NOTE

Evaluation of Systemic Insecticides for Control of *Elatobium abietinum* (Homoptera: Aphididae) on *Picea sitchensis* in Southeast Alaska[1]

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J. Entomol. Sci. 44(1): 78-84 (January 2009)

Key Words spruce aphid, Sitka spruce, tree injections, acephate, imidacloprid

Spruce aphid, *Elatobium abietinum* (Walker) (Homoptera: Aphididae), causes chlorosis, defoliation and mortality of spruce, *Picea* spp., but has also been recorded infesting pine, *Pinus* spp., and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco (Furniss and Carolin 1977, U.S. Dept. of Agric. For. Serv. Misc. Publ. 1339). This species, an exotic invasive in North America, was first reported in British Columbia in 1916 presumably originating from native populations in Europe (Carter and Halldórsson 1998, Scot. For. Comm. Tech. Pap. 24) and has since spread throughout coastal areas of the Pacific Northwest where maritime climates moderate temperatures and increase *E. abietinum* survivability (Bejer-Petersen 1962, Oikos 13: 155-168). Little has been published on *E. abietinum* in North America. Sitka spruce, *Picea sitchensis* (Bong.) Carr., is a preferred host and grows in a narrow band along the Pacific coast from a latitude of about 61°N in south-central Alaska to 39°N in northern California. Extensive amounts of *P. sitchensis* mortality has been attributed to *E. abietinum* infestations in British Columbia (Koot 1991, Can. For. Serv. For. Pest Leafl. 16), but appears to be a rare occurrence elsewhere. Since 1998, large-scale outbreaks have occurred in Southeast Alaska resulting in defoliation of *P. sitchensis* over extensive areas (Wittwer 2003, U.S. Dept. of Agric. For. Serv. Tech. Rept. R10-TP-113) and some tree mortality.

Elatobium abietinum overwinters as wingless, parthenogenetic females, which allows populations to rapidly increase following mild winters. There are usually several generations per year. Feeding is restricted to 1-yr-old and older needles as settling on younger needles is deterred by volatiles present in the epicuticular wax (Jackson and Dixon 1996, Ecol. Entomol. 21: 358-364). Needles that are fed upon quickly turn

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yellow and generally fall from the tree within a few weeks. Infestations tend to begin in shaded portions of the lower crown, rarely affecting the upper crown except during severe infestations (Eglitis 1994, A.K. Coop. Exten. Rept. 100C-1-063). In Europe, *E. abietinum* populations tend to peak in spring or early summer and then decline until August (Parry 1974, Oecologia 15: 305-320; Parry 1976, Oecologia 23: 297-313). A brief period of population growth occasionally occurs in mid-August through October, which agrees with observations in Southeast Alaska (M.E.S., unpubl. data). In Europe, it has been shown that the production of alates, changes in fecundity and other aspects of performance are largely dictated by changes in sap nutritional levels, primarily amino acids (Day et al. 2004, Ecol. Entomol. 29: 555-565).

The most common method for controlling *E. abietinum* on *P. sitchensis* in Southeast Alaska is to implant the tree bole with acephate (M.E.S., unpubl. data), a systemic organophosphate insecticide that has received wide-spread use for control of sucking and chewing insects on trees. However, there is a limit to the number of times that a tree can be treated as implantation requires drilling a hole every 10 cm around the tree bole. Imidacloprid, a systemic neonicotinoid insecticide, is effective for control of hemlock woolly adelgid, *Adelges tsugae* Annand (Homoptera: Adelgidae) (Steward and Horner 1994, J. Arbor. 20: 287-288; Webb et al. 2003, J. Arbor. 29: 298-302), among other insects with similar feeding mechanisms (Steward et al. 1998, J. Arbor. 24: 344-346), but has not received wide-spread use for control of *E. abietinum*. The objective of this study was to evaluate the efficacy of bole implants of acephate and soil and tree injections of imidacloprid for control of *E. abietinum* on *P. sitchensis* in Southeast Alaska.

