Protection of Disease-Resistant Western White Pine Seed from Insect Damage[1]

Michael I. Haverty *and* **Patrick J. Shea,** *Pacific Southwest Forest and Range Experiment Station, USDA Forest Service, P.O. Box 245, Berkeley, CA 94701, and* **Lawrence E. Stipe,** *Cooperative Forestry and Pest Management, Northern Region, USDA Forest Service, P.O. Box 7669, Missoula, MT 59807.*[1]

*ABSTRACT. Seed produced in blister rust-resistant western white pine (*Pinus monticola *Douglas) seed orchards is in high demand. The fir coneworm,* Dioryctria abietivorella *(Groté), and the lodgepole pine coneworm,* Eucosma recissoriana *(Heinrich), cause considerable damage to seed crops in the Moscow Arboretum seed orchard. Single (May or June) and repeated (May and June) applications of 0.025% fenvalerate, and repeated applications (May and June) of 0.0125% fenvalerate, a synthetic botanical insecticide, were evaluated in 1986 for protection of cone crops. Results in 1986 confirm results in 1984 (Haverty et al. 1986): an application of 0.025% fenvalerate in May and June significantly reduces insect damage, regardless of the relative abundance of cones or insects. The decision to use a single or repeated application depends on demand for seed, projected seed crop and insect populations, and socioeconomic costs of the treatment.*

West. J. Appl. For. 3(1):18–20, January 1988.

Western white pine is valued for its clear-boled form, soft, white, easily-processed lumber and rapid growth. The effect and history of the white pine blister rust, caused by the fungus *Cronartium ribicola* Fisher, on western white pine, and attempts by federal and state agencies to combat the spread of blister rust, are well known (Haig et al. 1941). Because of western white pine's economic importance, forest managers in the northern Rockies have made its reestablishment a priority management objective, partly through a breeding program for blister rust-resistance and the establishment of seed orchards in Sandpoint, Coeur D'Alene, and Moscow, Idaho (Bingham 1983). The high cost of seed-orchard seeds, however, makes it necessary to protect seed crops from insect pests.

The effect of such pests on seed production varies from year to year, depending on the size of the cone crop and insect populations during current and previous years (Shea 1986, Shea et al. 1987). The perceived importance of insects in cone and seed destruction also varies from person to person. For example, a forest geneticist might claim that "good crops of western white pine cones are so frequent that the loss of a crop or two is not serious" (Hoff and Coffen 1982), whereas foresters who must plant disease-resistant western white pines wish to maximize seed production. To them, any seed loss may be viewed as intolerable.

Insecticides for protecting western white pine cone crops from the pine cone beetle, *Conophthorus ponderosae* Hopkins, were evaluated in the laboratory (Haverty and Wood 1981) and in a production seed orchard in Sandpoint, ID (Shea et al. 1984, Haverty and Shea 1986). The field study demonstrated that single or repeated applications of permethrin, a synthetic botanical insecticide, at concentrations of 0.03, 0.06, or 0.12%, significantly reduced loss of cones to cone beetles. In another field experiment (Haverty et al. 1986, Haverty and Shea 1986), we demonstrated that western white pine cones could be protected from the fir coneworm with single or repeated applications of 0.025% fenvalerate, another synthetic botanical insecticide. This later study did not determine whether a single application at a different time or repeated applications at a reduced concentration could also provide adequate protection.

Here we report the results of an additional experiment to evaluate single (May or June) and repeated applications (May and June) of 0.025% fenvalerate and repeated applications (May and June) of 0.0125% fenvalerate for protection of cones and seeds of blister rust-resistant western white pine from insect damage. Our objective was to protect the seed crop from the three major pests, the fir coneworm, the lodgepole cone moth and the western conifer seed bug (*Leptoglossus occidentalis* Heidemann), that attack cones at different times during the second year of cone development.

METHODS AND MATERIALS

The Moscow Arboretum is a production seed orchard located on the western edge of the University of Idaho campus adjacent to the Idaho-Washington state boundary line. It is rectangular, covers about 4.9 ha, and has over 1000 blister rust-resistant western white pine trees of cone-bearing age.

