will coax the insect from its concealed location leading to greater contact with the chemical. Acephate (e.g. Orthene) would also be effective, considering its systemic activity. As always, monitoring the crop is essential in minimizing damage.

Literature Cited:

1. McAuslane, H.J. 2000. Featured creatures- lesser canna leaf roller. Univ. of Fl. http.//www.ifas.ufl.edu/-insect/om/L - canna - leaf roller.htm

2. Baker, J.R. 1994. Insect and related pests of flowers and foliage plants: some important, common, and potential pests in the southeastern United States. NCSU. Bull. AG 136. Raleigh.

3. Kimball,C.P. 1965. The Lepidopteraof Florida: An annotated checklist. Div.Plnt.Ind. Fl. Dept. Agric., Gainesville.

Arthropod Predators Associated with the Yellow-Poplar, *Liriodendron tulipifera* L.

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Index Words: Yellow-poplar, Tuliptree, *Liriodendron tulipifera* (L.), Predator, Arthropod

Nature of Work: Yellow-poplar (*Liriodendron tulipifera* L.), also known as tuliptree or tulip- poplar, is a favorite ornamental and shade tree, primarily due to its large tulip-like flowers and pyramidal shape. This fast growing, large tree needs plenty of room to be fully appreciated. In addition, it is a valuable timber and honey resource with a botanical range that covers most of the eastern United States (1). The relatively high population number of yellow-poplars in the eastern United States make this species an important hardwood in forest ecology providing food and shelter for a myriad of organisms.

Several insect pests often pose a threat to the yellow-poplar. The tuliptree scale (*Toumeyella liriodendri* (Gemlin)) and the tuliptree aphid (*Illinoia liriodendri* (Monell)) are the two most common insect pests of yellow-poplar and are found anywhere yellow-poplar grows. Honeydew excreted by these two insects provides a substrate for sooty mold development which turns the leaves and bark black reducing photosynthesis and the aesthetic value of the host tree (3). The tuliptree scale is particularly harmful to small trees, where populations as low as 38 individuals per tree have been reported to kill 2-year-old saplings (2). The objective of this study was to identify the arthropod predators that are associated with yellow-poplar in two settings, a mixed hardwood forest and a plantation, with the goal of identifying potential biological control agents.

Arthropods were collected from May 1999 through October 1999 at the University of Tennessee Plant Science Experiment Station in Knox County, TN and at the University of Tennessee Forest Experiment Station and Arboretum in Anderson County, TN. using three sampling methods: flight interception trapping, fogging, and direct sampling techniques. A total of 12 flight interception traps, 6 at each site, were placed in the canopies of mature yellow-poplars where they continuously collected specimens. Directly collected samples were taken weekly from each site using a beat sheet, sweep net, tweezers and an aspirator. Fog samples were taken monthly from mature trees at each site using a modified

Dyna-Fog Golden Eagle™ fogger and a standard, broad spectrum, synthetic, pyrethroid insecticide (Asana XI, 0.66 emulsifiable concentrate). Tarpaulins were placed under the canopy to catch the fallen arthropods, and a modified handheld Dustbuster™ vacuum was used to collect the arthropods.

The physical characteristics of the two sites are quite different. The plantation site consists of a pure stand of 100 mature tuliptrees bordered by the Tennessee River, a mature 200 tree pine plantation, and an adjacent grassy meadow. In addition, farm land is directly across the river and a major highway passes a few hundred yards away. In contrast, the mixed hardwood forest site is located on approximately 2,260 acres of managed forest land. About 50% of this acreage has always had forest cover. Approximately, 80% of the forest is greater than 5 years old, 15% is less than 5 years old, and 5% is experimental tree plots and power line right of ways.

