

TRANSPORT, STORAGE, AND RELEASE OF TRICHOGRAMMA PRETIOSUM<sup>1/,2/</sup>

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## ABSTRACT

Technology was developed for transporting large quantities of Sitotroga cerealella (Olivier) eggs parasitized by Trichogramma pretiosum Riley several hundred miles, storing the eggs during cold-programming of the parasite pupae, and broadcasting the pupae over large areas by aircraft. This technology was evaluated and successfully used during a pilot test conducted in Arkansas in 1981-82 and North Carolina in 1983. Parasite releases were made on ca. 5400 ha (total of all releases) during the three years of the pilot test at rates ranging from 125,000 to 370,000 pupae/ha. After minor adjustments and revisions during the pilot test, the transportation, storage, and release technology was sufficiently developed for use in future wide-area Trichogramma release programs.

## INTRODUCTION

Successful, timely field releases of Trichogramma pretiosum at planned rates during the ARS pilot test in Arkansas (1981-82) and North Carolina (1983) required the development of satisfactory techniques for parasite transportation and storage and rapid, uniform distribution of parasites over treated fields. Previous research on augmentation of beneficial insect populations by entomologists and engineers at College Station, TX provided considerable background information and experience (Jones et al., 1977; Morrison et al., 1978; Jones et al., 1979; Morrison, 1977; Stinner et al., 1974). Ahles et al. (1979) discussed various biological and engineering considerations pertinent to both ground and aircraft releases of parasites and predators. Bouse et al. (1980, 1981) described two aircraft release systems for broadcasting Trichogramma.

This paper reports results of continued multidiscipline research to develop technology for augmentation of Trichogramma for control of Heliothis spp. through broadcast aerial release of parasite pupae. More specifically, the paper presents the technology developed and used to successfully transport parasitized Sitotroga cerealella (Olivier) eggs from the ARS insect rearing facility at College Station to a parasite cold-programming facility in either Stoneville, MS or Raleigh, NC; store the parasites during cold-programming and until needed for field releases; transport the programmed pupae to landing strips near

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Portland, AR or Dunn, NC; and distribute the parasites over treated fields by aircraft.

Relocation of the pilot test from Portland, AR to Dunn, NC for 1983 required revision of methods and plans for transportation of the parasites. Likewise, the need to develop and evaluate a large capacity aerial release system for possible future use in area-wide Heliothis spp. suppression programs resulted in a major change in the release equipment used during 1983.

#### MATERIALS AND METHODS

**Transportation.** During the 1981 and 1982 phases of the pilot test, non-programmed parasites were transported in portable refrigerators from the rearing facility at College Station to the programming and storage facility at Stoneville, either\*by light aircraft or by automobile. In all cases, parasites were transported prior to the 8th day of development. Programmed parasites were transported in the refrigerators from the programming and storage facility to the airstrip at Portland by automobile prior to scheduled releases. During transportation, the refrigerator thermostats were adjusted to maintain the temperature of the air in the cavity at ca. 13°C which is below the temperature at which the programmed parasites emerge.

Parasitized eggs prepared for transport were screened through a standard sieve screen (No. 20), weighed, and then funneled into open top, thin-walled aluminum cans. The cans were labeled with the date of egg parasitization, then placed into holding racks within a modified portable electronic refrigerator (Koolatron Industries, 56 Harvester Ave., Batavia, NY 14020)<sup>27</sup> that had been precooled and was operating at ca. 13°C. The refrigerator was then placed in the transporting vehicle, attached to the electrical system, and delivered to the programming and storage facility at Stoneville, MS for further programming.

The portable refrigerators that were used operate on 12-volts d.c. and draw ca. 4 amps current when cooling. Solid-state, thermostatically controlled, thermoelectric cooling devices supply the refrigeration. The units are normally operated from an automobile or aircraft lighter receptacle. The dimensions of the cold compartment of the refrigerator are ca. 41-cm long x 29-cm wide x 30-cm high. The refrigerators were modified by the addition of wire racks to hold egg containers and an air circulation system to improve temperature uniformity in the compartment. As purchased, the refrigerators provided no means for air circulation to prevent temperature stratification within the cold compartment. Our measurements indicated that the air temperature varied as much as 5°C from one part of the compartment to another.

A schematic of a modified unit is shown in Fig. 1. A plenum chamber was formed in the bottom of the refrigerator compartment and a small fan was used to circulate the air. Several openings (1.3-cm diam.) in the top of the plenum directed air around and between the egg containers. A slot in the plenum directed air over the heat exchanger cooling fins. We used aluminum soft drink cans (6.5-cm diam. x 12.3-cm tall) as egg containers. The tops were cut from the cans to facilitate filling and emptying. Each refrigerator rack was designed to hold 15 egg containers (30 containers if two layers used).

