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COMPARATIVE COST OF CHEMICAL AND BIOLOGICAL WHITEFLY CONTROL IN POINSETTIA: IS THERE A GAP?

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ABSTRACT

Cost is the principal constraint on the use of biological control against whiteflies in poinsettia (*Euphorbia pulcherrima* Willd. ex Koltz.) crops in the United States. Here we show that a new, lower release rate of the whitefly parasitoid *Eretmocerus eremicus* Rose and Zolnerowich (Hymenoptera: Aphelinidae), 0.5 females per plant per week, maintains whiteflies (*Bemisia argentifolii* Bellows and Perring) at harvest below the economic threshold of 2 live nymphs + pupae per leaf, when used in combination with two mid-crop applications of the insect growth regulator fenoxycarb (Precision®). Cost of this program (for 16.5 cm dia single stem pots, with 30,000 plants under protection) varies from 21 to 34 cents per plant for the season, for cropping periods from 12 to 18 weeks. Shipping costs are calculated and included in estimated costs. These values compare favorably to the real cost of whitefly chemical control incurred by Massachusetts poinsettia growers in fall of 2000, which was 14 cents for a 16.5 cm dia single stem pot, with a range of 1 to 40 cents. Programs consisting of a single application of the systemic insecticide imidacloprid alone cost 12 cents per pot per season. This difference between 21 cents for the biological control program and 14 cents for the chemical control program is the smallest yet reported for biological control of whiteflies in poinsettia.

Key Words: *Bemisia argentifolii, Eretmocerus eremicus*, poinsettia, biological control, whiteflies, cost evaluation, augmentation

RESUMEN

El costo es el impedimento principal del uso de control biológico contra la mosca blanca en el cultivo de poinsetia [=nochebuena] (*Euphorbia pulcherrima* Willd. ex Koltz) en los Estados Unidos. Aqui, mostramos que liberaciones del parasito *Eretmocerus eremicus* Rose and Zolnerowich (Hymenoptera: Aphelinidae) a un nuevo, menor tasa de 0.5 hembras por planta por semana, mantiene la mosca blanca (*Bemisia argentifolii* Bellows and Perring) debajo el umbral económico de 2 ninfas vivas + pupas por hoja en el tiempo de la cosecha, cuando se usa en combinación con un regulador de crecimiento de insectos fenoxycarb (Precision®) aplicado dos veces en medio del tiempo de crecimiento del cultivo. El costo del programa por cada maceta de 16.5 cm de dia., para plantas del tallo singular, con 30,000 plantas baja protección varía entre 21 a 34 centavos por planta por toda la estación, para el período del cultivo de 12 a 18 semanas. Los costos de envio estan calculados e incluidos en la estimación del costos. Estos valores se compararon favorablemente con el costo real de control químico de mosca blanca incurridos por los agricultores de poinsetia en Massachusetts en el otoño de 2000, lo cual fué 14 centavos por maceta de diámetro de 16.5 cm para plantas del tallo singular, con un rango de 1 a 40 centavos. Los programas que consiste de una sola aplicación de la insecticida sistemica imidacloprid costó 12 centavos por maceta por cada estación. La diferencia entre 21 centavos por el programa de control biológico y 14 centavos por el programa de control químico es el menor [cuantidad] reportado jamás para el control biológico de mosca blanca en poinsetia.

