Single and Multiple Applications of Fenvalerate to Protect Western White Pine Cones from *Dioryctria abietivorella* (Lepidoptera: Pyralidae)[1]

MICHAEL I. HAVERTY, PATRICK J. SHEA, AND LAWRENCE E. STIPE[2]

Pacific Southwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, Berkeley, California 94701

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ABSTRACT Cones of blister rust-resistant western white pine were treated with high-volume ground applications of 0.025% fenvalerate during spring and summer 1984. Four treatments were compared: an untreated check, a single application (9 May), a double application (9 May and 13 June), and a triple application (9 May, 13 June, and 18 July). *Dioryctria abietivorella* (Groté) infested 46.6% of cones in the untreated check, significantly more than the 13.6% in the single application. The double application increased seed yield significantly compared to the untreated check from 31.3 to 56.0 seeds per cone. We are 95% confident that this treatment increased seed production by at least 30% and possibly as much as 128%. The third application in July was apparently unnecessary.

WESTERN WHITE PINE (*Pinus monticola* Douglas) is one of the most valuable timber species in the northern Rocky Mountains. However, the introduction of a pathogenic fungus, *Cronartium ribicola* Fischer, from Europe in the early 1900's nearly eliminated western white pine (Haig et al. 1941). To preserve this species for timber, a breeding program was initiated to select for resistance to this disease (Bingham 1983).

Beginning in 1959, an arboretum was established on the University of Idaho campus, Moscow, using western white pine seedlings that survived intense, artificial innoculation with blister rust spores. The purpose of the aboretum was to provide trees for advanced breeding for blister rust resistance, to provide a gene bank for rust-resistant western white pine, and to establish a plantation for seed orchard management research (Hoff and Coffen 1982). The arboretum is also a source of seed for production planting for 11 cooperators in the Inland Empire Cooperative Tree Improvement Association, including the USDA Forest Service and the state of Idaho. Insects recently destroyed a large portion of the seed crop, so insect control was considered necessary.

Three insect species are responsible for substantial seed losses in the arboretum: *Leptoglossus occidentalis* Heidemann, *Eucosma recissoriana* Heinrich, and *Dioryctria abietivorella* (Groté). No insecticides have been evaluated for control of any of these insects in western white pine seed orchards. Three insecticides, however, are registered for control of coneworms, *Dioryctria* spp., and leaf-footed pine seed bugs, *L. corculus* (Say), in pine seed orchards in the southern United States (Hamel 1983). These insecticides, azinphos-methyl (Guthion), carbofuran (Furadan) and fenvalerate (Pydrin), are effective in reducing seed losses (DeBarr et al. 1982, Nord et al. 1984, 1985).

Here we report the results of an experiment done to evaluate single and multiple high-volume ground applications of 0.025% fenvalerate for protection of cones of blister rust-resistant western white pine. Our objective was to protect the cone crop from the three major pests that attack cones at different times during the second year of cone development.

Materials and Methods

Study Area. The seed orchard is rectangular in shape and covers ca. 4.9 ha on the western edge of the University of Idaho campus adjacent to the Idaho–Washington state boundary. Our study area comprised the NE quarter of the seed orchard and had >340 *P. monticola* of cone-bearing age. Only trees with an initial cone crop of ≥20 second-year cones were used. The remainder of the seed orchard was separated from the study area by a draw ≥20 m wide. This remaining portion of the seed orchard was treated three times (once in May, June, and July) with fenvalerate (applied aerially at a rate of 0.84 kg [AI]/ha delivered in 93.5 liters of water per ha) to protect the majority of the cone crop from seed-destroying insects. The draw served as a clearly visible buffer to guide the helicopter

[1] This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by USDA.

[2] Northern Region, State and Private Forestry, USDA Forest Service, Missoula, MT 59807.