This study was conducted in 3 coastal communities in Southeast Alaska: (1) Juneau (58.30°N, 134.42°W), (2) Sitka (57.05°N, 135.32°W), and (3) Craig (55.46°N, 133.14°W) in 2005 and 2006. At each site, 4 treatments were applied to each of 12 randomly-selected *P. sitchensis*: (1) acephate bole implants (97.0% a.i.; Acecaps® 97 [0.95 cm]; Creative Sales Inc., Fremont, NE; USEPA Reg. No. 37,979-1), (2) imidacloprid tree injection (5.0% a.i.; IMA-jet; Arborjet Inc., Woburn, MA; USEPA Reg. No. 74,578-1), (3) imidacloprid soil injection (21.4% a.i.; Merit® 2F; Bayer Environmental Science, Research Triangle Park, NC; USEPA Reg. No. 432-1312), and (4) an untreated control. Application methods and rates are detailed in Table 1. Insecticide treatments were implemented once annually during 17-26 April 2005 and 17-25 April 2006. Experimental trees were 60.7 ± 2.1 cm (mean ± SEM) in diameter at breast height (1.37 m in height) and 22.9 ± 0.7 m tall, and located in areas where extensive amounts of tree defoliation were observed in 2004 (M.E.S., pers. obs.).

Efficacy was monitored twice annually in June and September of each year during the 2-yr period. One branch was randomly-selected from the lower midcrown of each tree at 4 aspects (*n* = 4/tree) and severed with pole pruners. Depending on branch size, each was further randomly subsampled or left intact and placed in 1 individually labeled plastic bag per tree. Samples were immediately returned to the laboratory and stored in a refrigerator at about 4.5°C to prevent aphids from dislodging. For each tree, foliage was randomly-selected from each bag and numbers of *E. abietinum* were counted under a magnifying lamp until at least 600 needles were examined. Count data were converted to numbers of *E. abietinum* per 100 needles (Straw et al. 2005, For. Ecol. Manage. 213: 349-368). To determine changes in levels of defoliation attributed to treatment, vertical and horizontal digital photographs were taken of each tree crown in April and September of 2005. The HemiView System-HMV1 (Delta-T

Table 1. Treatments evaluated for control of *E. abietinum* on *P. sitchensis* in Southeast Alaska, 2005-2006

Treatment	Application method and rate	Treatment duration	Costs of materials (2007 US$)	Comments
Acecaps® 97	Inserted into holes drilled every 10 cm around the tree bole at 1 m in height.	<5 min. per tree.	Cost for 45.7-cm dbh tree is about $21.	Easy to implement. Treatment results in a large number of wounds per tree.
IMA-jet	Injected using the Tree I.V. system (Arborjet Inc., Woburn, MA). Rates per 2.54 cm of dbh (diameter at 1.37 m in height) were 2, 4, 6 and 8 ml for 5-28 cm, 30.5-58 cm, 61-89 cm and >91.4 cm dbh trees, respectively.	15-60 min. per tree depending on rate of uptake.	Tree I.V. 2-pack kit is $599. IMA-jet cost for 45.7-cm dbh tree is about $28 at rate examined.	Requires tree injection system. Cool climates are less conductive to uptake and increase injection times. Treatment results in few wounds (usually 4-6) per tree.
Merit® 2F	Injected using the Kioritz soil injector (Kioritz Corp., Tokyo, Japan). A 2.0% solution (mixed with water) was applied at 29.57 ml per 2.54 cm dbh. Using the highest setting on the Kioritz (5; = 5 ml per stroke) 29.57 ml was applied into each injection hole using six strokes. Injection holes (number = dbh in inches) were equally distributed around the drip line of each tree.	About 10 min. per tree.	Kiortiz soil injector is $369. Merit® 2F cost for 45.7-cm dbh tree is about $35, but declining.	Treatment requires measurement of insecticide and mixing with water. Leaching may occur in some soils. Soil injections do not wound trees.

Devices Ltd., Burwell, Cambridge), normally used to determine crown cover using a fish-eye lens, was used to determine the percentage of pixels that were scored as containing skylight. Photos that had too much direct branch lighting could not be used because this showed up as sky in the analysis. Each photo was adjusted at high power so that light flecks that appeared in the photo in normal lighting were of the correct dimensions when converted by the program to black and white pixels. The circle of crown where analyses were done was carefully compared between pre and posttreatment samples and percent change was calculated.

