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3.4 DEPOSIT AND DISTRIBUTION OF *TRICHOGRAMMA MINUTUM* RILEY FOLLOWING AERIAL RELEASE

S.M. SMITH
Faculty of Forestry, University of Toronto, Toronto, Ontario, Canada M5S 3B3

D.R. WALLACE
Forestry Canada, Ontario Region, Great Lakes Forestry Centre, PO Box 490, Sault Ste. Marie, Ontario, Canada P6A 5M7

J.E. LAING and G.M. EDEN
Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1

and S.A. NICHOLSON
Pestechcon Inc., King City, Ontario, Canada L0G 1K0

Abstract

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The egg parasitoid, *Trichogramma minutum* Riley, was distributed by helicopter over forest stands near Hearst, Ont., to control the spruce budworm, *Choristoneura fumiferana* (Clemens). The quality of the parasitoids in terms of emergence, proportion of females, longevity, and fecundity was not affected by aerial release. Based on monitoring with deposit cards, at 10 m above ground, the helicopter had an effective swath width of ca. 10 m. Aerial release provided an uneven distribution of deposit on 1.0-ha plots, with significantly less parasitized material reaching the outer edges of each plot than in the centre; parasitism of sentinel egg masses within the plots corresponded to the distribution of deposit. Over 50% of the released material was deposited on the ground. Drift outside the plots was generally less than 25 m, never exceeding 100 m. The extent of drift was dependent on the application technique, and to a lesser extent, wind direction. Deposit cards provided an extensive rather than an intensive sampling method for monitoring the aerial distribution of *T. minutum*.

Résumé

Le parasitoïde des oeufs, *Trichogramma minutum* Riley, a été distribué par hélicoptère au-dessus des terrains forestiers près de Hearst, Ont., pour maîtriser la tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* (Clemens). La qualité des parasitoïdes en fonction d'éclosion, de proportion de femelles, de longévité et de fécondité n'a pas été touchée par le relâchement aérien. Selon le contrôle sur les cartes de dépôt, à 10 m au-dessus de la terre, l'hélicoptère a eu une bande d'efficacité d'une largeur de ca. 10 m. Le relâchement aérien a donné une distribution de dépôt inégale aux lotissements de terre de 1,0 ha, fournissant significativement moins de matières parasitées autour des bords qu'au centre de chaque lot; le parasitisme des masses d'oeufs posées en sentinelles en dedans des lots ont été en conformité à la distribution des matières déposées. Au-dessus de 50% des matières relâchées ont été déposées à terre. La diffusion en dehors des lots a été généralement moins de 25 m et n'a jamais excédé 100 m. L'étendue de la diffusion dépendait de la technique d'applicage, et à un degré moindre à la direction du vent. Les cartes de dépôt n'ont fourni qu'une méthode extensive pour contrôler la distribution aérienne de *T. minutum*.

INTRODUCTION

In China and the USSR, *Trichogramma* species are the most widely used beneficial insects for biological control of pests on agricultural and forest crops (Beglyarov and Smetnik 1977; Li 1983). In these countries, the success of this approach has been due mainly to the comparatively low costs of labour; parasitoids are produced in factories and distributed in the field either manually or by limited mechanical methods. However, automated techniques for the production and distribution of *Trichogramma* would be required to ensure the economic feasibility of inundative releases in North American markets (Ables

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et al. 1979). Initial attempts in the United States employed hand application methods and were followed by more mechanized ground level releases (Jones *et al.* 1977; also see Section 3.2). In recent years, systems have been developed for attaching parasitized eggs of *Sitotroga cerealella* (Olivier) to wheat carriers and applying them by aircraft (Jones *et al.* 1979; Bouse *et al.* 1980).

