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MORTALITY OF SPRUCE BEETLE BROODS IN BOLTS SUBMERGED IN WATER

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ABSTRACT

Six weeks of continuous submersion in water of spruce bolts containing larvae and young adults of the spruce beetle resulted in complete mortality. We estimated that 22 days of continuous submersion would be required to kill 50% of the brood. Brood development ceased in the submerged bolts even though water temperature, which increased from 13.3°C to 17.8°Cduring the experiments, was well above the larval development threshold (6.1 C).

RESUME

Après six semaines d'immersion complete dans ;'eau, les larves et les jeunes adultes du dendroctone de l'épinette qui infestent des billes d'épinette sont complètement dués. Nous avons estimé que 22 jours d'immersion teuraient la moitié des dendroctones. Dans les billes immergeés, la croissance des dendroctones a cessé même si la temperature de l'eau qui est passée de 13,3 a 17,8°C, au cours de l'expérience, était bien au-dessus du seuil propice au développement larvaire (6,1°C).

INTRODUCTION

The spruce beetle, *Dendroctonus rufipennis* (Kirby) (Coleoptera: Scolytidae), is one of the most destructive insect pests of mature spruce *(Picea* spp.) in North America (Schmid and Frye 1977). In British Columbia, this bark beetle causes widespread killing of white and Engelmann spruce during periodic outbreaks.

Logging of currently infested trees combined with processing of the logs before emergence of the beetles and treatment of the bark and slabs are common practices for reducing further damage. At mill sites or log storage areas, the infested logs represent a hazard to surrounding spruce stands, from early May to late June, when the new generation of beetles emerges and flies to attack new host material such as live trees, logging residue, or wind-felled trees. When infested logs cannot be used before the beetles fly, alternative treatments are needed to destroy the beetles. For example, infested logs could be debarked and the bark buried or burned, or they could be treated with bark penetrating insecticides; however, these treatments are expensive and the latter may be environmentally undesirable.

Water sprinkling has been used effectively for reducing emergence of the mountain pine beetle, *D. ponderosae* Hopk. from decked lodgepole pine (McMullen and Betts 1982). Miller and Keen (1960) reported that ponderosa pine bark infested by broods of the western pine beetle, *D. brevicomis* Lec., submerged in water at constant 21°C. required 5 weeks of treatment to bring about 100% mortality. This report describes the mortality and development of spruce beetle broods (larvae and young adults) in bolts submerged in water for various periods.

MATERIALS AND METHODS

On April 29, 1981, five logs were cut from two infested, wind-felled spruce *(P. glauca* Moench — *P. engelmannii* Parry hybrid population) on the Naver Forest, about 65 km southeast of Prince George, British Columbia. The windfall became infested during the spring of 1980 and contained mature larvae, pupae and some brood adults.

Four logs (avg diameter 18.1 cm, avg length 90 cm) were cut from windfall no. 1 and one log (mid-diameter 15.3 cm, length 110 cm) was cut from windfall no. 2. Apart from ease of handling, the number and length of the logs from the windfalls were determined by the distribution of undistrubed bark and the density and development of spruce beetle broods. The four logs from windfall no. 1 were cut into a total of 14 bolts; seven bolts, each about 19 cm long, were cut from two of the logs and six bolts, each about 36 cm long, were cut from the other two logs. The log from windfall no. 2 was cut into 7 bolts of approximately equal length. The ends of each bolt were waxed to prevent water soaking from the ends during treatment and to reduce the rate of drying of the controls. The 7 short bolts from windfall no. 1 and 4 bolts from windfall no. 2 were designated as control and the balance of the bolts were assigned to the submersion treatments. On May 6, the treatment bolts were submerged in Glen Lake, near Victoria, British Columbia, at depths of 0.5 cm to 1.00 m and all but one control bolt from each windfall were placed in a rearing room at constant 21 + C ± 1.5°C. On the remaining two control bolts, the length and mid-circumference were measured and recorded. The bark was carefully removed and the numbers of living and freshly-dead individuals were tallied by stages of development. Larval instars were determined from the ranges of head capsule widths given for the four instars in Hall and Dyer (1974). Freshly dead larvae and pupae were identified based on their natural (creamy-white) colouration and turgidity of the integument. Subsequently, one treated and one control bolt were sampled at weekly and bi-weekly intervals from windfall no. 1 and no. 2, respectively, and in the same manner as described above except that the following procedure was added: Because a proportion of the living individuals from submerged bolts were dormant at the time of sampling, specimens that did not show detectable signs of movement when probed and viewed under 3X magnification were kept at room temperature on moist filter paper in a covered Petri dish for 24 hours for final determination of mortality.