The experimental design was a randomized complete block with 4 treatments, 3 blocks (locations) and 12 replicates/treatment/block. A test of normality was performed and square root transformations were used when data deviated significantly from a normal distribution. A two-way analysis of variance (block X treatment) was performed on the number of *E. abietinum* per 100 needles using $\alpha = 0.05$ (SigmaStat Version 2.0, SPSS Inc., Chicago, IL). If a significant treatment effect was detected, the Tukey's multiple comparison test (Tukey's HSD) was used for separation of treatment means. During each sample period, a few trees could not be sampled due to limited accessibility and, therefore, the numbers of degrees of freedom error vary among analyses. Differences in crown density between each insecticide treatment and the untreated control were compared by *t*-tests.

The highest *E. abietinum* densities occurred during June 2005 when 12.2 ± 6.0 (mean ± SEM) were recorded in the untreated control (Fig. 1A). Populations declined during subsequent sample periods in September 2005 (Fig. 1B) and June 2006 (Fig. 2A), but rebounded slightly in September 2006 (Fig. 2B). Generally, *E. abietinum* populations peak in spring or early summer. We attribute the population decline between September 2005 and June 2006 to abnormally cold temperatures in March and April of 2006. In Europe, it is well documented that *E. abietinum* population reductions occur due to mortality attributed to freezing and starvation, or a lack of reproduction below certain temperature thresholds (Powell and Parry 1976, Ann. App. Biol. 82: 209-219; Carter 1982, Scot. For. Comm. For. Record. No. 84). In March 2006, Craig, Juneau and Sitka recorded 6, 13 and 6 d with temperatures below −6.7°C, respectively. Minimum temperatures recorded for each were −12.2°C, −19.4°C and −15.0°C, respectively. Powell and Parry (1976) reported that in Scotland overwintering populations are noticeably reduced when ambient temperatures fall below −7°C. To that end, only 3,691 ha of defoliation were caused by *E. abietinum* in 2006 compared with 12,395 ha in 2003 (Snyder and Lundquist 2007, U.S. Dept. of Agric. For. Serv. R10-PR-11). Recent aerial surveys indicate the current outbreak has subsided over much of Southeast Alaska (M.E.S., unpubl. data).

Acecaps® significantly reduced the density of *E. abietinum* by 92.4% and 100% compared with the untreated control during the first ($F = 4.85$; df = 3, 125; $P = 0.003$; Fig. 1A) and fourth sample periods ($F = 4.09$; df = 3, 120; $P = 0.008$; Fig. 2B), respectively. No *E. abietinum* were detected on Acecaps®-treated trees during the third sample period, but a significant treatment effect was not observed ($F = 2.59$; df = 3, 125; $P = 0.056$; Fig. 2A), which is not surprising given such few *E. abietinum* were found overall (Fig. 2A). No other significant differences were observed among treatments (Figs. 1, 2) despite relatively substantial reductions in *E. abietinum* densities compared with the untreated control during some sample periods. Untreated control trees lost foliage (−1.4 ± 0.9%) during 2005 whereas Acecaps® (1.8 ± 0.8%), IMA-jet (1.6 ± 0.9%) and Merit® 2F (1.3 ± 0.8%) -treated trees increased foliage ($P < 0.02$, all cases).

