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Seasonal Phenology, Management, and Host Preferences of Potato Leafhopper on Nursery-Grown Maples[1]

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Abstract

Seasonal phenology and control of the potato leafhopper (*Empoasca fabae* (Harris)) on red maples (*Acer rubrum* L.) were studied for three years in nurseries in central Kentucky. Migratory adult leafhoppers were first captured on yellow sticky traps in early May. Peak population density ranged from late May to late June. The second flush of leaves was most heavily damaged in each year. Foliar sprays of cyfluthrin (Tempo 2), a synthetic pyrethroid, beginning 1 to 2 weeks after first capture of leathoppers and repeated at biweekly intervals during May and June, greatly reduced symptoms of injury. Acephate (Orthene) was less effective than cyfluthrin, whereas treatment of the soil with disulfoton (Di-syston) was ineffective. Oviposition and development of the leafhopper on red maple were confirmed. Field evaluations of selected cultivars showed that red maples were more severely damaged than sugar (*A. saccharum* L.) or Norway (*A. platanoides* L.) maples. 'Autumn Blaze', an *A. rubrum* × *saccharinum* hybrid, was relatively resistant.

Index words: *Empoasca fabae*, insect resistance, *Acer rubrum*, pest management

Significance to the Nursery Industry

Feeding by the potato lealhopper on nursery-grown maples causes severe cupping and stunting of expanding leaves, browning of leaf margins, "witches' brooming," loss of annual growth, and reduced market value of trees. This study shows that nurserymen can greatly reduce damage caused by potato leafhoppers by using yellow sticky traps to monitor for first appearance of the migratory adults, followed by timed, biweekly applications of cyfluthrin (Tempo 2) during the period of greatest leafhopper activity in May and June. Field evaluations of selected cultivars showed that red maples (*Acer rubrum* L.) were more severely damaged than sugar (*A. saccharum* L.) or Norway (*A. platanoides* L.) maples. 'Autumn Blaze', an *A. rubrum* × *saccharinum* hybrid, was relatively resistant.

[1]Received for publication February 8, 1993; in revised form April 12, 1993. Kentucky Agricultural Experiment Station Journal Article No. 93-7-9. This work was supported in part by the Louis & Martha Hillenmeyer Grant administered by the Horticultural Research Institute, Inc., 1250 I Street, N.W.. Suite 500, Washington, DC 20005, and by the Kentucky Nurserymen's Assoc.

[2]The authors wish to thank the staffs of Waterford Valley Nursery, Taylorsville, and Hillenmeyer Nurseries, Lexington, for their cooperation. Cory Orchard & Turf, Louisville, donated insecticides. We also thank G. M. Timmons for calling our attention to this problem, J. C. Parr for assistance with sampling for eggs, and P. F. Freytag for verifying identity of the leafhoppers.

Introduction

The potato leafhopper (PLH), *Empoasca fabae* (Harris) (Homoptera: Cicadellidae), is a common destructive pest of nearly 200 kinds of plants including forage legumes, vegetable crops, and deciduous nursery stock (1). Adults are small (3.5 mm), wedge-shaped, and pale green. Adults and nymphs feed mainly from the undersides of succulent young leaves, inserting their piercing-sucking mouthparts into plant tissue and removing sap. Physical damage to phloem and reaction to salivary phytotoxins cause affected leaves to become severely stunted and cupped downward, with necrotic margins. Severely damaged trees suffer "witches' brooming" of shoots, loss of annual growth, and reduced market value. In Kentucky and neighboring states the PLH causes severe economic damage to maples, especially *Acer rubrum*, in nurseries and landscape settings.

The PLH overwinters along the Gulf of Mexico and migrates northward each year, typically arriving in the north-central states between late April and early June (3). In central Kentucky, dates of first collection of adult PLH from mature alfalfa ranged from 4 May to 30 May, with populations peaking in early July (4). Development from egg to adult takes about 3 weeks during warm weather; several overlapping generations may occur during each growing season. Uncertainty regarding the dates of first occurrence of PLH in nurseries and the period of greatest damage to maples have resulted in some nurserymen applying as many as 10 cover sprays each growing season in an effort to prevent significant damage.