During 1983, outbreak populations of the spruce budworm, *Choristoneura fumiferana* (Clemens), occurred in Ontario on more than 12.1×10^6 ha of boreal forest (Howse and Applejohn 1983). At this time, *Trichogramma minutum* Riley was the only known egg parasitoid of the spruce budworm and was considered for use in Canada. The magnitude of forest infestations requires aerial release of the parasite and in 1982 the Pest Management Section of the Ontario Ministry of Natural Resources developed a helicopter system for distributing *T. minutum* uniformly on forest stands (see Section 3.3). Application rates, distribution of deposit, and meteorological and biological factors influence the success of such a system (Joyce 1985). We examined the distribution and quality of *T. minutum*, aerially released on plantation forests near Hearst, Ont., under different weather and stand conditions from 1983 to 1985 (see Section 3.5). These factors also were measured for an orchard release near Guelph, Ont., in 1985.

Materials and Methods

Parasitoid Quality

Trichogramma minutum were reared at the Biological Control Laboratory, University of Guelph, Guelph, Ont., and transported to the field (see Section 2.0). Parasitoid quality was assessed following aerial release in 1985 (Table 1). Prior to the release of 10×10^6 *T. minutum*, a sample of ca. 2000 parasitized eggs was taken from (A) the glass of the parasitization unit, (B) the bulk supply of parasitized eggs, and (C) the hopper of the release mechanism (see Table 2). The remaining eggs were aerially released in September from a height of 20 m over an orchard at Guelph, Ont. Deposits from this release were determined by sampling eggs with (D) 45-cm-wide cardboard funnels, (E) cloth-covered trays (60 by 120 cm), both placed at ground level, and (F) a sheet (250 by 150 cm) held horizontally 1 m above the ground. All samples of parasitized eggs (A to F) were incubated at 25°C. Twenty females from each sample were placed in vials (1 ♀ per vial) and provided daily with 50 gamma-sterilized, fresh host eggs. Emergence from the samples and longevity and fecundity (e.g. total number of host eggs parasitized) for each emerged female parasitoid were determined.

Parasitoid quality was assessed under field conditions following releases near Hearst, Ont., in 1983 and 1984. Samples of (ca. 500) parasitized host eggs were collected prior to being placed in the dispenser unit (pre-release), and after the eggs had passed through the dispenser unit (post-release). Emergence and sex ratio of parasitoids from these two samples were compared. In 1984 and 1985, the post-release sample was collected with funnels (30 cm diameter) placed 1 m above ground level on the release plots. Seven funnels on one plot in 1984 and five funnels in each of five plots in 1985 were used. In a field laboratory, pre- and post-release longevity and daily fecundity were measured for 20 ♀ ♀ *T. minutum* by isolating each insect in a 1.9-mL vial and providing her with two fresh spruce budworm egg masses. Fecundity was estimated from the number of eggs parasitized and the number of progeny emerged.

Release in an Orchard

In 1985, deposit cards (25 by 25 cm) were used to assess the width of a single swath in a dwarf apple orchard at Guelph, Ont. Cards sprayed with aerosol Tanglefoot® were placed on the ground in a line perpendicular to the flight path of the helicopter. The cards were spaced at intervals of 1.75 m for 15 m on either side of the intended flight path. The Bell® helicopter, described in Section 3.3, flew one swath over the orchard, releasing

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parasitized host eggs at ca. 10 m above the ground. After the release, the number of parasitized and non-parasitized host eggs on each card was counted.

Release in Plantation Forests

From 1983 to 1985, aerial releases were made between 0600 and 0800 hours on the stands described in Section 3.1. All study areas were oriented in the same cardinal direction to standardize the flight path of the helicopter. Stand composition and condition were measured in each area and weather conditions were monitored 15 km from the release sites. As in the orchard, deposit cards were used to assess rates of deposit and distribution. Prior to release, each card was stapled to a plywood board, horizontally on top of a 3-m stake. This allowed the cards to be disassembled and collected rapidly. After the release, each card was covered with Saran Wrap®, removed from the board, and taken to the laboratory for enumeration of parasitized and non-parasitized host eggs.

Only small quantities of parasitized host material were available in 1983; consequently, only one 2.0-ha plot was used. On this plot, the *Trichogramma* was released in three adjacent diagonal swaths with 20 deposit cards placed randomly along the flight path. Parasitized eggs were released on 14 July at 20.1×10^6 per hectare. In addition to the deposit cards, six branches, three each of balsam fir and white spruce, were sprayed with Tanglefoot® and placed on the ground in the study area prior to release. The surface area (Sanders 1980) and number of parasitized eggs and unparasitized host eggs were recorded for each branch.

