Evaluation of New Systemic Insecticides for Elm Insect Pest Control[1]

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Abstract

Use of systemic insecticides that can be injected either into the root system or trunk of woody plants provides several potential advantages, notably in control of drift during application. Recently, new classes of insecticides with systemic activity have been developed, which may supplant the organophosphate and carbamate systemic insecticides that have previously been available. To evaluate their potential to control insects affecting shade trees, studies were conducted using imidacloprid and abamectin on elm. Soil injections of imidacloprid appeared particularly effective, controlling all three of the target pest species in this study (elm leaf beetle, European elm scale, elm leaf aphid). Both imidacloprid and abamectin also were effective against at least some elm insects when injected into trunks. Persistence of imidacloprid was unusually long, providing second season control of all elm insect pests, although root uptake following soil injections was slow.

Index words: systemic insecticide, *Ulmus*, trunk injection, soil injection, landscape plants.

Insecticides used in this study: Arbor$_x$ capsule, abamectin (2AE, 4E, 5's, 6S, 6'R, 7S, 8E, 11R, 13R, 15S, 17aR, 20R, 20aR, 206S)-6'-((R)-sec-Butyl)-7-((2,6-dideoxy-3-0-methyl-x-L-arabino-hexopyranosyl)oxy)-5'c6,6',7,10,11,14,15,17a,20,20a,20b-dodecanydro-20b-dihydroxy-5',6,8,19-tetramethylspiro(11,16-methano-2H,13H,17H-furo(4,3,2-pg)(2,6) benzodioxacyclooctadecin-13,2'-(2H)pyran)17-one); Arbor$_x$ capsule, imidacloprid (2-(4,5-Dihydro-4-methyl-4-(1-[(Chloro-3-pyridinyl)methyl]-4,5-dihydro-*N*-nitro-1*H*-imidazol-2-amine); Avid, abamectin (2AE, 4E, 5's, 6S, 6'R, 7S, 8E, 11R, 13R, 15S, 17aR, 20R, 20aR, 206S)-6'-((R)-sec-Butyl)-7-((2,6-dideoxy-3-0-methyl-x-L-arabino-hexopyranosyl)oxy)-5'c6,6',7,10,11,14,15,17a,20,20a,20b-dodecanydro-20b-dihydroxy-5',6,8,19-tetramethylspiro(11,16-methano-2H,13H,17H-furo(4,3,2-pg)(2,6) benzodioxacyclooctadecin-13,2'-(2H)pyran)17-one); Bay NTN338893, imidacloprid (2-(4,5-Dihydro-4-methyl-4-(1-[(Chloro-3-pyridinyl)methyl]-4,5-dihydro-*N*-nitro-1*H*-imidazol-2-amine); Merit, imidacloprid (2-(4,5-Dihydro-4-methyl-4-(1-[(Chloro-3-pyridinyl)methyl]-4,5-dihydro-*N*-nitro-1*H*-imidazol-2-amine); Orthene 75S, acephate (*0 S*-Dimethyl *N*-acetyl phosphoramidothioate).

Species used in this study: American elm (*Ulmus americana* L.); Siberian elm (*Ulmus pumila* L.).

Insect species used in this study: elm leaf beetle (*Xanthogaleruca luteola* (Müller)); European elm scale (*Gossyparia spuria* (Modeer)); elm leaf aphid (*Tinocallis ulmifolii* (Monell)).

Significance to the Nursery Industry

Several important insects are associated with elm, including European elm scale, elm leaf beetle and elm leaf aphid. Although several insecticides are currently used for their management, problems associated with foliar applications, such as drift, can restrict their use. Systemic insecticides, introduced either into the root system or directly into the trunk, provide an alternative, although high mammalian toxicity and/or limited registration limit their use. However, tests of new classes of insecticides with systemic activity, the chloronicotinyls and avermectins, indicate good control of several important elm insect pests when applied to the soil or trunk. In addition, one treatment, imidacloprid (Merit) shows unusual persistence, providing control one year following application. This material has the benefit of reducing application frequency.

