CONES OF BLISTER RUST-RESISTANT WESTERN WHITE PINE PROTECTED FROM *CONOPHTHORUS PONDEROSAE* HOPKINS (= *C. MONTICOLAE HOPKINS*)[1, 2]

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(Accepted for publication Oct. 13, 1983)

ABSTRACT

Recently, the production of seed from blister rust-resistant western white pine in western Montana, northern Idaho, and eastern Washington has been severely reduced because of periodic infestations of the mountain pine cone beetle, *Conopthorus ponderosae* Hopkins. Between 1977 and 1981, experiments were done at the Sandpoint Seed Orchard in Idaho to predict and

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[1]Coleoptera: Scolytidae.
[2]This paper does not recommend the chemical used, nor does it imply that the uses described here have been registered by any agency.
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monitor beetle emergence, evaluate chemical treatments, and formulate a decision support system to control *C. ponderosae* and thereby facilitate maximum seed production. Permethrin applied at 0.3 g/liter significantly reduced loss of cones to *C. ponderosae*, however, 0.6 g/liter appears to be the most cost-effective treatment. On average adult beetles begin to emerge from overwintering sites after 487 degree-days have been accumulated. The decision to use an insecticide control should be made only after considering the demand for resistant seed, size of the developing cone crop, and previous beetle populations.

Key Words: Western white pine, mountain pine cone·beetle, *Conopthorus*, monitoring, chemical control, degree-days

INTRODUCTION

Western white pine (*Pinus monticolae* Douglas) is one of the most valuable and highest volume producing tree species in the northern Rocky Mountains.[5] The introduction of blister rust (*Cronartium ribicola* Fischer) to the United States from Europe in the early 1900's (Haig *et al.* 1941) virtually eliminated stands in western Montana, northern Idaho, and eastern Washington (Hepting 1971). Within stands with disease-caused mortality, however, individual trees were observed to be unaffected by blister rust. Recently, the production of blister rust-resistant seed from western white pine in seed orchards has been severely reduced in Montana, Idaho, and Washington because of periodic infestations of *Conophthorus ponderosae* Hopkins (= *C. monticolae*)[6] (Wood 1977).

The biology and life history of *C. ponderosae* and concomitant phenology of white pine cones has been described in some detail by various investigators (Hopkins 1915, Miller 1915, Chamberlain 1958, Keen 1958, Williamson *et al.* 1966). White pine cones require about 15 months to reach maturity and produce sound seed (Bingham and Squillace 1957, Owens and Molder 1977). Adult cone beetles emerge from overwintering sites within old cones that have fallen to the ground the previous fall. Beetles emerge in early spring as second-year cones begin to elongate and swell. Female beetles initiate attack and bore into the young cones. They rapidly girdle the axis of the cone just below the junction of the pedicle and cone, thereby severing the conductive tissue and killing the cone. Adult males soon enter through the hole made by the female, mate with the female and assist her in keeping the single egg gallery clear of debris. The female lays eggs along the single gallery, larvae hatch, mine the cone, complete their development to callow adults, and

[5]Hoff, R. J. 1964. Mountain pine cone beetle damage in the Sandpoint Seed Orchard, p. 40. *In* Progress report for Inland Empire cooperative forest tree improvement program. Univ. of Idaho, Moscow.

[6]In this paper, *C. ponderosae* is used as the scientific name, although it should be pointed out that before Wood's (1977) synonomy, the mountain pine cone beetle was described as *C. monticolae*.

overwinter in the same cone. Adult females may attack up to four cones, depositing a maximum of 100 eggs. Normally, however, only 4-8 adults emerge from an infested cone (Jenkins 1982). The rapid attack and subsequent mortality before the cones are half-grown (Furniss and Carolin 1977) make successful control difficult.

This paper reports on experiments conducted in Idaho between 1977 and 1981 to find ways to predict and monitor beetle emergence from cones, evaluate chemical treatments, and formulate a decision support system to protect valuable seed from western white pine cones that are blister rust resistant.

MATERIALS AND METHODS

The study site was located in the Sandpoint Seed Orchard, Sandpoint, Idaho, which is administered by the Sandpoint Ranger District of the Idaho Panhandle National Forest. The orchard, 7.0 ha in size, contains 800 grafts of 21-year-old western white pine. Trees range in height from 5.0 to 15 m.

