Effect of pheromone dosage on the mating disruption of Douglas-fir tussock moth

MICHAEL HULME and TOM GRAY

NATURAL RESOURCES CANADA, CANADIAN FOREST SERVICE, PACIFIC FORESTRY CENTRE, 506 WEST BURNSIDE ROAD, VICTORIA, B.C. V8Z 1M5

ABSTRACT

Z-6-heneicosen-11-one, the major synthetic component of the sex pheromone of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), was used to disrupt insect mating. Dosages of 72, 36, 18, and 9 g/ha of the synthetic pheromone in polyvinyl chloride beads were each applied to three 2-ha plots using conventional aerial spray equipment. Observation of the spraying operation, and catches of male moths in traps baited with standardized synthetic pheromone indicated that two of the 12 plots were not completely sprayed. The efficacy of mating disruption was monitored over the 9 weeks following spraying, using traps baited with feral females interspersed among the standardized traps. When trap catches by feral females in the two unsprayed plot sections were discarded, the mean catch increased as the synthetic dosage decreased. These catches compared with those in the untreated plots were reduced over 99.5% in plots treated with dosages of 72, 36, or 18 g/ha; and by 97.5% with a dosage of 9 g/ha of synthetic pheromone. In our experimental conditions, the difference in numbers of trapped males among the 72, 36, 18, and 9 g/ha dosage groups was marginally non-significant. Our data thus indicate that in operational use, dosages near or below 9 g/ha would be significantly different in effectiveness from the 3 higher dosages.

Key words: dosage, tussock moth, pheromone, mating disruption, *Orgyia pseudotsugata*, Lepidoptera:Tortricidae, biological control.

INTRODUCTION

The Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough) is one of the most damaging defoliators of interior Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco; and also defoliates true firs, *Abies* spp., and pines, *Pinus* spp. (Furniss and Carolin 1977). About every ten years, irruptions of the pest result in defoliation, top-kill or even death of the tree. Eggs are laid by the flightless female on her cocoon in late summer, and larvae emerge late the following spring to feed on the tree foliage. Pupation in midsummer is followed about 2 weeks later by adult eclosion. Males then fly to mate with the female on her cocoon.

Female moths release a pheromone to attract males for mating. A synthetic component, Z-6-heneicosen-11-one (Smith et al. 1975), which also attracts males, has been sprayed from aircraft to disrupt mate location and mating. Generally around 75% mating disruption was obtained using dosages ranging from 2.3 to 36 g/ha in Conrel ® fibres (Sower et al. 1979, 1983, 1990). More recently, no mating at all was detected using 72 g/ha of synthetic pheromone in polyvinyl chloride beads (Hulme and Gray 1994).

Our recently published work (Hulme and Gray 1994) was concerned only with establishing if complete mating disruption was possible. We made no attempt to optimize the amount of synthetic pheromone required. Our objective here is to extend our earlier observations by finding the minimum dose of synthetic pheromone in polyvinyl chloride beads that would disrupt mating as effectively as the 72 g/ha treatment used earlier.

MATERIALS AND METHODS

Plot selection and description. The test area was near Kamloops, BC. (50° 39' N, 120° 24' W). The trees, mostly up to 30 m tall and about 10 m apart, were predominantly interior Douglas-fir and ponderosa pine, *Pinus ponderosa* Laws. Fifteen 2-ha plots separated by at least 300m were selected following a survey for egg masses of Douglas-fir tussock moth in November 1992 using the guidelines of Shepherd and Otvos (1986). Each plot was then randomly assigned to one of five groups. The abundance of first- and second-instar larvae in each plot, estimated in June 1993 by counting the larvae beaten from three branches on each of 20 trees (Shepherd 1985), did not differ significantly between groups ($p > 0.05$, $\chi^2 = 6.8$). Insect defoliation was very light before egg hatch in the year of spraying. During the week before spraying, male Douglas-fir tussock moths were caught in sticky traps baited with the synthetic pheromone (the trap design is described below), but no adult females were found to have emerged from their cocoons.

Formulation and application of the spray mixture. The synthetic pheromone, Z-6-heneicosen-11-one (Phero Tech, Delta, BC), was assayed, impregnated in polyvinyl chloride beads, and formulated in a spray mixture as described previously (Hulme and Gray 1994). Batches were prepared for 72, 36, 18, and 9 g/ha of Z-6-heneicosen-11-one.

A Hiller UH12E helicopter equipped with a boom-and-nozzle spray system, flying approximately 50 m above ground level, was used for the aerial treatment on 30 July. The equipment, fitted with D-6 nozzles, was calibrated to deliver a swath 20 m wide at ground level. Each plot was completely sprayed in five passes at daybreak. Ground observers watched the descent of the spray cloud to check that all parts of the plot were fully sprayed. The wind measured at Kamloops airport was calm.