Results and Discussion: Of the 725 insect species identified from this study, 124 were predators representing 70 genera, 33 families, and 7 orders (Table 1). The number of insect predator species and families collected at the two sites was similar. However, only 31 species were collected at both sites. Predaceous Coleoptera were represented by 38 species at the plantation site and by 46 species at the mixed hardwood forest site. The highest number of Coleoptera species at the plantation site were primarily Coccinellidae and Staphylinidae. Coccinellidae were represented at the plantation site by 18 species and at the mixed hardwood forest site by 11 species of which 10 species were found in both sites. The Asian lady beetle, *Harmonia axyridis* (Pallas), introduced into the United States in the late 1970's and early 1980's from East Asia to control orchard and field crop aphids, was the most common insect predator collected at the two sites. Higher population numbers were obtained from the plantation site compared to the mixed forest site. *Didion punctatum* (Melsheimer), *Chilocorus stigma* (Say), and *Zilus horni* Gordon where abundant at the plantation site. The non-predaceous, mildew eating *Psyllobora vigintimaculta* (Say) was collected only at the mixed hardwood forest site. The Staphylinids constitute a group of primarily predaceous beetles which typically hunt prey on the ground. This family was represented by 12 species at the plantation site and by 8 species at the mixed hardwood forest site. Clerids are common predators of bark and wood boring beetles and were represented by three species at the plantation site and by seven species at the mixed hardwood forest site. Of these, *Cymatodera undulata* (Say) was the most abundant species collected at both sites. The cantharids were represented by 11 species (5 species in mixed hardwood forest, 8 at plantation forest) with two species, *Cantharis bilineatus* Say and *Chauliognathus marginatus* (Fab.), collected from both sites.

Predaceous Hemiptera were represented by 12 species in 8 families, 9 species from the mixed hardwood site and 6 from the plantation site. *Jaylsus spinosus* (Say), (Berytidae) and *Podisus maculiventris* Say, (Pentatomidae) were only collected at the mixed hardwood forest site, while *Myodocha serripes* Olivier, (Lygaeidae), *Geocoris uliginosus* (Say), (Lygaeidae), and *Corticoris pulchellus* Neidemann, (Isomatopidae) were only collected at the plantation site. Fifteen specimens of the uncommon group Isomatopids (jumping tree bugs) were collected from a fog sample at the plantation site, but none were collected at the mixed hardwood forest site. Anthocoridae were represented at the mixed hardwood forest site by 4 species with *Asthenidea temnostethoides* Reuter the most common, while *Orius insidiosus* Say was the only anthocorid collected at the plantation site.

Four species of Neuroptera representing 4 families were collected with the species being three times more abundant at the mixed hardwood forest site than at the plantation site. The yellowjacket, *Vespula maculifrons* (Buysson) (Vespidae), was abundant at the mixed hardwood forest site, but not collected from the plantation site. The leaf-rolling cricket, *Camptonotus carolinensis (*Gerstaeker), a nocturnal predator of aphids, was the most common orthopteran collected from both sites. An arboreal cricket, *Oecanthus augustipennis* Fitch (Gryllidae), was commonly collected at the mixed hardwood forest site. Females may seriously damage host plants during oviposition, which may out weigh any benefit gained from their feeding habits.

The spider taxa constituted 25.6% of the predator population at the plantation site and 16.5% at the mixed hardwood forest site. Some 35 spider species were collected from the two sites with the plantation site having more than twice the number of species as the mixed hardwood forest site. The high numbers may be due to the lower and larger canopy characteristic of the plantation trees, the availability of grass between rows of trees providing additional habitats for prey species, or possibly the large amount of prey coming from the Tennessee River in the form of aquatic insects.

Significance to Industry: The results of this study provide a better understanding of the predaceous arthropods associated with yellow-poplar, about which little is known. Such information will be useful in development of management programs for pests of yellow-poplar and possibly other nursery plants. For example, the yellow-poplar may serve as a cultivated field border to increase predator populations within agricultural systems. Home owners and landscapers may use this information to enhance the diversity of beneficial arthropods in an area

by their choice of shade tree species for their properties. Also, this study provides insight on the effects of landscape characteristics on the arthropod predator guild associated with the yellow-poplar.

Literature Cited:

1. Beck, D. E. and L. Della-Bianca. 1981. Yellow poplar characteristics and management. U.S. Dept. Agric. For. Serv. Handbook No. 583.

2. Burns, D. P. 1964. Formicidae associated with the tuliptree scale. Ann. Entomol.Soc. Amer. 57:137-39

3. Simpson, J. D. and P. L. Lambdin. 1983. Life history of the tuliptree scale, *Toumeyella liriodendri* (Gmelin), on yellow-poplar in Tennessee. Tennessee Farm and Home Sci. 125: 2-5.