Whiteflies (Homoptera: Aleyrodidae) continue to be important pests of poinsettia (*Euphorbia pulcherrima* Willd. ex Koltz.) crops in the northeastern United States, even following the development of more effective pesticides in the mid-1990s. There are four commonly used options for chemical control of whiteflies in poinsettia: (1) treatment of poinsettia plants with systemic formulations of imidacloprid (Marathon®, absorbed through the roots); (2) treatment of the foliage with the same material (as Marathon II ®); (3) application of other, non-systemic, insecticides to the foliage, or (4) use of a fumigant to kill adults. In practice many growers use two or more of these approaches, often in an unplanned sequence in response to whitefly problems as they are encountered over the course of the growing season. Imidacloprid is often applied first, soon after potting of the cuttings. This may be followed, up to the time of bract coloration (about mid crop), by the use of foliar-applied pesticides if whiteflies are noticed later in the crop. Finally, if whiteflies are still apparent after bract coloration, smoke fumigation may be used, to replace wet sprays, which may leave objectionable residues on bracts. Because the number of applications and the cost of individual materials may vary greatly, many growers do not know how much season-long chemical control of whiteflies in poinsettia costs per potted plant or per unit of greenhouse space. Nor can they say if their chemical control costs are higher or lower than the use of whitefly parasitoids for biological control, an alternative for managing whiteflies in poinsettia. Growers often compare costs of biological control to best case scenarios, rather than the average scenario for chemical control.

The goal of this study was to provide this missing information. We compare the cost of biological whitefly (*Bemisia argentifolii* Bellows and Perring) control employing a reduced release rate of the parasite *Eretmocerus eremicus* Rose and Zolnerowich (0.5 female parasites per plant per week) (commercially available from Koppert Biological, Inc. and other suppliers) to the cost of chemical control as used by 22 Massachusetts commercial poinsettia growers for the fall 2000 cropping season. We sought to answer two questions: does this newly reduced parasite release rate provide effective control (producing plants with acceptable market quality) and how does the cost of this biological control program compare to the average cost of chemical control as currently practiced by Massachusetts poinsettia growers.

Materials and Methods

The Biological Control Program

The efficacy trial. In previous work (Van Driesche et al. 2001), we demonstrated that a rate of 1 female *E. eremicus* per plant per week, when combined with two mid-season applications of an insect growth regulator, provided acceptable control of whitefly in commercial poinsettia. In fall of 2000, we conducted a further trial to determine if a still lower parasitoid release rate might also be effective, as this would further lower the cost. At each of two commercial poinsettia growers in western Massachusetts, we examined two treatments, one in which we applied 1 female *E. eremicus* per plant per week and one in which we applied only 0.5 females. In both treatments, we made two mid-season applications of the insect growth regulator fenoxycarb (Precision®).

At site #1 (Westover Greenhouses, Chicopee, MA), we used two greenhouses for the trial. One greenhouse (used for the 0.5 female parasitoids treatment) was a 9.2 × 29.5 m plastic hoop house, filled with the cultivar Peterstar Red, of which there were 585 pots (22 cm dia) with 3 plants each and 40 pots (30.5 cm dia) with five plants each. The other Westover greenhouse (used for the 1.0 female parasitoids treatment) was a 6.2 × 31 m glasshouse, planted to a mixture of five cultivars (Peterstar Red, Jinglebells, Angelica White, Angelica Marble and Angelica Pink), in 282 pots (22 cm dia) with 3 plants each and 107 pots (30.5 cm dia) with five plants each. At site #2 (Grandview Farms, Chicopee, MA), a single wooden frame, plastic covered greenhouse was divided with plastic into two compartments, one for each of the treatments. Each compartment was 8.3 m wide by 14.8 m long. All plants were Freedom Red and all were potted as single plants in 16.5 cm dia pots, with 2,340 pots in each compartment.

At site #1 (Westover Greenhouses), the poinsettias were potted in the first week of August and the trial continued until plants were removed for sale between 29 November and 7 December. At site #2 (Grandview Farms), poinsettias were potted approximately 15 August and the trial continued until plants were removed for sale between 22 and 28 November.

At both sites, poinsettias were sampled weekly by haphazardly selecting 90 plants distributed over the greenhouse and examining 3 leaves (one top, one middle, and one bottom), counting the number of live whitefly nymphs and pupae per leaf (n = 270), to assess the efficacy of control. At mid-crop (21 and 28 of October for site #1 and 16 and 23 of October for site #2), two applications (0.075 g A.I. per liter, equivalent to 2 weight oz of product [25% A.I] per 50 gallons of spray solution) of fenoxycarb were made to all plants in the trial.