We studied the seasonal phenology of PLH on nursery-grown maples and evaluated methods and treatment timing for more efficient management of this pest. We also evaluated cultivars of red maple, sugar maple, Norway maple, and an *A. rubrum* × *saccharinum* hybrid for their comparative susceptibility to leafhopper injury.

Materials and Methods

Phenology and Control, 1990. This study was conducted in a block of 2500 red maple trees, cv. 'Red Sunset', growing at Waterford Valley Nursery, near Taylorsville, Kentucky. Tree diameter was 3.2 to 3.8 cm (1.25 to 1.5 inch) at 1 m (3.3 ft) above ground. The trees had been transplanted to the nursery as 2-yr-old liners in 1989. Within-row and between-row spacing of trees was 1.85 m (6 ft) and 3.7 m (12 ft), respectively. The trees had been fertilized twice annually with ammonium nitrate at 146 kg N/ha (3 lbs N/1000 ft^2) per yr. Weeds were controlled with pre- and post-emergent herbicides as needed. The site was surrounded by tall fescue (*Festuca arundinacea*) which was regularly mown to 8 cm height.

Seventy-two subplots, each consisting of three consecutive trees within a row, were established and marked with colored flagging tape on 19 February. Subplots within rows were separated by buffer zones consisting of three consecutive untreated trees. The experimental design was a randomized block 3 × 2 factorial with 12 replications, the main factors being treatment and spray timing. Six terminal shoots, evenly distributed within the middle tree of each subplot, were marked by wire twist-ties before bud break. This facilitated non-biased selection of shoot samples for treatment evaluation in late summer.

Seasonal activity of PLH was monitored with yellow cardboard sticky traps (28 × 25 cm; Scentry Multigard #10315; Scentry Inc., Buckeye, AZ). Traps were placed in twelve red maples, half of which were interspersed throughout the experimental trees in the unsprayed buffer zones, and half of which were in unsprayed border rows. The traps were hung from a lower branch and folded and stapled around the trunk just below the crown. Traps were hung on April 18 and were replaced weekly until early September. Exposed traps were examined for PLH in the laboratory and voucher specimens were deposited in the University of Kentucky Insect Museum.

The three trees within each subplot were treated with either cyfluthrin (Tempo 2 Ornamental Insecticide, Miles Inc., Kansas City, MO), a synthetic pyrethroid insecticide, acephate (Orthene Tree, Turf, & Ornamental Spray, Chevron Chemical Co., San Francisco, CA), an organophosphate, or were unsprayed (controls). Foliage was sprayed to runoff using Solo 425 compressed air backpack sprayers equipped with a Solo E04-80 fan-type nozzle that delivered 0.33 gal spray/min at 29 psi. Treatments were applied at labeled rates: 45 ml formulation/378.5 liters (1.5 oz/100 gal) for cyfluthrin and 1500 ml/378.5 liters (50 oz/100 gal) for acephate.

We evaluated two treatment timings in 1990. The first set of trees was sprayed on 23 May, when the traps suggested initial build-up of the PLH population in the nursery, and biweekly thereafter until July 5, for a total of four applications at 2 wk intervals. The second set was first treated on June 21 and was retreated 2 wk later on July 5.

Effectiveness of treatments was evaluated on August 30. For tree quality ratings, three observers independently ranked the middle tree of each subplot on a scale of 1–5, where 1 = severe stunting of foliage on nearly all shoots, and 5 = trees that were nearly free of PLH damage symptoms. Damage ratings were averaged to obtain one value per tree. Length of new growth on the terminal leader of six marked shoots per tree was measured in the field on the same date. Marked shoots were then harvested and all leaves originating from current year growth were excised, counted, oven-dried and collectively weighed. The relationship between leaf area and leaf dry weight was determined by harvesting eight additional fully-expanded, non-damaged leaves from trees within each of four replicates. Leaf area was measured with an electronic area meter; leaves were then dried and weighed to determine a weight/area constant which was used to calculate average leaf size of shoots from the experimental trees.