The exact phenology of the attacking insects is not yet fully understood. From previous studies (Haverty et al. 1986, Shea 1986) we know that lodgepole cone moth adults began to appear in pheromone traps and light traps in the first week of May in 1984. To assure an effective insecticide residue when all pests first appeared, we selected May 19 as the time of the first application and delayed the second application until June 19. This is a modification of the schedule suggested by Nord et al. (1984) for coneworms and seed bugs in pine seed orchards in the South, and verified in our previous study (Haverty et al. 1986). The first application in May should have coincided with the beginning of oviposition of the lodgepole cone moth, and a second application in June should have coincided with the oviposition of the fir coneworm and the first appearance of the western conifer seed bug (Shea 1986, Shea et al. 1987).

The experiment was conducted using a completely randomized design. Five treatments were compared: an untreated check, a single, early application of 0.025% a.i. fenvalerate (May 19, 1986), a single late application of 0.025% a.i. fenvalerate (June 19, 1986), a repeated application of 0.025% a.i. fenvalerate (once in May and once in June), and a repeated application of 0.0125% a.i. fenvalerate (once in May and once in June). Fenvalerate (Pydrin® Insecticide 2.4 EC) was diluted in water to a concentration of 0.0125 or 0.025% (a.i. W/W) and applied to near the point of runoff with a trailer-mounted hydraulic sprayer (tank capacity 1,900 l), set at

[1] We thank Rodney Nakamoto, Lori Nelson, Doria Mueller-Bielschmidt, Gina Ruskauff, and Kristina Schierenbeck for extracting and cleaning seed lots, and Thomas Koerber for radiographs of seed. We extend our special thanks to Mel Morton for help in the field tests. 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.

ca. 30–40 kg/cm^3, using a hand-operated gun. Insecticide was applied immediately after mixing. Trees were sprayed when the wind was minimal to avoid contamination of adjacent trees. Between applications equipment was cleaned and rinsed with detergent (Nutra Sol®).

All of the trees in the seed orchard were examined, and only trees with an initial cone crop of ≥20 second-year cones were used. We only selected trees sufficiently far apart (our goal was at least one intervening tree) to avoid contamination of one treatment with another. After the population of acceptable trees was determined, each of the insecticide treatments was randomly assigned to 15 trees. Occasionally we eliminated randomly selected trees if they were too tall to be effectively treated or too close to adjacent trees to avoid contamination of another treatment. The treatment was then assigned to the next randomly selected tree. Based on the data from Haverty et al. (1986), 15 trees would allow us to detect a difference of 16.9 seed/cone (25% difference) between a treatment mean and the mean of the untreated check with 90% power at $\alpha = 0.05$.

When the cones were ready for harvest they were collected from each tree, collected from the ground under each tree, counted and kept in separate burlap bags. Totally damaged cones were counted then discarded. All but the totally damaged cones were air dried and extracted at the Forest Service Nursery in Coeur D'Alene, ID. Uncleaned seed lots from each tree were kept in separate, plastic bags and mailed to Berkeley, CA. All seeds were carefully separated from debris. Eight groups of 100 seeds from each tree were weighed and placed in envelopes. (If a tree had less than 800 seeds, all seeds were counted.) The remainder of the seed was weighed, and the total number of seeds/cone estimated based on the mean weight of the 800 seeds from the damaged and undamaged cones for that tree. The 8 envelopes with 100 seeds per envelope were taped to a sheet of paper (20 × 25 cm) and radiographed to determine the percentage of seed that was either filled with an apparently viable embryo and endosperm, empty, damaged by *L. occidentalis*, or damaged by some unknown cause.

The response variables were number of cones harvested/tree, number of damaged cones/tree, proportion of cones infested (transformed to arc sine of the square root of the proportion), number of seed/cone, and number of filled seed/cone. Differences among treatments were evaluated by analysis of variance. Dunnett's test (Steel and Torrie 1960) was used to determine significant differences between means for each insecticide treatment and the mean of the untreated check to maintain an experiment-wise $\alpha = 0.05$ (Jones 1984). Percentages of filled, empty, or damaged seeds are also presented for each year.