Permethrin (Pounce®) was sprayed in April, 1981. Ten trees between 7.5 and 15 m tall were randomly assigned to each of seven treatments. Ramets were from three clones with similar susceptibility to *C. ponderosae* attack (Jenkins 1982). Trees next to a previously selected tree or in a previously designated buffer zone were not used. The seven treatments consisted of an untreated check, 0.3, 0.6 and 1.2 g/liter permethrin applied once and the same concentrations applied again in 14 days. Trees were sprayed between 0500 and 0930 within a 2-day period with a Bean hydraulic sprayer[7] mounted on a trailer. The sprayer was calibrated to deliver 18.9 liters per tree within 48 sec. Mixing was done just before application and all trees within a treatment were treated consecutively. The order of treatment within any morning was randomly assigned. Twenty-one days following the second application and after all attacks had occurred, all cones on all trees were inspected and counted as infested vs. noninfested. Because timing is critical to protection of the cone crop, five screened cages, each with 50 infested cones collected in the orchard or from the surrounding area, were placed throughout the orchard. Spraying began 1 day after the first beetle emerged. Treatments were analyzed by pairwise tests of differences with a 2 x 2 contingency table (noninfested vs. infested vs. treatment) and a Chi-square statistic at $p = 0.01$.

Previous work in the orchard indicated a high probability that the beetle population would be low in 1981 (Jenkins 1982). Because of concern that insufficient attacks would not allow an adequate test of the insecticide (as occurred in 1980), beetles were collected elsewhere and placed throughout the orchard. Infested cones containing overwintering beetles were collected in and around Sandpoint, Idaho, and held until treated. Immediately after spraying, equal numbers (15) of infested cones were placed around test trees (including checks) to ensure adequate attack.

[7]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty by the USDA, and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

During 1980, 1981, and 1982, temperature maxima and minima were obtained from records of the National Oceanic and Atmospheric Administration (NOAA) Weather Station, at Sandpoint, Idaho. We selected January 1 of each year as the date to begin accumulating degree-days with o C and 4.4 C as threshold temperatures. Calculation of degree-days accumulated followed the procedure reported by Ives (1973) and Mattson and Erickson (1978).

RESULTS

Beetles began to emerge on April 18, 1981 and trees were first sprayed on April 19 and 20. Trees were sprayed again on May 2. Analysis of variance of the mean number of cones per tree by treatment indicated that differences among treatments were not significant (Table 1) ($p = 0.05$). All permethrin treatments had levels of infested cones that were significantly different from the untreated controls ($p = 0.05$). Additional pairwise comparisons revealed the following relationships in percent loss of cones: $0.3<0.6<1.2 = 0.3$ x <0.6 x <1.2 x g/liter application rate ($p = 0.01$) (Table 1) (x denotes double treatment). Percent loss of cones ranged from 75.8% in the untreated controls to 4.9% in the 1.2-g/liter double treatment (Table 1). The latter treatment would have had a much lower infestation rate but for one tree that accounted for 18 of the 26 total cones infested. This tree was the last treated in its group. Field notes taken at the time of treatment indicate it was incompletely covered during the first treatment because of lack of spray.

Jenkins (1982) described the relationship between cone production and beetle attack rate for a 5-year period in the Sandpoint Seed Orchard (Fig. 1). In 1977 and 1978, beetle numbers were high in relation to the total number of cones (Fig. 1). In 1979, the number of cones produced was very low and almost all (>90%) were killed by beetles. Because cones were limited and beetle numbers were high in 1979, the beetle population suffered high mortality through competition for oviposition sites. In 1980, the production of cones was the highest in the history of the orchard and this, after a year of

Table 1. – Number of infested and noninfested western white pine cones, by treatment.