Phenology and Control, 1991. This study site was another block of several thousand red maples at Waterford Valley Nursery, Taylorsville. Age and size of trees, row spacing, and management practices were the same as described for 1990. The experimental design was a randomized complete block with nine replications and three trees per subplot (135 total trees). The arrangement of trees within subplots and untreated buffer zones and placement of yellow sticky traps were as indicated before. Six shoots within the middle tree of each subplot were marked with flagging tape on March 19. Traps were hung on April 22 and monitored weekly until September 10.

Treatment regimes evaluated in 1991 were: 1) cyfluthrin (Tempo 2) applied biweekly from May 15 until July 24 (6 sprays); 2) cyfluthrin applied biweekly from May 15 to June 26 (four sprays); 3) disulfoton (Di-syston 2G) applied at the beginning of PLH activity (May 15); and 5) untreated check. Rates and application methods for cyfluthrin were the same as in 1990. Disulfoton (Miles Inc., Kansas City, MO) is a broad spectrum, systemic, organophosphate insecticide that is registered for use against leafhoppers and other pests of woody ornamental plants. According to label specifications it provides up to 7-wk protection from sap-feeding insects. Disulfoton granules were broadcast on the soil from the trunk to the dripline at the labeled rate, 532 g (18.75 oz) of formulated product per tree. There was 1.5 cm (0.6 inch) of rain during the first 24 h after application and another 3.2 cm (1.25 inch) during the next 5 days which resulted in the insecticide being leached into the soil.

Leafhopper damage to experimental trees was rated and marked terminals were harvested on September 3 for evaluation of treatment effectiveness. Tree quality ratings, length of new growth, and number and area of leaves were measured as described for 1990.

Phenology, Control, and Oviposition, 1992. Monitoring of seasonal phenology of PLH and evaluation of effectiveness of disulfoton were repeated in 1992. The study site was a block of unsprayed red maples (cv. 'Red Sunset') planted at Hillenmeyer Nurseries, Lexington, KY. Size and age of trees, row spacing, and management tactics were similar to those described for 1990-91 study sites. Yellow sticky traps were hung in twelve trees on April 15 and were replaced weekly until September 8.

Subplots consisting of three consecutive trees within a row were marked with flagging tape in early April. The subplots were arranged in a randomized complete block with five replications and were separated by buffer zones consisting of three consecutive untreated trees. Six terminal shoots were marked on the middle tree of each subplot as in 1991. Treatments consisted of: 1) one application of Di-syston 15G at the labeled rate, 71 g (2.5 oz) of formulated product per 2.54 cm (1 in) of trunk diameter, on April 20; 2) two applications of Di-syston 15G, the first at the labeled rate as described above, and the second at one-half the labeled rate on June 11; 3) an untreated control. The granules were broadcast beneath the trees and immediately harrowed into the moist soil. About 2 cm (0.8 in) of rain fell within 36 hr after the first application, and about 0.6 cm (0.25 in) fell within 96 hr after the second application.

To evaluate effectiveness of the treatments, we examined all leaves on the six marked shoots of the middle tree in each subplot in the field on June 23 and counted all living adults and nymphs of PLH that were present. Trees were rated by three independent observers for symptoms of PLH damage on August 12 as described before. Finally, we measured shoot elongation and harvested all leaves on the marked shoots. Leaves were counted and weighed, and average leaf size was determined as described for the 1990 test.

Eggs and oviposition scars of PLH were sampled in new growth of red maples on June 8, at which time the shoots had five to six pairs of leaves below the bud. Single shoots were randomly harvested from each of 10 trees, cut below each node, and the leaves were then cleared and stained by a lactophenol-acid fuchsin method (6). Eggs and oviposition scars (marking locations of hatched eggs) were counted under 25 × magnification.