Assessment of uniformity of spraying. The attraction of male Douglas-fir tussock moths to a standardized lure of Z-6-heneicosen-11-one was assessed with delta sticky traps (trapping surface 855 cm^2) made from 2-liter milk cartons coated inside with Bird Tanglefoot (Tanglefoot, Grand Rapids, MI). The trap baits were 0.01% wt:wt Z-6-heneicosen-11-one impregnated into polyvinyl chloride rods 3 mm in diameter and 5 mm long, following the method of Daterman (1974). Within each plot, 10 traps, hung from branches about 2 m above the ground, were spaced in 3 lines 25 m apart and at least 10m from the plot boundary. Within a line, traps were 50m apart. Trap counts were recorded biweekly, starting 1 week after spray application and continuing for 9 weeks after spraying, i.e., until adult flight essentially ended. The sticky milk carton, but not the lure, was replaced when more than 20 moths were found in the trap during counting.

Assessment of mating disruption. The attraction of male Douglas-fir tussock moths to feral females was assessed biweekly for 9 weeks following spraying. Delta sticky traps described above were used, but the lure was a mature female pupa in a cocoon held within a 30-dram pill vial that had been modified by replacing the solid plastic ends with fiberglass mesh 0.3 mm in diameter having openings 1.4 by 1.2 mm. The female pupae were obtained from areas near the test site by collecting mature larvae and allowing them to spin cocoons on fiberglass mesh. One cocoon, attached to a cut piece of mesh, was then inserted into each vial so that the female, expected to emerge within 3 d, could hang naturally from the cocoon. In each plot, 10 traps were spaced along the same 3 lines used for the traps with synthetic bait. Traps baited with synthetic bait and feral females were alternated. All traps were at least 25 m apart. Each of the 3 trap lines thus contained either 6 or 7 traps. Some traps baited with a live insect did not contain an attractive female during the week the trap was placed in the field, either because no adult emerged during the week, or because a male emerged from the cocoon instead of the expected female. On average, 23 of the 30 traps per treatment baited with live insects contained attractive feral females. Results from the remaining traps without attractive females were not used.

Statistical methods. We followed our published methods (Hulme and Gray 1994). Pretreatment counts of Douglas-fir tussock moth larvae, were analyzed by a chi-square test (Zelen and Severo 1964). Trap catches after spraying were grouped by pheromone dosage (0, 9, 18, 36, and 72 g/ha) and tested for significant intergroup difference with the Kruskal-Wallis test at α =0.05 (Kruskal 1952, Kruskal and Wallis 1952). When a significant intergroup difference was found, the test was rerun with all combinations of 4 dosage groups (i.e. one group deleted) to see whether one dosage group accounted for the significant difference measured among all 5 dosage groups.

RESULTS AND DISCUSSION

In general, the entire area of each plot was seen to be sprayed. However, ground observers noted that 2 plots appeared incompletely sprayed, especially along one edge. The trapping results given below support these observations. Edge spraying would be less important for the overall success of a large operational trial, but is critical for evaluation of results from our small research plots.

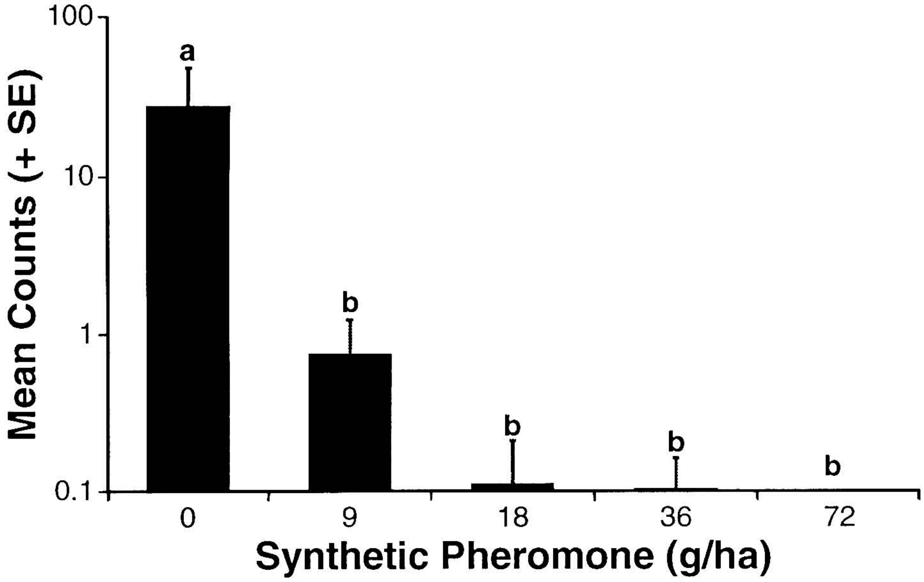

Figure 1. Mean count of male Douglas-fir tussock moths, in delta sticky traps baited with feral females at Kamloops, B.C. after no treatment, or treatment with dosages of 9, 18, 36, or 72 g/ha of *Z*-6-heneicosen-11-one ($\bar{n}$ = 23). Vertical scale logarithmic. Means headed by different letters are significantly different (Kruskal-Wallis test, α = 0.05).

