Research Updates

Evaluation of Biological Control Agent Shipments from Three United States Suppliers

V. Bruce Steward,
Janet L. Kintz¹, and
Tracy A. Horner²

Additional index words.

Cryptolaemus montrouzieri, *Encarsia formosa*, *Orius insidiosus*, *Phytoseiulus persimilis*, quantity assessment

Summary. Biological control agents were ordered from three U.S. suppliers three times during 1994 and were evaluated (total of nine orders evaluated). Biological control agents evaluated were a whitefly parasitoid [*Encarsia formosa* Gahan (Hymenoptera: Aphelinidae)], mealybug destroyer [*Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae)], insidious flower bug [*Orius insidiosus* (Say) (Heteroptera: Anthracoridae)], and a predatory mite [*Phytoseiulus persimilis* Athias-Henriot (Acari:

Phytoseiidae)]. Arrival time, packaging methods, cost, quality, and quantity for each shipment were recorded. Six of the nine orders evaluated did not arrive by the date promised by the supplier. Most biological control agents were shipped in styrofoam boxes; the method by which they were packed in the box differed among suppliers. The cost of each biological control agent order ranged from \$260.64 to \$327.03 and varied with the same supplier. The number of viable *E. formosa* emerging ranged from 745 to 4901; two of the nine orders met the quota of 2000 live wasps. The total number of live *C. montrouzieri* received ranged from 234 to 288; five orders contained the expected number of 250 live beetles. For the expected order of 1000 *O. insidiosus*, quantities of live insects ranged from 423 to 1333; three orders contained at least the expected amount. The number of live *P. persimilis* ranged from 199 to 4447. Three orders contained the targeted amount of 2000. Our findings indicate that there are problems with the quantity of viable biological control agents being shipped. To build consumer confidence in the potential effectiveness of biological control, suppliers and producers of biological control agents must address ways to ensure that the consumer receives a high-quality product, in quantity and viability.

Biological control of pests continues to be an important topic at public gardens and zoos (Gimenez-Ferrer and Steward, 1995; Johnson, 1995; Kleber, 1995; Kriegel, 1995; Latham, 1995; Sandham and Morley, 1995; Stauffer, 1995; Stauffer et al., 1996; Stewart, 1995; Van Over and Ellingsworth, 1995). When bio-

logical control agents are introduced effectively into an interior-landscape pest-management program, they eliminate many problems that often are encountered when relying on pesticides (e.g., odor, residue, restricted-entry intervals, phytotoxicity, toxicity to humans, etc.). Due to the large number of suppliers selling biological control agents [>95 in the United States (Hunter, 1994)], the ease with which these organisms can be obtained, and competitive pricing, biological control in public gardens is a truly viable option.

In implementing a successful biological control program in the interior landscape, proper identification of the pest (to ensure that the proper biological control agent is released) and a reliable source of biological control agents needs to be established (Steiner and Elliott, 1987). If a shipment of biological control agents does not contain the stated species or number of viable organisms, a potentially successful program could be terminated under the false notion that biological control is not an effective option. Furthermore, since careful timing is frequently an important factor in effective pest suppression, timely shipment of purchased biological control agents is critical.

The quality and quantity of biological control agents received from commercial producers were questioned by vegetable growers in southern Alberta, Canada. Steiner (1993) conducted a study to address this question, and her results revealed that many shipments from commercial producers were short of the stated contents and of poor quality or were infected by various pathogens.

Our study was initiated to further assess shipments of biological control agents. Since most pest managers order biological control agents not from commercial producers but from commercial suppliers, all biological control agents evaluated in this study were ordered from the commercial suppliers, whereas Steiner (1993) evaluated biological control agents from commercial producers. Four biological control agents commonly used by pest managers at public gardens, a whitefly parasitoid, a mealybug destroyer, an insidious flower bug, and a predatory mite were ordered from three suppliers at three times of the year. The promptness, packaging methods, cost,

Longwood Gardens, P.O. Box 501, Kennett Square PA 19348-0501.

¹Clemson University, Department of Entomology, Clemson, SC 29634-0365.

²University of Maryland, Department of Entomology, College Park, MD 20742.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

quality, and quantity of the biological control agent shipments received were evaluated.

Materials and methods

Two criteria were used to select suppliers for this study. First, suppliers were chosen based on their distance from Longwood Gardens, Kennett Square, Pa.; supplier A, <100 miles; supplier B, ≈400 miles; and supplier C, ≈2000 miles. Second, suppliers were selected that were not receiving all of their biological control agents from the same commercial producers.