Introduction

Insect control can be critical to maintaining the health and aesthetic appearance of shade trees. However, the proximity of plantings to areas of high human traffic, and the large size of the plants present significant problems during application of insecticides. In particular, drift of the insecticide is a concern. The use of systemic insecticides that can be injected into the soil for root uptake or directly into tree trunks provides an attractive alternative for reducing drift. However, only a limited number of injectable systemic insecticides have been available for shade tree insect management. All potential soil/trunk injectable systemic insecticides (e.g., oxydemetonmethyl, dimethoate, disulfoton, dicrotophos) are organophosphate insecticides with high mammalian toxicity and limited registration. The most broadly labelled product, Metasystox-R 2 (oxydemetonmethyl), has Restricted Use status.

Recently, new classes of insecticides have been developed with systemic activity. Among these are imidacloprid, a chloronicotinyl compound, and abamectin, an avermectin. To evaluate how these products might be used to control pests of shade trees, a series of studies was conducted during 1993–1994 on a wide variety of woody plant materials, with particular emphasis on insect pest species affecting elm (*Ulmus* spp.). Nationwide, elm is the third most widely planted shade tree (3) and is particularly important in the Rocky Mountain region. It hosts several significant insect pests including elm leaf beetle, *Xanthogaleruca luteola* (Müller), European elm scale, Gossyparia spuria (Modeer), and elm leaf aphid, Tinocallis ulmifolii (Monell), thus necessitating frequent insecticide application. The use of effective systemic insecticides to control these insects could reduce foliar sprays and associated drift.

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Materials and Methods

Trunk and soil injection trial, site 1. The primary study site involved a parkway median planting of American elm, U. *americana* L., in Denver, CO. Trees were mature, approximately 66 cm (26 in) in diameter, and had a history of infestation by European elm scale. The site was regularly irrigated but some dieback was present and some root disruption had occurred at the site two years prior to the start of the experiment.

Treatments were applied to single trees and experimental design was a randomized complete block with four replications. All $Arbor_x$® trunk injections and Orthene® 75S (acephate) soil injections were made July 5, 1993. Bay NTN33893 (imidacloprid) soil injections were made a week later, on July 12, 1993. Soil injections were applied using a Kioritz® soil injector (Wilbur-Ellis Corp., Seattle, WA). During soil injection applications, insecticides were diluted with water to produce a slurry that allowed a uniform 30 ml (1 fl oz) of solution to be introduced in each injection hole. An injection hole was made per each 1.25 cm (0.5 in) of tree diameter at breast height (dbh), in a regularly distributed pattern around and within the drip line of the tree. Two different rates of both insecticides were applied. Rates of Orthene® 75S (acephate) were 1 g (0.035 oz) and 4 g (0.140 oz). Rates of Bay NTN33893 (imidacloprid) soil injections were 1 g (0.035 oz) and 2 g (0.070 oz) per 2.5 cm (1 in) dbh.

Trunk injections involved use of $Arbor_x$® capsules (Tree Technologies, Inc., Cheektowaga, NY) containing either 5 ml (0.169 fl oz) of Bay NTN33893 200SL (imidacloprid) or 4 ml (0.135 fl oz) of abamectin. Injections were made July 5, 1993, into the root flare of the tree at a rate of one capsule per 15 cm (6 in) of tree circumference at breast height (cbh).

During 1993, evaluations for European elm scale were made on three dates, each with a different sampling method. On the August 2, 1993, evaluation, when scales were feeding on foliage, two terminals were clipped from each tree. Counts were made of the number of Instar II scales present on 10 leaves/terminal. A subsequent count on August 24 was similarly sampled, but data were of percent mortality. Percent mortality was determined by counting the number of live and dead Instar II scales present along the midrib of ten randomly selected mature elm leaves and subsequent calculation through use of the equation:

$$\frac{\text{(\# of Dead Scales)}}{\text{(\# of Dead Scales + \# of Live Scales)}} \times 100$$

The final evaluation of the 1993 season, on September 30, was made of scales that had migrated to overwintering sites on twigs. Data were based on counts of nymphs found on five (4 cm (1.5 in) length each) twig sections collected from each of four cardinal points/tree.

Second season evaluations (1994) were made on two dates. During June 7–8, four 46-cm (28-in) length twig samples were collected, one from each cardinal point of the tree. Scales were mature at this point and many were maturing eggs, but crawler stages were not yet present. Evaluations were made of all mature living scales present on these twigs. A final evaluation was similarly made October 26 after the summer generation was complete and scales had again migrated back to the twigs.