Most of the approximately 1,000 male Douglas-fir tussock moths caught in traps baited with feral females were in the untreated plots, indicating abundant mating opportunities where no synthetic pheromone was applied. Few moths were caught in any of the treated plots except for traps on one edge of one plot treated with 9 g/ha, and in one plot of 18 g/ha of *Z*-6-heneicosen-11-one, the same 2 plots that appeared to be incompletely sprayed. Standardized traps baited with synthetic pheromone also showed the same edge-spraying problem; otherwise these traps caught no moths in the treated plots. Traps baited with synthetic pheromone help to check for uniform spraying since all the baits are equally attractive at any given time, whereas the attractiveness of traps baited with live pupae and adults, depends on the age of the insect bait.

When the results are deleted for moths caught by feral females in the plot sections incompletely sprayed, no significant difference in mating disruption was found among the 72, 36, 18, and 9 g/ha pheromone dosage groups (Fig.1; Kruskal-Wallis test, p = 0.06). However, the test p value indicates that the trap catch in plots treated with 9 g/ha has almost reached the number where a significant intergroup difference among these 4 dosage groups would be measured. We thus expect that operational results using 9 g/ha would be significantly less effective than those using the higher dosages we employed.

As expected, the trap catch by feral females increased as the applied synthetic pheromone dosage decreased (Fig.1). Mean trap catches in plots treated with 72, 36, or 18 g/ha of synthetic pheromone were less than 0.5% of the catches in the untreated plots indicating over 99.5% disruption of mating. The trap catch in the 9 g/ha treatment indicated 97.5% disruption of mating.

Our results at Kamloops thus suggest that the dosage of synthetic pheromone sprayed in polyvinyl chloride beads can be reduced 4-fold to 18 g/ha from the 72 g/ha used in our earlier work and still maintain virtually 100% disruption of mating. The amount by which the dosage can be further lowered and still provide successful control will depend on the target set by the applicator for foliage protection. If 95% mating disruption meets this target, then a dosage close to 9 g/ha should be satisfactory. Our related work at Keremeos, showed that the pheromone-impregnated beads continue to emit pheromone for at least 2 years after treatment (Gray and Hulme 1995), further improving the appeal of this new pest control option.

ACKNOWLEDGEMENT

We thank Lorraine Maclauchlan (British Columbia Ministry of Forests, Kamloops) for providing the helicopter and crew, and for help in setting up our plots.

REFERENCES

Daterman, G.E. 1974. Synthetic pheromone for detection survey of European pine shoot moth. U.S. Dep. Agric. For. Serv. Res. Pap. PNW-180.

Gray, T. G. and M. A. Hulme. 1995. Mating disruption of Douglas-fir tussock moth one and two years after the application of pheromone. J. Entomol. Soc. Brit. Columbia. 92:101-105.

Furniss, R. L. and V. M. Carolin. 1977. Western forest insects. U.S. Dep. Agric. For. Serv. Misc. Publ. 1339.

Hulme, M. and T. Gray. 1994. Mating disruption of Douglas-fir tussock moth, *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae) using a sprayable bead formulation of Z-6-heneicosen-11-one. Environ. Entomol. 23: 1097-1100.

Kruskal, W. H. 1952. A nonparametric test for the several sample problem. Ann. Math. Stat. 12: 461-463.

Kruskal, W. H. and W. A. Wallis. 1952. Use of ranks in one-criterion variance analysis. J. Am. Stat. Assoc. 47: 583-621.

Shepherd, R. F. 1985. Pest management of Douglas-fir tussock moth: estimating larval density by sequential sampling. Can. Entomol. 117: 1111-1115.

Shepherd, R. F. and I. S. Otvos. 1986. Pest management of Douglas-fir tussock moth: procedures for insect monitoring, problem evaluation and control actions. Can. For. Serv. BC-X-270.

Smith, R. G., G. E. Daterman and G. D. Daves, Jr. 1975. Douglas-fir tussock moth: sex pheromone identification and synthesis. Science 188: 63-64.

Sower, L. L., G. E. Daterman, R. D. Orchard and C. Sartwell. 1979. Reduction of Douglas-fir tussock moth reproduction with synthetic sex pheromone. J. Econ. Entomol. 72: 739-742.

Sower, L. L., G. E. Daterman, W. Funkhouser and C. Sartwell. 1983. Pheromone disruption controls Douglas-fir tussock moth (Lepidoptera: Lymantriidae) reproduction at high insect densities. Can. Entomol. 115: 965-969.

Sower, L. L., J. W. Wenz, D. L. Dahlsten and G. E. Daterman. 1990. Field testing of pheromone disruption on preoutbreak populations of Douglas-fir tussock moth (Lepidoptera: Lymantriidae). J. Econ. Entomol. 83: 1487-1491.

Zelen, M. and N. C. Severo. 1964. Probability functions, pp. 925-995. In: M. Abramowitz and I. Stegum (Eds.), Handbook of mathematical functions. National Bureau of Standards, Washington, DC.