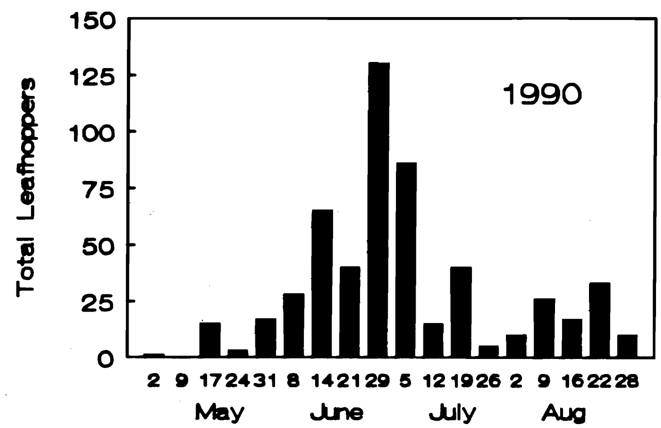
Susceptibility of Maple Species and Cultivars. Twelve replicates of each of three red maples (*A. rubrum* seedling trees; cvs. 'Red Sunset' and 'October Glory'), two sugar maple cultivars ('Legacy' and 'Green Mountain'), two Norway maple cultivars ('Emerald Queen' and 'Parkway'), and an *A. rubrum* × *saccharinum* hybrid (cv. 'Autumn Blaze') were established in an experimental plot at Waterford Valley Nursery, Taylorsville, Ky. Trees were obtained from J.F. Schmidt & Son Co., Boring Ore., as 2-year old liners (2.5 cm [1 in] in diameter, 1.8 to 2.1 m [6 to 7 ft] height). Trees were planted on April 11, 1991. Cultivars were planted in a randomized complete block design, with spacing between trees and rows and management practices as described before. Because of variation in leaf flush phenology related to transplanting, the cultivars were not evaluated for PLH injury until the year after they were planted.

All leaves on six terminal shoots of each tree were examined for adults and nymphs of PLH on June 6, 1992. A second, similar census was taken on June 23, 1992, except that only ten of the 12 trees of each cultivar could be examined before sampling was interrupted by a severe thunderstorm. Finally, two independent observers rated each tree for symptoms of PLH damage (1-6 scale) on August 21.

Results and Discussion

Phenology and Control, 1990. The first adult PLH were captured in red maple trees in early May (Fig. 1). Populations of adults were highest between June 8 and July 5, coincident with the second flush of leaves. Stunting and cupping of leaves were evident by June 14. Nymphs, which cannot fly, were rarely found on the sticky traps. Weekly inspections of leaves of unsprayed trees revealed large numbers of late instar nymphs in early to mid-June, indicating maturation of the first generation of progeny from migrating adults. Abundance of PLH declined during late July and remained relatively low throughout the rest of the growing season, except for a smaller peak in mid-August, during which the leafhoppers fed mainly on late-flushing leaves. Throughout the growing season, activity of both nymphs and adults was concentrated on young, partially expanded leaves.

Leafhopper feeding damage resulted in severe stunting of foliage, reduced shoot elongation, and lower quality ratings for unsprayed trees (Table 1). Treated trees overall had significantly larger leaves, greater shoot elongation, and higher quality ratings than did unsprayed trees. The overall effect of spray timing was also significant for each of these parameters; trees that received four biweekly treatments had greater shoot elongation, larger leaves, and higher quality ratings than trees that were sprayed only twice. Within each timing, cyfluthrin generally provided better protection than acephate (Table 1).



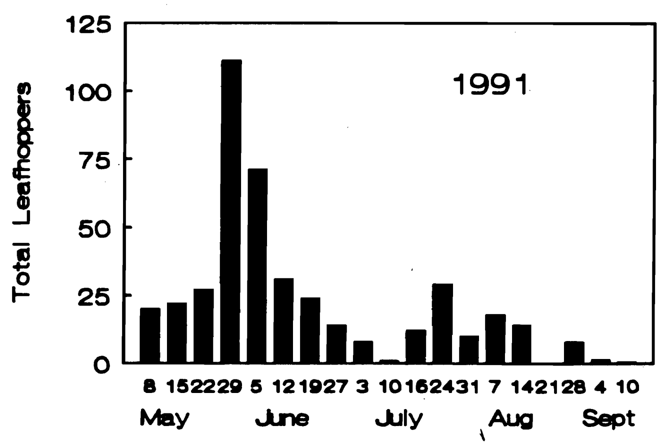


Fig 1. Seasonal abundance of adult potato leafhoppers on red maples at Waterford Valley Nursery, Taylorsville, KY, 1990–1991. Bars represent the total number of leafhoppers captured on 12 yellow sticky traps during the week preceding the sample date.