Table 1. Number of cones harvested per tree, percentage of coneworm-infested cones and number of seeds per cone for trees treated once, twice, or three times with 0.025% fenvalerate

Treatments	Cones/tree	Infested cones (%)	Seeds/cone (*n*)	Filled seed (%)	Empty seed (%)	Damaged seed (%)
One application	59.8 (8.8)a	13.6 (9.7)b	43.4 (9.0)ab	82.4a	17.1a	0.5a
Two applications	62.1 (8.8)a	4.1 (9.7)b	56.0 (9.0)b	84.9a	14.8a	0.3a
Three applications	65.8 (8.8)a	5.1 (9.7)b	50.0 (9.0)b	85.5a	13.8a	0.7a
Check	56.8 (6.5)a	46.6 (6.7)a	31.3 (6.6)a	85.9a	13.5a	0.6a

Mean (±95% CL). Means in a column followed by the same letter are not significantly different ($\alpha = 0.05$; Bonferroni's t statistic [Miller 1980]).

pilot so that insecticide drift into the study area would be minimal. Insecticide drift was monitored during each spray application with water-sensitive spray deposit cards. No drift was detected, and the study area was assumed to be free of insecticide contamination from the adjacent control operation.

Insecticide Treatments and Application. Fenvalerate (Pydrin Insecticide 2.4 emulsifiable concentrate [EC]) was diluted in water to a concentration of 0.025% (wt/wt) and applied with a trailer-mounted sprayer. Mixing was done just before application. The tank mixture was applied to near the point of runoff with an hydraulic pumper (Bean) (tank capacity 1,900 liters) set at ca. 30–40 kg/cm^2 using a hand-operated gun. Trees were sprayed in the early morning and late evening when the wind was minimal to avoid contamination of adjacent trees. Between applications, spray equipment was cleaned and rinsed with a detergent (Nutra Sol).

Treatments were done on three dates in 1984: 9 May, 13 June, and 18 July. Since exact phenologies of the three insect pests were unknown, the application schedules were modified after Nord et al. (1984) to be ca. 30 days apart. Pheromone traps baited with candidate *E. recissoriana* pheromone were distributed diagonally across the orchard at ca. 2 m above the ground in trees, and inspected every other day for the appearance of adult males. The first application coincided with the first *E. recissoriana* catch.

Experimental Design, Response Variables, and Data Analysis. The experiment was conducted using a completely randomized design. Four treatments were compared: an untreated check, a single application (9 May), a double application (9 May and 13 June), and a triple application (9 May, 13 June, and 18 July). Each of the insecticide treatments was randomly assigned to 12 trees; 22 trees were randomly assigned to the untreated check. We selected trees spaced sufficiently far apart to avoid contamination. As a result, we occasionally replaced randomly selected trees if they were too tall or too close to adjacent trees.

Before the first insecticide application, all of the cones on the treatment and check trees were examined and counted. Before each subsequent insecticide application, all cones were examined again for obvious insect damage or for the presence of *L. occidentalis* adults or nymphs. Cones with insect damage or insects present were flagged, numbered, and left on the tree. A final observation was made on 21 and 22 August. Previously infested and newly infested cones were collected and bagged separately and returned to the laboratory in Berkeley, California. The remaining cones were picked from 22–25 August. Cones were counted, put in separate burlap bags, and air-dried. The seed was extracted at the USDA Forest Service Coeur D'Alene Nursery. Uncleaned seed lots from each tree were put in plastic bags and mailed to Berkeley, Calif. All seed lots were carefully cleaned and eight groups of 100 seeds from each tree were weighed and placed in envelopes. The remaining 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. In lots with less than 800 seeds, all seeds were counted.

The eight envelopes with 100 seeds per envelope were taped to a sheet of paper (20 by 25 cm) and radiographed to determine percentages of filled seeds with a viable embryo and empty seeds, or seeds damaged by *L. occidentalis* or some unknown cause. Individually collected cones damaged by insects were air-dried and the seeds extracted by shaking. Seeds from each cone were counted and radiographed. Combined data from infested and noninfested cones were used to calculate cone and seed yields for each tree.

The response variables evaluated were number of cones harvested per tree, proportion of cones infested, and number of seeds per cone. Analysis of variance and analysis of covariance with the number of cones per tree as the covariate were used to detect differences between treatments at the $\alpha = 0.05$ level. Bonferroni's t statistic (Miller 1980) was used to compare means and to maintain an $\alpha = 0.05$ level for all comparisons (Jones 1984). Percentages of filled, empty, or damaged seeds are also presented.