Evaluations of elm leaf aphid were made July 15, 1993, August 2, 1993, and July 19, 1994. Aphid counts were made of all foliage present on two randomly chosen, 1 m (39 in) length branch terminals collected one each from the north and south side of each tree, respectively. Approximately 100 leaves were present on each branch terminal sampled.

Trunk injection trial, site 2. A second series of Denver street trees involved elm (*Ulmus* sp.) lining a municipal park. Trees were approximately 18 m (60 ft.) tall and 61 cm (24 in) in dbh, with a history of infestation by elm leaf beetle. Plots consisted of single trees, arranged in a RCB design with 4 replications.

Two different trunk injection techniques were employed. $Arbor_x$® capsules (Tree Technologies, Inc., Cheektowaga, NY) were applied June 30, 1993 by drilling a series of small (0.5 cm (0.2 in) dia. × 2 cm (0.75 in) deep) holes in the root flare of the tree. One capsule for every 15 cm (6 in) of tree cbh was applied. Individual capsules used for injection contained either 5 ml (0.169 fl oz) of Bay NTN33893 200SL (imidacloprid) or 4 ml (0.135 fl oz) of abamectin. Direct trunk injections were made July 26, 1993, and used a modified veteranarian's syringe that placed 1 ml (0.34 fl oz) of each insecticide under the bark of the tree at intervals of one injection site per every 15 cm (6 in) of cbh.

Plots were not sampled during the season of application since peak populations of elm leaf beetle had already occurred. Two evaluations were made the season subsequent to application (1994), coincident with both first and second generation elm leaf beetle larval injury. Terminals from four branches per tree were evaluated for the amount of leaf defoliation (skeletonizing) using a graduated 0–10 numerical damage rating system similar to that used by Dahlsten et al. (2) and Brewer (1) where 0 = No damage present, 1 = 1–10% skeletonizing per branch (SPB), 2 = 11–20% SPB, 3 = 21–30% SPB, 4 = 31–40% SPB, 5 = 41–50% SPB, 6 = 51–60% SPB, 7 = 61–70% SPB, 8 = 71–80% SPB, 9 = 81–90% SPB, 10 = 91–100% SPB.

Trunk injection trial, site 3. A second field evaluation of trunk injection systems was made at a shelterbelt planting of Siberian elm (U. *pumila* L.) at the Colorado State Forest Service Nursery in Fort Collins, CO. Treatments were applied July 21, 1993, with the same injection methods used at site 2. Plot design was a randomized complete block with five replications.

European elm scale was the primary insect pest species present at the site. First year evaluations (August 10, 1993) assessed the percent mortality of Instar II scales present on 10 leaves randomly removed from trees. Second year evaluations (June 15, 1994) counted the number of overwintered scales present on two randomly chosen 0.5 m (19.5 in) twig samples per tree.

Direct trunk injection test, site 4. A limited field evaluation of just direct trunk injections using the modified veteraniarian's syringe was conducted at a city park in Fort Morgan, CO. Four mature American elm trees, between 25 and 40 cm (9.8 and 15.7 in) dbh, were injected with imidacloprid on July 15, 1993, with four other adjacent elms used as untreated controls. Injections of 1 ml (0.34 fl oz) Bay NTN33893 200SL (imidacloprid) were applied at 15 cm (6 in) of cbh, directly under the bark.

Treatments were evaluated on September 18, 1993, by counting the number of settled Instar II scales on ten (4 cm (1.5 in) in length ea.) stems collected from each tree (5 from north side, 5 from south side).

Soil treatment persistence test, site 5. An evaluation of persistence of soil injected imidacloprid and acephate was conducted on seedling Siberian elm, at the Colorado State University Horticulture Research Farm north of Fort Collins, CO. A row of 0.3 m (1 ft.) tall field grown Siberian elm trees, transplanted in 1992, was utilized. Plot design was a randomized complete block with four replications.

Applications were made on either May 26 or 28, 1993. Treatments were applied either as soil injections using the Kioritz® soil injector at 1.25 g (0.044 oz) AI and 1.50 g (0.053 oz) AI per plant of Bay NTN33893 (imidacloprid) or Orthene 75S (acephate), respectively, or an imidacloprid soil drench of 1.25 g (0.044 oz) AI per plant. Plot design was a RCB with five replications.