Three separate orders for biological control agents were placed with each supplier and were evaluated: evaluation 1: 10 to 24 Feb., evaluation 2: 24 May–8 June, and evaluation 3: 13–22 Sept. 1994. Each biological control agent received from a supplier during an evaluation period was defined as a shipment. In some cases, not all biological control agents for one order arrived at the same time because the supplier sometimes would send a portion of the order and have producers send the remaining order directly to us. Arrival time, packaging method, cost, and quantity of each shipment were noted. Suppliers were not informed that their biological control agent shipments were being evaluated.

***Encarsia formosa*.** Two-thousand viable *E. formosa* were expected per supplier for each evaluation. On arrival, cards on which parasitized whitefly pupae were glued were examined under a dissecting microscope at about ×30 to determine the number of pupal cases with emergence holes; these whitefly pupae were noted as emerged on arrival. After the cards were examined, they were placed in clear plastic 55-mm petri dishes, held in a greenhouse at 21 to 27 °C with 60% to 80%

relative humidity, and exposed to a minimum light intensity of 7300 lux (not in direct sunlight) on a 16-h light : 8-h dark schedule. After 14 d, the cards again were examined microscopically. Empty pupal cases with emergence holes were recorded as emerged. Pupal cases with parasitoids not fully emerged and pupal cases without emergence holes were recorded as not emerged. The quantity of viable parasitoids was determined by subtracting the number of parasitoids emerged on arrival from the total number emerged after 14 d. The total number of nonviable parasitoids was determined by adding the number of parasitoids emerged on arrival plus the number of non-emerged parasitoids.

***Cryptolaemus montrouzieri*.**

Two-hundred and fifty *C. montrouzieri* were ordered from each supplier per evaluation. On arrival, dead beetles were counted and sexed, and live beetles were cooled for several minutes to slow their activity. Live beetles then were divided into groups of ≈25, placed in 55-mm plastic petri dishes, and held for 2 d under the same environmental conditions as *E. formosa*. Beetles were held for 2 d in an attempt to estimate their vigor. In evaluation 1, one drop of a commercial food supplement (Bug Pro, Gardens Alive!, Lawrenceburg, Ind.) and one drop of water were placed in each dish. In evaluations 2 and 3, a half-circle of paper towel soaked in a water solution of Bug Pro was used in each dish. After 2 d, dead and live beetles were counted and sexed.

***Orius insidiosus*.** One-thousand *O. insidiosus* were ordered from each supplier per evaluation. On arrival, *O. insidiosus* and the buckwheat shell-vermiculite carrier were divided evenly among four rectangular plastic con-

tainers (45.7 × 17.8 × 5 cm) in which all but one of the four sides were painted black. In each container, a 17.8 × 7.5-cm yellow sticky card was placed underneath the nonpainted area, and the container was covered promptly and tightly with a lid. The nonpainted end of the box then was positioned toward a natural light source. The numbers of adults and nymphs adhering to the yellow sticky card were counted as alive. Within 24 h, the contents of the boxes were examined carefully, and the number of live and dead adults and nymphs was determined.

***Phytoseiulus persimilis*.** Two-thousand *P. persimilis* were ordered from each supplier per evaluation. On arrival, the mites and vermiculite carrier were poured into separators similar to that designed by Steiner (1993). Each separator consisted of a 55-mm petri dish glued to the bottom center of a larger no. 16 floral dish (Syndicate Sales, Kokomo, Ind.). The outer dish was filled with a solution of soapy water, and the inner petri dish was filled with the carrier and mites. Each shipment required four to six separators, depending on the volume of the carrier (25 to 450 ml) in which they were shipped.

Two 60-W incandescent bulbs were suspended ≈10 cm above the separators, causing the mites to become very active. As they attempted to leave the carrier, they fell into the soapy water and drowned. For the first several hours, a paintbrush was used periodically to brush active mites that were crawling on the edge of the petri dish into the soapy water. After 24 h, the soapy water was poured into a vial, and the carrier was stored in a dry container. The soapy water was examined using a dissecting microscope at about ×30, and the number of mites was recorded. In evaluation 1, the carrier was sieved using a no. 60 and no. 200 (number of openings per inch) sieve under high-pressure water to collect dead mites. Dead mites were rinsed from the sieve and counted in the same manner as live mites. In evaluations 2 and 3, a 20-ml subsample was taken from the vermiculite carrier, and the number of dead mites was counted microscopically. The total number of dead mites was estimated based on the total volume of the carrier and the number of mites counted in a subsample.