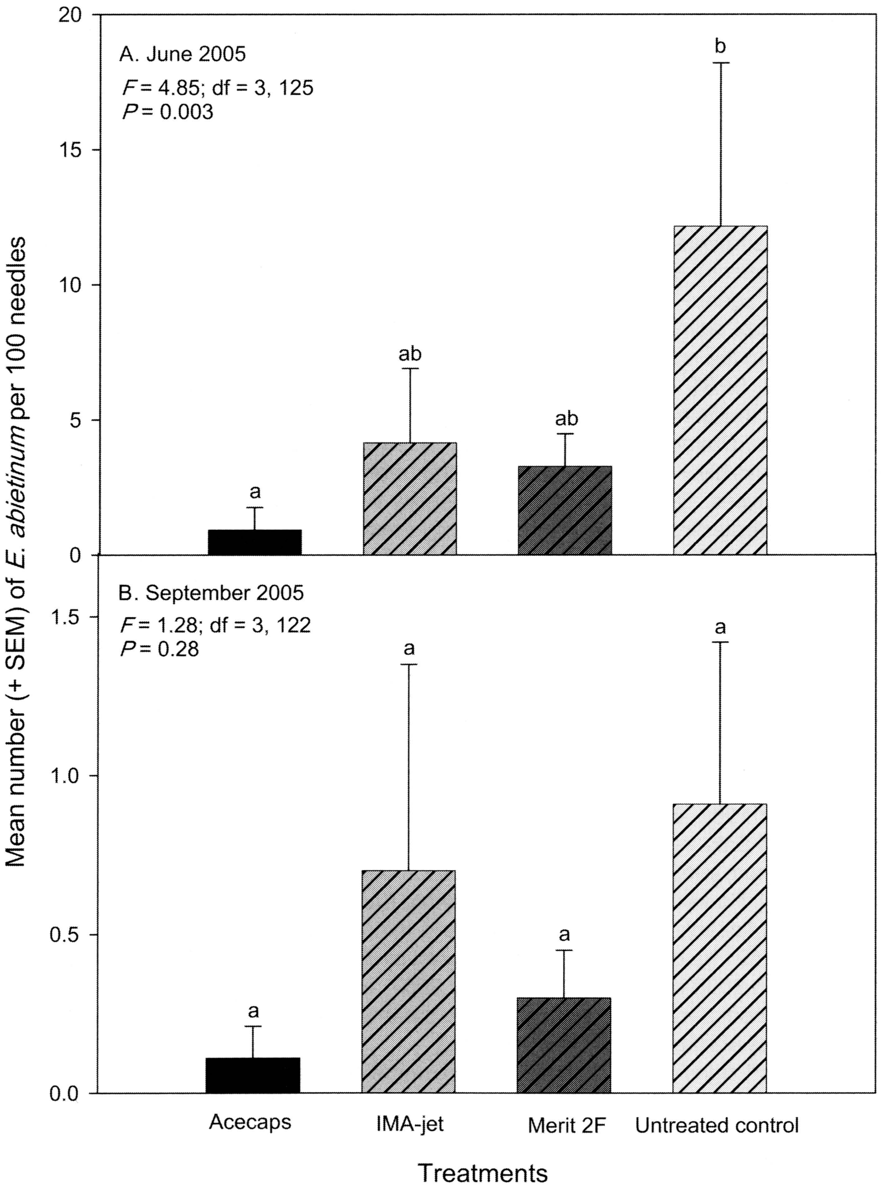

Fig. 1. Mean number (+ SEM) of *E. abietinum* per 100 needles based on data collected in June (A) and September (B), 2005. Means followed by the same letter are not significantly different (Tukey's HSD; $P > 0.05$)