Treatment evaluations involved a laboratory bioassay of field collected elm leaf beetle larvae. Larvae were placed 10 per Petri dish for a total of 10 larvae per experimental unit (5 replications). They were then fed foliage collected June 10, 1994, from the previously treated trees. Foliage was changed in the dishes every 72 h, and used either freshly collected or <1-week-old refrigerated foliage (foliage was re-collected on June 16, 1994) from appropriately treated plants in the experiment as a replacement. Mortality was assessed on eight dates between June 10 and June 22, 1994.

Statistical analysis of all trials was accomplished through the use of SAS® (Statistical Analysis System, Cary, NC) Software using PROC GLM syntax and the Student-Neuman-Keuls (SNK) test (P = 0.05) for means comparison.

Results and Discussion

Trunk and soil injection trial, site 1. No treatments provided significant control of European elm scale in the season of application (Table 1), although wide variability in populations between trees may have obscured differences. Plots of 1994 data for European elm scale samples were not normally distributed. To correct for this source of error, count data from both 1994 samples were transformed using a population rating scale. We feel that this rating scale provides a better indication of scale infestation. Numbers above 4 on the scale would indicate populations that might cause significant problems with nuisance honeydew and/or contribute to the loss of tree vigor. The rating scale was as follows: 0 = No scales present on a 0.5 m (19.5 in) branch sample, 1= 1 scale present, 2 = 2 scales present, 3 = 3–4 scales present, 4 = 5–8 scales present, 5 = 9–16 scales present, 6 = 17–32 scales present, 7 = 33–64 scales present, 8 = 65–128 scales present, 9 = 129–256 scales present and 10 = > 256 scales present.

Evaluations made 11 months after application (June 7–8, 1994) showed that all treatments had provided significant control (SNK test, P = 0.05) compared to untreated plants (Table 1). Soil injections of Bay NTN33893 (imidacloprid) were particularly effective, sustaining far fewer scales on average compared to the control (Table 1). Data analyzed from a subsequent evaluation at the end of the second season (October 26, 1994) indicated significant differences (SNK test, P = 0.05) in scale control between the trunk-injected imidacloprid treatments and the high rate soil-injected imidacloprid, compared to the control (Table 1).

Similarly, elm leaf aphid control was not observed during the season of application (July 15 and August 2, 1993) (Table 2). However, evaluations made one year after application

Table 1. Insecticides, rates, application methods and mean number (or mortality) of European elm scales on 1993 and 1994 sampling dates for American elm trees growing along a median strip in Denver, CO.[z]

			Date				
Treatment/formulation	**Rate[y]**	**Application method**	**August 2 1993[x]**	**August 24 1993[w]**	**September 30 1993[v]**	**June 7–8 1994[u]**	**October 26 1994[t]**
			Num[r]	Mort[r]	Num[r]	Pop[r,s]	Pop[r,s]
Bay NTN33893 200 SL		$Arbor_x$® capsule	382.8a	72.0a	675.7a	3.94ab	1.27ab
Orthene 75S	1 g	Soil injection	436.3a	65.7a	577.2a	4.86b	3.47abc
Orthene 75S	4 g	Soil injection	470.8a	67.7a	1013.7a	5.31b	4.82c
Bay NTN33893 75W	1 g	Soil injection	362.3a	62.6a	400.8a	3.63ab	4.14bc
Bay NTN33893 75W	2 g	Soil injection	362.5a	60.9a	325.8a	1.81a	0.81a
Abamectin		$Arbor_x$® capsule	559.3a	76.5a	657.0a	5.25b	5.94c
Untreated check			935.8a	57.7a	903.7a	8.00c	4.50c

[z]$Arbor_x$® treatments and acephate soil injections applied July 5, 1993; Bay NTN33893 soil injections applied July 12, 1993.

[y]Rate is grams AI per 2.5 cm (1 in) dbh.

[x]Number of European elm scale crawlers present on 10 randomly chosen leaves from four branches excised. Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

[w]Percent mortality to Instar II European elm scale crawlers. Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

[v]Twigs were 4 cm (1.5 in) long and approximately 1 cm (0.5 in) diameter and were collected randomly from four excised branches per tree. Numbers within columns followed by the same letter are not significantly different by SNK (P = 0.05).