Two of the refrigerators (Model FIA-M), purchased in 1980, used on-off thermostat-type switches for temperature control. Since the on-off temperature lag was excessive (ca. 3°C), we designed and constructed proportional temperature control systems to replace the on-off thermostats. Refrigerators purchased in 1981 (Model P34A) were equipped with proportional temperature controllers as purchased.

Due to the change of location from Arkansas to North Carolina in 1983, and the resulting greater transport distance from College Station,

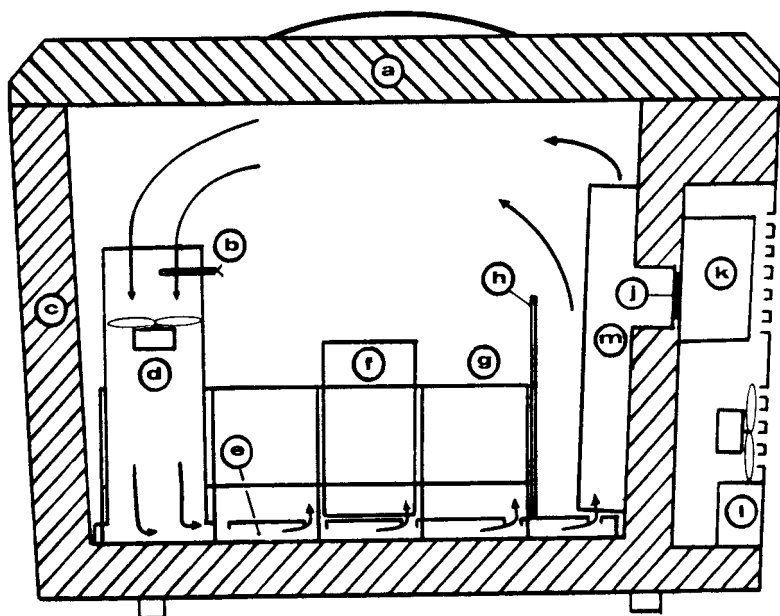


FIG. 1. Schematic of modified portable electronic refrigerator used for parasite transportation. Components labeled are: a) hinged lid of refrigerator, b) thermistor probe to monitor air temperature, c) insulated refrigerator wall, d) air-circulation blower, e) plenum chamber with perforated cover to distribute air, f) egg container, g) wire rack for egg containers, h) air baffle, j) thermoelectric cooling element, k) heat exchanger to dissipate removed heat, l) refrigerator temperature controls, and m) refrigerator heat exchanger fins.

it was not feasible to transport parasitized eggs as in 1981-1982. Therefore, commercial air freight was used since flights from College Station to Houston, TX were closely connected to direct flights from Houston to Raleigh, NC and total elapsed time was ca. 5 h. Since the transport time was relatively short and the use of electrical equipment on air freight shipments not feasible, passive temperature control was used. A molded polystyrene container (57 x 39 x 36 cm) with 3.8-cm thick walls and lid, was placed inside a cardboard shipping carton (Polyfoam Packer Corp., Wheeling, IL 60090). The polystyrene container was fitted with twenty pieces of polystyrene light diffusion grid (47 x 30 x 1.5 cm). The bottom four grids had 22 x 22-cm sections cut out from the center so that a "Karry Kool" chemical reusable ice pack (21 x 21 x 5 cm) mfg. by Wellington Home Production Inc., Paterson, NJ 07503, could be placed in the cavity. The remaining 16 grids had pieces of nylon organdy (47 x 30 cm) permanently bonded to one side of the grid with methylene chloride so as to form trays with 504 open-top cells (1.5 x 1.5 x 1.5 cm).

On a shipment day, 2-5 day-old parasitized eggs were first separately screened through a standard sieve screen (No. 20) then evenly distributed into the cloth-bottomed cells of the trays to a depth of ca. 1 cm. The tray(s) were then labeled with the appropriate parasitism date. After the trays were filled and dated, they were evenly stacked

and one empty tray placed on top. The stacked trays were then tightly strapped together with filament tape (2.5 cm); one strapping was placed at each of the four outside edges. The plastic-to-cloth bond prevented escape of the parasitized eggs from the cells. The precooled container then was removed from 16.7°C and a frozen ice pack was placed in the cavity. The stacked and strapped trays were then placed as a unit in the container, a minimum-maximum thermometer (set at 26.7°C) was placed in a cavity previously cut from the lid, the lid closed and the container closed and sealed for shipment. A telephone call was made after the shipment to alert the receiver.