Table 1. Number of families and species of predators collected from a mixed hardwood and plantation forest in Anderson and Knox Counties, TN, respectively.

Order	Mixed Hardwood Forest		Plantation Forest		Total Number		
	Families	Species	Families	Species	Families	Species	Shared Species
Orthoptera	2	2	2	1	2	2	1
Mantodea	0	0	1	1	1	1	0
Hemiptera	6	9	5	6	8	12	3
Coleoptera	13	45	9	40	13	68	17
Neuroptera	4	4	3	3	4	4	3
Diptera	2	7	2	6	2	10	3
Hymenoptera	3	17	3	14	3	27	4
Aranea		29		14		35	

Identification of Native Pollinators for Use in Dogwood Breeding Programs

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Index Words: Flowering Dogwood, Pollinators, Andrenidae, Halictidae, Anthracnose Resistance

Nature of Work: The flowering dogwood, *Cornus florida* L., is one of the most popular ornamental trees, especially in residential neighborhoods in the eastern United States, where it is the focus of many community springtime festivals (2). Dogwoods contribute significantly to the economy of communities throughout this region. For example, dogwood sales in Tennessee alone were estimated at 30 million dollars in 1989 (8), and dogwoods can generate gross receipts of $60,000 per acre in well managed nurseries in the eastern and northwestern United States (Windham, personal communication). Dogwoods are also important to the ecology of eastern forests, as their decaying leaves provide high levels of calcium (1), and the lipid-rich berries provide food for more than 80 species of birds and mammals (3, 7).

Beginning in the late 1970s, dogwood populations have declined dramatically in the northeastern United States. This decline has been attributed primarily to dogwood anthracnose, a fungal disease caused by *Discula destructiva* Redlin (6). Dogwood anthracnose has spread throughout much of the northeastern United States and south through the Appalachian Mountain region into Tennessee and northern Alabama. This disease causes leaf spots and blights, profusion of water sprouts (epicormic shoots) along limbs and trunks, annual limb and trunk cankers, and eventual tree death. Dogwoods in commercial nurseries and landscape plantings also have been impacted by this disease, but generally have not been as devastated as natural populations. In the landscape and commercial nursery settings, dogwoods can be grown under sunny, airy conditions that place the trees at low risk for dogwood anthracnose. Unfortunately, public misconception about the nature of dogwood anthracnose has discouraged buyers and depressed sales of dogwood. Research is underway at The University of Tennessee to enhance the efficiency and profitability of commercial nurseries involved in dogwood production by developing a pest management system for dogwood anthracnose that utilizes host plant resistance, i.e., the use of characteristic genetic traits that enable plants to survive, tolerate, or resist the mechanisms of disease. This research has led to the development of cultivars of flowering dogwood via discovery and breeding that are resistant to dogwood anthracnose. One of the limiting factors to breeding efforts is the efficiency of seed set of dogwoods. Improvement

in seed set efficiency would provide more breeding material, as well as plant material for propagation and evaluation. Seed set efficiency is, most likely, directly related to pollination of dogwood flowers, highlighting the importance of insect pollinators in efforts to breed disease-resistant cultivars. The most ubiquitous insect pollinators, honey bees, are not attracted to dogwood flowers in large numbers. Fewer than 25 specimens have been collected during two seasons of observing insects on flowers of dogwood. In breeding experiments, honey bees are enticed to visit the flowers by placing a drop of honey on the bracts. This procedure is labor intensive, time consuming and expensive, and may yield poor results in terms of seed set.

This research is part of an ongoing study of the insects visiting flowers of flowering dogwood. A description of the sample sites, collecting methods and a partial list of species collected can be found in the initial study (5). To determine which native pollinators may be used to enhance fruit set in the dogwood-breeding program, we analyzed the pollen gathered by bees foraging on the flowers of flowering dogwood. Bees were chosen for pollen analysis based on the large number of species and individuals collected on dogwood flowers. Many of these were females foraging for pollen. During the course of this study we have identified 71 species of insects from flowers of flowering dogwood, including 28 species of bees. Once the data from the current season have been analyzed we expect the total number of species to exceed 100, and that the number of bees will approach 40 species.

