The Canadian Entomologist

Vol. 126 Ottawa, Canada, January/February 1994 No. 1

EFFICACY OF ESFENVALERATE FOR CONTROL OF INSECTS HARMFUL TO SEED PRODUCTION IN DISEASE-RESISTANT WESTERN WHITE PINES

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Abstract

The Canadian Entomologist **126**: 1–5 (1994)

We tested the pyrethroid insecticide esfenvalerate in single, double, and triple applications for control of insects affecting seed production of blister rust-resistant western white pine, *Pinus monticola* Douglas. All treatments increased the proportion of normal seed produced and reduced the proportion of seed damaged by the western conifer seed bug, *Leptoglossus occidentalis* Heidemann. Only the triple application reduced the proportion of cones killed by the pine cone beetle, *Conophthorus ponderosae* Hopkins. Other seed-damaging insect species [seed chalcids, *Megastigmus* sp.; the fir coneworm, *Dioryctria abietivorella* (Grote); and seedworms, *Cydia* sp.] were present but in numbers too low to test for insecticide efficacy.

Rappaport, N.G., M.I. Haverty, P.J. Shea et R.E. Sandquist. 1994. L'éfficace de l'esfenvalérate contre les insectes nuisibles des cônes et graines de *Pinus monticola* amélioré de résistance contre la rouille. *The Canadian Entomologist* **126**: 1–5.

Résumé

On a constaté l'éfficace de l'esfenvalérate avec des traitements simples, doubles, et triples contre les insectes nuisibles des cônes et graines de *Pinus monticola* Douglas amélioré de résistance contre la rouille. Tous les traitements ont augmenté la proportion des graines saines et tous les trois ont réduit la proportion de graines endommagées par la punaise à pattes feuilleuses, *Leptoglossus occidentalis* Heidemann. Uniquement le traitement triple a réduit la proportion des cônes tuée par le scolyte des cônes du pin, *Conophthorus ponderosae* Hopkins. Les autres espèces d'insectes nuisibles présentes à ce verger à graines [chalcidiens, *Megastigmus* sp.; la pyrale des cônes du sapin, *Dioryctria abietivorella* (Grote); et la pyrale des graines, *Cydia* sp.] ont été présentes aux niveaux trop bas d'essayer l'éfficace de l'insecticide.

Introduction

Seeds of blister rust-resistant western white pine, *Pinus monticola* Douglas, are being grown at two seed orchards in northern Idaho and at the Dorena Tree Improvement Center (Dorena TIC) in Cottage Grove, OR. Seed from such genetically improved trees is important for the maintenance of this native species in the forest ecosystems of the Pacific Northwest because of the extreme susceptibility of western white pine to white pine blister rust (*Cronartium ribicola* Fisher), an introduced pathogen (Haig et al. 1941). Insect impact on western white pine seed production varies from year to year but can exceed 90% (Shea 1986; Shea et al. 1987). Acute shortages of disease-resistant western white pine progeny for reforestation in the northwestern United States highlight the need for effective control methods against insects that destroy this important seed resource.

The insect complex damaging western white pine seeds at Dorena TIC has not yet been fully characterized, but a concurrent study has shown that the western conifer seed bug

(*Leptoglossus occidentalis* Heidemann) (Hemiptera: Coreidae) is often the most damaging (Shea and Rappaport 1994). Other insect species in the complex include the fir coneworm [*Dioryctria abietivorella* (Grote)] (Lepidoptera: Pyralidae), seedworms (*Cydia* sp.) (Lepidoptera: Olethreutidae), seed chalcids (*Megastigmus* sp.) (Hymenoptera: Torymidae), and the pine cone beetle (*Conophthorus ponderosae* Hopkins) (Coleoptera: Scolytidae).

Haverty and Wood (1981) evaluated insecticides against the pine cone beetle in the laboratory, and Shea et al. (1984) tested promising chemicals in a western white pine seed orchard in Sandpoint, ID. The latter study showed that permethrin applied once or twice at 0.3, 0.6, or 1.2 g per L reduced losses of cones to the pine cone beetle, but the most cost-effective treatment was 0.6 g per L applied only once. Haverty and Shea (1986) and Haverty et al. (1986) showed that two applications of 0.025% fenvalerate, one in mid-May and one in mid-June, protected western white pine cones from fir coneworm attack in the Moscow Arboretum near Moscow, ID. In another field experiment, Haverty et al. (1988) demonstrated that a single application of fenvalerate at 0.025% in mid-May gave adequate protection from the coneworm, but two applications were better. A double application of 0.0125% fenvalerate, once in May and once in June, did not give adequate protection.

Since the completion of the fenvalerate study in the Moscow Arboretum (Haverty et al. 1986), E.I. du Pont de Nemours & Co. has separated racemic fenvalerate (Pydrin®) into its optical isomers. The S-isomer, called esfenvalerate, is 4-fold as toxic as fenvalerate and is now marketed as Asana® XL Insecticide in a 79 g per L emulsifiable concentrate. The objective of this study was to evaluate whether single or multiple applications of 0.006% esfenvalerate would provide protection from western white pine cone and seed insects at Dorena TIC and thereby increase seed production.

