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3.2 GROUND SYSTEMS FOR RELEASING *TRICHOGRAMMA MINUTUM* RILEY IN PLANTATION FORESTS

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Abstract

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Two systems for releasing the egg parasitoid, *Trichogramma minutum* Riley, from ground level in forest stands are described: (1) a gridded point-source release using parasitized host eggs attached to cards, and (2) a hand-held leafblower distributing parasitized eggs in bulk. Neither technique affected the emergence of the parasitoids released. Parasitoids emerging from eggs released in bulk had a similar sex ratio, longevity, and fecundity to those not released. Both methods of ground release achieved uniform parasitoid distribution and resulted in levels of parasitism similar to those achieved with aerial releases. Parasitism was greater in the mid- to upper canopy of trees than in the lower canopy. The difficulties associated with each technique and its comparative usefulness in experimental and operational programs are discussed.

Résumé

Deux systèmes pour le relâchement du parasitoïde de l'oeuf, *Trichogramma minutum* Riley, à partir du niveau de la terre dans les terrains forestiers sont décrits: (1) un relâchement d'un point-source dans une superficie quadrillée en utilisant les oeufs parasités de l'hôte attachés aux cartes et (2) un relâchement en utilisant une souffleuse de feuilles tenue dans la main pour disperser en volume les oeufs parasités. Les parasitoïdes éclos des oeufs relâchés en volume avaient le rapport sexuel, la longévité et la fécondité semblables à ceux non relâchés. Les deux méthodes de relâchement terrestre ont accompli une distribution uniforme de parasitoïdes et ont abouti aux niveaux de parasitisme semblables à ceux accomplis par les relâchements aériens. Le parasitisme était plus important aux niveaux moyens et hauts des voûtes de feuillage qu'au niveau bas. Les difficultés associées à chaque méthode et l'utilité comparative de chacune aux programmes expérimentaux et opérants sont discutées.

INTRODUCTION

The application of pupal *Trichogramma* from the ground is a standard method of release in countries such as China where production and labour costs are low (Huffaker 1977). In North America, early studies relied exclusively on this approach (Smith 1929; Van Steenburgh and Boyce 1938; Jaynes and Bynum 1941) but, now, the widespread use of ground releases is precluded by the large areas requiring treatment and the high cost of labour. In agriculture, this has led to the development of aerial release systems for treatment of large areas (Jones *et al.* 1979; Bouse *et al.* 1980; Bouse and Morrison 1985; also Section 3.3).

Although aerial systems have made releases of *Trichogramma* more cost-effective, there remains a need for ground applications. As shown by Parker *et al.* (1971), Oatman and Platner (1971, 1978), and Smith *et al.* (1987), ground release may be more appropriate for research where controlled applications on a number of small plots are required. As with liquid insecticides, ground releases of parasitoids reduce the chance of drift and, thus, allow the researcher to use smaller buffer zones; this, in turn, reduces the cost of establishing field experiments. Where the supply of *T. minutum* Riley is limited, ground releases make more efficient use of available parasitoids. Ground releases are also particularly useful in specific conditions: small discrete areas, areas of human habitation or high public use, environmentally sensitive areas, and private plantations and woodlots.

Jones *et al.* (1977) developed a mechanized technique for ground release of *T. pretiosum* Riley in cotton; however, forest stands have greater biomass, require more *Trichogramma*, and are more difficult to work in than cotton fields. This paper describes two systems developed for ground release of *T. minutum* in forest stands. Specifically, our interest was to develop systems that would (1) provide a uniform distribution of parasitoids simulating aerial release, (2) have little or no effect on the quality of parasitoids, (3) apply low quantities of parasitoids on specific areas in small forest plots, and (4) be easy to use in the forest environment.

Materials and Methods

In 1983 and 1986, two ground systems were examined for the release of *Trichogramma* against the spruce budworm, *Choristoneura fumiferana* (Clemens). The studies were conducted in those forest stands described in Section 3.1.