Development index (D.I.) was computed for the live broods from each sampled bolt according to the method of Dyer (1969). This method assigns index numbers to the brood stages (egg = 1, larval instars = 2-5, pupa = 6, adult = 7), and D.I. is computed as the weighted average of these values. An empirical relationship between treatment duration and mortality was determined by adjusting mortality in the treatments with mortality in the controls using Abbott's formula (Abbott 1925). For this analysis we have combined the mortality data in bolts from the two windfalls.

RESULTS AND DISCUSSION

At the outset, the numbers of live brood/100 cm^2 ($\pm$ 1 s$^-$) in the control and treated bolts averaged 4.92 ± 0.67 and 5.06 ± 0.90, respectively. Percent mortality ($\pm$ 1 s$_{\bar{x}}$) in the control bolts averaged 4.15 ± 1.40 and was not related to the incubation period whereas percent mortality in the submerged bolts increased with the duration of submersion and complete mortality occurred after 43 days (Table 1). The relationship between adjusted mortality in the submerged bolts (adjusted for mortality in the control bolts) and duration of submersion was

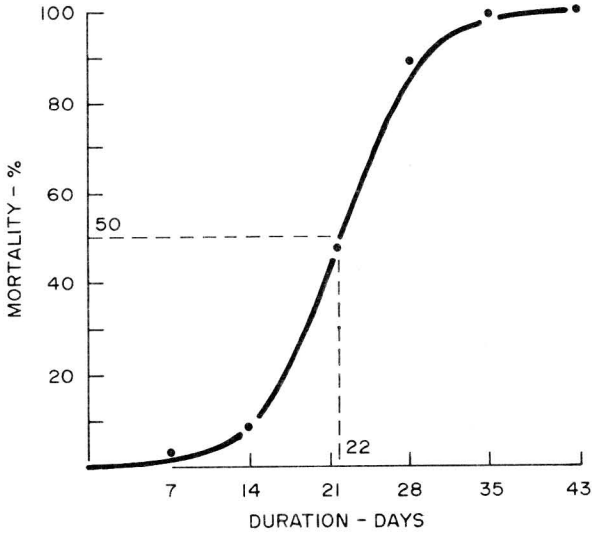

Fig. 1. Relation between % mortality of spruce beetle broods in submerged bolts and duration of submersion. Mortality in submerged bolts was adjusted for mortality in control bolts. The following empirical equation was fitted to the data points: $y = 100/[1 - \exp[-0.305(x - 22.00)]$.

TABLE 1. Percent mortality and development of spruce beetle broods in untreated (control) bolts and bolts submerged in water for various time periods.

No. days treated	Windfall 1				Windfall 2				Development index[1]	
	Control		Treated		Control		Treated			
	No. brood	% mort.	No. brood	% mort.	No. brood	% mort.	No. brood	% mort.	Control	Treated
0	88	0.0	–	–	48	0.0	–	–	5.02	–
7	40	0.0	140	7.9	–	–	–	–	5.00	4.88
14	18	11.2	116	15.6	23	0.0	9	11.2	5.08	5.09
21	16	6.2	101	47.5	–	–	–	–	5.47	5.00
28	60	6.7	120	90.0	57	12.3	27	92.6	5.79	5.00
35	27	0.0	108	99.1	–	–	–	–	5.96	5.00
43	29	3.4	112	100.0	34	5.9	52	100.0	6.06	–

[1] See Materials and Methods.

sigmoid, typical of dosage-mortality curves for insects (Fig. 1). Mortality increased slowly during the first 14 days of submersion and the greatest mortality occurred during the next 14 day period (90%). The estimated duration of submersion to attain 50% mortality was 22 days (Fig. 1). Adjusted treatment mortality was 99.1% after 35 days, agreeing closely with the 100% mortality reported in Miller and Keen (1960) for submerged western pine beetle broods in ponderosa pine bark after 35 days, and the 97% mortality of adult mountain pine beetles in continuously sprinkled lodgepole pine logs after 42 days (McMullen and Betts 1981). This agreement is interesting considering the differences in the species of test insects, brood stages, methods of treatment and water temperatures. In the experiments reported in Miller and Keen (1960) water temperature was 21°C constant whereas in our work water temperature increased from 13.3°C (May 6) to 17.8°C (June 18) during the period of submersion.