Storage. When a shipment was received, the parasitized eggs were immediately spread out on organdy bottomed trays (45 x 45 x 2.5 cm). The trays were identified with the parasitism date and placed on open racks in an environmental room operated at 26.7°C and 75±5% RH under constant dark. Photographic red lights in the room were used for human convenience.

Eggs that had been parasitized 8 days previously were transferred from 26.7°C to another environmental chamber operated at 15.6°C and 75±5% RH in constant darkness. The parasitized eggs that remained at 15.6°C for 5-9 days were used for aerial release.

Preparation for Field Release. On a release day, trays with sufficient numbers of parasitized eggs of the proper age were emptied onto a piece of white butcher paper (ca. 1-m<sup>2</sup>) together with ca. 2-3 g of Dri Flo<sup>®</sup> (National Starch and Chemical Corporation, Bridgewater, NJ 08807), an industrial starch powder used to promote "flowability" of the eggs. The eggs then were sieved through a No. 20 standard sieve. After sieving, the eggs were weighed. In 1981-1982, the prepared eggs were then placed into thin-walled aluminum open top cans and the cans placed in the holding rack within a pre-cooled (13°C) portable refrigerator. In 1983, the prepared eggs were placed in an open top organdy bag which was then placed directly into the holding funnel of the portable refrigerator release device (described later) used to release the parasites from the aircraft. These preparations were done within the 15.6°C environmental chamber. The refrigerators were then transported to the aircraft by automobile. Temperatures were maintained in the portable refrigerator during transit, using the electrical system of the transport vehicle.

Release. Parasites were broadcast released on the treated fields during the pilot test by aircraft using specially designed, refrigerated delivery systems. In 1981 and 1982, two small refrigerated units, mounted about 1 m to each side of the aircraft centerline, near the trailing edge of each wing of a Piper PA25-260 agricultural aircraft, were used for the releases. A vaned rotor (2.9-cm diam. x 5-mm wide) metered the parasitized eggs from a refrigerated hopper (440 ml) on each release unit (Fig. 2). Usable capacity for the two release units was ca. 20 million parasite pupae.

A solid-state thermoelectric element provided the refrigeration. A panel mounted in the aircraft cockpit permitted the pilot to adjust and control the egg flow rate, to detect when the egg hoppers were empty, and to monitor and adjust the temperature. A feedback signal from a temperature sensor in the egg hopper automatically adjusted the voltage applied to the thermoelectric cooling unit. Constant temperature was maintained, provided that the heat gain of the system did not exceed the cooling capacity of the thermoelectric element.

Calibration tests revealed that the pupae flow rate was linearly related to the rotational speed of the release unit metering rotors. Based on this information, the aircraft ground speed, and the swath spacing, the proper rotor speed was determined for the required parasite application rate (pupae/ha). A 24-m swath spacing was used for the 1981 and 1982 releases. The aircraft height during release was ca. 12 m in