The parasitoids used in 1983 were reared on eggs of *Sitotroga cerealella* (Olivier) by a commercial insectary, Rincon Vitova, Oak View, CA; in 1986, they were produced by the biological Control Laboratory, University of Guelph, Guelph, Ont. (see Section 2.0). Parasitoid pupae within eggs of the rearing host were transported by aircraft to the field. Prior to release, a subsample (ca. 1000 host eggs) was taken from each production batch to determine emergence, sex ratio, longevity, and fecundity. Parasitism of spruce budworm following releases was assessed with sentinel egg masses. Each sentinel egg mass consisted of a single egg mass laid in the laboraory on a balsam fir twig (5–10 cm in length) by spruce budworm reared on artificial diet. Each twig was tied to a pulley system which moved between the ground to the top of a single sample tree (see Section 3.5 and Smith 1985). These fresh egg masses were placed on randomly selected trees in the plots at three different heights, 1.25, 2.25, and 3.25 m above ground, and changed every 3 days throughout the summer. Weather conditions were monitored 15 km from the study sites.

Grid Point Releases

Trichogramma minutum were released on 7, 14, and 21 July 1983 at the rate of 12×10^6 ♀ ♀ per hectare per release from point sources in a grid pattern. Host eggs were attached to cardboard sheets using diluted Elmer's white glue. The cards were placed in cone-shaped paper cups (25–150 mL), with openings at the top and bottom to permit escape of the parasitoids, and taken, under cool conditions (<15°C), to the field. The cups were pinned 25 cm above the ground on release stakes in five plots (50 by 50 m; 0.25 ha). To achieve a uniform grid distribution, the stakes were located in a 7 by 7 m spacing (Smith 1985). The distance from each stake to the nearest sample tree with sentinel egg masses was measured (Fig. 1*a*). Three weeks after each release, 10 cards (ca. 10 000 host eggs per card) were selected randomly from each plot and successful emergence of the parasitoids was calculated to compare with emergence from the subsample collected prior to the release. Because the parasitoids had already emerged, no assessment of sex ratio and female longevity or fecundity could be made post-release.

Broadcast Releases

An electric hand-held leafblower (Model No. PB 100C-50, Allegretti Manufacturing Co. [Canada] Inc., Tilbury, Ont.) powered by a portable generator was used to release *T. minutum* from the ground at a rate of 12×10^6 ♀ ♀ per hectare per release. Two releases, one each on 5 and 12 July 1986, were made on a single plot (25 by 25 m). The parasitoids were shipped in bulk from the production facility where the number of female *T. minutum* in a given volume of host eggs was estimated. A shoulder strap was used to maintain the blower at a 45° angle from the applicator. This provided freedom for one of the applicator's arms to control the direction of the nozzle and the flow rate of the parasitized material.