At the start of the experiment, 3% of the broods were 3rd instar larvae, 94% were 4th instar larvae and 3% were young adults. The D.I. of the broods in the control bolts increased from 5.02 (94% 4th instar larvae) to 6.06 (62% pupae, 48% new adults) during the period of the experiments but the D.I. of broods in the submerged bolts did not change after about 14 days of submersion (Table 1). This finding indicated the submersion in water affected growth and development, possibly through disruption of feeding and respiratory processes. Development ceased even though the water temperature was considerably above the development threshold of 6.1°C reported by Dyer *et. al.*(1968) for spruce beetle larvae.

Since about only 3% of the broods were adults at the commencement of the experiments and no new adults developed in the submerged logs, there was not sufficient data to evaluate adult mortality in relation to the duration of submersion. No adult mortality was observed in the submerged logs during the first two weeks of treatment (5 adults) and complete mortality occurred after 43 days (6 adults). These observations imply that larval and adult mortality would be similar in relation to the duration of submersion.

The results indicate that 5 weeks of continuous submersion in water of infested spruce logs will kill nearly all larvae and adults of the spruce beetle and that at least 3 weeks of continuous submersion of the logs is required to kill 50% of the broods. Our data and related published information indicate that mortality of adult spruce beetles in submerged logs would be similar to that of the larvae in relation to the duration of the submersion. However, further studies are needed to answer this question.

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THE EFFECT OF HEIGHT AND DENSITY OF SEX PHEROMONE TRAPS ON CAPTURES OF MALE FRUITTREE LEAFROLLER, *ARCHIPS ARGYROSPILUS* AND THREELINED LEAFROLLER, *PANDEMIS LIMITATA* (LEPID.: TORTRICIDAE)

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When sex pheromone traps in the upper third of a standard apple tree were compared with traps at head height, the upper traps captured far more fruittree leafroller moths (*Archips argyrospilus* (Walker) than the lower traps. The results with threelined leafroller (*Pandemis limitata* (Rob.) were reversed; traps at head height captured nearly twice as many moths as traps in the upper portion of a tree. Trap captures increased with trap/area up to 1 trap/ha. This density is probably sufficient for monitoring purposes.

The development of monitoring programs for lepidoptera using sex pheromones is dependent upon a number of factors. The most important of these are the release rate of the pheromone, the use of efficient traps, the proper placement of traps and the trap density. Unless these procedures are standardized for each insect species, it is not possible to draw sound conclusions on population levels or develop treatment thresholds based upon trap captures.

A number of studies have been made on codling moth trap density (Riedl and Croft 1974; Riedl 1980), and on the effect of trap height on codling moth captures (Riedl *et al.* 1979; McNalley and Barnes 1980). There is little information on this subject with respect to leafrollers. As part of the study on the establishment of monitoring programs for the important species of leafrollers attacking tree fruits in British Columbia, the effect of trap height and trap density on captures were evaluated in apple orchards.

MATERIALS AND METHODS

The traps used in all of the field experiments were Zoecon 1C traps (Zoecon Corporation, Palo Alto, California). Madsen and Vakenti (1973) demonstrated that this trap design was the most efficient for trapping male fruittree leafrollers. The lures for both fruittree leafroller and threelined leafroller were also obtained from Zoecon Corp. and consisted of rubber cap stoppers containing 5 mg of the synthetic sex pheromone of each species. The lures were pinned to the top inside portion of each trap and replaced at monthly intervals. Trap bottoms were replaced when the sticky surface became contaminated with moth wing scales or other debris. All traps were examined at weekly intervals, when the trapped males were recorded and removed.

Trap height — This experiment was located in 2 apple orchards in the Kelowna area where the fruittree leafroller is dominant and in 2 orchards in the Oliver-Osoyoos area about 100 km south, where the threelined leafroller is most abundant (Madsen and Madsen 1980). In each orchard, 6 locations were selected, at about 1 trapping site per 0.3 ha. At each site, a trap was placed at head height on a convenient limb and another in the upper third of the same tree on a rope and pulley arrangement. On alternate weeks, the top traps were removed from 3 of the locations and left in place in the other 3. Therefore, each week the low and high traps were

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