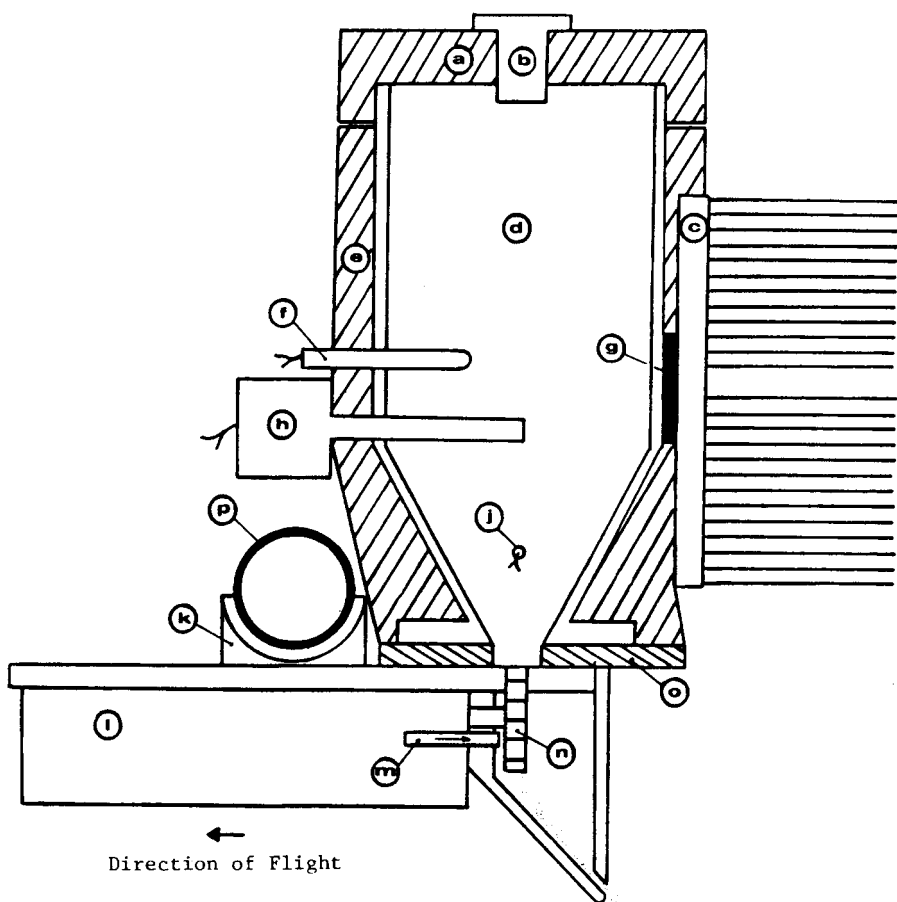


FIG. 2. Schematic of refrigerated parasite release device used on agricultural aircraft during 1981 and 1982 pilot test releases. Components labeled are: a) insulated removable lid for egg hopper, b) removable stopper for filling egg hopper, c) heat sink for dissipating removed heat, d) egg hopper cavity, e) aluminum-foil-covered foam insulation surrounding aluminum egg hopper, f) thermistor probe to monitor egg temperature, g) thermoelectric cooling element, h) thermistor probe for temperature control circuitry, j) egg level detector, k) mounting bracket, l) gearmotor-tachometer drive for vaned metering rotor, m) air intake tube to prevent egg attachment to vaned rotor, n) vaned metering rotor, o) rigid insulator to reduce heat transfer from egg hopper, and p) aircraft mounting bracket.

order to provide satisfactory parasite distribution. Based on the 24-m swath spacing and an aircraft speed of 168 km/h, the rotor speed required for an application rate of 250,000 pupae/ha was determined to be 40 rev./min when using pupae reared for the 1981 pilot test. The flow calibration for pupae reared for the 1982 pilot test was somewhat different than that for 1981 (Fig. 3).

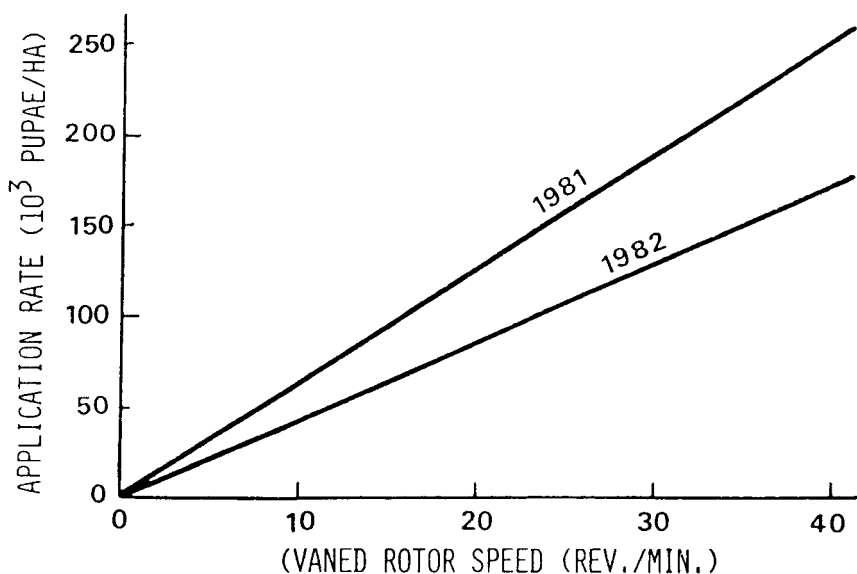


FIG. 3. Linear relationship of parasite pupae application rate to vane-rotor speed for refrigerated release devices used in 1981 and 1982 pilot test releases. Application rate shown is based on the use of two release units on the aircraft, on an airspeed of 168 km/h and a swath of 24 m.

Procedures for making a release in 1981 and 1982 included transporting the parasites from Stoneville to Portland in the electric refrigerators, precooling the release unit hoppers to ca. 12°C, transferring the parasites into the precooled hoppers, and flying the fields. The parasitized eggs were transferred from the aluminum containers into the precooled egg hoppers through openings (1.4-cm diam.) in the lids of the hoppers (Fig. 2). A short length of flexible tubing attached to an insulated funnel and an insulating jacket for the aluminum containers facilitated the transfer operation. This method prevented moisture condensation on the inside walls of the precooled hoppers due to entry of ambient air. After all parasite releases were completed for a given day, the parasitized eggs remaining in the hoppers were removed by means of a small portable vacuum cleaner. These eggs were then weighed and the weight subtracted from the initial parasitized egg weight to determine the weight of the parasitized eggs released. Weight was then related to number of parasitized eggs to give the total number of parasitized eggs released to the field.