During 1984 and 1985, additional studies were conducted with larger numbers of parasitoids. In each year, 1.0-ha study plots (100 by 100 m) were established: three in 1984 and five in 1985. The distribution pattern within each plot was examined both years by placing deposit cards on stakes, at the centre and at 10-m intervals for 50 m in each of the four cardinal directions (21 cards per plot). This provided an extensive sample of deposit. Egg deposit between plots was compared using ANOVA and Duncan's new multiple range test (Duncan 1955). Drift outside each plot was also assessed both years. In 1984, deposit cards were placed at 25, 50, 100, 150, and 200 m in the four cardinal directions outside the plots, and in 1985, cards were located at 25-m intervals from the four edges of each plot up to 100 m.

Parasitism of naturally laid spruce budworm egg masses in each plot was compared with relative deposit within each plot. In each plot, nine groups of two balsam fir and two white spruce trees were selected. One group was located at the plot centre, one at 10–20 m from the centre, and one at 40–50 m from the centre in each cardinal direction. During early August, in both 1984 and 1985, one 45-cm branch tip was taken from the upper mid-crown of each of the balsam fir and white spruce trees in each group (total 36 branches per plot). This design allowed us to compare parasitism with deposit by both direction and distance from the centre of the plot. Student's t test was used to examine deposit at the centre versus the edges of the plot while ANOVA and Duncan's new multiple range test tested significance of deposit by cardinal direction. Ostle and Mensing's (1975) χ^2 test for proportions with binomial distribution was used to compare parasitism of the egg masses on the branches.

In 1984, two releases were conducted on each plot at 19.8×10^6 parasitized eggs per hectare on 10 July and 22.9×10^6 parasitized eggs per hectare on 16 July. One plot was used to determine the sampling intensity for parasitoid deposit. Deposit cards were placed on 3-m stakes at 2.5-m intervals from the centre of the plot up to 10 m in each cardinal direction. These 17 cards, in an area of 314 m^2, provided intensive samples to obtain more precise information on the effective swath width as well as an estimate of variability in deposit between cards. This allowed us to determine the minimum number of cards needed to measure parasitoid deposit on these stands accurately.

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Table 1. Emergence, longevity, and fecundity of *Trichogramma minutum* before and after release by helicopter in an apple orchard at Guelph, Ont., during 1985

	Pre-release			Post-release		
	A*	B	C	D	E	F
Emergence (%)	89.7†	87.5	90.9	87.9	88.5	87.2
Female longevity (days)	6.3	7.1	4.7	7.3	7.5	6.1
First-day fecundity (no. parasitized eggs per ♀)	38.2	31.0	32.9	36.0	34.2	32.8
Total fecundity (no. parasitized eggs per ♀)	68.2	65.4	58.5	77.7	68.8	73.7

**Trichogramma* taken from (A) glass of window box parasitization unit, (B) bulk parasitized eggs; (C) hopper; (D) cardboard funnel; (E) cloth trays, and (F) sheet on ground.
†Means in each row are not significantly different at the $p = 0.05$ level (Duncan's new multiple range test).

To examine vertical deposition, additional deposit cards were placed on the ground, beneath each of the 17 cards described above. The number of parasitized eggs deposited at 3 m and at ground level could then be compared with the number released from the helicopter (10 m).

In 1985, the 21 extensive cards on the plots were also used to examine the effect of different release rates on the distribution pattern of parasitized eggs. Parasitized eggs were released on these plots at 4.8, 9.6, and 19.2×10^6 per hectare on 9 July and at 4.8, 9.5, and 19.0×10^6 per hectare on 19 July. The highest rate was applied on a single plot while the two lower rates were each replicated on two plots.

