COMPARATIVE EVALUATION OF TRAPS FOR MONITORING THE DOUGLAS-FIR TUSSOCK MOTH (LEPIDOPTERA:LYMANTRIIDAE)

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ABSTRACT

Delta sticky traps consistently caught at least as many Douglas-fir tussock moths as did five other trap types in field experiments. Omni-directional non-sticky traps based on the Lindgren multiple funnel trap were relatively successful, but highly variable. Wind tunnel tests with a simulated pheromone (= titanium tetrachloride smoke), showed that plums generated from Lindgren 2-funnel traps contaminated the exterior surfaces of the traps and inhibited entry. Modified Lindgren 2-funnel traps with a plastic insert to reduce turbulence in the plume and with collecting jars containing water only, caught significantly fewer Douglas-fir tussock moths than traps with empty jars or jars containing soapy water or DDVP insecticide (No-Pest Strip). Traps with jars containing soapy water caught more Douglas-fir tussock moths than traps with jars containing DDVP, but catches were not different from those in traps with empty jars. The catches in traps with empty jars and jars containing DDVP were not significantly different.

Non-sticky traps show promise for monitoring the Douglas-fir tussock moth. However, improved designs must facilitate rapid capture of moths landing on the trap, and contamination of exterior surfaces must be minimized.

Population trends of the Douglas-fir tussock moth, *Orygia pseudotsugata* (McDunnough) (DFTM), can be monitored by traps baited with the synthetic sex pheromone, (Z)-6-heneicosen-11-one (Livingston and Daterman 1977, Shepherd and Gray 1984). Sticky traps currently employed for this purpose have two major disadvantages — they saturate at relatively low catch levels and the saturation point varies with the area and amount of adhesive. Sanders (1978) outlined the requirements for a trap suitable for monitoring the eastern spruce budworm, *Choristoneura fumiferana* (Clem.). The most important characteristics were: sensitivity, i.e. the ability to detect low populations; consistent trapping ability from year-to-year and place-to-place to reflect population trends accurately and comparably; durability; and reasonable cost. Similar requirements are important for other species of moths (Ramaswamy and Cardé 1982, and references therein).

Non-sticky traps, which are not subject to saturation effects at low levels, have been tested, but the insects often escape from these traps after entering (Struble 1983). To overcome this problem a vaporous insecticide such as dichlorvos, or soapy water has been used (Ramaswamy and Cardé 1982; Snodgrass and Cross 1982; Struble 1983; Lindgren 1983), but the effects of these materials on trap catches need to be evaluated in field experiments.

The efficiency of a moth trap depends in part on how the pheromone is dispersed as it leaves the trap (Lewis and Macaulay 1976). Titanium tetrachloride ($TiCl_4$), or other smoke of neutral density, can be used in wind tunnel tests to evaluate plume characteristics that may affect insect behavior and catch rates (Angerilli and McLean 1984).

The objectives of these investigations were to define the plume characteristics of two versions of a trap not previously tested; to evaluate the effect of various killing agents in a non-sticky trap on catch rates of DFTM in the field; and to compare four models of non-sticky traps with two sticky traps for monitoring the DFTM.

MATERIALS AND METHODS

Field experiments 1 to 3 were conducted in a severly defoliated Douglas-fir stand alongside the Oregon Jack Creek Road, ca. 15 km south of Ashcroft, British Columbia, in late August and early September, 1982. Experiments 4 and 5 were conducted in a lightly defoliated stand of Douglas-fir alongside the Green Stone Road, Cherry Creek, ca. 18 km west of Kamloops, B.C. in August 1983.

In experiment 1, the synthetic pheromone was formulated at 0.1% in PVC rods of 2 mm d x 5 mm long (Daterman 1974). The release rate from these rods is unknown (R. F. Shepherd[2], pers. comm.). The formulation is used by the Canadian Forestry Service for minitoring the DFTM in B.C. In experiments 2 to 5, the pheromone was released from

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1 μL capillaries placed in a half dram glass vial with a 3 mm inner diam. orifice, giving a release rate of 10 mg/24 hrs at 25°C. and 30-50% R.H. in the laboratory.

Experiments 1 to 3 compared two sticky traps, the Pherocon® 1CP (Zoecon Corp., Palo Alto, California, U.S.A.), and a delta trap made from a two litre milk carton (Daterman *et al.* 1976), as used by the Canadian Forestry Service (Shepherd 1984), with two non-sticky traps, the Kendall trap (Kendall *et al.* 1982) and the Lindgren 8-funnel trap (PMG/Stratford Projects Ltd., Vancouver, B.C., Canada). Collecting jars of the non-sticky traps contained 200 mL of water with about 1 mL non-scented detergent/litre of water. The lure in the Lindgren funnel trap was placed in the centre of the trap between the two lowest funnels to optimize pheromone dispersal (Lindgren 1983). Experiments 1 and 2 were each run for about 20 hours on August 23-24 and 24-25, respectively, and experiment 3 was run from August 25 - September 8, to determine saturation effects in the sticky traps (Table 1).