A large-capacity, refrigerated, parasite release system was developed and used for the 1983 releases near Dunn, NC. Two units were fabricated, one to be available as a backup in case of equipment failure. This release system was designed for use in a small, passenger-type aircraft and used a portable electronic refrigerator

(Koolatron Industries Model P34A) to house the egg hopper and metering device (Fig. 4). The egg hopper was cone shaped with a 25-cm diam. top and was 23-cm tall. The capacity of the hopper was ca. 3850 ml. Based on 21,000 pupae/ml and a release rate of 125,000 pupae/ha, this hopper capacity would be sufficient to treat ca. 650 ha or 2.5 square miles. The refrigerated release system was operated from either a 12-volt battery or lighter recepticle.

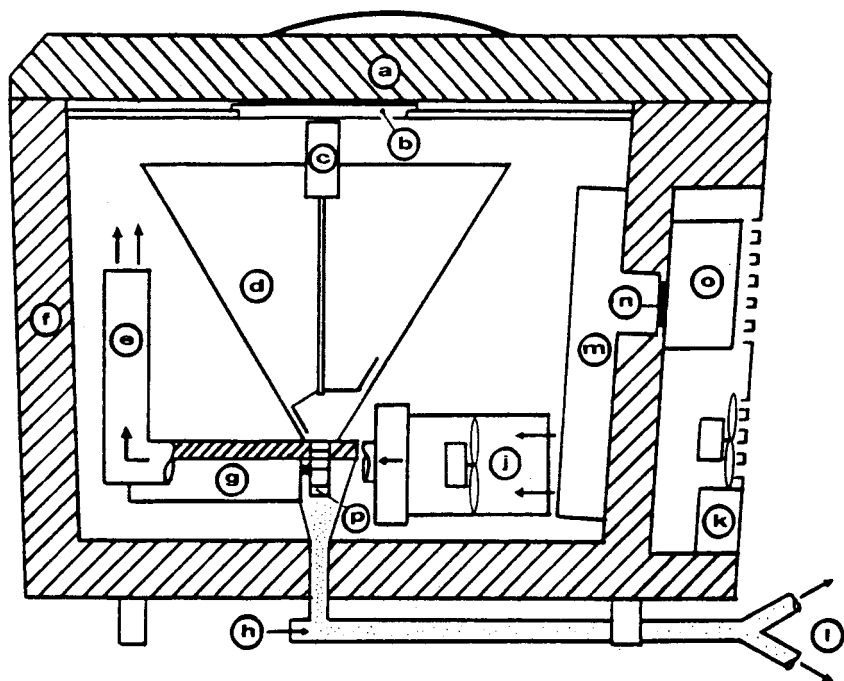


FIG. 4. Schematic of wide-area parasite release system mounted in a portable electronic refrigerator. Components labeled are: a) hinged lid of refrigerator, b) removable acrylic cover for cold compartment, c) gearmotor drive for rotating agitator, d) funnel-shaped egg hopper, e) air-circulation duct, f) insulated refrigerator wall, g) gearmotor-tachometer drive for vaned metering rotor, h) air intake for pneumatic conveying of eggs, j) air-circulation blower, k) refrigerator temperature controls, l) pneumatic conveyor tubes leading outside aircraft cabin to venturi release tubes, m) refrigerator heat exchanger fins, n) thermoelectric cooling element, o) heat exchanger to dissipate removed heat, and p) vaned-rotor for metering parasitized *Sitotroga* eggs.

Parasitized eggs were metered from the cone-shaped hopper thru a bottom opening using a vaned rotor (3.7-cm diam. x 1.3-cm wide). The rotor was driven by a small gearmotor-tachometer unit. A gearmotor-driven, slow-turning agitator was used in the bottom of the egg hopper to prevent bridging of the eggs and insure uniform feeding of the vaned rotor. As the eggs emptied from the rotor they dropped into a tube that passed thru an opening cut in the bottom of the refrigerator.

After passing from the refrigerator, the eggs were pneumatically conveyed to the outside of the aircraft thru flexible tubing. A T-fitting attached to the bottom of the refrigerator provided the air intake for the pneumatic conveying system. A Y-fitting in the tubing divided the air and egg flow so that the eggs were released from venturi-tubes attached to each landing gear strut of the fixed-gear aircraft. The venturi-tubes were fabricated using copper tubing (1-cm inside diam.). The tubing was formed so that it pointed opposite the direction of flight (rearward) and was flared on the end to increase suction. Preliminary wind tunnel tests were conducted to assure proper operation of the vaned rotor metering system and the pneumatic conveying system.