RESULTS

Parasitoid Quality

The orchard study at Guelph showed that parasitoids were unaffected by aerial release (Table 1). There were no significant differences in emergence, longevity, or first-day or total fecundity before and after release ($p = 0.05$, Duncan's new multiple range test, Duncan [1955]). Similarly, in forest stands near Hearst during 1983 and 1984, the quality of parasitoids passing through the release mechanism was relatively unchanged (Table 2). Where slight reductions did occur, they were not significantly different ($p = 0.05$, Student's

Table 2. Biological parameters of parasitoid quality measured before and after aerial release of *Trichogramma minutum* near Hearst, Ont., in 1983 and 1984

		First release			Second release		
Year	Parameter	A*	B	C	A	B	C
1983	Emergence (%)	—	85.8†	79.5	—	—	—
	Sex ratio (% ♀♀)	—	56.0	50.9	—	—	—
1984	Emergence (%)	94.5	73.5	78.8	89.5	84.7	88.7
	Sex ratio (% ♀♀)	65.2	58.0	65.2	61.4	57.5	61.4
	Female longevity (days)	—	2.5	2.4	—	2.0	2.3
	Total fecundity (no. parasitized eggs per ♀)	—	14.7	16.6	—	17.6	11.5

*Values determined (A) prior to shipping from Biocontrol Laboratory, Guelph, Ont., (B) pre-release sample, and (C) post-release sample.
†Means between pre-release (B) and post-release (C) columns are not significantly different for either year or release at the $p = 0.05$ level (Student's t test).

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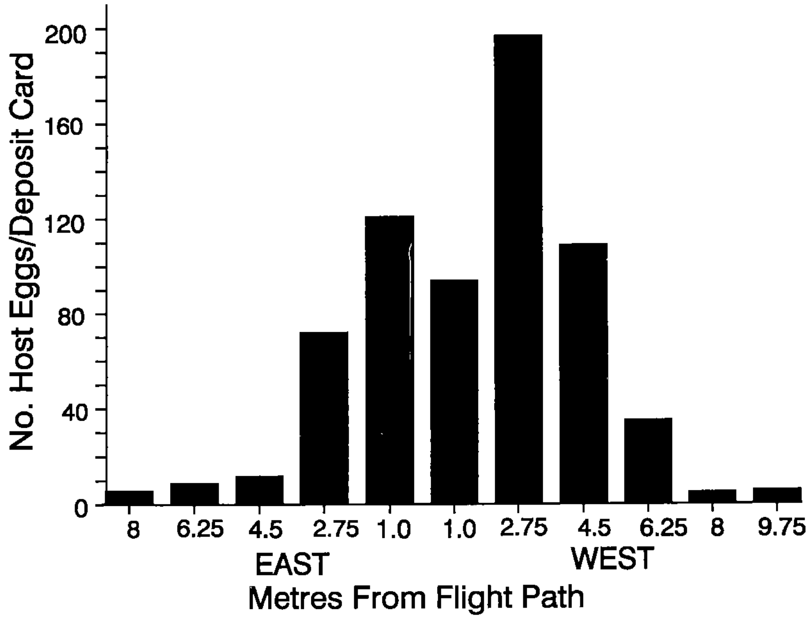

FIG. 1. The number of host eggs collected on deposit cards under the flight path of the helicopter releasing *Trichogramma minutum* over an apple orchard near Guelph, Ont.

t test). These results clearly show that the mechanism for aerially releasing *T. minutum* from 10 m in height over forest stands was not harmful to the viability of the parasitoids.

Distribution of Deposit

(*i*) Orchard: Host eggs released over an orchard from a single helicopter swath were deposited normally. Peak deposition occurred ca. 3 m to the west of the flight path and was probably the result of a 5- to 10-km/h east wind at the time of release (Fig. 1). Although host eggs were deposited over a width of about 18 m, the effective swath width (within which over 90% of the eggs were deposited) was about 11 m. For application purposes, an effective swath width of 10 m was used.

(*ii*) Forest: Parasitized material was deposited somewhat unevenly across individual plots in forest releases (Figs. 2 and 3). This effect was more apparent in 1984 (Fig. 2) when the aerial technique was still being perfected than in 1985 (Fig. 3). Infrequently, on all plots, no deposit was recorded in 10- to 20-m sections, particularly near the plot edges. More uniform distribution was achieved in 1985 at all three rates of release (Fig. 3). The different release rates, however, were not clearly evident on the deposit cards. For both releases, the greatest number of eggs were collected on plot 9 ($\bar{X} = 19.1 \times 10^6$ per hectare released); however, a clear trend in deposit relative to release rate was observed only for the second release.