Experiment 4 compared dry collecting jars, with and without a 2 x 2 cm piece of a Non-Pest Strip (Shell Chemical Co., 19.2% DDVP[3] by weight), to collecting jars containing 200 mL of water with or without 1 mL non-scented detergent/litre of water. The trap used in this experiment was a 2-funnel Lindgren trap, modified with a plactic insert (Fig. 1) to improve wind flow over the lure and to prevent moths from escaping once inside the trap (Fig. 1B). Each Latin square replicate was run for 2 days, August 20-22 and 22-24, respectively (Table 2).

Experiment 5 compared the delta trap with the Lindgren funnel trap (8-funnel, 2-funnel, and the modified 2-funnel used in experiment 4). The two Latin square replicates were run for 2 and 3 days, August 24-26 and 26-29, respectively (Table 3).

The smoke plumes from the 2-funnel and the modified 2-funnel traps were defined by wind tunnel observations of $TiCl_4$ smoke (Angerilli and McLean 1984) generated from a wick in a 1.0 cm d x 3.5 cm long shell vial at 25 cm/s wind speed. The vial was placed in the traps in a manner similar to the way in which pheromone containing vials were placed in traps in the field (Fig. 1).

Experimental Designs. All field experiments were laid out as 4 x 4 Latin squares to allow for positional effects often encountered in this type of experiment (Perry *et al.* 1980). Rows and columns were oriented parallel to a road and to prevailing winds, respectively. Replicated Latin squares (Steel and Torrie 1960) were used in experiments 4 and 5 to increase the power of error estimation.

Data Analysis. All data were transformed as $X' = \log 10\ (x + 1)$, to obtain normality of the data and homogeneity of variances, before analyses of variance. Mean separation was evaluated by the Student-Newman-Keul's Test.

[3]2,2-dichlorovinyl dimethyl phosphate.

RESULTS AND DISCUSSIONS

Field Experiments

In experiment 1, where all traps were baited with the sex pheromone formulated in PVC, the delta sticky trap caught significantly more moths than all other traps (Table 1). When the experiment was repeated with the pheromone released from capillary tubes in vials (experiment 2), the means could not be separated by the Student-Newman-Keul's Test, althought the treatment effect in the analysis of variance was significant (Table 1). In experiment 3, the same traps were tested over a two week period to assess the effect of total saturation in the sticky traps. However, the flight of DFTM males tapered off considerably during this experiment, and the estimated saturation levels of 250 and 50 for the delta trap and Pherocon 1CP trap, respectively, were not reached. Therefore, the objective of this experiment was not reached. It is noteworthy that although saturation effects in the delta trap are detectable when catches of DFTM exceed 40 moths per trap (Shepherd and Gray 1984), the delta trap compared favorably with the non-sticky traps at considerably higher catch levels.

A problem in experiments 1 and 2 was the high variability of some traps, particularly the Lindgren 8-funnel trap. This problem was partly overcome in experiment 3, mainly by consistent trap placement relative to surrounding vegetation, but the variability of the two non-sticky traps remained considerably higher than that of the sticky traps. Similar problems have been noted with non-sticky traps for the western spruce budworm, *Choristoneura occidentalis* Freeman (Shepherd 1984). The coefficients of variation for the Pherocon 1CP trap were 29.0 and 14.1% in experiments 1 and 3, respectively, but was 84.1% in experiment 2. Similarly, the coefficient of variation was higher (103.6%) for the Lindgren 8-funnel trap in experiment 2 than in experiment 1 (72.6%) or experiment 3 (40.0%). The delta trap had consistently low variability in the three experiments with coefficients of variation of 13.5, 16.8 and 10.4%, in experiments 1, 2 and 3, respectively. Such consistency must also be achieved with non-sticky traps for them to be useful in monitoring programs for the DFTM, since high variability results in a large number of traps being required to assess the population trends with reasonable accuracy.