Table 1. Effectiveness of insecticides and spray timings for preventing potato leafhopper injury to nursery-grown red maples, Taylorsville, KY, 1990.

Treatment[z]	Tree quality rating (scane 1–5)[y]	Shoot eclongation (cm)	No. leaves per shoot	Ave. leaf size (cm²)
Timing 1: four biweekly applications beginning May 23, 1990				
cyfluthrin (Tempo 2)	4.42 a	21.7 a	33.5 a	29.3 a
acephate (Orthene)	3.65 b	18.4 ab	33.2 a	25.1 b
untreated	2.42 c	16.2 b	38.4 a	16.7 c
Timing 2: two biweekly applications beginning June 21, 1990				
cyfluthrin (Tempo 2)	3.62 a	17.5 a	39.3 a	22.2 a
acephate (Orthene)	3.23 a	12.8 b	30.7 a	18.5 ab
untreated	2.52 b	16.0 ab	39.9 a	17.0 b

[z]Rates were 45 m./378.5 liters (1.5 fluid oz/100 gal) for cyfluthrin; 1500 ml/378.5 liters (50 fluid oz/100 gal) for acephate.

[y]Trees were evaluated on August 28. Within columns, means not followed by the same letter differ significantly ($P < 0.05$, LSD test following ANOVA). Data were analyzed separately within each timing.

Table 2. Effectiveness of insecticides and treatment timings for preventing potato leafhopper injury to nursery-grown red maples, Taylorsville, KY, 1991.

Treatment[z]	No. of applications	Tree quality rating (scale 1–5)[y]	Shoot elongation (cm)	No. leaves per shoot	Ave. leaf size (cm²)
cyfluthrin (Tempo 2)	6	4.53 a	22.5 a	22.8 a	45.0 a
cyfluthrin (Tempo 2)	4	4.15 b	23.2 a	21.0 a	48.2 a
disulfoton (Di-syston 2G)	1	2.70 c	23.1 a	37.6 b	28.2 b
untreated	—	3.39 c	23.3 a	32.1 b	30.7 b

[z]Rates were 45 ml/378.5 liters (1.5 fluid oz/100 gal) for cyfluthrin; 532 g (18.75 oz)/tree for disulfoton. Cyfluthrin-treated trees were sprayed four or six times at biweekly intervals beginning 15 May. Disulfoton was applied on 15 May.

[y]Trees were evaluated on September 3. Within columns, means not followed by the same letter differ significantly ($P < 0.05$, LSD test following ANOVA).

Phenology and Control, 1991. Migrating adult PLH first appeared on the sticky traps during the first week of May in 1991. Population growth was more rapid, and peak densities occurred nearly a month earlier in 1991 than in 1990 (Fig. 1). As before, the greatest damage occurred to the second flush of leaves.

As in 1990, leafhopper feeding resulted in stunting of leaves and reduced tree quality ratings (Table 2) relative to trees treated with cyfluthrin. In contrast to 1990, shoot elongation was not significantly increased by insecticide treatments. Unsprayed trees produced greater numbers of small leaves which reflects the symptoms of witches' brooming which were obvious from mid-June until leaf fall. Trees that received six biweekly applications of cyfluthrin had higher quality ratings than those that received four sprays. Disulfoton was not effective for preventing PLH damage symptoms (Table 2).

Phenology, Control, and Oviposition, 1992. Adult PLH were first captured from red maples in Lexington on May 2, and were very abundant on the trees from mid-May until mid-July (Fig. 2). Large numbers of nymphs were also observed on partially expanded leaves by June 5, and significant cupping and stunting of foliage, necrosis of leaf margins, and witches' brooming of leaves were obvious by mid-June. As in previous years, nymphs and adults were observed almost exclusively on the undersides of partially expanded, young leaves.