Table 1. Average cost (±SD) of biological control agent shipments from three U.S. suppliers.

Biological control agent	No. ordered (n = 3)	Supplier cost (\$)		
		A	B	C
<i>Encarsia formosa</i>	3000	30.75 ± 0.00	27.70 ± 2.68	43.50 ± 2.60
<i>Cryptolaemus montrouzieri</i>	250	91.67 ± 57.74	133.33 ± 14.43	50.00 ± 0.00
<i>Orius insidiosus</i>	1000	110.00 ± 0.00	127.00 ± 0.00	90.00 ± 0.00
<i>Phytoseiulus persimilis</i>	2000	24.00 ± 0.00	20.75 ± 0.00	33.33 ± 14.43
Shipping and handling	NA	27.75 ± 8.65	18.25 ± 2.38	43.81 ± 9.01
Total cost		284.17 ± 65.64	327.03 ± 16.25	260.64 ± 12.41

Results and discussion

Delivery. Six of the nine orders did not arrive on the date specified by the supplier, five being late (usually by 1 d) and one being 1 d early. All orders were late in evaluation 1, probably the result of a major snow and ice storm. In evaluation 2, two orders were not on time, and in evaluation 3, one order was not on time. Suppliers did not necessarily receive all biological control agents from the same commercial producer; some suppliers had the producers send the biological control agents directly to us; therefore, portions of some orders arrived on different days. Timely delivery of biological control agents is important to ensure release soon after receipt. If an order is not received on the expected date, be it early or late, it may not be released

promptly, and the viability of the organisms may be reduced. It is imperative that orders arrive on the specified date so that the full benefit from the control agents can be achieved.

Shipping materials. All suppliers used styrofoam boxes to ship biological control agents, except supplier B, who, during evaluation 3, used a lightweight cardboard box. Typically, individual biological control agent containers were positioned to immobilize each other, otherwise newspaper was used. No ice packs were placed in boxes for evaluation 1, and supplier B did not use ice packs during evaluation 3. A chemically activated heat pack was included by supplier C with the shipment of *C. montrouzieri* during evaluation 1.

Ensuring that biological control agents are kept at a suitable tempera-

ture during transit can be a difficult task. Suppliers must try to protect and anticipate temperature changes during shipping, especially if the order is being delivered to a different region of the country, and attempt to buffer those temperature changes. Styrofoam boxes appear to be highly efficient in protecting organisms from temperature extremes.

Informative enclosures discussing the life cycle and proper use and care of the biological control agents were included with all of supplier A's shipments and once and twice with shipments from suppliers B and C, respectively. The enclosures often inform the consumer of how to use the product properly, how many organisms to release, etc. and are important for consumers to gain the most benefit from the product.

Fig. 1. Number of biological control agents received from three U.S. suppliers (A, B, and C) at three times of year (1994).

Packaging. *Encarsia formosa* was sent in the form of parasitized whitefly pupae glued to paper cards. Attachment of the pupae to the card and density per card varied with supplier. Supplier B sent an average ($\pm$ SD) of 111.9 ± 26.2 parasitized pupae in 2.5 cm^2 , using a nontacky adhesive. Suppliers A and C attached an average ($\pm$ SD) of 125.2 ± 18.1 and 162.6 ± 32.7 parasitized pupae, respectively, in a 3- to 5-mm circle using an adhesive that was still sticky on arrival.

In evaluation 1, supplier A sent 25 *C. montrouzieri* in plastic tubes containing a piece of moist filter paper. Suppliers A (during evaluations 2 and 3) and C placed beetles, food, and shredded paper in a 180-ml plastic container. Supplier B placed 25 beetles in 50-ml diet cups with no other material.

Orius insidiosus orders were sent by all suppliers in two 500-ml plastic bottles filled with a buckwheat shell-vermiculite carrier with screen caps.

Supplier A packaged *P. persimilis* orders in two 100-ml plastic vials filled with vermiculite carrier. Suppliers B and C shipped the mite orders in 500-ml plastic bottles filled with $\approx 400 \text{ ml}$ of vermiculite carrier.

Cost. The average total cost of biological control agent orders for each supplier ranged from \$260.64 to \$327.03 (Table 1). Variation in the cost of orders for suppliers A and C was often a result of variation in shipping costs. In all nine orders, shipping costs varied. Shipping charges for orders sent as complete shipments (i.e., having only one shipping charge) accounted for an average of 6.4% of the total cost, compared to orders having multiple shipments averaging 14.1% attributable to shipping charges.