[u]Overwintered European elm scales. Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

[t]Newly settled nymphs of European elm scale. Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

[s]Rating of population size based on number of scales on 0.5 m (19.5 in) sample of twig, as indicated above. Scale is 0 = No scales, 1= 1 scale present, 2 = 2 scales present, 3 = 3–4 scales present, 4 = 5–8 scales present, 5 = 9–16 scales present, 6 = 17–32 scales present, 7 = 33–64 scales present, 8 = 65–128 scales present, 9 = 129–256 scales present and 10 = > 256 scales present on samples. Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

[r]Mean number of scales (Num), percent mortality (Mort), or population rating (Pop) respectively.

Table 2. **Insecticides, rates, application methods and mean number of aphids per two terminals sampled for three sampling dates for elm leaf aphid evaluation in 1993 and 1994 on American elm trees growing along a median strip in Denver, CO.**[z]

			Mean no. aphids/sample[x]		
Treatment/formulation	**Rate**[y]	**Application method**	**July 15, 1993**	**August 2, 1993**	**July 19, 1994**
Bay NTN33893 200 SL		$Arbor_x$® capsule	675.7a	2.2a	12.0a
Orthene 75S	1 g	Soil injection	577.2a	10.2a	1742.5d
Orthene 75S	4 g	Soil injection	1013.7a	3.5a	614.5bc
Bay NTN33893 75W	1 g	Soil injection		14.7a	70.0ab
Bay NTN33893 75W	2 g	Soil injection		4.8a	6.3a
Abamectin		$Arbor_x$® capsule	657.0a	10.5a	1060.5cd
Untreated check			903.7a	14.3a	1379.5d

[z]$Arbor_x$® treatments and acephate soil injections applied 5 July 1993, Bay NTN33893 soil injections applied 12 July 1993.

[y]Rate is grams AI per 2.5 cm (1 in) dbh.

[x]Number of elm leaf aphids counted on two freshly clipped 1 m branch sections. Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

Table 3. **Insecticides, application methods and damage rating on two dates due to first and second generation elm leaf beetle feeding on mature street tree elms growing in Denver, CO.**[z]

		Mean damage rating/tree[y]	
Treatment/formulation	**Application method**	**June 21, 1994**	**August 19, 1994**
Bay NTN33893 200SL	$Arbor_x$® Capsule	0.9a	1.3a
Bay NTN33893 240FS	Direct trunk injection	1.8a	4.1ab
Abamectin	$Arbor_x$® Capsule	2.4a	4.5ab
Avid 0.15E	Direct trunk injection	1.8a	6.0b
Untreated Check		4.7b	7.4b

[z]$Arbor_x$® treatments applied June 30, 1993; direct trunk injections made July 26, 1993.

[y]Damage rating is a 1–10 scale based on percent skeletonization of leaves where 0 is no damage and 10 is total skeletonization of leaves on trees in the study. Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

Table 4. **Insecticides, trunk injection system type and statistics for 1993 and 1994 samples for European elm scale on Siberian elm trees located in Fort Collins, CO.**[z]

Insecticide	**Injection system**	**Mean percent mortality, 1993**[y]	**Scales/18-in twig sample, 1994**[y]
Abamectin	$Arbor_x$® capsule	91.4a	43.2a
Bay NTN 33893 200SL	$Arbor_x$® capsule	89.8a	15.2a
Bay NTN 33893 240FS	Direct trunk injection	67.4b	28.2a
Untreated check		55.8b	90.6ab
Avid 0.15E	Direct trunk injection	47.0b	127.2b

[z]Treatments applied July 21, 1993.

[y]Means within columns followed by the same letter are not significantly different by SNK (P = 0.05).

(July 19, 1994) showed significant control with several treatments. Lower (1 g (0.035 oz) AI/2.5 cm (1 in) dbh) soil injection rates of Bay NTN33893 (imidacloprid) provided approximately 95 percent control and both trunk injections and high (2 g (0.070 oz) AI/2.5 cm (1 in) dbh) soil injection rates of Bay NTN33893 (imidacloprid) provided over 99 percent control. In contrast, high soil injection rates (4 g (0.141 oz) AI per 2.5 cm (1 in) dbh) of Orthene 75S (acephate) provided approximately 44 percent control. Lower soil injection rates of Orthene 75S (acephate) and trunk injections of abamectin did not reduce elm leaf aphid populations on any of the sampling dates.