Parasitism of spruce budworm egg masses in the plots in 1984 and 1985 was usually lower on the edges (30–50 m) than in the centre (0–20 m) (Table 3). Although the level of this reduction varied (0–35%), it was similar to the reduction in deposit (Table 3).

Cardinal direction did not significantly affect deposit of host eggs. In each directional quadrant, the mean number of eggs deposited was relatively uniform within the plots (frequency for each quadrant, $\bar{X} = 25\%$, range = 9–40%). In 1984, the deposit for both releases in north, south, east, and west quadrants was 28, 33, 18, and 21%, respectively ($F = 2.51$; df = 23; $p = 0.05$) and in 1985 it was 22, 16, 36, and 26%, respectively ($F = 2.14$;

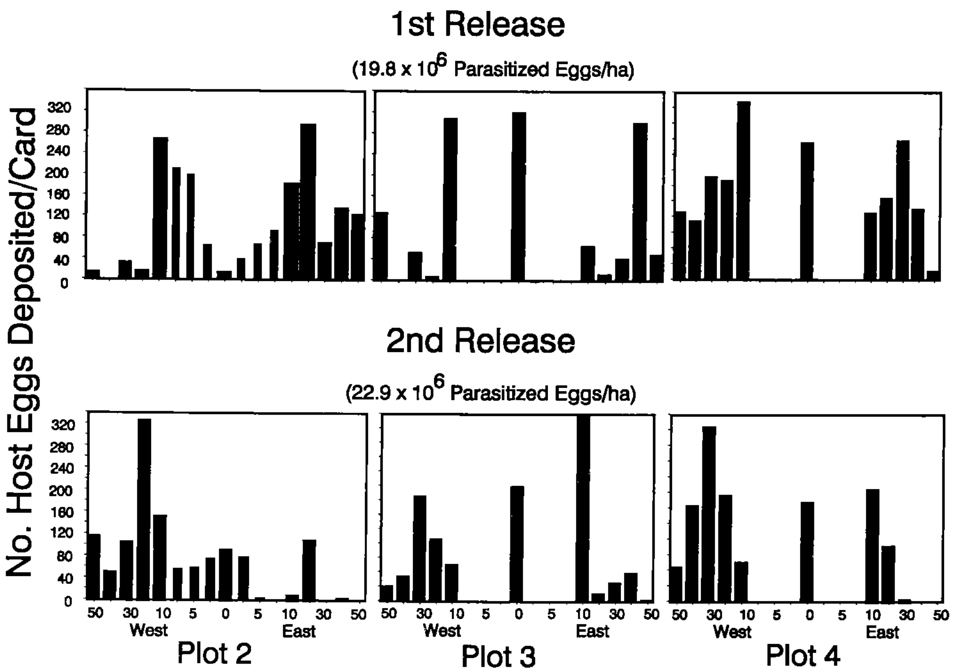

FIG. 2. Distribution of deposit on forest plots receiving aerial releases of *Trichogramma minutum* near Hearst, Ont., in 1984.