Materials and Methods

Study Area. The Dorena TIC is a grafted, clonal seed orchard located on the east side of the Willamette Valley near Cottage Grove, OR. This production orchard, formerly a breeding orchard, covers about 2.5 ha and has about 430 cone-bearing western white pines. The orchard is nearly 30 years old, and has been producing large quantities of seed for outplanting for more than 10 years (Sniezko 1992). We used trees from a single block of trees that had a predicted crop of greater than 20, 2nd-year cones per tree.

Insecticide Treatments and Application. Esfenvalerate was diluted in water to a concentration of 0.006% (w/w) (75 mL per 100 L water) and applied with a trailer-mounted hydraulic sprayer. Mixing was done just prior to insecticide application, and trees were sprayed to run-off in the early morning when wind speed was low to reduce drift so that adjacent trees would not be contaminated. Insecticides were applied in mid-April 1989, and again 30 and 60 days after the first application. The first application was timed to coincide with the beginning of cone elongation in the spring, because that is when pest insects first begin to appear. Timing of subsequent applications at 30 and 60 days after the first spray, which is consistent with label recommendations, was intended to provide continuous protection from cone and seed insects.

Experimental Design, Response Variables, and Data Analyses. The experiment was conducted as a completely randomized design. There were four treatments: an untreated check; an application of 0.006% esfenvalerate in mid-April; an application of 0.006% esfenvalerate in mid-April and mid-May; and an application of 0.006% esfenvalerate in mid-April, mid-May, and mid-June 1989. Each treatment was randomly assigned to 15 trees. Trees were selected so that spacing of treated trees minimized the chance of contamination among treatments.

At maturity, all cones on each tree were harvested, counted, placed in separate, labelled burlap bags, air-dried, and subjected to seed extraction at Dorena TIC. Uncleaned seed lots

TABLE 1. Mean number (±SD) of cones per tree and seeds per cone of western white pine damaged by various insects, Dorena TIC, 1989*

Esfenvalerate Trt.†	No. trees	No. cones infested by cone beetles	Number of seeds per cone in each category: Normal	Seed bug-damaged	Moth-damaged	Chalcid-damaged
1	15	2.80 (4.33)	144.8 (50.7)	7.3 (3.8)	0.022 (0.084)	0 (0)
2	15	4.27 (6.51)	126.2 (34.0)	5.6 (4.6)	0 (0)	0.01 (0.04)
3	15	*0.87 (1.51)	125.4 (51.4)	9.1 (16.0)	0.026 (0.069)	0 (0)
4 (check)	15	6.07 (6.01)	115.7 (63.1)	11.9 (6.1)	0.009 (0.037)	0 (0)

*Means in a column preceded by an asterisk are significantly different from the untreated check ($\alpha = 0.05$); Dunnett's procedure (Steel and Torrie 1980). Cone beetle = *Conophthorus ponderosae*; seed bug = *Leptoglossus occidentalis*; moth = *Dioryctria abietivorella* or *Cydia* sp.; chalcid = *Megastigmus* sp.
†Treatment 1 = esfenvalerate 0.006% applied in mid-April; treatment 2 = esfenvalerate 0.006% applied in mid-April and mid-May; treatment 3 = esfenvalerate 0.006% applied in mid-April, mid-May, and mid-June; treatment 4 = untreated control.

all seeds were carefully separated from the debris. Eight groups of 100 seeds per tree were randomly selected, weighed, and placed in envelopes. For trees with fewer than 800 seeds, all seeds were counted. The remainder of the seeds were weighed and the total number of seeds per tree was estimated based on the mean weight of the 800 seeds for that tree and the weight of the extra seed. The eight envelopes, with 100 seeds per envelope, were taped to 20- by 25-cm sheets of cardstock, then were radiographed to determine the percentage of seed that was either filled with an apparently viable embryo and endosperm, empty, or damaged by the western conifer seed bug, seed chalcids, moths, or other unknown agents.

The response variables that we evaluated included the following: numbers and percentages of cone beetle-infested cones per tree; number of seeds per cone; number or weight of seeds per tree; and numbers and percentages of seeds per cone damaged by seed bugs, moths, or chalcids. Empty seeds were not included in damage estimates, because those seeds are thought to result from physiological problems or pollination failure (DeBarr and Ebel 1973). Cones attacked by cone beetles were not included in the seed analysis because they produced no extractable seed. Variances of derived variables were approximated using the Delta method (Bishop et al. 1977). Differences among treatments were evaluated by analysis of variance and analysis of covariance, with the number of cones per tree as the covariate ($\alpha = 0.05$). Significant differences between insecticide treatments and the control were tested using Dunnett's procedure (experiment-wise error rate $\alpha = 0.05$) (Steele and Torrie 1980). Using data from Haverty et al. (1986), we determined that a sample size of 15 trees was sufficient to detect a difference of a treatment mean from the untreated check mean of 16.9 seeds per cone (25% difference) with 90% power at $\alpha = 0.05$ or 12.2 seeds per cone with 80% power at $\alpha = 0.10$.