An air circulation system, consisting of a small blower, a plenum chamber, and associated air ducts maintained the air temperature throughout the refrigerator cold chamber within a range of ca.  $\pm 1^\circ\text{C}$  of the set temperature. In addition, a removable rigid cover made of clear acrylic was placed below the hinged refrigerator lid. This acrylic cover permitted the hinged refrigerator lid to be opened briefly for inspection of system operation without admitting ambient air that would result in moisture condensation on the cold surfaces in the chamber. An opening (11.5-cm diam.) was cut in the acrylic cover directly above the egg hopper. A cover over this opening was removed to provide access to the hopper for adding eggs without exposing the refrigerator chamber to ambient air.

The rate of parasite flow from the egg hopper was controlled by varying the speed of the vaned rotor. The metering system was designed for an intended maximum flow rate sufficient to permit the application of 250,000 pupae/ha when flying the aircraft at a speed of 160 km/h and using a swath spacing of 48 m. Calibration of the two units indicated that one delivered ca. 65,700 pupae/rev. and the other ca. 73,700 pupae/rev. Delivery rate was linearly related to rotor speed. Table 1 presents calibration information for the two units. This table was provided to the aircraft pilot for reference during the applications.

TABLE 1. Calibration of Aerial Release Units Used in 1983 Pilot Test near Dunn, NC.

Aircraft ground speed, km/h	130	160	190
Application rate, pupae/ha	Rotor speed, rev./min <sup>a/</sup>		
Release unit no. 1			
125,000	10	12	15
187,500	15	18	22
250,000	20	25	29
Release unit no. 2			
125,000	9	11	13
187,500	13	16	19
250,000	18	22	26

<sup>a/</sup>Swath width = 24 m

The 1983 parasite releases were made with a Cessna 172 aircraft. Procedures for making a release were to: (1) precool the release unit refrigerator to ca.  $12^\circ\text{C}$  at the parasite storage facility at Raleigh, NC; (2) place the required amount of parasitized eggs in an organdy bag; (3) place the bag into the egg hopper; (4) transport the release unit refrigerator to the airstrip at Dunn, NC; (5) transfer the



refrigerator into the aircraft; (6) empty the parasitized eggs into the egg hopper and remove the organdy bag; (7) connect the flexible conveyor tubing to the release unit; and (8) fly the fields. Use of the organdy bag rather than placing the eggs directly into the egg hopper at the storage facility was a precaution to prevent settling and possible packing of the eggs during the trip from Raleigh to Dunn. Emptying the eggs from the bag assured that the eggs were loose and free-flowing prior to starting the release on the fields. The aircraft height during the release was ca. 12 m, the swath width was 24 m and the ground speed was 130 km/h.

Quality Control. In addition to Trichogramma production quality control, it was also necessary to determine that the effects of transportation, storage and release were not deleterious. Samples of parasitized eggs were therefore taken after storage, and after release. Other groups of eggs were caught on a ground sheet (3 x 3-m muslin cloth with a collecting funnel in the center) held at the corners while the operating release aircraft passed directly overhead to determine if release from the aircraft would damage the parasites.

All samples were held in the laboratory at ca. 26.7°C and 50% RH for 4 h. Where possible, samples consisted of three groups of ca. 200 eggs each, except for the ground catches where the numbers caught were generally small. The samples were held in 30-ml covered plastic cups. After the 4 h. at 26.7°C, the cups were frozen overnight at -10°C. The emerged adults were then counted and sexed.

## RESULTS AND DISCUSSION

Transportation. In an initial test of the refrigerated transportation system in August, 1980, 11 cans, each containing ca. 75 ml (1/4 full) of precooled parasitized Sitotroga eggs, were placed in a portable refrigerator and transported by van from College Station to Stoneville. The eggs were transferred from rearing facility storage trays into the aluminum cans in a cold sink to prevent exposure to ambient temperatures. The cans were then placed into a portable refrigerator that had been precooled to 12°C. Thermocouples were used to monitor the temperature of the ambient air, the air inside the refrigerator, and the temperature of the eggs in six of the containers. The trip from College Station to Stoneville required ca. 10 h. During the trip, the ambient temperature in the van ranged from 23°C to 32°C and the temperature of the air inside the refrigerator ranged from 11.3°C to 14.5°C. The temperature of the eggs in the containers was initially low, due to the low temperature in the cold sink when the eggs were transferred into the containers. After 1 h, the egg temperatures ranged from 11.8°C to 13.7°C in the six containers being monitored. As the outside air temperature increased, supplemental cooling was provided by operating the van air conditioner at its maximum cooling capacity. Throughout the trip, the temperature of the eggs in the warmest container never exceeded 14.7°C.