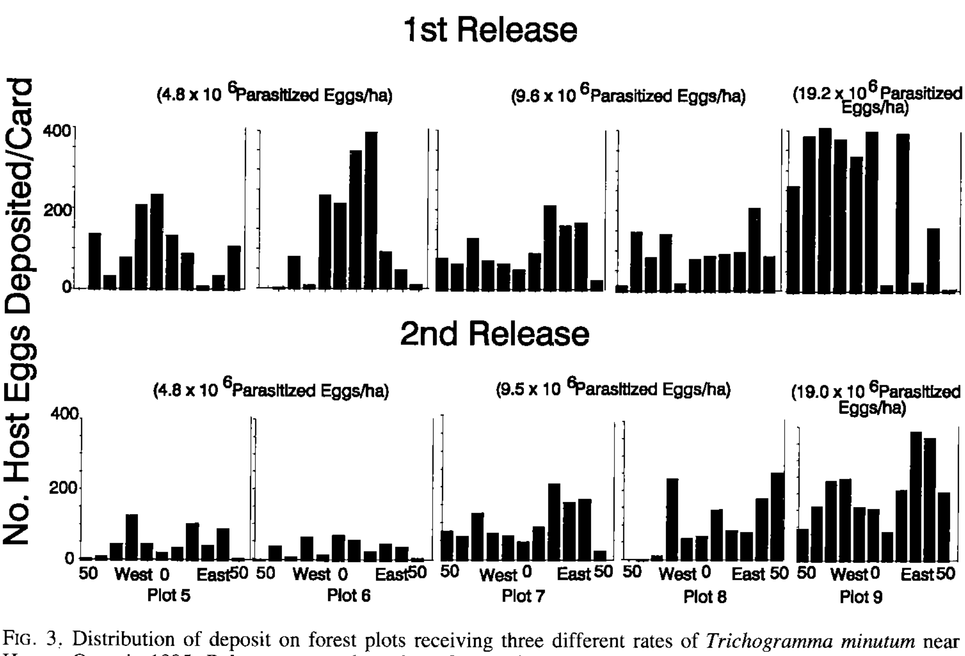

FIG. 3. Distribution of deposit on forest plots receiving three different rates of *Trichogramma minutum* near Hearst, Ont., in 1985. Release rates and number of parasitized eggs per hectare for each plot are indicated in parentheses.

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Table 3. Parasitism of naturally laid spruce budworm egg masses and deposit by distance on forest plots receiving *Trichogramma minutum* reared at the Biocontrol Laboratory, Guelph, Ont., in 1984 and 1985

Year	Plot	Variable	Distance from centre of plot (m) 0–20	30–50	Reduction* (%)
1984	2	Parasitism†	99	90	9
		Deposit‡	100	99	2
	3	Parasitism	95	79	17§
		Deposit	113	86	23§
	4	Parasitism	42	29	32§
		Deposit	145	99	32§
1985	5	Parasitism	49	41	16
		Deposit	49	39	21§
	6	Parasitism	50	50	0
		Deposit	42	50	0
	7	Parasitism	46	43	7
		Deposit	44	39	12
	8	Parasitism	62	43	31§
		Deposit	71	46	35§
	9	Parasitism	60	61	0
		Deposit	67	50	27§

*Percentage reduction in variable between 0–20 m and 30–50 m.
†Percentage of viable, naturally occurring spruce budworm egg masses parasitized by *T. minutum*.
‡Mean number of parasitized eggs deposited on a 0.0625-m^2 card.
§Significant reduction at the $p<0.05$ level for values between 0–20 m and 30–50 m. (Parasitism, χ^2 test for proportions with binomial distributions, Ostle and Mensing [1975]; Deposit, Student's t test.)

df = 39; $p = 0.05$). Similarly, parasitism of budworm egg masses was not affected by cardinal direction. In 1984, parasitism in the north, south, east, and west quadrants was 65, 62, 65, and 64%, respectively ($F = 1.52$; df = 107; $p = 0.01$) while in 1985 parasitism was 45, 53, 53, and 48%, respectively ($F = 2.07$; df = 164; $p = 0.05$).

Wind speed was always below 3 km/h at the time of each release in 1984 and 1985 (Table 4). The deposit data collected by cardinal direction inside each plot indicated that wind had little effect on the distribution of deposit within each plot although it may have had a limited effect on deposit drifted outside the plots.

In 1985, drift at 25 m was higher downwind than upwind (Table 4). Over 90% of this drift material was within 25 m of a plot boundary, with no drift found beyond 100 m. In three instances, the number of eggs on a card 25 m outside the plot was as high as on any card inside that plot. In addition, the mean for each directional quadrant at 25 m was always associated with a high standard error. This suggests that the plot edges received irregular deposit, more likely a result of the application technique than the direction of the wind. The location of the drift with respect to the direction of the application supports this theory. Parasitoids were applied in swaths on the plots running from north to south in 1984 and east to west in 1985. In each year, significant drift at 25 m was observed only along that transect flown by the helicopter. The corners of the plots were marked with helium balloons; thus, it may have been difficult for the applicator to identify the plot edge when closing the release mechanism.