Results and Discussion

Analyses of covariance showed that cone crop was linearly related to percentage of normal seeds per cone, percentage of damaged seeds per cone, percentage of seed bug-damaged seeds per cone, and percentage of chalcid-attacked seeds per cone ($\alpha = 0.05$). In all cases, however, the coefficients were so minuscule as to render the associations meaningless.

The third treatment, 0.006% esfenvalerate applied three times at 1-month intervals, reduced the number of cone beetle-infested cones per tree, but the other treatments did not (Table 1). Similarly, the third treatment was the only one to reduce the percentage of cone beetle-infested cones per tree (Table 2). The percentage of infested cones per tree, however,

TABLE 2. Mean percentage (±SD) of cones per tree and seeds per cone of western white pine damaged by various insects, Dorena TIC, 1989*

Esfenvalerate Trt.†	No. trees	Percentage cone beetle-damaged cones per tree	Percentage of seeds per cone in each category: Normal	Seed bug-damaged	Moth-damaged	Chalcid-damaged
1	15	1.15 (2.38)	*94.7 (3.3)	*5.3 (3.2)	0.023 (0.09)	0 (0)
2	15	1.18 (1.37)	*95.1 (5.2)	*4.9 (5.2)	0 (0)	0.01 (0.2)
3	15	*0.43 (1.09)	*93.4 (8.4)	*6.6 (8.3)	0.032 (0.09)	0 (0)
4 (check)	15	2.61 (4.18)	87.9 (9.5)	12.0 (9.5)	0.023 (0.08)	0 (0)

*Means in a column preceded by an asterisk are significantly different from the untreated check ($\alpha = 0.05$); Dunnett's procedure (Steel and Torrie 1980). Cone beetle = *Conophthorus ponderosae*; seed bug = *Leptoglossus occidentalis*; moth = *Dioryctria abietivorella* or *Cydia* sp.; chalcid = *Megastigmus* sp.
†Treatment 1 = esfenvalerate 0.006% applied in mid-April; treatment 2 = esfenvalerate 0.006% applied in mid-April and mid-May; treatment 3 = esfenvalerate 0.006% applied in mid-April, mid-May, and mid-June; treatment 4 = untreated control.

was so small even in untreated checks that these differences, although statistically significant, are of limited economic or biological interest.

All treatments increased the percentage of normal seeds per cone, but not the number of normal seeds per cone (Tables 1 and 2). This phenomenon may result from the fact that the data expressed as percentages had much smaller coefficients of variation than did the data expressed as numbers per cone. In addition, numbers of normal seed per cone were high even in cones from untreated trees, so values were already close to the upper limit that could be achieved with an insecticide treatment. Low levels of insect damage can result from either low insect populations, high cone populations, or both. In this case, we believe that high cone populations were responsible because concurrent cone analysis studies indicate that 1989 was a better than average year for western white pine cone crops at Dorena TIC (Sniezko 1992).

Virtually all of the insect damage seen was caused by seed bugs (Tables 1 and 2). The results for seed bug damage parallel those for normal seeds (Tables 1 and 2): all treatments reduced the percentage of seed bug-damaged seeds per cone, but not the numbers of seed bug-damaged seeds per cone. The reduction in percentage seed bug damage is reflected in a significant increase in percentage of normal seeds for each of the three treatments. None of the treatments reduced either the percentages or the numbers of seeds damaged by pests other than seed bugs and cone beetles (Tables 1 and 2).

It is apparent from these data that 0.006% esfenvalerate applied once, twice, or three times at monthly intervals was effective in reducing the proportion of western white pine seeds damaged by the western conifer seed bug in a seed orchard setting. Only the triple treatment was effective in reducing the proportion of cones damaged by cone beetles. Significant control of these two pests was achieved even in a year when insect populations were low with respect to cone crops (i.e. when it might be difficult to demonstrate control). Populations of the other groups of insects in Dorena TIC (seed chalcids and moths) were too low to assess the effects of the insecticide treatments. Replication of this experiment during a year of low cone production is needed to test efficacy of esfenvalerate against the seed chalcid and cone moths.

Acknowledgments

We thank the staff of Dorena Tree Improvement Center, USDA Forest Service, for their assistance in executing this study. James Baldwin, Station Statistician, and Sylvia Mori, Mathematical Statistician, (both of USDA Forest Service Pacific Southwest Research Station, Albany CA) provided helpful statistical advice. This article reports only the results

of research; mention of a proprietary product constitutes neither an endorsement nor a recommendation by USDA for its use.

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(Date received: 29 May 1992; date accepted: 16 November 1993)