

THE EFFECT OF LACEWING LARVAE ON APHID POPULATIONS
ON GREENHOUSE SNAPDRAGONS

by

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INTRODUCTION

Year-round production of crops in the greenhouse provides an environment suitable for the life and reproduction of many insects. Favorable temperatures and humidities increase reproduction rates of red spider mites, whiteflies, aphids, thrips, and mealy bugs. If left uncontrolled, one or more of these pests inevitably damages greenhouse crops within a few days or weeks. One aspect of the problem stems from the demand for high quality in greenhouse crops. For instance, the public tolerates little or no pest damage to cut flowers, either to the foliage or the actual flower. The constant threat of insect damage has led to arduous use of insecticides to produce quality crops. Spray programs on a weekly or a bi-weekly basis are considered necessary by most growers.

Before the discovery of DDT and other chemical insecticides, natural enemies and/or other methods were used to suppress populations of greenhouse pests (3). With the advantage of a quick and predictable kill, chemical controls have replaced biological controls. However, insect resistance, cost of preventive spray programs, and hazards associated with chemical control have created a desire for better control programs.

Pest management, a concept involving integration of biological, chemical, and cultural controls, requires knowledge of the entire sequence of biotic and abiotic factors associated with pest populations and their reduction. Harcourt (8) described the use of life tables

and their importance in viewing these factors over several generations. The lack of scientific research on the effects of natural enemies on pest populations has led to the haphazard, unpredictable use of natural enemies as biological control agents. To be a functional unit in a pest management system, natural enemies must be studied so that they may be manipulated and integrated to obtain predictable control of insect populations.

Although biological control systems have been primarily studied on field or forest crops, the insect problems on greenhouse crops are serious enough to justify a need for investigation. Indeed, the controlled environment of a greenhouse is ideal for manipulation of natural enemies (16). With new designs in greenhouse construction and advances in cooling, heating, and shading, the greenhouse operator can effectively control light, temperature, and photoperiod. The greenhouse might well be considered as a large cage with a controlled environmental system. The full potential control obtainable by natural enemies can be realized as time and reproduction rates of insect pests become more consistent under specified greenhouse conditions. Furthermore, research utilizing biological control on greenhouse crops should apply to field or forest crops, or at least facilitate research in the whole area of biological control by providing information on environmental effects.

Some work has been done on the common greenhouse insects using a system of establishing the pest in known numbers before predators or parasites are released. Hussey (9, 10) has demonstrated the efficient use of the predatory mite Phytoseiulus persimilis to control red spider

mites on cucumbers. Parr (11) developed a system for the control of whiteflies on tomatoes by using the whitefly parasite Encarsia formosa. Scopes (15) devised a system for control of aphids on greenhouse chrysanthemums using the parasite Aphidus matricariae.

Aphids are the most serious pest of the greenhouse snapdragon. Thus, this crop lends itself well to use of one biological agent without the difficulties that arise from multiple pest problems. Although aphids have a number of natural enemies, ranging from lady beetles to tiny wasp parasites, preliminary work and information in the literature led to the use of green lacewings as a control of aphids on greenhouse snapdragons.

Chrysopids have shown potential as inundative biological control agents on several pests of greenhouse and field crops. To be an economic or practical biological agent, predators must be mass reared. Finney (6) worked out a system for mass-culturing lacewings as early as 1950, and Ridgway et al. (13) recently improved on the technique. The lacewing larvae (adults are not predaceous) randomly search a plant until they find their prey. They have been shown to be very efficient and their searching capacity ranked high (7). Another important attribute of lacewings is that they are resistant to some pesticides (1). Lacewings are tolerant to residues and spray drift from other sections of a greenhouse that would kill other predators and parasites whose pesticide tolerance is low.

By placing chrysopid eggs at the base and trunk areas of pear trees, Douth and Hagen (4) suppressed mealy bug populations below a level of economic importance. Douth also used lacewing larvae to control

mealy bugs on greenhouse gardenias (5). Ridgway and Jones (12) reported a 96% reduction in bollworms on cotton and a threefold increase in yield by utilizing Chrysopa carnea. Scopes (14) found that aphids could be eliminated on greenhouse chrysanthemums under caged conditions. He also found lacewing larvae to be effective under uncaged conditions. An aphid:chrysopid ratio of 50:1 was necessary before the aphid populations could be effectively controlled.

The objectives of this thesis were to determine if a biological system could be used in a greenhouse environment to economically produce a floricultural crop. Specifically, the green lacewing (Chrysopa carnea) was studied as a predator of aphids on greenhouse snapdragons. Rates of release of lacewing larvae were investigated. Also, different treatments comparing chemical and biological controls were studied to determine if the quality of snapdragons produced would be similar.