Results and Discussion

There were no significant differences between treatments in the number of cones harvested per tree (Table 1). However, the number of cones per tree varied considerably between trees and ranged from 11 to 186. *D. abietivorella* infested 46.6% of

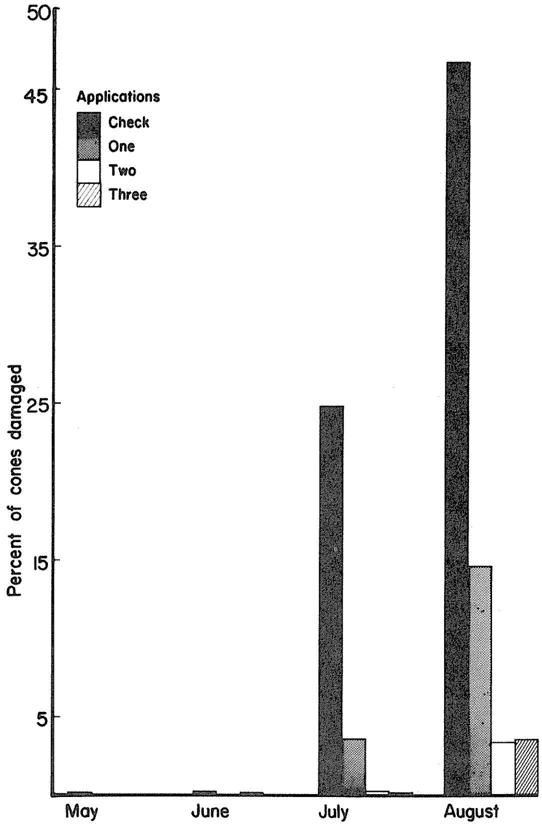

Fig. 1. Percent of western white pine cones damaged by *D. abietivorella*. A single application of 0.025% fenvalerate was applied on 9 May, a second on 13 June, and a third on 18 July.

the cones in the untreated check. This was significantly more than in any of the insecticide treatments. The proportion of infested cones among insecticide treatments did not differ significantly (Table 1). Furthermore, we found no significant relationship between the number of cones on a tree and the proportion of the cones that were infested.

Observations in the Moscow Arboretum in previous years indicated the presence of three potential pests of cones and seeds. Although *E. recissoriana* was present and captured in pheromone traps during 1984, we saw no evidence of damage by this species. *L. occidentalis* also had been abundant during past years, but very few insects were observed during our test. Little cone damage was observed until 16 July 1984 (Fig. 1). All of this damage was caused by *D. abietivorella* and was first observed on 16 July. During July ca. 25% of the untreated cones were infested while <4% of the cones receiving the single fenvalerate application were damaged. By August the proportion of damaged cones on untreated trees increased to 46.6% while only 13.6% of the cones on trees sprayed once, and 4.1 and 5.1% of the cones on trees receiving two and three sprays, respectively, were damaged (Fig. 1, Table 1).

Double or triple applications of fenvalerate increased seed yield significantly compared to the untreated check (Table 1). The 95% confidence interval for the difference in mean seeds per cone between two applications of fenvalerate and the untreated check is 24.7 ± 15.3. In other words, we are 95% confident that this treatment increased seed production by at least 9.4 seeds per cone (an increase of 30.0%) and possibly as much as 40.0 seeds per cone (an increase of 127.8%).

Analysis of covariance showed no effect of cone crop size on number of seeds per cone during 1984. All treatments also had approximately the same proportion of filled, empty, and damaged seeds (Table 1). This is undoubtedly the result of little to no feeding by *L. occidentalis* and random oviposition behavior of *D. abietivorella*.

The coneworm *D. abietivorella* was the only insect species of concern in the Moscow Arboretum in 1984. This insect damaged almost half of the cone crop on unprotected trees and reduced seed yield by ca. 44%. Two applications of 0.025% fenvalerate, once in May and once in June, significantly increased seed yield. A single application in mid-June might have been sufficient to prevent coneworm damage, but was not tested. A third application in July was apparently unnecessary.

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