Experiment 4 demonstrated that the modified Lindgren 2-funnel traps caught significantly more moths when the collecting jars contained soapy water rather than DDVP or water alone (Table 2). The catches in traps with empty collecting jars were not significantly different from those in traps with soapy water or DDVP. The low catches in traps with only water in the collecting jars could be explained if the moths were repelled by the water. Since there was no significant difference between the catches in traps with an empty jar and those in traps with soapy water and assuming that water alone did repel moths and that soapy water did not,

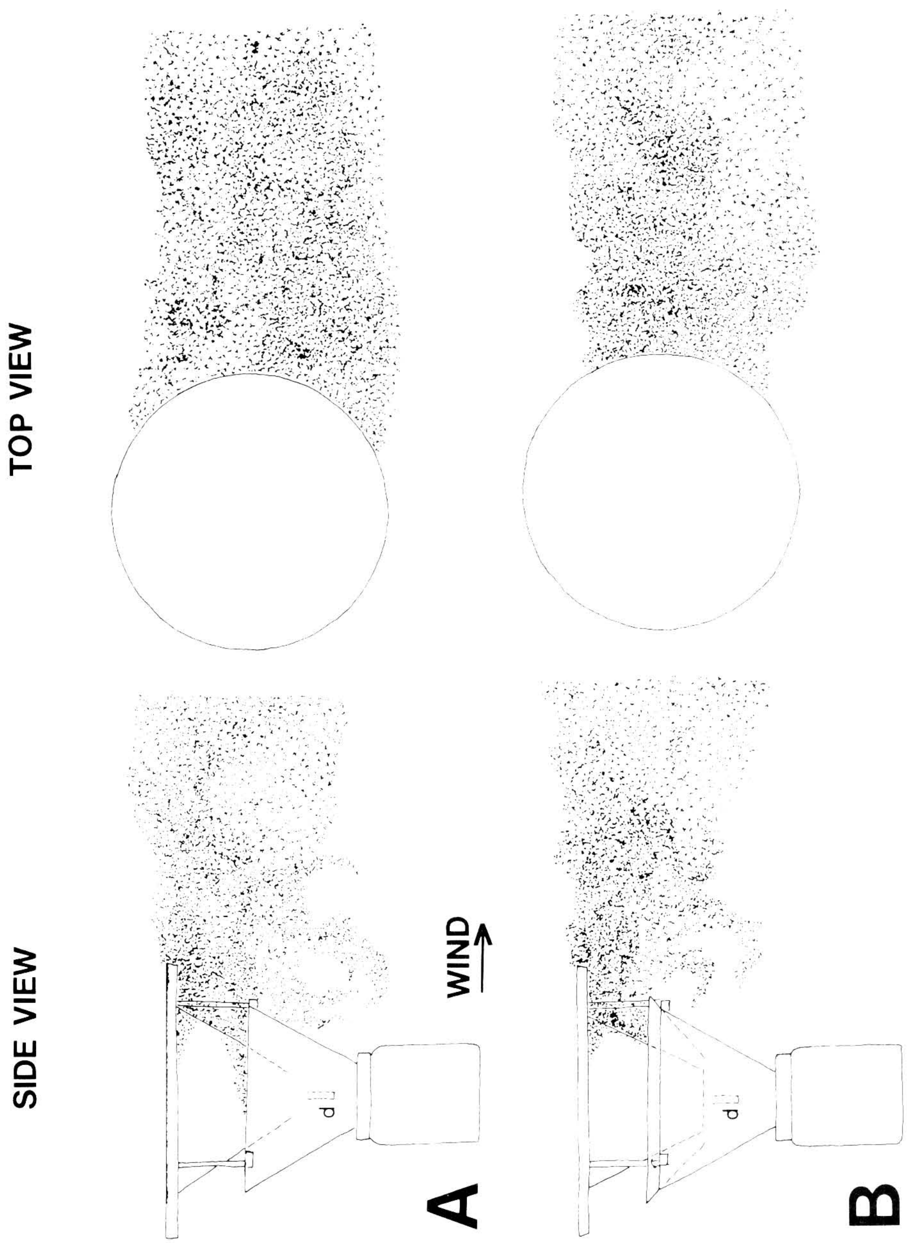

Fig. 1. Diagrammatic representation of plume formation from a Lindgren 2-funnel trap (A), and from a modified version (B) in which a plastic insert (i) was used to improve air flow over the lure and to decrease the tendency of the plume to curl down and contaminate the exterior of the trap. The pheromone dispenser is in the centre of the trap (d).

TABLE 1. Evaluation of experiments 1, 2 and 3, with two sticky traps and two non-sticky traps for trapping Douglas-fir tussock moths. Oregon Jack Creek Road, Ashcroft, B.C. experiments run as 4 x 4 Latin squares.

Trap	Experiment 1[a]		Experiment 2[b]		Experiment 3[c]	
	Mean Catch[d]	Range	Mean Catch[d]	Range	Mean Catch[d]	Range
Kendall trap	7.0a	2-12	27.0a	13-54	58.0a	31-82
Pherocon 1CP sticky trap	21.7b	17-31	13.5a	6-30	39.0a	31-43
Lindgren 8-funnel trap	42.0b	11-84	99.0a	1-205	191.0b	133-301
Delta sticky trap	67.3c	56-78	85.8a	72-101	209.0b	182-232

[a] August 23-24, 1982; PVC rod lure.

[b] August 24-25, 1982; 1 μL capillary tube release system.