RESULTS AND DISCUSSION

From the results of our insecticide experiments (Haverty et al. 1986) and our impact studies (Shea 1986, Shea et al. 1987) we feel that both the lodgepole cone moth and the fir coneworm are significant pests of blister rust-resistant western white pine in the Moscow Arboretum and are responsible for nearly all of the seed losses. We have yet to determine a significant impact in seed losses attributable to the western conifer seed bug in second-year cones.

The results of our first experiment in 1984 were dramatic and have been previously published (Haverty et al. 1986). We concluded that single, double, or triple applications of 0.025% fenvalerate significantly increased seed yield compared to the untreated check. The double treatment provided additional cone and seed protection over the single treatment, but the difference was not statistically significant. We felt the additional application in July was unnecessary. These results did not, however, allow us to determine whether a single application in mid-June would provide the same level of protection as a single application in mid-May or if a reduced concentration would provide the same level of protection. These questions, which would reduce the amount of insecticide applied in the seed orchard, were addressed in this experiment on the 1986 cone crop.

We observed no statistical differences among treatments in the number of cones per tree (Table 1). The number of cones per tree varied from 22 to 693. The mean number of infested cones per tree was 14.1 on the untreated check. Only the 0.025% June and the 0.025% May and June treatments resulted in a statistically lower number of infested cones per tree, 6.2 and 3.3, respectively. Eighteen percent of the cones on untreated trees were infested. All treatments had a smaller proportion of infested cones than the untreated check but only the 0.025% May and June treatment provided a statistically significant reduction in the proportion of infested cones.

Two treatments, May only or May and June 0.025% fenvalerate, differ significantly from the untreated check in the number of seed per cone (Table 1). None of the treatments resulted in a statistically significant increase in filled seed per cone, although all treatments had an average of at least 43% more filled seed per cone than the average for untreated trees. Percentages of filled and empty seed are not significantly different among treatments. A statistically greater percentage of the seed from the untreated trees was damaged, but this difference (<2.4%) does not appear to us to be practically meaningful. The cause of this damage is due to feeding by *L. oc-*

Table 1. Number of cones harvested per tree, percentage of infested cones, and number of seeds per cone for trees treated with fenvalerate.[1]

Fenvalerate treatment	No. trees	Cones/ tree	Infested cones/tree	Infested cones (%)	Seeds/ cone (n)	Filled seed/cone (n)	Filled seed (%)	Empty seed (%)	Damaged seed (%)
0.025% May	15	86.4 (57.9)	8.4 (8.8)	12.7 (17.4)	88.6 (32.8)*	55.7 (33.0)	61.5	36.8	1.7*
0.025% June	15	74.2 (36.7)	6.2 (4.2)*	11.3 (9.7)	75.6 (23.3)	49.8 (17.8)	67.5	31.8	0.7*
0.025% May + June	15	62.6 (23.1)	3.3 (4.2)*	5.5 (6.4)*	83.5 (38.1)*	49.2 (36.3)	60.1	38.7	1.2*
0.0125% May + June	15	75.3 (33.1)	8.2 (8.8)	11.7 (13.9)	71.6 (28.7)	53.3 (28.9)	71.3	28.1	0.6*
Untreated check	15	122.1[2] (161.1)	14.1[2] (12.6)	18.0[2] (16.7)	55.2 (20.9)	34.4 (18.8)	62.2	34.7	3.0
		80.4[3]	84[3]	13.5[3]	29.4[3]	28.2[3]			

[1] Mean (±S.D.). Means in a column followed by an asterisk are significantly different from the untreated check [$\alpha = 0.05$; Dunnett's procedure (Steel and Torrie 1960)].
[2] Means are skewed because one of the untreated check trees had 693 cones, of which only 6 were infested. If this highly unusual tree were omitted from the experiment the mean number of cones/tree would be 81.4, the mean number of infested cones would be 14.6, and the mean percent infested cones would be 19. The statistical inferences, however, would not change.
[3] Root mean square error for the response variable in the same column.

cidentalis, attacks by fungi, and other unknown causes.