The cost of biological control agent orders varied widely within the same supplier and among suppliers. For example, supplier A's shipment cost ranged from \$208.50 to \$325.75, a difference of \$117.25. This variation in cost might discourage a consumer from ordering biological control agents in the future.

***Encarsia formosa*.** The actual number of parasitized whitefly pupae shipped for each expected order of 2000 ranged from 2364 to 10,129 (Fig. 1). The number of viable parasitoids emerging after 14 d ranged from 745 to 4901, resulting in 25.7% to 48.4% successful emergence. The percentage of parasitoids emerging be-

fore arrival ranged from 1.1% to 33.4%, and non-emerged parasitoids comprised 30.1% to 73.1% of the total number of parasitoids shipped.

In evaluations 2 and 3, supplier B was the only supplier to send 2000 or more viable parasitoids. Supplier B supplied an average of 36 fewer pupae per card glued across a larger area compared to that of suppliers A and C. Supplier B used a glue that was dry to the touch, whereas the adhesive used by suppliers A and C was still tacky 2 weeks after the order was received. *Encarsia formosa* orders from suppliers A and C had poor emergence success throughout the study. This might be due to the method of attachment of parasitized pupae to the card. Pupae were packed into a small area causing them to be tightly crowded, often touching or on top of other pupae, and parasitoids often were observed tangled in the adhesive. Because on average only 25% to 50% of the parasitized whitefly pupae successfully emerged, suppliers may find it necessary to compensate orders accordingly.

***Cryptolaemus montrouzieri*.**

The actual number of *C. montrouzieri* shipped for the expected order of 250 ranged from 238 to 288. The number of live beetles received ranged from 234 to 288, resulting in 0% to 5.6% mortality during shipping (Fig. 1). Five of nine orders of *C. montrouzieri* contained the expected number of live beetles. Supplier B had all three orders meeting the quota of live beetles at arrival, while suppliers A and C only had one order each containing the expected number of live beetles. When beetles were held for 2 d and provided an artificial food source, mortality ranged from 0.4% to 35.4%, with an average mortality of 9.3% for all orders. Only supplier B's shipment in evaluation 1 still contained the expected number of live beetles after 2 d. The male : female sex ratio of live beetles on arrival was $\approx 1:1$ throughout all evaluations.

Because of the beetle's larger size compared to the other biological control agents evaluated, we expected the proper number to be sent. However, three orders did not contain the stated number of beetles on arrival. Mortality during shipping appears to be quite low (1.7%), but for suppliers to ensure that the expected number of live beetles arrive, suppliers could compensate by adding $\approx 2\%$ more beetles than ordered.

Beetles were placed in optimal conditions soon after arrival, and still, high mortality occurred after 2 d. To reduce stress to these beetles, they should be released by the consumer immediately after arrival, ensuring the highest chance of survival.

***Orius insidiosus*.** For the expected order of 1000 *O. insidiosus*, quantities ranged from 509 to 2259 (Fig. 1). Three orders contained the expected number of live *O. insidiosus*, quantities ranging from 423 to 1333 (Fig. 1). Supplier A sent two orders and supplier C one order with the required number of live *O. insidiosus*. The percent dead *O. insidiosus* per order ranged from 3.4% to 41.0%, an average of 20.8% dead for all shipments combined. Most orders were comprised of $>97\%$ adults; however, in evaluation 1, suppliers A and B had 32% and 36% nymphs, respectively.

Providing the correct quantity of *O. insidiosus* may be difficult for the supplier due to the small size and rapid movement of the insect. Based on the number of dead *O. insidiosus* in each order, it may be advisable for suppliers or producers to add $\approx 20\%$ more *O. insidiosus* than the number ordered.

***Phytoseiulus persimilis*.** In all but one order, the stated 2000 *P. persimilis* were received, ranging from 1693 to 5595 (Fig. 1). However, only three of the orders contained the expected number of live mites, ranging from 199 to 4447. Supplier C sent two orders and supplier B one order with the required number of live mites. The number of dead mites contained in each order ranged from 8.4% to 91.6%.

The estimate of live mites in an order may be somewhat conservative because some live mites may not have been able to climb to the lip of the petri dish. However, these mites are probably not vigorous enough to prey on other mites and would add little to the predatory mite population.