In 1981, parasites were transported from College Station to Stoneville seven times by light aircraft and five times by automobile. The trips occurred once each wk, so that parasites produced over a 7-day period were transported each trip. Good temperature control was maintained when the parasites were transported by air. When ground transportation was used and afternoon ambient temperatures were high, temperature control became marginal before the parasites were delivered to Stoneville, MS. Occasionally, the cold compartment air temperature reached 2-3°C above the set temperature of 13°C. Irregular adult emergence, following field releases in 1981, may have been partially due to inadequate temperature control and partially due to the transportation and use of parasites having an age range of 7 days.

In 1982, eggs were transported twice each wk, seven times by aircraft and three by automobile. Temperature control was good during both air and ground transportation. The two transports/wk resulted in a smaller age range for the parasites than that of the 1981 parasites. The more frequent transportation of parasites in 1982 apparently allowed more precise cold programming, as evidenced by increased and more uniform adult emergence of the released parasites (30-70% in 1981 and 70-95% in 1982).

The portable refrigerator system was also used to transport programmed parasites from the programming and storage facility at Stoneville to the airstrip at Portland for 18 releases in 1981 and 10 releases in 1982. During transport, the cooling compartment air temperature was monitored by use of a portable meter and a temperature probe mounted in the compartment. By keeping the refrigerators out of direct sunlight and transporting them in air conditioned vehicles when the ambient temperature was high, the system was adequate.

The transportation system used in 1983 was very satisfactory and probably less expensive than the system used in 1981-1982. All shipments were received in ca. 5 h and, although slight fluctuations of temperature occurred as recorded on the minimum-maximum thermometer, the differences above and below 26.7°C probably balanced out during the 5 h of transportation. The cold programming regime thus was more precise as evidenced by the quality control results for 1983 (Table 2).

Storage and Cold Programming. The storage and cold programming of parasites during the 3 yrs of the pilot program were carried out satisfactorily. Pre-emergence of adults was noted for given dates of parasitism, especially in 1981. This was attributed to temperature variations encountered in shipping and to the 7 day age range of the parasites.

Preparation for Field Release. The preparation of the parasites for field release was carried out successfully during all 3 years of the program. More than adequate numbers of parasites were available for field release. If excessive adult pre-emergence was detected in a given day's production of parasites, they were replaced by other dates of parasitism.

Release. Initial field testing of the small refrigerated release units (Fig. 2) mounted on the Piper PA25-260 agricultural airplane was conducted in August, 1980 at Portland, AR. Parasitized eggs were released at the rate of 250,000/ha on a 32-ha field on three different dates as part of a check of the planned pilot test system. With an ambient temperature of 22°C, ca. 15 min were required to precool the release unit hoppers to 10°C. After the units were precooled and the parasites loaded, the releases were each completed in ca. 80 min (includes 10 min ferry time). During the releases, the temperature was held constant at 11°C in one release unit hopper and 12°C in the other. Overall, the release units performed exceptionally well during the initial field tests. No problems were encountered with metering the parasitized eggs or with maintaining parasite temperature within the desired limits.

During the pilot test, the small refrigerated release units (Fig. 2) were used to release parasites on fields near Portland, AR on 18 different dates in 1981 (June 10 to August 17) and 10 different dates in 1982 (July 4 to August 6). The releases totaled ca. 2930 ha in 1981 and 1940 ha in 1982. Release rates ranged from 130,000 to 250,000 parasitized eggs/ha. The size of the individual treated fields ranged from 17 to 32 ha. Due to the limited size of the egg hoppers on the release units, it was necessary for the aircraft to return to the airstrip to obtain additional parasites after releases were made on each two fields.

Unexpected problems were encountered with clogging of the metering

rotors and with excessively high parasite temperatures in the release units during the first few releases in 1981. The major cause of the problems was moisture condensation which short-circuited the thermoelectric cooling elements. This disabled the elements and prevented cooling. The problem was solved by encasing the thermoelectric elements in silicon to seal them from the humid, ambient air. Minor problems were encountered with failure of the temperature sensors used. This was solved by redesigning the sensor housing for improved sensor protection. The units operated essentially trouble free during the remaining 1981 and 1982 releases. However, we did discover in 1982 that one of the release units was positioned along the trailing edge of the aircraft wing so that part of the engine exhaust gas passed over it. The parasite temperature in that unit was usually ca. 2°C warmer than in the other unit. Moving the release unit outboard ca. 45 cm resulted in identical parasite temperature in the hoppers of the two release units.