Treatment g/l	No. of cones infested	No. of cones noninfested	$\bar{x}$ no. of[1] cones/tree	% loss of cones
0.3 once	254	234	48.8	52.0
0.6 once	203	379	58.2	34.8
1.2 once	105	353	45.8	22.9
0.3 twice	131	478	60.9	21.5
0.6 twice	66	600	66.6	9.9
1.2 twice	26	497	52.3	4.9[2]
Untreated	547	174	72.1	75.8

[1] No significant difference; $p = 0.01$, df = 6, 63.
[2] Deleting the last tree, which was incompletely treated, results in 448 noninfested cones, 8 infested cones, $\bar{x} = 45.6$ cones/treatment and 1.7% loss.

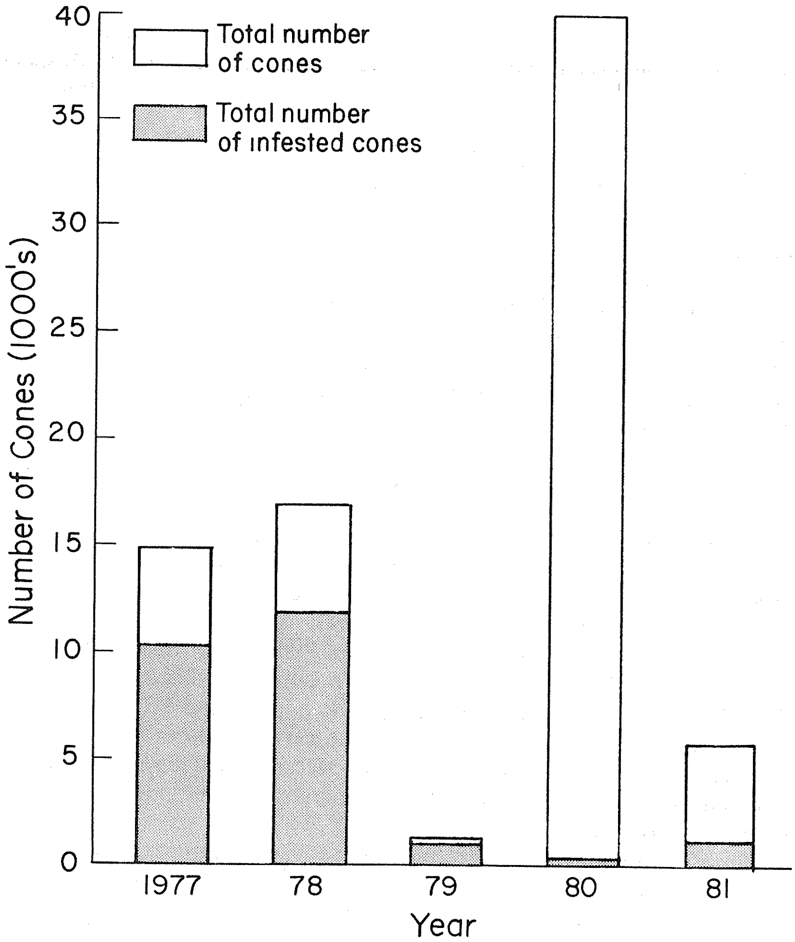

Fig. 1. – Cone production related to cone beetle attack levels in the Sandpoint Seed Orchard, Idaho, from 1977 to 1981 (Jenkins 1982).

low beetle carryover resulted in a low percentage of beetle attacks in 1980. Cone production was less in 1981 and beetle numbers showed a slight increase. These data tend to support the general hypothesis that cone crop size is a significant regulating mechanism of beetle populations (Forcella 1980, Mattson 1971, Hedlin 1964). Data such as these also can be used to make management decisions regarding the necessity for direct control.

Adult beetles required an average of 487 degree-days (range of 434-537) with a threshold temperature of 0 C and 153 degree-days (range 120-209) with a threshold temperature of 4.4 C to emerge from overwintering sites. Inspection of the data, however, indicated that the 0 C threshold was less variable with a coefficient of variation of 11% vs. 32% with 4.4 C. Further evidence of less variability is that the standard error was only 6% of the mean for 0 C, but was 18% of the mean for 4.4 C. Although the degree-day data is probably far too variable to precisely predict beetle emergence for purposes of timing an insecticide application, it can be used to alert the orchard manager that beetle emergence is eminent and preparations for application should begin.