Vertical deposit of parasitized host eggs in the forest canopy was assessed in 1984 (Table 5). In both releases, 50–55% of the parasitized eggs released from the helicopter remained in the canopy. The majority of these eggs (36.9–40.6%) were deposited between the helicopter (10 m) and 3 m above ground (height of the deposit cards) but the remaining 9.8–19.8% were trapped in the lower crown and shrubs. This suggests that about 50% of those eggs released aerially remain in the canopy and, of that material, at least 35% will be found in the upper crown.

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Table 4. Direction and distance of parasitized host eggs on deposit cards outside plots receiving aerial releases of *Trichogramma minutum* near Hearst, Ont., in 1984 and 1985

		Wind at release site		Mean no. parasitized host eggs per card outside plot						
					Distance (m)					
Year	Release	Speed (km/h)	Direction	Direction	25	50	75	100	150	200
1984	First	0	—	North	64.1*	6.4	—	0.9	0	0
	Second	2.9	Southwest	South	0.7	0	—	0	0	0
				East	0	0.3	—	0	0	0
1985	First	1.6	Northeast	North	0	0	0.4	0	—	—
				East	2.0*	0.2	0	0	—	—
				West	17.2	1.4	0	0	—	—
	Second	2.1	West	North	0	0	0	0.4	—	—
				South	0.2	0.2	0.4	0	—	—
				East	43.4*	1.4*	0.6*	0	—	—
				West	2.2*	1.0	0	0.2	—	—
Frequency of occurrence (%)					90.5	7.2	1.2	1.1	0	0

*Standard errors associated with each mean are equal to the mean unless designated by an asterisk where they are equal to 50% of the value of the mean.

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Table 5. Deposit of parasitized host eggs by vertical position in the canopy following aerial release of *Trichogramma minutum* near Hearst, Ont., in 1984

			First release		Second release	
Height above ground (m)	Plot(s)	No. cards	Mean no. eggs counted ($\times 10^6$ per hectare)	Difference (%)	Mean no. eggs counted ($\times 10^6$ per hectare)	Difference (%)
10*	—	—	19.8		22.9	
				36.9		40.6
3†	1,2	54	12.5		13.6	
3‡	1	17	9.6		16.3	
				19.8		9.8
0‡	1	17	7.7		14.7	

*Height of helicopter during both releases of parasitized host eggs.
†Height of sticky cards used to monitor deposit extensively.
‡Height of sticky cards used to monitor deposit intensively.

In 1984, deposit on the cards was compared by intensive and extensive sampling (Table 6). As expected, mean deposits of both parasitized and non-parasitized eggs were associated with lower standard errors for intensive samples (SE = 24% of mean) than for extensive samples (SE = 39% of mean). Both sampling systems were highly variable, with any single card providing an estimate with a confidence interval of 77% or less. To provide an estimate with 95% confidence in these stands, 250 deposit cards would be required within an area of 314 m^2.

The deposit of host eggs on branches of balsam fir and white spruce was compared in 1983. A mean of 4.0 ± 4.0 (SE) host eggs was found on each branch of balsam fir whereas 50.1 ± 22.2 (SE) eggs were collected on white spruce. Branches from the two species were similar in length and width; therefore, the 10-fold difference observed in deposit was probably due to the greater density and more cylindrical shape of needles on white spruce than balsam fir. This suggests that species composition may affect estimates of deposit as well as the amount of parasitized material deposited in the upper canopy.

Discussion and Conclusions

Information on the deposit of parasitized host eggs derived from deposit cards was extremely variable; only extensive sampling to determine where the parasitized material has been deposited is recommended. The cards provided little information on the exact amount of material applied, although they did indicate relative amounts and those areas that had been missed in the application or where drift had occurred outside the plots.