Orders containing the stated number of live mites could usually be determined by opening the container and noting high mite activity around the lip of the container. It appears that producers are sending the stated number of predatory mites; however, a significant amount of mortality seems to occur during transit.

Conclusion

None of the three suppliers consistently provided the stated number

of live biological control agents, except for supplier B's shipments of *C. montrouzieri*. Of the 36 separate biological control agent shipments, only 13 arrived with the stated amount. Thus, about two-thirds of the shipments did not contain the expected amounts. In addition, the distance of a supplier from a consumer does not appear to affect the quantity and quality of biological control agents received.

This study indicates that there should be a concern with biological control agent orders, but it does not specifically address where the problem is occurring (i.e., producer, supplier, or shipper). It is difficult for consumers to do more than a cursory check to determine if they are receiving the number of the biological control agents that they ordered (Steiner, 1993). However, customers want to be assured they are receiving what they paid for, and some type of quick assessment procedure is warranted, either performed by the producers, suppliers, or customers before shipments are sent or released.

There are >90 suppliers in the United States (Hunter, 1994), and only three suppliers were sampled in this study. The producers used by suppliers in this study provide beneficial organisms to numerous suppliers; thus, sampling more suppliers probably would reveal similar findings. The concern for the quality and quantity of biological control agent shipments is not new. Steiner (1993) revealed that shipments of three biologicals (*E. formosa*, *Amblyseius cucumeris* Oudemans, and *P. persimilis*) from producers frequently were low in quantity and quality. Low quantities were attributed to inefficient population estimates by the producer. Poor quality was attributed to lack of food during transit; prolonged storage, which is compounded by the supplier; possible genetic inbreeding; and diseases. The probability of proper quantities of biological control agents being received by the consumer could increase if suppliers padded the number that was ordered. By doing this, the inherent mortality en route would be accounted for and the consumer would be more apt to receive the proper quantity.

Using beneficial arthropods is a promising alternative to pesticides. However, if orders do not contain the stated number of viable biological con-

trol agents, a grower attempting to incorporate biological control for pest suppression may terminate what is perceived as an unreliable program and revert to more toxic methods. Even when orders are in excellent condition, the consumer's knowledge of how to use the biological control agents properly may be limited. To ensure that consumers are using biological control agents correctly, detailed information discussing the proper application of the biological control agent should accompany all orders.

It is essential that growers be provided with the best tools to carry out a successful biological control program. A successful program starts with a reliable source of biological control agents (Steiner and Elliott, 1987). Producers and suppliers of beneficial organisms must develop methods to ensure that the consumer is receiving the expected number of beneficial organisms. The consumer who receives the expected number of biological control agents and who is well educated about them can set an example for others contemplating their own biological control program. Consumers can influence the quality and quantity of products significantly. Consumers should request that explicit usage instructions be shipped with each order and should scrutinize the company's return policy for unsatisfactory orders received.

Literature Cited

Gimenez-Ferrer, R.M. and V.B. Steward.

1995. IPM at public gardens. The Public Garden 10:40-42.

Hunter, C.D. 1994. Suppliers of beneficial organisms in North America. California Environ. Protection Agency, Dept. of Pesticide Regulat., Sacramento.

Johnson, S. 1995. Biocontrol: The pest management tool for the modern zoo. AZH Nwsl. 29:4-5.

Kleber, K. 1995. Biological control at the Minnesota Zoo. AZH Nwsl. 29:6.

Kriegel, J. 1995. Moody Gardens research program. AABGA Nwsl. 246:2.

Latham, J. 1995. IPM update from the Oklahoma City Zoo. AZH Nwsl. 29:6.

Sandham, J. and B. Morley. 1995. Biological control techniques in large conservatories. The Public Garden 10:36-39.

Stauffer, S. 1995. Biological control in public gardens. IPM Practitioner. 17(9):1-11.

Stauffer, S., K. Ciombar, and M. Rose. 1996. Whither goest pest control? The Public Garden 11:23-40.

Steiner, M. and D.P. Elliott. 1987. Biological pest management for interior plantscapes. Alberta Environ. Centre, Vegreville, Alta. AECV87-E1.

Steiner, M. 1993. Quality control requirements for pest biological control agents. Alberta Environ. Centre, Vegreville, Alta., Canada. AECV93-R6.

Stewart, C. 1995. Tropical discovery IPM update. AZH Nwsl. 29:7.

Van Over, C. and J. Ellingsworth. 1995. IPM using biological controls. AZH Nwsl. 29:3.