Parasitoid releases were made by placing parasitoid pupae (purchased as loose pupae in sawdust from Koppert Biological, Inc.) in styrofoam coffee cups taped to poles. Bottoms of cups were removed and replaced with organdy fabric to provide drainage in case of wetting during watering of the crop. Poles bearing cups were stuck into poinsettia pots so that cups were approximately 10 cm above the foliage at the beginning of the season. Twelve cups were placed in each greenhouse for the weekly releases.

Quality control measures of *E. eremicus* were taken to ensure application of the desired rate. Weekly, we measured the sex ratio, emergence rate, and "fill rate." The sex ratio was measured in the laboratory by isolating in a vial a group of approximately 200-250 pupae from each shipment. After two weeks emerged adults were examined at random and sexed (based on antennal shape) until 100 had been sexed. Emergence rates were assessed weekly by collecting material left in emergence cups in test greenhouses for two weeks after release. To achieve this, on a weekly basis the old material from the previous release was moved to two additional cups that were left for a second week. Each subsequent week, we collected this two week old material and took it to the laboratory and used a 25× stereomicroscope to examine 100 exuviae or dead pupae chosen in random order. Each item was classified as having produced a parasitoid, whitefly adult, or having died. Percent emergence of parasitoids was calculated as number of emerged parasitoids divided by total number of items examined. The "fill rate" for each shipment was determined by counting the number of live parasitoid pupae per 0.2 grams for each of 10 samples taken at random from the container the day it was received. From these values we calculated the number of live pupae per gram. We then weighed the total amount of product in the containers received and multiplied it by the number of live pupae per gram to calculate the total number of pupae received (the "fill rate"). The fill rate was then used in conjunction with the running average of the % female and % emergence (for all previous weeks of the trial) to calculate the number of grams of product that had to be released in each greenhouse (in view of the number of plants present) to obtain the desired release rate.

Calculation of cost of biological control. We calculated the cost of our biological control program using the price for parasites in 2000 charged by a major supplier (Koppert Biological, Inc., $168.26 for a bottle described as containing 15,000 parasite pupae; shipping cost not included), together with necessary information on parasitoid quality. For this latter factor, we used the sex ratio and emergence rates from the 2000 trial as these were consistent with our previous experiences. Fill rate, however, was low in 2000 (80%) compared to earlier trials (>>100%) and so we present costs based on an assumed fill rate of 100%. Using this information, we calculated the cost of biological control to growers per plant, including the cost of application of the insect growth regulator and the parasitoid shipping costs.

Rather than calculate the biological control cost explicitly for the growers participating in the efficacy trial, we determined costs in relation to crop size and crop length, for greater generality. Per plant costs for shipping, for example, are higher for smaller producers because shipping price is spread over fewer pots. We based our calculations around production of the most common pot size (16.5 cm dia, = 6.5 inch dia.). We calculated costs for two crop sizes (10,000 and 30,000 pots) and three crop durations (12, 15, and 18 weeks).

The Chemical Control Program

To estimate the number of pesticide applications made to control whiteflies and the total cost of this control, we obtained the fall 2000 pesticide application records for 22 Massachusetts poinsettia producers, chosen at random from a list of growers. From these records we determined the number of applications of each pesticide, noting its brand, the rate used and the quantity applied. One use of one insecticide constituted an application. If label rates of two insecticides were tank mixed and applied together, this was counted as two applications. We quantified the cost per m^2 of greenhouse floor space of the pesticides applied for whitefly control (not including labor) using a spreadsheet that incorporated information on greenhouse size, the pesticide rate, the quantity of spray solution applied, and the cost of particular pesticide products used. We obtained 2000 pricing information for pesticides from two large regional distributors, from whom most of the growers surveyed had purchased their materials. Finally, we converted the cost per m^2 to cost per pot, using information on grower crop spacing practices, based on average values from four growers who provided both a pot count (of a specific size, in a filled greenhouse) and greenhouse size (i.e, 0.23 m^2 per 16.5 cm dia pot, n = 3; 0.28 m^2 per 22 cm dia pot, n = 2).