As in 1991, disulfoton was ineffective against PLH in the 1992 test. Numbers of total PLH on marked shoots did not differ significantly between treated and control trees. Mean

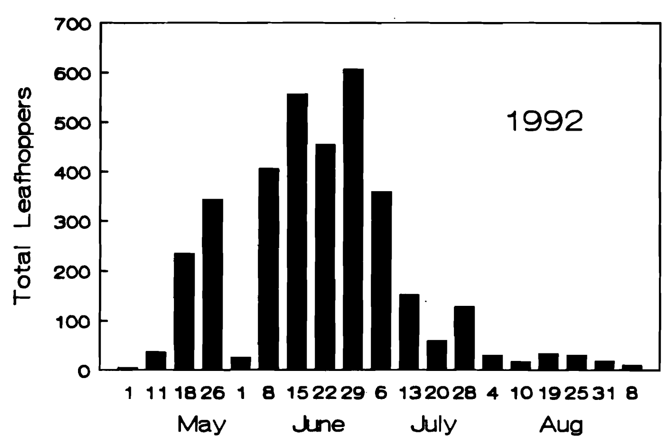


Fig. 2 Seasonal abundance of adult potato leafhoppers on red maples at Hillenmeyer Nurseries, Lexington, KY, 1992. Bars represent the total number of leafhoppers captured on 12 yellow sticky straps during the week preceding the sample date.

(± SE) number of PLH per six shoots for control, once-treated, and twice-treated trees was 16.0 ± 2.8, 11.2 ± 2.2, and 13.5 ± 2.5, respectively. Similarly, treatment with disulfoton did not affect shoot elongation, number of leaves, or average leaf area, nor did it improve overall tree quality rating. All trees were severely damaged by PLH (average rating = 1.9 ± 0.1).

Clearing and staining with lactophenol-acid fuchsin confirmed oviposition of PLH within red maple leaves. Beginning with the youngest, partially expanded leaf, the mean (±

SE) number of eggs per leaf was 0.1 ± 0.1, 0.2 ± 0.1, 0.1 ± 0.1, 0.9 ± 0.3, and 0.4 ± 0.3, and the mean number of oviposition scars was 0.7 ± 0.4, 1.4 ± 0.7, 2.7 ± 0.6, 6.9 ± 2.1, and 3.4 ± 1.06 The high ratio of oviposition scars to eggs (9:1) indicates that most of current cohort of eggs had hatched by the 8 June sample date. All eggs and oviposition scars were found in the leaf veins.

Susceptibility of Maple Species and Cultivars. In the mixed planting, red maple cultivars supported much higher populations of PLH and suffered greater damage than did other species of maple (Table 3). Symptoms of injury, as reflected by lower damage ratings, were more severe on 'Red Sunset' and 'October Glory' than on *A. rubrum* (seedling trees). Cultivar 'Autumn Blaze', an *A. rubrum* × *saccharinum* hybrid, supported moderate PLH populations but sustained almost no injury. Relatively small numbers of PLH were found on the sugar maple cultivars, and the trees showed only minor damage. Norway maple cultivars 'Parkway and 'Emerald Queen' were highly resistant to PLH.

Of the 1051 total PLH counted on the sampled shoots on June 6, 95.4% were nymphs and only 4.6% were adults. Similarly, 89.3% of the 894 total leafhoppers counted on June 23 were nymphs. As with total PLH, many more nymphs were found on the three cultivars of red maple than on the other species of maple. However, small numbers of nymphs were also found on the relatively resistant sugar and Norway maples, indicating some oviposition and at least partial development of PLH on all of the maple species tested.