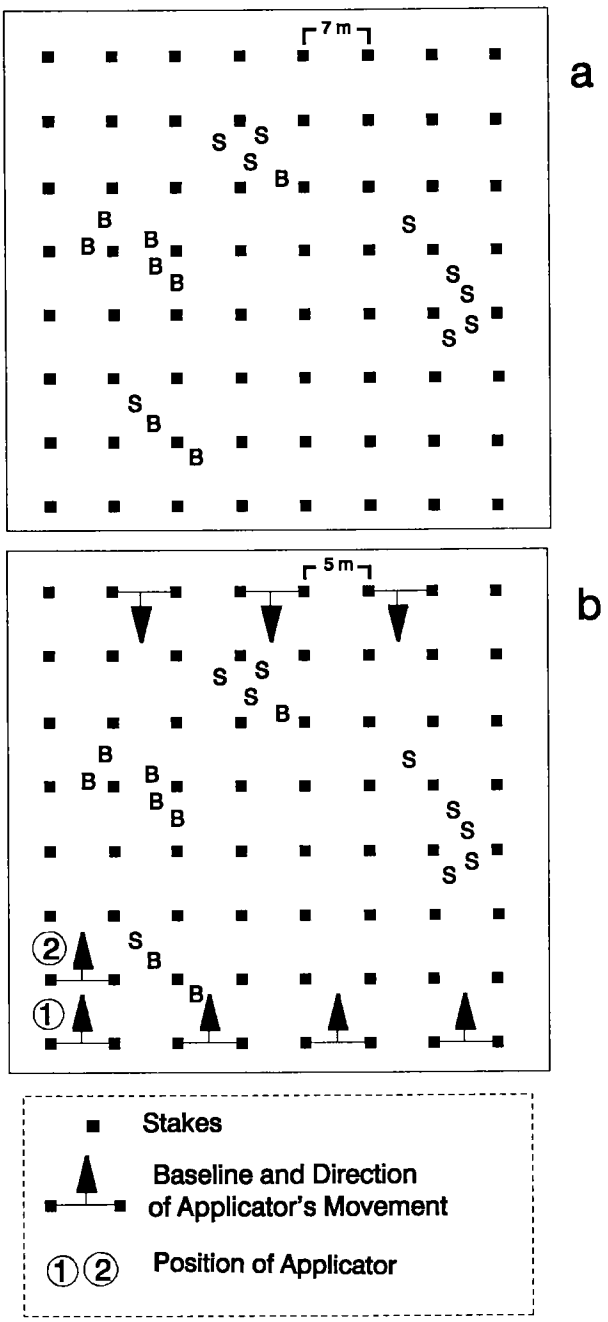

FIG. 1. Grid design for release stakes on experimental forest plots receiving ground releases of *Trichogramma minutum* in (*a*) 1983 and (*b*) 1986. Sample trees for monitoring parasitism with sentinel egg masses designated as follows: B = balsam fir; S = white spruce.

An initial test was made of the distribution pattern from the leafblower by placing deposit cards (625 cm^2) sprayed with Tanglefoot® in a 180° arc at intervals of 1 m from the applicator. Unparasitized eggs of the Angoumois grain moth were blown through the mechanism, directly in front of the applicator for ca. 10 s.

On each 0.0625-ha plot in the field (25 by 25 m), a grid pattern of stakes, 5 by 5 m, was established (Fig. 1*b*) and used to guide the application with the leafblower. Parasitized host material was divided equally, by volume, into 5-mL coffee creamer cups. With the applicator positioned on the baseline mid-way between two stakes (Fig. 1*b*, position 1), the contents of one container were dropped slowly in front of the air flow of the nozzle as the blower was rotated through a 180° arc. The applicator then walked to the next baseline (Fig. 1*b*, position 2) and repeated this procedure until all 25 grids had been treated. For each release date, small samples of the parasitized material that was distributed were collected randomly in funnels (see Section 3.5) on one plot to compare emergence, sex ratio, female longevity, and fecundity of the released parasitoids with those from the subsample taken before the release.

Results and Discussion

Both methods of ground release were effective. With the point release system, parasitism of sentinel egg masses on sample trees close to the point of release (X = 89.6% at 0–1.75 m) was not significantly higher than on trees furthest away (X = 85.3% at 1.75–3.5 m; $\chi^2 = 1.73$, df = 1, $p > 0.05$). At the same application rate, both the point and broadcast releases resulted in similar levels of maximum parasitism (1983 and 1986 in Table 1). Although slightly higher, both types of ground release also produced rates of maximum parasitism similar to those on plots where *T. minutum* was released aerially during 1984 and 1985 (Table 1; also see Section 3.5). Irrespective of the release technique, *T. minutum* tended to parasitize significantly more egg masses and eggs in the mid- to upper canopy than in the lower canopy (Table 1). The data suggest that the parasitoids released on the ground were deposited uniformly and dispersed into the upper canopy upon release. Previous studies also have shown that, even when released from grid points on the ground, female *T. minutum* will disperse vertically into the upper canopy where the majority of host eggs are laid (Smith 1985, 1988). The natural predominance of parasitism by *T. minutum* on eggs of spruce budworm in the upper canopy has been noted by Kemp and Simmons (1978) and Houseweart *et al.* (1984).