RESULTS

Efficacy of the Biological Control Program

At both growers, densities of whitefly (as live nymphs + pupae per leaf) stayed below the threshold of 2 N+P per leaf in both the greenhouses receiving the low (0.5) and those receiving the high (1.0) parasitoid release rates (Fig. 1).

Cost of the Biological Control Program

Shipping costs are relatively fixed (one shipping event per week), but the impact on the cost of biological control per plant depends on how many plants a grower is producing. The impact of shipping becomes smaller as more plants are produced because the cost of shipping is spread over larger numbers of plants. For a producer of 30,000 plants growing a 12 week crop, shipping costs add only one cent per pot ($0.01) (Table 1), but for a producer of a small (10,000 plants), long duration crop (18 weeks), shipping alone can have costs of five cents per pot.

Costs of whitefly biological control are further affected by the package size purchased. Koppert Biological, Inc. sells *E. eremicus* in two package sizes: 15,000 and 3,000 pupae. Analyses presented here assume purchase in lots of 15,000. To utilize this package size, growers need to produce a minimum of 10,000 plants. For smaller growers purchasing parasites in lots of 3,000 pupae, purchase costs are approximately 20% higher.

Parasitoid quality (sex ratio and percentage emergence) for *E. eremicus* in our trials has been consistently high (e.g., 50 ± 1.3% [SE]) female and 76 ± 1.5% [SE]) emergence in our fall 2000 trial)