In this paper we report on the evaluation of pollen loads found on 18 species of bees. Pollen was removed from the bees body with a fine camel hair brush and placed on scanning electron microscope stubs that had been prepared with the application of a carbon-coated disc of double sticky tape. The samples were sputter-coated with gold palladium and viewed with an Hitachi S-3000N Scanning Electron Microscope with an operation of 10kv. Pollen from the bees was identified by comparison with pollen from field-collected dogwood flowers, and by using published micrographs (4). Pollen identifications were confirmed using magnifications of 400-1000X.

Results and Discussion: Bees were the most abundant and diverse insect group found on dogwood flowers at all sites, with 229 specimens representing 6 families and 28 species collected during 1999 (Table 1). Pollen from flowering dogwood was found on 18 species of bees. The pollen from three species, *Lasioglossum* (*Dialictus*) *illinoense* (Robertson) (Halictidae), *Osmia lignaria* Say (Megachilidae) and *Apis mellifera* L. (Apidae), was dogwood pollen exclusively. The pollen from 15 species of bees was mixed, with one or several other pollens present,

usually crabapple, *Malus angustifolia* (Ait.) Michx., and/or holly, *Ilex* spp. One species, *Lasioglossum* (s. str.) *fuscipenne* (Smith), was carrying only a small amount of crabapple pollen.

Although many of the insects found on dogwood flowers may be contributing to pollination, we feel that several species of Andrenidae and Halictidae may have the greatest potential for enhancing pollination and fruit set in the dogwood breeding program. Females of these species [*Andrena illini* Bouseman & LaBerge, *A. miserabilis* Cresson and *A. nasonii* Roberson (Andrenidae), and *Lasioglossum* (*Dialictus*) *admirandum* (Sandhouse), *L.* (*Dialictus*) *imitatum* (Smith) and *L.* (*Dialictus*) *zephyrum* (Smith) (Halictidae)] carried large loads of dogwood pollen, and were collected at several of the sample sites. We feel that these species may potentially be used effectively to enhance pollination and fruit set in dogwood breeding programs.

Significance to Industry: Our study indicates that the miner bees *Andrena illini*, *A. miserabilis*, and *A. nasonii* (Andrenidae), and the sweat bees *Lasioglossum* (*Dialictus*) *admirandum*, *L.* (*Dialictus*) *imitatum*, and *L.* (*Dialictus*) *zephyrum* (Halictidae), are important to pollination and thus fruit set of flowering dogwood in both urban and natural forest environments in eastern Tennessee. It may be possible to use these species as pollinators in the dogwood breeding program to complete necessary crosses of resistant varieties in a timely, efficient and cost effective manner. Currently, these breeding efforts are time consuming, laborious, and costly; thus, the amount of successful breeding that can actually occur is limited. We feel that developing a program to utilize native bees as pollinators will enhance ongoing breeding efforts to develop anthracnose-resistant dogwoods.

Literature Cited:

1. Boring, L. R., C. D. Monk, and W. T. Swank. 1981. Early regeneration of a clear-cut southern Appalachian forest. Ecology 62: 1244-1253.

2. Chellemi, D. O., K. O. Britton, and W. T. Swank. 1992. Influence of site factors on dogwood anthracnose in the Nantahala Mountain Range of western North Carolina. Plant Dis. 76: 915-918.

3. Eyde, R. H. 1988. Comprehending *Cornus*: Puzzles and progress in the systematics of the dogwoods. The Bot. Rev. 54: 234-351.

4. Jones, G. D., V. M. Bryant, Jr., M. H. Lieux, S. D. Jones, and P. D. Lingren. 1995. Pollen of the Southeastern United States: With emphasis on melissopalynology and entomopalynology. AASP Contributions Series No. 30, 76pp. + 104 photographic plates.

5. Mayor, A. J., J. F. Grant, M. T. Windham, and R. N. Trigiano. 1999. Insect visitors to flowers of flowering dogwood, *Cornus florida* L., in eastern Tennessee: Potential pollinators. Proc. SNA Res. Conf. 44: 208-212.

6. Redlin, S. C. 1991. *Discula destructiva* sp. nov., cause of dogwood anthracnose. Mycologia 83: 633-642.

7. Whitmore, R. C. 1992. The importance of dogwood in the life history of wildlife species, pg. 15. *In* Proc. 1992 Dogwood Anthracnose Working Group, April 14-16, Pipestem, WV.