Initial field testing of the large-capacity, refrigerated, parasite release system was conducted on July 11 and 13, 1983, in North Carolina, prior to the first pilot test release. The release system was configured as shown in Fig. 4, except that the agitator and the acrylic cover at the top of the cold compartment were added later. For the July 11 test, parasitized eggs were released on three fields totaling about 32 ha. The rotor speed was adjusted to release ca. 250,000 pupae/ha; however, pre- and post-release weights of the parasitized eggs placed in the release unit hopper indicated that the actual release rate was only ca. 175,000 pupae/ha. The discrepancy between intended and measured release amounts may have been due to the use of improper swath widths, incorrect airspeed, incorrect field measurements, or intermittent bridging of eggs at the release hopper outlet. When the release was repeated on the same three fields on July 13, we observed bridging of parasitized eggs at the hopper outlet due to moisture condensation and premature parasite emergence. These problems apparently were the result of opening the cooling compartment lid for an excessive amount of time while transferring parasitized eggs into the release hopper.

To solve the moisture condensation and egg bridging problems, the acrylic cover and agitator (Fig. 4) were added to the release system. In addition, placing the parasitized *Sitotroga* eggs in an organdy bag for transport to the airstrip reduced the amount of time required for transferring the eggs into the release unit hopper. These modifications reduced the amount of time that the cold compartment was exposed to ambient air and the chance of moisture condensation on the cold hopper surfaces. The agitator aided egg flow, even in the presence of some premature emergence and/or condensed moisture.

Parasites were released on seven different dates, ranging from July 26 to August 10, during the 1983 pilot test in North Carolina. The total area covered during the seven releases was ca. 365 ha and the application rate was ca. 370,000 pupae/ha. No difficulties were experienced with the release system.

Quality Control. In 1981, quality control samples taken before and after the 18 releases showed wide variations in adult emergence after being held for 4 h at 26.7°C. Samples from seven of the releases showed adult emergence in excess of 70%. Emergence in five of the releases ranged from 50 to 70% and from 30 to 50% in the remaining six releases. The distribution of females among total emerged adults was quite uniform and averaged  $60.4 \pm 8.8\%$ .

The combination of transportation and temperature problems, the wide range in the age of parasites shipped, and possible cold-programming and release device problems together with inexperienced personnel, probably accounted for the unacceptable differences between predicted (75-80% in 4 h after release) and actual measured adult

emergence. Many of these problems were corrected as they were encountered during the 1981 release period.

Improvements in transportation, parasite programming, handling and release in 1982 were reflected in more uniform and increased % of adult emergence following release. The adult emergence as measured from quality control samples taken from each of the seven releases ranged from 70 to 95.2%. The % of females among total emerged adults from each release averaged slightly higher than in 1981 but was more variable ( $63.4 \pm 11.4\%$ ).

The results of quality control work during the seven releases in 1983 indicated that adult emergence was the highest and most uniform recorded during the 3-yr test ( $82.7 \pm 8.2\%$ ). Average % females among total emerged adults was  $64.9 \pm 5.5\%$ .

TABLE 2. Adult Emergence Following Aerial Release of *Trichogramma pretiosum* as Measured by Quality Control Samples. Dunn, N.C., 1983.

Release no.	Date	Pre-release samples			Post-release samples			
		Number		%	Number		%	%
		pupae	adults emerged in 4 h	emergence	pupae	adults emerged in 4 h	emergence	females
1	7/14	470	379	80.6	695	541	77.8	66.9
2	7/17	413	346	83.8	850	687	80.8	64.6
3	7/19	511	462	90.4	663	592	89.3	70.4
4	7/22	422	344	86.5	358	323	90.2	62.7
5	7/25	514	473	92.0	421	382	90.7	66.7
6	7/28	432	362	83.0	447	359	80.3	62.2
7	7/31	658	513	78.0	513	382	74.5	60.8
Mean				84.2			82.7	64.9

In order to obtain samples for quality control determinations of parasitized eggs caught on the ground during aerial release and to further test system reliability, a subsequent flight test of the release system (Fig. 4), was conducted at College Station on July 21, 1983. The system was mounted in a Cessna P206 aircraft and flown in an ambient air temperature of 38°C. Because of the high ambient air temperature, a frozen packet of "blue ice" was placed inside the portable refrigerator for added cooling capacity. During the test, the temperature in the cold compartment was maintained at or below 14°C for 2 h. Several aircraft passes were made over a muslin egg collection cloth (3 m x 3 m) held ca. 1 m above ground. Three pre-flight samples of cold programmed parasites released during the passes and held 3 days averaged 98.8% emergence. Eight samples of parasitized eggs released from the aircraft and collected on the cloth averaged 93.8% emergence and three post-flight samples removed from the refrigerator hopper averaged 97.9% emergence. No problems were encountered with egg flow and the system performance was considered to be satisfactory for use in the pilot test. Since the aerial release caused less than 5% loss of parasites, we consider the technology to be sufficiently developed for use in commercial parasite release programs.

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