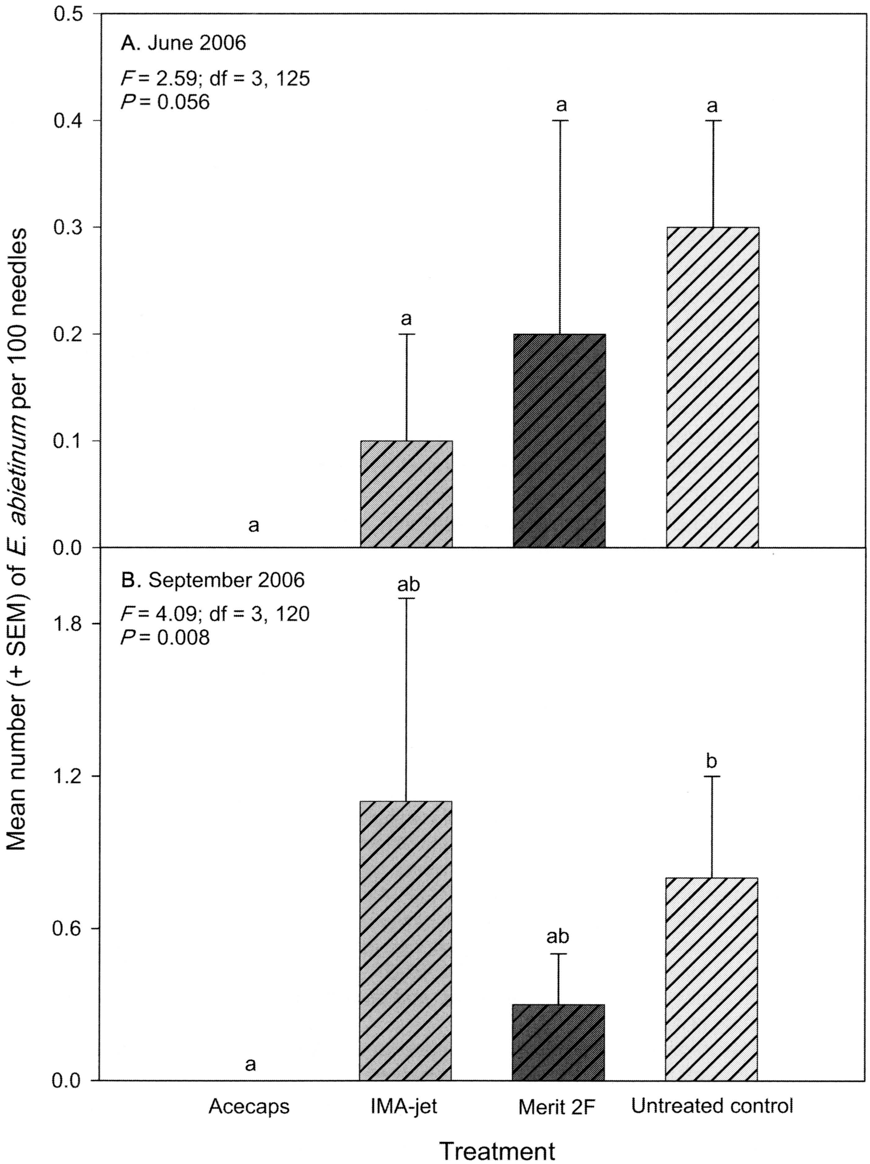

Fig. 2. Mean number (+ SEM) of *E. abietinum* per 100 needles based on data collected in June (A) and September (B), 2006. Means followed by the same letter are not significantly different (Tukey's HSD; $P > 0.05$)

Acecaps® were the quickest and easiest control method to implement (Table 1). Little or no training is required to become proficient with this technique as only a cordless drill, small hammer and a ≤ 0.95 cm diameter dowel are necessary for implanting. The Tree I.V. system requires fewer holes and thus results in less tree damage (Table 1), but the IMA-jet formulation is expensive and some training is required to become proficient with use of the Tree I.V. system. An injected formulation of acephate is now available for use with the Tree I.V. system, but has yet to be evaluated for *E. abietinum* control. IMA-jet was applied at the maximum rate published on the 2005 label. Since that time, the label has been revised and maximum rates have increased 2-fold (e.g., from 6-12 ml/2.54 cm dbh for a 61 cm tree). The original label was based on efficacy data obtained from similar tree injection methods using imidacloprid, but was later modified based on data specific to IMA-jet, which allows for incremental increases in dosage based on tree biomass. Higher application rates will likely improve efficacy and should be evaluated for *E. abietinum* control. In other studies, analyses of acephate and imidacloprid residues in tree foliage suggest that both active ingredients are rapidly translocated to the crown reaching levels adequate to cause aphid mortality within several days to several weeks (Reardon and Barrett 1984, For. Ecol. Manage. 81: 1-10; Shea et al. 1991, W. J. Appl. For. 6: 4-7; Poland et al. 2006, J. Econ. Entomol. 99: 383-392). Accordingly, treatments implemented in early spring should be sufficient to allow materials to translocate to the tree crown prior to *E. abietinum* population increases in late spring.

Acknowledgments

The authors thank C.P. Dabney and S.R. McKelvey (Pacific Southwest Research Station, USDA Forest Service), M. Lamb and P. Adkins (Forest Health Protection, USDA Forest Service) and B. Templin (Craig Public Works) for technical assistance. In addition, the authors thank B. Templin, S. McLeod (Sitka Public Works) and T. Hinkley (Department of Parks and Recreation, Juneau) for helping to procure study sites, and C. Olsen (Bayer Environmental Science), E. Bristol and J. Doccola (Arborjet Inc.) for their helpful insights regarding treatments. Accommodations and vehicles were often provided by the Craig and Sitka Ranger Districts, Tongass National Forest. Arborjet Inc. provided IMA-jet at a cost savings and loaned us several Tree I.V. systems. Bayer Environmental Science donated the Merit® 2F. A special thanks to E. Bristol, C.P. Dabney, J. Doccola, S.R. McKelvey and C. Olsen for their critiques, which improved earlier versions of this manuscript. This research was supported, in part, by a grant from the Special Technology Development Program, USDA Forest Service (R10-2005-01) to M.E.S. and C.J.F. the Pacific Southwest Research Station, Forest Health Protection, and Department of Natural Resources, Division of Forestry, State of Alaska.

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