8. Witte, W. T. 1995. Dogwood culture in nursery and landscape. Tennessee Agri. Sci. 175: 47-51.

Table 1. Collection and pollen load records from bees collected on flowers of flowering dogwood, 1999.

Family / Species	Site: No. Collected and Sex[1]	No. with *Cornus florida* pollen	No. with other pollen
Colletidae			
Colletes inaequalis Say	B: 1f	1	1
C. thoracicus Smith	C: 1m	0	0
Hylaeus modestus Say	C: 2m	0	0
H. cressoni (Cockerell)	D: 1m	0	0
Andrenidae			
Andrena barbara Bouseman & LaBerge	A: 2f	1	1
A. confederata Viereck	A: 9m, B: 3m, D: 4m	1	2
A. crataegi Robertson	A: 6m, B: 1m, C:1m	1	2
A. cressoni Robertson	B: 1f, C: 1f	1	1
A. hilaris Smith	B: 1m	0	0
A. illini Bouseman & LaBerge	A: 10m, 3f, B: 12f, C: 2m, 2f	3	3
A. imitatrix Cresson	A: 5m, B: 2m, 1f, C: 1f	2	2
A. miserabilis Cresson	A: 6m, 2f, B: 1m, C: 3m, 2f, D: 1m	1	1
A. nasonii Robertson	B: 2m, 4f, C: 4m, 2f	2	2
A. personata Robertson	B: 1m, D: 1f		
A. vicina Smith	C: 1f	1	1
Halictidae			
Augochlorella persimilis (Viereck)	D: 2f	0	0
A. striata Provancher	D: 2f	1	1
Evylaeus truncatus (Robertson)	B: 1f	1	1
Halictus confusus Smith[2]	D: 1f		
Lasioglossum (s. str.) *fuscipenne* (Smith)	C: 1f	0	1
L. (*Dialictus*) *admirandum* (Sandhouse)	A: 2f, B: 1f, C: 1f, D: 6f	1	1
L. (*Dialictus*) *illinoense* (Robertson)	A: 7f	1	0
L. (*Dialictus*) *imitatum* (Smith)	B: 4f, C:10f, D: 65f	2	1
L. (*Dialictus*) *versatum* (Robertson)	D: 3f	0	0
L. (*Dialictus*) *zephyrum* (Smith)	A: 1f, B:2f, C: 2f, D: 1f	2	2
Megachilidae			
Osmia lignaria Say	B: 5f	1	0
Anthophoridae			
Nomada bishoppi Cockerell	A: 1m, B: 3m	0	0
Apidae			
Apis mellifera L.	A: 2f, C: 4f	1	0

[1] Numbers represent number of specimens collected at each site. A = Sequoyah Hills, B = Island Home, C = UT Agr. Campus, in Knox County, TN; D = UT Arboretum, in Anderson County, TN; f = female, m = male.

[2] Blank row for *H. confusus* indicates that pollen load has not been analyzed for this species.

IR-4 Research for Pest Control in Nursery Crops – 1999

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Index Words: Pesticides, biopesticides, label, registration, insecticides, fungicides, herbicides, nematicides, plant growth regulators, PGRs, .

Nature of Work: Research trials were conducted by the IR-4 Ornamental Program to help in the develop data for the national label registration of pesticides for nursery, greenhouse, forestry, Christmas tree, tissue culture, commercial landscape and the interior plantscape industries. Most of the 1999 trials evaluated phytotoxicity but some efficacy trials were also conducted. 101 protocols for 29 fungicides, 34 herbicides, 29 insecticides, 3 nematicides and 6 plant growth regulators were developed to insure uniform and accurate data required for national label registration. Of these 101 protocols, 53 were used for 1999 trials. 640 trials were conducted by 37 state, federal and private researchers at 35 sites in 32 states. (A trial consists of a single pesticide and a single plant taxa or pest species.) These trials evaluated 324 plant taxa and 51 active ingredients (an average of approximately two trials per active ingredient).