Lastly, we did a cost-benefit analysis by treatment (Table 2). The values we used to compute the cost-benefit were: \$485/lb, \$970/lb, and \$1940/lb[8] for western white pine, \$51.56/lb for permethrin; \$1.32/tree labor cost (5 min/tree, 3-person crew). All values are based on a per-tree basis. Dollar value of cones per tree is based on the mean number of cones per tree of all trees in the experiment. Note that the most favorable cost-benefit is not associated with the most effective treatment but rather with the next to least effective rate. These data provide the orchard manager with a basis for prescribing treatments, if necessary, based on information other than simply using what is the most effective treatment.

DISCUSSION

The high cost of establishing the Sandpoint Seed Orchard and the fact that this orchard is the sole source of resistant seed (and will continue to be until 1986) make the development of a management strategy for the mountain pine cone beetle an important research effort.

Guidelines for establishing an Integrated Pest Management (IPM) program have been described by Bottrell (1979). In summary, they are: (1) establish that the organism in question is, in fact, a pest, and establish economic thresholds for that specific organism; (2) devise schemes for lowering the equilibrium positions of the pest(s); (3) seek remedial measures that cause minimum ecological disruption during emergency situations; and (4) devise monitoring techniques.

Specific economic thresholds in the classical agricultural sense are difficult to arrive at in a context of forest entomology. Generally, we refer to effects of pest-caused damage on resource values and management objectives (Stark 1980). In 1960, the Forest Service, U. S. Department of Agriculture, established a 7.0-ha (17-acre) experimental seed orchard in Sandpoint, Idaho, with grafts from 13 trees showing resistance to blister rust.[9] Seed from the F_1 generation has since been used to establish several F_2 orchards in northern Idaho. The long range goal is to establish 40.4 ha (100 acres) of F_2 orchards producing sufficient seed for forest planting (Bingham *et al.* 1963). *Conopthorus ponderosae* is the key pest and interruption of the production of resistant seed seriously affects management objectives, namely, the reestablishment of western white pine to its former habitat. Our cost-benefit analysis in which all values were based on a per-tree basis provides a way of comparing

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[8]Howe, G., G. Manning, and R. Barth. 1982. Genetic gains realizable in rust resistance programs – What are we buying? Forest Genetics Workshop, Eugene, OR.

[9]Hanover, James W. 1961. Establishment report of a pilot scale seed orchard. Forest Mgmt. Res. 4000(4100) Line No. 1-S-INT-2302-64.

Table 2. – Cost-benefits of treatments compared.

Treatment g/l	$ Cost of treatment/ tree	Benefit-cost[1] $485/lb	$970/lb	$1940/lb
0.3 once	1.96	6.12:1	12.25:1	24.45:1
0.6 once	2.60	8.34:1	16.68:1	33.37:1
1.2 once	3.89	7.01:1	14.03:1	28.06:1
0.3 twice	3.92	7.17:1	14.35:1	28.67:1
0.6 twice	3.92	6.48:1	12.96:1	25.93:1
1.2 twice	7.78	4.25:1	8.53:1	17.06:1
Untreated	0	0	0	0

$^1 = \dfrac{\text{\$ value/tree with treatment - \$ value/tree without treatment}^{10}}{\text{treatment cost/tree}}$

treatments on information other than simply effectiveness. An orchard manager, however, may prefer no chemical control program if an adequate supply of seed is available, even if beetle populations are predicted to be high.

Permethrin was chosen over other laboratory-tested insecticides (Haverty and Wood 1981) because of its low toxicity to warm-blooded animals such as birds and small mammals, and its safety to users. Several insecticides, including lindane, have a lower LC_{90} than permethrin but are not as environmentally acceptable (Koerber 1976).

Before deciding on chemical control, the orchard manager should consider demand for resistant seed, previous beetle populations, and size of cone crop. For instance, if the current cone crop is predicted to be low (about 10 cones/tree) and the previous year's level of beetle infestation was medium to high (as in 1977 or 1978, Fig. 1), the orchard manager should consider treatment (Fig. 2) if the supply of resistant seed is low. But, if the current cone crop is predicted to be high (about 50 cones/tree) and the previous year's crop was extremely low (as in 1979, Fig. 1), the manager's decision might be no treatment unless the demand for seed is extremely high. If the manager continues to question what to do, he should consider other factors than only cone crop size, beetle populations from the previous year and amount of seed on hand. These factors might include social, political, and other economic consideration not directly associated with production of blister rust resistant seed.