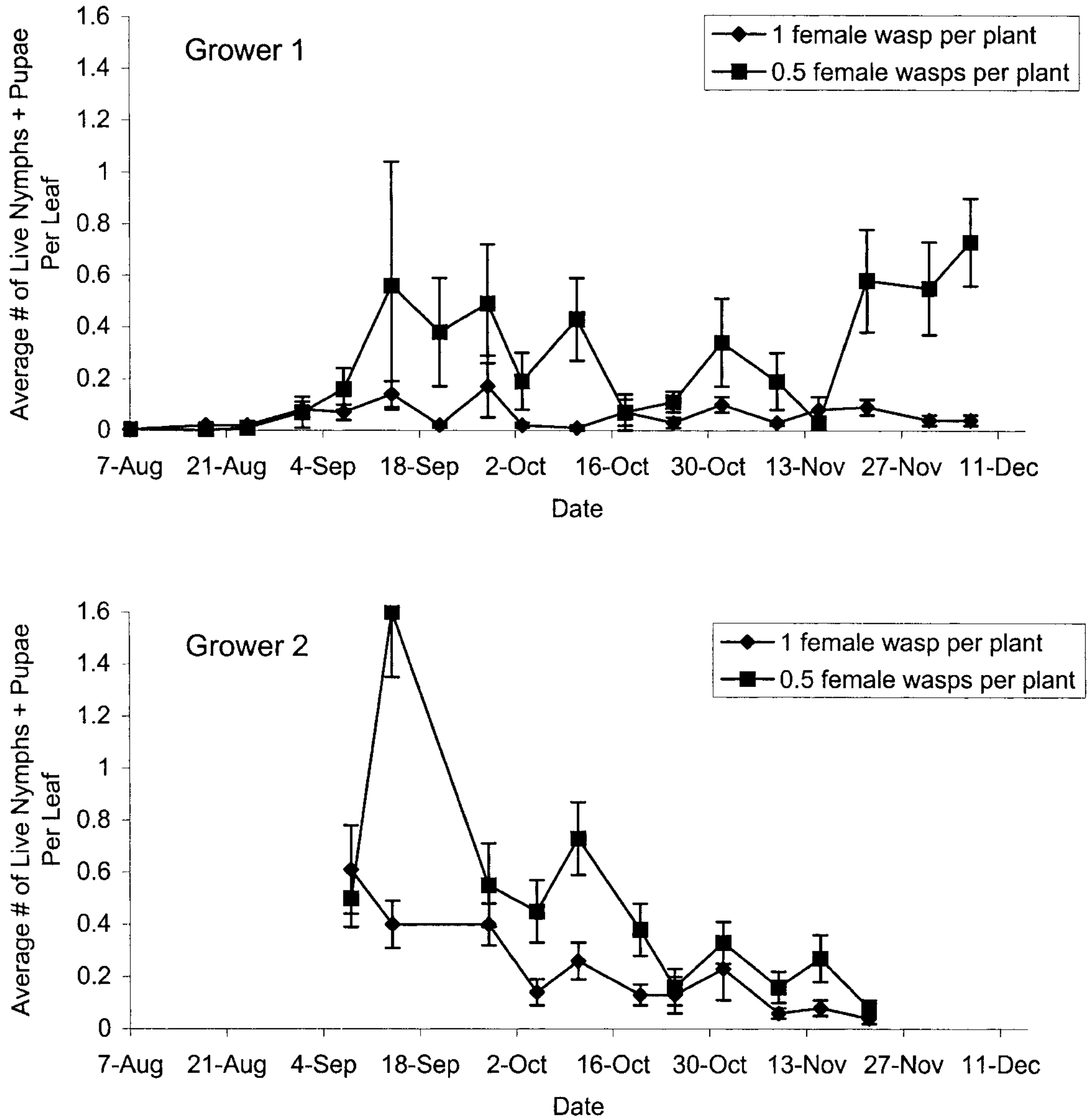

Fig. 1. Densities per leaf of live nymphs + pupae of *Bemisia argentifolii* on poinsettia crops in 2000 at two Massachusetts growers in greenhouses treated with either a low (1 female wasp per plant per week) or superlow (0.5 female wasps per plant per week) rate of the parasitoid *Eretmocerus eremicus*, plus two mid-season applications of fenoxycarb.

and does not contribute much variation to control cost. Fill rate of packages, however, is more variable. Parasites are sold in bottles advertised as having a fixed number of pupae, but actual numbers present vary. Variation in fill rate, if growers react to under filling by ordering more product, changes the cost of the biological control program. However, if suppliers make good on under filled orders with free supplemental material, there is no cost. In our 2000 trial reported here, we experienced an 80% fill rate, but in our 1997 trials, we received an overfill rate of 173%. Assuming a 100% fill rate, costs for parasitoids (per single stem 16.5 cm pot) for season long control range from 18 cents for a 12 week crop to 27 cents for an 18 week crop. For multi-stem plants, cost of control increases proportionately.

Cost of the Chemical Control Program

Growers made an average of 8.3 ± 2.1 (SE) insecticide applications for season long whitefly control (n = 22, range = 1-36). Only 7 of 22 growers were able to control whiteflies with a single appli-

TABLE 1. COST (U.S. $) PER PLANT OF A WHITEFLY BIOLOGICAL CONTROL PROGRAM FOR POINSETTIA USING *ERETMOCERUS EREMICUS*.[1]

Item	12 week crop		15 week crop		18 week crop	
	10,000 plants	30,000 plants	10,000 plants	30,000 plants	10,000 plants	30,000 plants
Shipping	0.03	0.01	0.04	0.01	0.05	0.02
Parasitoids	0.18	0.18	0.22	0.22	0.27	0.27
IGR	0.02	0.02	0.02	0.02	0.02	0.02
Total program	0.23	0.21	0.28	0.25	0.34	0.31

[1]Assuming a 100% fill rate, 50% female sex ratio, 76% emergence rate, purchase of parasitoids in lots of 15,000 at $168.26 per 15,000 pupae, and release on single-stemmed plants in 16.5 cm pots.

cation of imidacloprid. The remaining 15 growers applied multiple foliar applications to suppress whiteflies, some as tank mixtures of two or more products. The average seasonal cost of chemical whitefly control for these growers per single stem 16.5 cm diameter pot (not counting labor) was $0.14 ± $0.02 (SE), with a range from $0.01 to $0.40. One application of imidacloprid had an average cost per 16.5 cm pot of $0.12 (n = 18). The average seasonal chemical control cost per triple stem 21.6 cm pot was $0.17 ± $0.02 (SE).