Table 6. Comparison of intensive and extensive sample cards to monitor deposit of host eggs released aerially on forest plots near Hearst, Ont., in 1984

		No. host eggs per card			
		Parasitized		Non-parasitized	
Release	Height above ground (m)	Intensive ($\bar{X} \pm$ SE)*	Extensive ($\bar{X} \pm$ SE)	Intensive ($\bar{X} \pm$ SE)	Extensive ($\bar{X} \pm$ SE)
First	3	60 ± 19	85 ± 46	32 ± 8	39 ± 17
	0	48 ± 13	56 ± 29	23 ± 8	30 ± 11
Second	3	102 ± 22	122 ± 49	34 ± 6	39 ± 15
	0	92 ± 19	102 ± 33	31 ± 5	29 ± 6
Mean		76 ± 18	91 ± 39	30 ± 7	34 ± 12

*N = 17 cards in 314 m^2 for intensive samples and 21 cards in 7850 m^2 for extensive samples. Extensive samples for 0 m above ground included the single card at the centre of the plot and the five cards at 10-m intervals from the centre in each cardinal direction.

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Further work, in different stands, using more intensive sampling with either cards or branch samples is needed to characterize the distribution of aerially released *T. minutum*.

Little drift was observed in this study. Where parasitized material was deposited outside the plots, it was associated with poorly defined plot boundaries or inadequate control of the release mechanism at the edges of the plot. The little wind that was present determined the location of drift only to a limited extent. This suggests that aerial releases of *T. minutum* can be conducted with a minimal buffer zone of 100 m between experimental areas or release sites provided that wind speeds at the time of release are less than 3 km/h.

The present study has shown that aerial releases do not affect parasitoid quality, as measured by emergence, sex ratio, longevity, and fecundity. In addition, when released aerially over stands, almost half of the parasitized material is deposited in the canopy. It appears, therefore, that uniform releases of *Trichogramma*, either aerially or from the ground, will provide similar information on parasitism if the predation of parasitized eggs is unaffected by their vertical location in the stand.

The helicopter release system developed by the Ontario Ministry of Natural Resources deposited parasitized eggs on forest stands in effective swaths of ca. 10 m but with a relatively uneven swath pattern. This uneven pattern is characteristic of small aircraft and can be corrected through altered flight patterns as described by Fleming *et al.* (1985). In addition, almost half of the material released fell to the ground. Despite this concentration of parasitoids near the ground, greater parasitism of spruce budworm egg masses was always observed in the upper canopy (also see Smith 1985; Smith *et al.* 1987; and Section 3.5). In contrast with insecticides, *T. minutum* is an active control agent which moves from its point of application to locate specific target pest(s) in forest stands. This makes uniform coverage of foliage, essential with insecticides, less important for aerial releases of *T. minutum*.

Houseweart *et al.* (1984) recommended the use of broadcast, aerial releases of *T. minutum* for control of the spruce budworm. The decision to release *T. minutum* either by broadcast (aerial or ground) or in a series of points on the ground will probably be based upon (1) size, type, and value of the areas to be covered, (2) access to the stand(s), (3) number of releases and density of parasitoids required, and (4) relative costs of manual labour versus a helicopter. In the present study, parasitism of egg masses was lower at the edges of the plots, where fewer parasitized eggs were deposited, than in the centre. Female parasitoids, therefore, dispersed horizontally only a short distance from the point of release. Smith (1988) has shown that *T. minutum* released in these stands will move less than 5 m. Thus, for aerial releases, *T. minutum* should be deposited directly on target areas and if point releases are to be used, they should be spaced at 10 m or less to provide relatively uniform parasitism.

The cost of aerial application was a major component of the total cost of releasing *T. minutum*, due to the small areas treated. With larger treatment areas, the unit area cost of application per unit area would be less. Costs may be reduced further and the pattern of distribution improved if the system were modified through increased mechanization. Gross *et al.* (1981) described an improved system for applying, concurrently, both *Trichogramma* and kairomones for the management of *Heliothis zea* (Boddie). In the USSR, parasitized eggs were effectively dispersed from aircraft in suspensions of water (Sokhta *et al.* 1984; Pas'ko *et al.* 1982). Because of the experimental success shown by *T. minutum* in suppressing pest populations (Section 3.5), continued research in this area of release technology is warranted to make this approach more cost-effective in North America.

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