Trunk injection trial, site 2. A significant reduction (SNK test, P = 0.05) in elm leaf beetle damage was observed from the use of all insecticide treatments on June 21, 1994, almost one year following application (Table 3). Elm leaf beetle populations remained high at the site providing a large second generation and significant control from injected imidacloprid using the $Arbor_x$® capsule was observed through August 19, 1994. Trunk injected abamectin and direct injections of imidacloprid using the modified syringe did not control elm leaf beetle injury on this latter evaluation date. Previously, Harrell and Pierce (4) had reported successful control of elm leaf beetle with abamectin injected directly under the bark of Siberian elm trunks.

Trunk injection trial, site 3. At the 1993 evaluation (August 10, 1993), $Arbor_x$® capsule injections of abamectin and imidacloprid provided slight, but significant control (SNK

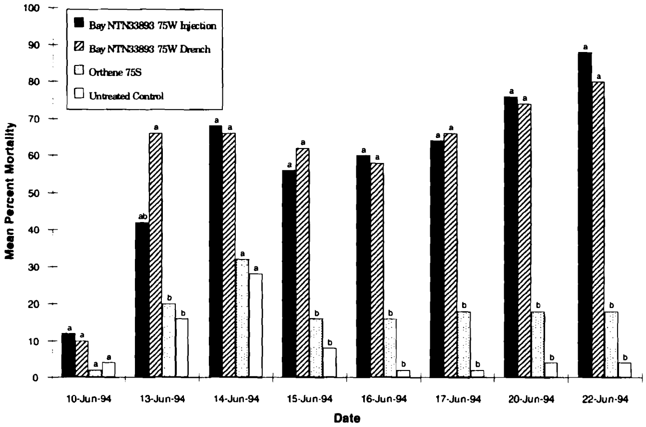

Fig. 1. **Mean percent mortality of elm leaf beetle larvae fed Siberian elm foliage for eight dates in the laboratory (foliage from Site Five). Columns with the same letter are not significantly different by SNK (P = 0.05). Treatments applied May 26 and 28, 1993.**

test, P = 0.05) of European elm scale (Table 4). However, persistence of control the following season (June 15, 1994) was not observed from either imidacloprid or abamectin. Direct trunk injections of abamectin did not significantly reduce scale populations (SNK test, P = 0.05) on either sampling date (Table 4).

Direct trunk injection test, site 4. Direct trunk injections of Bay NTN33893 240FS (imidacloprid) did provide current season control of European elm scale at this site. Mean numbers of Instar II scales on sampled twigs of treated trees were 3.6, compared to 14.2 on untreated trees, and were significantly different (SNK test, P = 0.05).

Soil treatment persistence test, site 5. Both soil injected and soil drench applications of imidacloprid, but not soil injected acephate, provided control of elm leaf beetle for more than one year post-application. On June 13, 1994, Bay NTN33893 (imidacloprid) soil drench treatments caused significant mortality (SNK test, P = 0.05) to ELB larvae fed treated foliage, compared to larvae fed untreated leaves (Fig. 1). Samples taken on June 15, 16, 17, 20 and 22 indicated significant differences (SNK test, P = 0.05) between both Bay NTN33893 application methods and all other treatments in mortality to ELB larvae. On June 22, both Bay NTN33893 treatments resulted in mortality of 80% or greater. Orthene treatments did not display significant control on any sampling date. No significant differences were observed between all treatments on June 10 and 14, 1994, for mortality to ELB larvae (Fig. 1).

Interpretation of the data presented here suggest that both soil and trunk injections of the newer systemic insecticides, particularly imidacloprid, have the potential to control most of the significant insect pests associated with elm. Furthermore, an unusually high degree of persistence was observed with both soil and trunk applied imidacloprid, providing excellent control of all three pest species a year following application. This desirable feature, however, must be balanced by the relatively slow rate of uptake and expression of control, as current season control (of European elm scale) was observed in only one of the trials, involving direct injections under the bark of the trunk. This will require uses made in anticipation of problems, rather than as a treatment of acute outbreaks requiring rapid control.

During the 1994 season, imidacloprid received US registration for soil injection and soil drench uses on trees and shrubs, under the trade name Merit. Label directions do indicate that translocation may be slow, requiring up to 60 days for expression of control, although data here suggest it may require an even longer interval on established trees. Registration for imidacloprid or abamectin trunk injection uses, as well as soil injection uses of acephate are currently pending.

(*Ed. note*: This paper reports the results of research only and does not imply registration of a product under amended FIFRA. Before using any of the products mentioned in this research paper, be certain of their registration by appropriate state and/or federal authorities.)

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