Results and Discussion: ***The following eleven (11) fungicides were evaluated:***

Azoxystrobin (Heritage 50)
Cinnamaldehyde (Cinnamite 30)
Fenhexamid (Decree 50 WDG)
Fluazinam (Shirlan)
Fludioxonil (Medallion 50)
Fludiolanil (Prostar 70 WSP)
Milsana Bioprotectant
Tebuconazole (Lynx 45 WP)
Trifloxystrobin (Compass 50 W)
Trichoderma harzianum Rifai Strain (Root Shield)
Sodium Tetrathiocaarbonate (Enzone)

The following eighteen (18) herbicides were evaluated:

Azafenidin (Milestone)
Napropamide (Devrinol 5G, 50DF)
Bentazon (Basagran T/O)
Clethodim (Envoy)
Clopyralid (Stinger)
Diclobenil (Casoron 4 G)
Dithiopyr (Dimension 1 EC)
Fluazifop-P-Butyl (Fusilade II)
Imazethapyr (Pursuit)
Thiazopyr (Visor 2 E)
Metolachlor (Pennant Liquid)
Oryzalin (Surflan AS)
Oxadiazon (Chipco Ronstar G, 50WP)
Oxyfluorfen + Oryzalin (Rout 3G)
Oxyfluorfen + Pendimethalin (OHII)
Pendimethalin (Pendulum 60WDG)
Prodiamine (Barricade 65WG, Factor 65)
Trifluralin (Trifluralin 10G)

The following 19 insecticides were evaluated:

Abamectin (Avermectin) (Avid – 0.15 EC)
Acephate (Orthene Turf, Tree & Orn. Spray)
Acetamiprid (Chipco Brand Acetamiprid 70 WP)
Bendiocarb (Turcam 2.5G, 76, Dycarb 76WP)
Bifenazate (Floramite 50)
Carbaryl (Sevin SL)
Chlorfenapyr (Pylon)
Chlorpyrifos (Dursban 50W, 4E, Pt 1325 ME Duraguard)
Clofentezine (Ovation EC)
Deltamethrin (Decis 1.5EC, Deltagard GC5SC,Deltagard GC, T+O)
Diazinon (Knoxout 2FM,Diazinon 50W)
Fipronil (Regent)
Formetanate-Hydrochloride (Carzol SP)
Oxydemeton-Methyl (Metasystox 2R)
Pyrimicarb (Pirimor 50 DF)
Pyridaben (Sanmite)
Tefluthrin (Fireban 1.5 G)
Cinnamaldehyde (Cinnamite 30)
Chlorpyrifos (Super IQ Insecticide)

The following nematicide was evaluated:

Sodium tetrathiocarbamate (Enzone)

The following four (4) plant growth regulators (PGRs) were evaluated:

Chlormequat Chloride (Cycocel)
Ethephon (Florel)
Paclobutrazol (Bonzi)
Uniconazole P (Sumagic)

The IR-4 research led to 532 new label registrations in 1999 for use by the ornamental industry (Table 1).

Significance to Industry: Since its inception the IR-4 Ornamental Research Program has been responsible for over 8600 national label registrations for use by the ornamental horticulture industry.

For further information about the IR-4 Program please consult the following publications:

1. IR-4. 1998. IR-4 Project Statement: October 1, 1998 to September 30, 2003. Cook College, Rutgers The State University of New Jersey, New Brunswick, NJ. 46pp.

2. IR-4. 1999. IR-4 Annual Report. Cook College, Rutgers The State University of New Jersey, New Brunswick, NJ. 26pp.

3. IR-4. 2000. “Commercially Grown Floral, Forestry, Nursery and Turf Crops”. IR-4 Minor Use Report Card – 2000 Update. 24pp.

Table 1. 1999 Pesticide Registrations supported by IR-4 data.

Acephate (Ortene Turf, Tree and Ornamental Spray)
- Birch

Ampelomyces quisqualis
- African Violet
- Azalea
- Begonia
- Flowering Dogwood
- Japanese Dogwood
- Palm-beach-bells
- Poinsettia
- Rhododendron
- Rose
- Snapdragon
- Transvaal Daisy
- Vervain (Verbena)
- Zinnia

Azadirachtin
- Ornamental Cabbage

Azoxystrobin
- Abelia
- Arborvitae
- Bolton Aster (Boltonia)
- Azalea
- Barberry
- Birch
- Boxwood
- Bridal Wreath (Spirea)
- Bugleweed (Ajuga)
- Butterfly Bush (Buddleia)
- Cedar (Cedrus)
- Chrysanthemum
- Cotoneaster
- Crape Myrtle
- English Ivy
- False Cypress
- Flowering Dogwood
- Forsythia
- Foxglove
- Geranium