DISCUSSION

While biological control options have been available for whiteflies in greenhouse poinsettia since the early work of Helgesen and Tauber (1974), the approach has not been adopted by growers because such programs are more expensive than the use of pesticides. Use of *Encarsia formosa* Gahan, the same species tested by Helgesen and Tauber (1974), was found by Hoddle and Van Driesche (1996a) to cost $1.02 per plant for season long control, over ten times the cost of competing pesticides. Stevens et al. (2000), reported the cost of use of this parasitoid to be $1.13 per pot, when the cost of scouting was included.

The initial estimate of the cost to use *E. eremicus* was even higher ($2.70 per plant per season, Hoddle and Van Driesche, 1996b). However, progress has been made in lowering these costs. Van Driesche et al. (2001) found that even the standard rate of 3 females of *E. eremicus* per plant per week, the same rate as tested by Hoddle and Van Driesche (1996b) then cost only $1.18 per plant, due to decreases in price for the parasitoid from commercial suppliers. The same study showed that substantially lower costs could be achieved by simultaneously lowering the parasitoid application rate and combining biological control with limited mid-crop use of insect growth regulators, which were found to be compatible with *E. eremicus* (Hoddle et al. 2001). Using this approach, costs of whitefly biological control fell to $0.38, when a rate of 1 female parasitoid per plant per week was applied. In the trial presented here, we show that a still lower rate of 0.5 female parasitoids per plant per week also provides control. Cost for this program is only $0.25 per plant, which includes shipping costs and the price of the insect growth regulator, costs not included in values cited from earlier cited studies.

For the most widely grown size of poinsettia—the standard single stem plant in a 16.5 cm pot—we found the cost of chemical control to be 14 cents, which compared well to 25 cents for the biological control program (assuming a 15 week crop and a 100% fill rate), including the cost of shipping (assuming 30,000 plants under protection). Our estimate of the cost of the chemical control program is consistent with the estimate of Stevens et al. (2000) who reported a value of 28 cents per pot when scouting costs were included. For Massachusetts growers, the cost of our biological control program for smaller growers (10,000 pots) would be 28 cents, due to the effect of shipping costs. For very small growers (below 10,000), purchasing parasitoids in the smaller package size (of 3000 rather than 15,000) increases the cost further, by about 20% per pot, to approximately 34 cents. Costs per pot for multiple stem plants increase in direct proportion, if current release recommendations are followed.

Trials to date have been conducted based on release rates calculated as parasitoids per stem rather than per pot. Under this criterion, a triple-stemmed plant requires the release of three times as many parasitoids as a single-stemmed plant, at three times the cost. No trials have yet been run to determine if this increase in release rates is really necessary. Because of the impact on cost, we recommend that growers release wasps at a rate of 0.5 parasitoids per pot (rather than per stem), recognizing that data supporting this release rate exist only for single-stemmed plants. Efficacy data are not available for crops with multiple stems per pot treated at this rate. Growers using this rate should monitor whitefly numbers and be prepared to intervene chemically if necessary until practical experience establishes the efficacy of this application rate.

Further reduction in the cost of this biological control program seems possible. Costs to use biological control might be reduced as much as one third in a 15 week crop by deleting parasite releases in the weeks in which insect growth regulators are applied (weeks 7 and 8) and the last 2 or 3 weeks before harvest (if whitefly levels are well suppressed in week 12, as determined by your IPM scout). While these methods have not been validated in controlled trials, they could be incorporated into IPM programs and validated by whitefly monitoring during the crop. Using these modifications, the cost of biological control in a 15 week crop for a grower producing 30,000 would be 17 cents per plant, nearly the same as the cost of chemical control (14 cents). Costs of chemical control do not include labor costs for mixing, application and clean up; nor are times for safety training or record keeping considered.

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