Northward movement of PLH into the north-central states in the spring is usually associated with warm south winds and moist air masses moving up the Mississippi Valley, a high pressure area over the Atlantic coast, and rain in the fallout area (5). Dates of first occurrence in Kentucky vary by as much as 4 weeks from year to year (4). Dates of first capture of PLH adults in nurseries in central Kentucky (Fig. 1,2) were closely correlated with those recorded for alfalfa

Table 3. Abundance of potato leafhoppers and severity of damage symptoms on eight species/cultivars of maples, Taylorsville, KY, 1992.

Tree species Cultivar	No. leafhoppers per 6 shoots on[y]: June 6	June 23	Damage rating[z] (August 23)
Acer rubrum			
'October Glory'	28.8 a	19.0 b	2.31 a
A. rubrum	22.5 ab	20.9 b	3.50 b
'Red Sunset'	20.5 b	31.9 a	2.25 a
A. rubrum × *saccharinum*			
'Autumn Blaze'	8.4 c	10.4 c	5.67 d
A. saccharum			
'Green Mountain'	2.9 cd	4.1 cd	4.35 c
'Legacy'	1.1 cd	1.0 d	4.71 c
A. platanoides			
'Parkway'	0.4 d	1.8 d	5.91 d
'Emerald Queen'	0 d	2.4 d	5.95 d

[z]Trees were rated on a 1–6 scale by two independent observers, where 1 = all leaves stunted and cupped with necrotic edges, and 6 = no visible symptoms of leafhopper injury.

[y]Within columns, means not followed by the same letter differ significantly ($P < 0.05$, LSD test following ANOVA).

(April 26, 1990, April 29, 1991, May 2, 1992; J. Parr, personal communication) indicating simultaneous invasion of both crops. This suggests that phenological data for PLH in field crops, available from many state cooperative extension offices, may be useful for predicting first occurrence of the pest in nurseries.

Peak activity of PLH in nurseries varied by as much as a month (Fig. 1). The earlier population increase in 1991 was correlate with a much warmer spring; daily air temperatures averaged 2.4°C (5°F) warmer in April, and 3.8°C (8°F) warmer in May than for the same months in 1990. Development of PLH from egg to adult on broad bean requires about 22 days at fluctuating temperatures of 18–29°C (64–84°F), and 15 to 16 days at 23–34°C (73–93°F), and females begin to lay eggs about 4 to 6 days after becoming adults (2). Our observation of large numbers of eggs and nymphs on red maples by early to mid-June and severe injury to the second flush of leaves therefore coincides with expected dates of maturation of the first generation of progeny from the migrating adults. We have reared PLH from newly hatched nymphs to adults on detached bouquets of red maple foliage in the laboratory (Parr and Potter, unpublished).

Part and Pass (4) observed that PLH populations in alfalfa collapsed after harvest in mid-July and remained low for the rest of the growing season. They suggested adults disperse from cut fields and that nymphs either starve or are killed by desiccation. We also observed declines in PLH populations on red maples after mid-July (Figs. 1,2). The proximate cause may have been the decreasing availability of young leaves.

This study indicates that damage by PLH to nursery-grown red maples can be greatly reduced by using yellow sticky traps to monitor initial increase of the leafhopper population, followed by two, four, or six foliar sprays at biweekly intervals depending upon the degree of protection required. Treatment of the soil with disulfoton was not effective. Cyfluthrin provided better protection than acephate. Dermal contact with cyfluthrin spray drift causes mild skin sensitization and temporary itching in some persons. These effects reportedly can be alleviated by preventative application of vitamin E cream (D. Booth, personal communication).

This study also confirmed that among the cultivars tested, red maples are much more susceptible to PLH injury than are sugar or Norway maples. Cultivar 'Autumn Blaze', an *A. rubrum* × *saccharinum* hybrid, supported moderate numbers of PLH but sustained little damage. Townsend (7) observed that variation in susceptibility to PLH injury among red maple progenies in Ohio was at least partly phenological, with those trees initiating growth earliest in the spring sustaining the least injury. He suggested that early-flushing genotypes would have less succulent stem tissue and more fully developed, leathery leaves by the time of PLH migration and subsequent feeding and egg-laying. In our study, however, all cultivars and species of maples continued to flush new leaves well into the period of maximum leafhopper activity in mid- to late June, with the greatest damage occurring to the second flush of leaves. Further study is needed to clarify the extent to which variation in susceptibility of maples to PLH injury is determined by differences in leaf flush phenology or other factors such as leaf morphology or chemistry.