Azoxystrobin (cont.'d)
- Heath
- Heavenly Bamboo
- Hemlock
- Holly
- Japanese Andromeda
- Juniper
- Lily
- Lilyturf
- Magnolia
- Maple
- Michaelmas Daisy
- Oak
- Pampas Grass
- Periwinkle (Vinea)
- Photinia
- Pine
- Primrose
- Privet
- Red Bud
- Rhododendron
- Rose
- Rose Mallow (Hibiscus)
- Sage (Salvia)
- Shasta Daisy
- Spruce
- Stonecrop (Sedum)
- Summersweet (Clethra)
- Virginia Sweetspire (Itea)
- Weigela
- Winged Euonymus
- Wormwood (Artemisia)
- Yew

Bendiocarb
- Bird's-nest Fern (Asplenium)
- Cotoneaster
- Fatsia
- Kentucky Bluegrass
- Southern Yew (Podocarpus)

Befenazate
- Balsam (Impatiens)
- Cannan Fir (Abies)
- Chrysanthemum
- Concolor Fir
- Douglas Fir (Pseudotsuga)
- Fraser Fir
- Gloxinia
- Scotch Pine
- White Pine
- Colorado Spruce

Bifenthrin
- Ash
- Camellia
- Crape Myrtle
- Elm
- Chinese Holly
- Japanese Holly
- English Ivy
- Juniper
- Linden
- Rhododendron
- Tailflower (Anthurium)
- Lavender Cotton (Santolina)
- Pear (non-bearing)
- Sweet Bay (Magnolia)
- Sweet Woodruff (Galium)
- Elm

Chlormequat Chloride
- Egyptian-star-cluster (Pentas)
- Yellow Shrimp Plant (Pachystachys)

Clethodim (Envoy)
- Bleeding Heart
- Coralbells (Heuchera)
- Loosestrife (Lysimachia)

Clofentazine
- African Violet
- Agertum
- Azalea

Clofentazine (cont'd)
- Balsam (Impatiens)
- Begonia
- Dahlia
- English Ivy
- Fern (Polypodium)
- Fuchsia
- Gardenia
- Hibiscus
- Holly
- Madwort (Alyssum)
- Pansy
- Periwinkle (Vinca)
- Persian Violet (Cyclamen)
- Scotch Pine
- White Pine
- Pinks (Dianthus)
- Pothos
- Rose
- Scarlet Sage (Salvia)
- Shasta Daisy
- Shrub Verbena (Lantana)
- Transvaal Daisy
- Vervain (Verbena)
- Zinnia

Clopyralid (Stinger)
- Apple (non-bearing)
- Boxwood
- Bridal-Wreath (Spirea)
- Flowering Dogwood
- Juniper
- Plane Tree
- Potentilla (Cinquefoil)
- Sycamore

Cyromazine
- Lobelia

Daminozide
- Angelonia
- Balloon Flower (Platycodon)
- Candytuft (Iberis)
- Coleus
- Coral Plant (Russelia)

Daminozide (cont'd)
- Coral Porterweed (Stachytarpheta)
- Egyptian-star-cluster (Pentes)
- Mexican Petunia (Ruellia)
- Sweet Potato Vine
- Yellow Shrimp Plant (Pachystachys)

Deltamethrin
- African Violet
- Ageratum
- Azalea
- Balsam
- Begonia
- Carnation
- Chrysanthemum
- Dumb Cane (Dieffenbachia)
- English Ivy
- Fern (Polypodium)
- Gardenia
- Geranium
- Hibiscus
- Hydrangea
- Madwort (Alyssum)
- Pansy
- Periwinkle (Vinca)
- Persian Violet (Cyclamen)
- Pinks (Dianthus)
- Poinsettia
- Scarlet Sage (Salvia)
- Shasta Daisy
- Shrub Verbena (Lantana)
- Transvaal Daisy
- Umbrella Tree (Schefflera)
- Vervain (Verbena)