The results of the test conducted in 1986 generally corroborate the results of the 1984 test (Haverty et al. 1986). All insecticide treatments resulted in reduced damage to cones and an increase in filled seed per cone. Thus all treatments apparently provide sufficient residue at an appropriate time to protect the seed crop from both of the dominant pests in this seed orchard, *E. recissoriana* and *D. abietivorella*. Cone damage and seed losses are reduced for all treatments but are not always significantly ($\alpha = 0.05$) less than no treatment at all. The treatment most consistent in reducing seed losses to a statistically significant level is the repeated application of 0.025% fenvalerate in May and June.

The decision to use the consistently effective, repeated application of 0.025% fenvalerate instead of a single application or a repeated application of 0.0125% fenvalerate must be made with consideration for the demand or "value" of the seed, the projected seed crop and insect populations, and the socioeconomic costs of the treatment (Shea et al. 1984). Also to be considered is the confidence the pest management specialists have in the treatment and the amount of risk they are willing to take. Selecting a treatment on statistically significant differences with an experiment-wise $\alpha = 0.05$ might be more stringent than most pest management specialists or seed orchard managers require.

The incidence of cone damage was much reduced in 1986 compared to 1984: 18.0% versus 46.6% of the untreated cones. We suspect this is the result of a significant reduction of the resident insect populations by repeated insecticide applications in 1984 and 1985 over two thirds of the seed orchard (see Haverty et al. 1986). The 18.0% cone-infestion rate with an apparent 40% reduction in seed yield we observed in 1986 would probably justify the cost of at least one application of fenvalerate. Furthermore, failure to suppress the lodgepole cone moth and fir coneworm populations one year might result in unacceptable losses in subsequent years (similar to 1984) due to a buildup of the resident populations in the seed orchard. □

LITERATURE CITED

Haig, I. T., K. P. Davis, and R. H. Weidman. 1941. Natural regeneration in the western white pine type. USDA Tech. Bull. 767. 98 p.

Haverty, M. I., and P. J. Shea. 1986. Protection of blister rust-resistant western white pine cones from insect damage with permethrin and fenvalerate. P. 246–250 *in* Proc. symp. on conifer tree seed in the inland mountain West. USDA For. Serv. Gen. Tech. Rep. INT-203.

Haverty, M. I., and J. R. Wood. 1981. Residual toxicity of eleven insecticide formulations to the mountain pine cone beetle, *Conophthorus monticolae* Hopkins. J. Ga. Entomol. Soc. 16:77–83.

Haverty, M. I., P. J. Shea, and L. E. Stipe. 1986. Single and multiple applications of fenvalerate to protect western white pine cones from *Dioryctria abietivorella* (Lepidoptera: Pyralidae). J. Econ. Entomol. 79:158–161.

Hoff, R. J., and D. O. Coffen. 1982. Recommendations for selection and management of seed orchards of western white pine. USDA For. Serv. Res. Note INT-325. 7 p.

Jones, D. 1984. Use, misuse, and role of multiple-comparison procedures in ecological and agricultural entomology. Environ. Entomol. 13:635–649.

Nord, J. C., et al. 1984. High-volume applications of azinphosmethyl, fenvalerate, permethrin, and phosmet for control of coneworms (Lepidoptera: Pyralidae) and seed bugs (Hemiptera: Coreidae and Pentatomidae) in southern pine seed orchards. J. Econ. Entomol. 77:1589–1595.

Shea, P. J. 1986. Impact of insects on cone/seed production in three blister rust-resistant western white pine seed orchards. P. 256–259 *in* Proc. symp. on conifer tree seed in the inland mountain West. USDA For. Serv. Gen. Tech. Rep. INT-203.

Shea, P. J., M. J. Jenkins, and M. I. Haverty. 1984. Cones of blister rust-resistant western white pine protected from *Conophthorus ponderosae* Hopkins (= *C. monticolae* Hopkins). J. Ga. Entomol. Soc. 19:129–138.

Shea, P. J., M. I. Haverty, and G. E. Daterman. 1987. Impact of insects and methodology for monitoring insects in western white pine seed orchards. P. 147–155 *in* Proc. Cone and Seed Insect Working Party Conf. IUFRO, Briancon, France.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics with special reference to the biological sciences. McGraw-Hill, New York. 481 p.