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Cupric Hydroxide-Treated Containers Affect Growth and Flowering of Annual and Perennial Bedding Plants[1]

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Abstract

Four annual cultivars, *Celosia cristata* L. 'Castle Pink', *Impatiens Wallerana* Hook. 'Super Elfin Red', *Pelargonium* × *domesticum* L.H. Bailey 'Ringo Scarlet' and *Tagetes patula* L. 'Discovery Yellow', and two perennial cultivars, *Chrysanthemum* × *superbum* Bergmans ex J. Ingram 'Alaska' and *Coreopsis lanceolata* L. 'Early Sunrise', of bedding plants were grown in a greenhouse for about 40 days in 0.3–1 (3.5 in.) containers treated with 25, 50, or 100 g $Cu(OH)_2$/1 (approximately 1.8, 3.5, and 7% (wt/wt), respectively) formulated as Spin Out™ or in non-treated containers. Following greenhouse production and a 4-day acclimation period in a shade-house, the plants were transplanted to a field plot. Cupric hydroxide concentrations that resulted in practical levels of control and/or elimination of root deformation (circled, kinked, and matted roots at container wall-media interfaces) were species dependent, varying between 25 and 100 g/l (1.8 and 7%). During greenhouse production $Cu(OH)_2$ treatments of 50 or 100 g/l (3.5 or 7%) increased the vegetative growth of *C. cristata* and increased the number of flowers on *I. Wallerana* compared to plants in non-treated containers. After field planting, *P.* × *domesticum* grown in 50 or 100 g $Cu(OH)_2$/l (3.5 or 7%) and *I. Wallerana* in 100 g $Cu(OH)_2$/l treated containers had increased vegetative growth. The flowering potential of *I. Wallerana* was increased by the 50 g $Cu(OH)_2$/l (3.5%) treatment following field planting.

Index words: Greenhouse production, postharvest quality, root morphology, transplant establishment, flowering potential

Species used in this study: Cockscomb 'Castle Pink' (*Celosia cristata* L. 'Castle Pink'); Coreopsis 'Early Sunrise' (*Coreopsis lanceolata* L. 'Early Sunrise'); Impatiens 'Super Elfin Red' (*Impatiens Wallerana* Hook. f. 'Super Elfin Red'); Geranium 'Ringo Scarlet' (*Pelargonium* × *domesticum* L. 'Ringo Scarlet'); Marigold 'Discovery Yellow' (*Tagetes patula* L. 'Discovery Yellow'); Chrysanthemum 'Alaska' (*Chrysanthemum* × *superbum* Bergmans ex. J. Ingram 'Alaska')

Significance to the Nursery Industry

Copper containing latex compounds applied to the interior surfaces of containers have been shown to reduce woody plant root deformation and increase fibrosity (branching) of roots (1, 2, 4, 5, 7, 11) during production. Copper treated-containers have increased the vegetative growth (1, 2, 5) and flowering (15) during container production and aided in transplant establishment of some species (4). Results of this study indicate that similar root growth control, increased vegetative growth and increased flowering can occur with certain herbaceous bedding plants, but the responses are species and concentration dependent. Additional cultivar testing is needed under varied environmental conditions and production systems before making specific recommendations. However, practical levels of reduction in root deformation occurred with concentrations of 25 or 50 g $Cu(OH)_2$/1 (1.8 or 3.5%) for most species tested.

Introduction

Container produced bedding plants are subject to the same root deformation as woody plants. Root deformation in woody plants can adversely affect plant establishment fol-

[1]Received for publication December 21, 1992; in revised form April 13, 1993. Tennessee Technological University College of Agriculture and Home Economics manuscript number 45. Funding, in part, for this project was supplied by a grant from the Griffin Corporation, Valdosta, GA. Appreciation is expressed for assistance on portions of this project by G. Renee Simms.

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