Diazinon
- Ageratum

Etridiazole
- Bleeding Heart (Dicentra)
- Fatsia

Fenpropathrin
- Carnation
- Cherry (non-bearing)
- Crape Myrtle
- Flowering Dogwood
- Hemsley Snowbell (Styrax)
- Maple
- Persian Violet (Cyclamen)

Ferbam
- Carnation
- Tulip

Fludioxinil
- Ageratum
- Bolton Aster (Boltonia)
- Japanese Aster (Kalimeris)
- Bleeding Heart
- Chrysanthemum
- Dahlia
- Silver & Gold Daisy (Ajania)
- Elephant's Ear (Caladium)
- False Sunflower (Heliopsis)
- Fern (Polypodium)
- Fescue (Festuca)
- Geranium
- Shasta Daisy

Isoxaben
- Amur Maple
- Pygmy Date Palm (Phoenix)

Kaolin
- Linden (Tilia)

Mancozeb
- Crape Myrtle

Metolachlor
- Privet
- Winged Elm

Oryzalin
- Cherry (non-bearing)
- Southern Magnolia

Oxyfluorfen
- Maple

Paclobutrazol
- Feather Reed Grass (Calamagrostis)
- Miscanthus sinensis
- Reed Grass (Calamagrostis)

Pendimethalin
- Ash
- Mexican Fan Palm (Washingtonia)
- Pygmy Date Palm (Phoenix)
- Serviceberry (Amelanchier)

Permethrin
- Cherry (non-bearing)
- Crape Myrtle
- Flowering Dogwood
- Hemsley Snowbell (Styrax)
- Maple
- Shortleaf Pine

Pyridaben
- Ageratum
- Arborvitae
- Arrowwood (Viburnum)
- Bolton Aster (Boltonia)
- Japanese Aster (Kalimeris)
- Azalea
- Barberry
- Boxwood
- Bridal-Wreath (Spirea)
- Chrysanthemum
- Dahlia
- Elephant's Ear (Caladium)
- Elm (Ulmus)
- English Ivy

Pyridaben (cont'd)
- False Cypress
- Fir (Abies)
- Firethorn
- Geranium
- Holly
- Honeysuckle (Lonicera)
- Hydrangea
- Juniper
- Lily
- Magnolia
- Mock Orange (Philadelphus)
- Pansy
- Pear (non-bearing)
- Periwinkle (Vinca)
- Photinia
- Pinks (Dianthus)
- Primrose
- Privet
- Purpleleaf Wintercreeper (Euonymus)
- Rhododendron
- Rose
- Rose Mallow (Hibiscus)
- Vervain (Verbena)
- Wisteria

Spinosad
- Rose
- Winged Euonymus

Sun Spray Ultra-Fine Spray Oil
- Ornamental Cabbage

Thiophanate Methyl
- African Violet
- Bromeliads
- Bush Violet (Browallia)
- Campanula
- Canna
- Cineraria
- German Violet (Exacum)
- Gloxinia
- Lavender

Thiophanate Methyl (cont'd)
- Lisianthus
- Lobelia
- Madwort (Alyssum)
- Ornamental Cabbage
- Ornamental Kale
- Palm-beach-bells
- Pansy
- Periwinkle (Vinca)
- Persian Violet (Cyclamen)
- Pinks (Dianthus)
- Stonecrop (Sedum)
- Strawflower (Helichrysum)
- Swan River Daisy (Brachycome)

Triadimefon
- Lawn Leaf (Dichondra)
- Sugar Maple
- White Oak
- Tailflower (Anthurium)

Trichoderma harzianum
- Daffodil
- Lily
- Tulip

Trifloxystrobin
- Azalea
- Bamboo (Phyllostachys)
- Barberry
- Bulbous Iris
- Cherry (non-bearing)
- Chrysanthemum
- Elephant's Ear (Caladium)
- Geranium
- Lilac
- Photinia
- Pinks (Dianthus)
- Shasta Daisy
- Sun Rose (Helianthemum)

Trifluralin
- Areca Palm (Chrysalidocarpus)
- Feverfew (Chysanthemum parthenium)
- Gazania
- Hair Grass (Deschampsia)
- Hardy Mum (Dendranthema)
- Matricaria
- Caspian Statice
- Seafoam Statice
- Stock

Uniconazole
- Coleus