Neither type of ground release affected parasitoid emergence (Table 2). In the broadcast release (1986), the sex ratio and female longevity and fecundity were not significantly different (p = 0.05, Student's t test) for both pre- and post-release samples. The point releases were a particularly good technique for releasing emerged parasitoids because there was no release mechanism to damage the adults. This technique would be useful where shipping schedules are uncertain. However, point release sources required more preparation time and were subject to predation by small mammals after 3 days in the field. Point releases are suited to well-managed plantations or individual trees in urban areas where the release can be controlled. The broadcast method is better suited to natural or unmanaged stands where dense brush may make the release of carded material difficult.

The leafblower distributed parasitized host eggs up to 7 m from the applicator; the majority were deposited at 3–5 m.

The gasoline-powered generator provided sufficient electricity to operate the blower continuously for 4 h. The exhaust fumes produced by the generator could be kept at least 50 m from the leafblower with extension cords, reducing their possible effect on the performance of the parasitoids. Because the blower could be directed upward, *T. minutum* were more likely to be placed directly in the canopy with this technique than with the point releases.

Table 1. Parasitism of sentinel spruce budworm egg masses following inundative release of 12×10^6 female *Trichogramma minutum* per hectare from the ground and by helicopter in forest stands near Hearst, Ont., from 1983 to 1986

Year	Method of release	No. of plots	Maximum parasitism* (%)	No. obs.	Mean parasitism of egg masses (%)			Mean parasitism of eggs (%)		
					Upper canopy	Middle canopy	Lower canopy	Upper canopy	Middle canopy	Lower canopy
1983	Ground: grid point	5	86.6	1683	74.3a†	65.4b	55.4c	80.0ab	83.1a	75.7b
1984	Aerial	2	84.1	1350	40.2a	38.9b	32.4c	83.9a	84.6a	76.5b
1985	Aerial	1	77.5	1800	40.5a	35.3ab	31.0b	80.0a	76.2a	67.7b
1986	Ground: broadcast	1	84.2	1444	22.5a	22.5a	19.0a	80.3a	78.8a	73.6a

*Parasitism of sentinel spruce budworm egg masses placed in the field for 3 days.
†Means for either egg mass parasitism or egg parasitism, followed by the same letter within each row, are not significantly different at the $p = 0.05$ level (Duncan's multiple range test 1955).

Table 2. The quality of *Trichogramma minutum* before and after point (1983) or broadcast (1986) release from the ground in forest stands near Hearst, Ont.

		Emergence (%)		Sex ratio (% ♀♀)		Longevity (days)*		Fecundity (no. SBW† eggs parasitized per ♀)	
Year	Release	Pre-release	Post-release	Pre-release	Post-release	Pre-release	Post-release	Pre-release	Post-release
1983	7 July	85	81	58	—	2.5	—	19.8	—
	14 July	83	86	55	—	1.5	—	4.2	—
	21 July	87	86	57	—	2.0	—	4.5	—
1986	5 July	81	75	45	52	1.8	1.8	5.7	5.4
	12 July	86	87	53	52	1.3	1.6	4.6	5.3

*Longevity of adult female parasitoids from time of emergence from host egg to death.
†SBW = spruce budworm.

Our study shows that ground releases of *T. minutum* have practical use in forestry. In some cases, such as urban environments, these techniques may be the most appropriate. Both point releases in grid patterns and broadcast releases provided uniform coverage. Results from the ground release plots were comparable with those from plots treated by aerial releases but without the associated high costs of releasing large numbers of parasitoids or large scale field expenses. The ground applications were relatively easy to use in the forest environment, their greatest cost being that for labour. In small woodlots or in urban areas, control measures are often implemented by the landowner and, thus, labour costs can be considered negligible. The broadcast technique needs further refining before it can be considered on a commercial scale.

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