If a decision is made to treat, data from Table 2 should be consulted for the most appropriate rate and application strategy. Assume that a medium to large cone crop is predicted ($\bar{x}$= 40+ cones/tree). The orchard manager may decide that the most efficient course would be to select the treatment providing the best cost-benefit ratio, *i.e.*, 0.6 g/liter. But, if the cone crop is

[10] Overgaard, N. A. 1981. Post-treatment evaluation seed and cone insect control project, Quachita Federal Seed Orchard. SE, State and Private Forestry, USDA Forest Service, Atlanta, GA. 30309. Report No. 81-2-21.

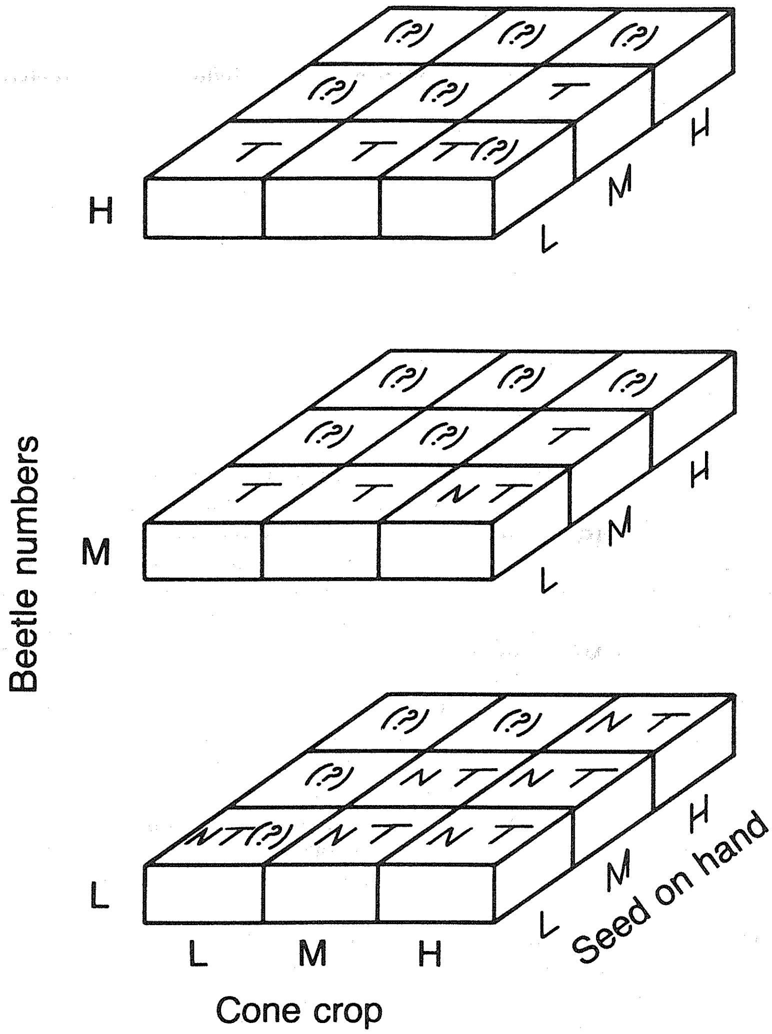

Fig. 2. – Decision matrix concerning treatment (T) or no treatment (NT) relative to size cone crop and expected beetle population. L = low; M = medium; H = high.

predicted to be low from counting the number of conelets in the year previous to maturation, or demand for seed is extremely high, or both, the decision, may be to maximize cone protection. In this situation the most efficacious treatment is recommended, *i.e.*, double application of 1.2 g/liter.

Monitoring of a pest population is not only helpful for deciding on whether remedial action is necessary but also when to treat. We monitored the beetles by caging them, and collecting daily temperature data and records of infested and noninfested cones taken during cone collection. The day-degree data forewarn the orchard manager that beetle emergence is approaching whereas monitoring emergence of caged beetles provides the manager more precise information on when to begin application. By using these techniques, the orchard manager has the essential monitoring data on which to base key decisions.

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