[c] August 25-September 8, 1982; 1 μL capillary tube release system.

[d] Means within columns followed by the same letter not significantly different, Student-Newman-Keul's Test, $P<0.05$.

TABLE 2. Results of experiment 4, a double 4 x 4 Latin square trial to evaluate the effect of collecting jar content on the catch of Douglas-fir tussock moths in pheromone-baited, modified Lindgren 2-funnel traps. Green Stone Road, Cherry Creek, B.C., August 20-24, 1983.

Collecting Jar Content	Mean Catch[a]	Range
Water	6.8a	2-17
DDVP	24.0b	4-75
Empty	24.1bc	6-48
Soapy water	40.6c	9-63

[a]Means followed by the same letter not significantly different, Student-Newman-Keul's Test ($p<0.05$).

the modified Lindgren 2-funnel trap would appear to be virtually escape proof. Although such a feature may be important in a commercial monitoring trap, a need for preservation of trapped insects for identification, and for rapid knockdown of possible predators may call for a killing agent to be incorporated into the design.

The catches in the four trap types tested in experiment 5 did not differ significantly (Table 3). The coefficients of variation were similar to those obtained in the earlier experiments for the non-sticky traps, but for the delta trap was unusually high (41.9%). This may indicate problems with trap placement, or possibly shifting winds. Fellin and Hengel (1983) placed traps for several species of defoliators on poles between trees, thereby avoiding any effects on the catch by variations in trap placement on branches. However, it may be necessary to

TABLE 3. Results of experiment 5, a double 4 x 4 Latin square trial comparing a sticky trap and three non-sticky traps for the Douglas-fir tussock moth. Green Stone Road, Cherry Creek, B.C., August 24-29, 1983.

Trap	Mean Catch[a]	Range
Lindgren 2-funnel trap	18.1	4-39
Modified Lindgren 2-funnel trap	18.9	8-42
Lindgren 8-funnel trap	23.4	7-34
Delta sticky trap	27.9	14-45

[a]No significant differences as determined by analysis of variance ($p<0.05$).

place traps for some species near foliage to make them sufficiently sensitive. The western spruce budworm responds more readily to traps close to foliage than to traps in the open. (Liebhold and Volney 1984; J. D. Sweeney, unpublished data).

Wind Tunnel Observations

Wind tunnel observations of $TiCl_4$ smoke showed that the "pheromone" plume had a slightly lower tendency to curl back on the downwind side of the modified Lindgren 2-funnel trap in comparison to the unmodified trap (Fig. 1). However, the effect was still pronounced enough to contaminate the outside of the lower funnel and the collecting jar of the modified trap. This self-contamination resulted in moths landing and wing-fanning on the outside of the lower funnel and collecting jar instead of entering the trap.

The plumes generated from 2-funnel traps, 8-funnel traps, Kendall traps and Pherocon 1CP traps were all relatively diffuse (Lindgren 1983; Angerilli and McLean 1984), whereas those of the delta sticky traps were linear when the traps were oriented in line with the wind (Angerilli and McLean 1984). Lewis and Macauley (1976) found a positive correlation between plume linearity (length/width ratio) and the catch of the pea moth, *Cydia nigricana* (Steph.), corrected to a standard retentive surface.

The Lindgren 8-funnel trap was originally designed for heavy fliers such as bark beetles (Lindgren 1983). Its relative success in capturing DFTM (experiments 1, 2, 3 and 5), may have been due to its vertical silhouette which elicited searching behavior by DFTM males, thereby increasing the probability of the moths remaining on the trap until they fell into the collecting jar.

Richerson *et al.* (1976) reported that male gypsy moths, *Lymantria dispar* L., search vertical silhouettes regardless of the presence or absence of females. Searching behavior of both DFTM and gypsy moth males may be similar, since, the females of both species usually remain on their cocoons after emergence. Many DFTM moths observed at traps in this study, would approach the trap, and then land and search on a nearby tree trunk or branch.

Lewis and Macauley (1976) noted that only 25-50% of pea moths approaching a trap were caught. Our field observations indicated that a similar problem existed with the trap-lure combinations tested for DFTM. No formal data on the capture rate were recorded, but it was apparent that more than half of the moths observed approaching the non-sticky traps did not enter. Typically, the moths would approach the trap to within 0.5 m, where they would cast back and forth for a limited time before flying away or landing on nearby branches or tree trunks.

The omnidirectional non-sticky trap designs tested in our experiments performed relatively well. However, they were generally too variable for use in a standardized monitoring program for the DFTM. Therefore, improvements in the design are necessary. The design must facilitate rapid capture of the moths, and contamination of the outside of the trap must be minimized.

The delta sticky trap caught about the same number of moths as the non-sticky designs, but with much less variability making it preferable for monitoring populations.

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