Results of this study were written in manuscript form to be submitted for publication in the Journal of the American Society for Horticulture Science.

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Lacewing larvae effectively control aphids
on greenhouse snapdragons¹

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Abstract: Four lacewing (Chrysopa carnea) larvae per greenhouse snapdragon (Antirrhinum majus) released twice during an 8 week period effectively controlled aphids (Myzus persicae). Two initial sprays of malathion and nicotine sulfate one week apart followed by one release of four lacewing larvae per plant also gave effective control. Flowers produced under chemical and biological control systems were found to have similar quality. Lacewing larvae in a 21° C greenhouse required an additional week to obtain effective control as compared to larvae in a 24° C greenhouse.

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INTRODUCTION

Green lacewing larvae (Chrysopa carnea) have shown potential as inundative biological control agents on several pests of greenhouse and field crops. Its effectiveness as a predator is facilitated by ease of mass rearing (6), efficient searching capacity (4), and resistance to some pesticides (1). Ridgway and Jones (5) reported a 96% reduction of bollworms on cotton and a threefold increase in yield by utilizing lacewings. Mealy bugs on pears and greenhouse gardenias have been suppressed by inundative releases of lacewings (2, 3). Scopes (7) has shown the potential use of lacewings as a control agent of aphids on greenhouse chrysanthemums.

MATERIALS AND METHODS

Release Rate Study: Individual 'Pan American Summer Pink' snapdragons were grown in 7.6 cm peat pots and sub-irrigated daily. Slow release fertilizer was mixed with a 1:1:1 soil, peat moss, haydite mixture. The greenhouse temperature was maintained at $21 \pm 8^{\circ}$ C.

Plants were infested at the sixth leaf pair stage by placing large aphid populations at the seedling bases. Infested seedlings were placed on a greenhouse bench under cages (10 x 15 x 30 cm) made from wood framed No. 52 Lumite screen. After one week, aphids of all sizes were counted on the stem and on the lower and upper leaf surfaces. Eight plants per treatment were placed in a completely randomized design. Initial counts ranged from 72-140 aphids per plant among treatments. Data was reported as percent control:

$$1 - \frac{100 \times \text{treatment population}}{\text{Check population (0 larvae)}}$$

First instar Chrysopa carnea (purchased from the Rincon-Vitova Insectaries, Inc., Realto, Calif. 92376) were placed in the cages at 0, 2, 4, 6, 8, or 10 larvae per plant. Aphids were counted at 3-5 day intervals and the number of aphids recorded.

Biological vs. Chemical Control Study: 'Pan American Summer Pink' snapdragons were infested as before, but experimental units consisted of nine plants placed in a 1 x 1 m greenhouse bench area. Two separate greenhouses were used with two replications of five treatments within

each house. Initial infestation rates averaged 40 aphids per plant in greenhouse I ($24 \pm 14^{\circ}$ C) and 31 aphids per plant in greenhouse II ($21 \pm 14^{\circ}$ C). The temperatures of each house were recorded continuously on hygrothermographs. Chrysopid eggs were hatched in Petri dishes and first instar larvae transferred to the biological treatment area at rates of 4 larvae per plant at the beginning of the experiment, and again 4 or 5 weeks later. Chemical treatments consisted of spraying the plants with recommended rates of malathion or nicotine sulfate on a weekly basis. Other treatments consisted of either an initial biological treatment followed by a chemical treatment (Bio-Chem), or with two sprays followed by a biological treatment two or three weeks later (Chem-Bio). No controls were applied to suppress aphid populations in the check treatment.

The treatment areas where larvae were released were surrounded with 10 cm high Teflon-coated fiberglass, thus providing a cage without a top since Teflon is too smooth for larvae mobility. Snapdragons were planted in 10 cm clay pots placed in wooden flats so the plants could be taken off a bench to be sprayed and then returned. Snapdragons were staked with bamboo poles. Aphid populations were recorded each week.

Harvested flowers were rated by two flower judges using a scale from 1-6. The highest possible score was 54 for the nine plants in a treatment.

RESULTS AND DISCUSSION

Release Rate Study: First instar lacewing larvae released at rates of 2, 4, 6, 8, or 10 per plant significantly reduced aphid populations below the check (Table 1). The aphid population in the check appeared to remain relatively stable. However, as the aphid populations increased, some of the plants died, resulting in a low average for eight plants. Percent control was significantly better with 4 larvae per plant than with 2 larvae per plant (Fig. 1). Rates of 4-10 larvae per plant gave similar control. Effective control of aphid populations was evident after 9 days.

Scopes (7) reported that an aphid:chrysopid ratio of 50:1 would effectively control Myzus persicae on greenhouse chrysanthemums. This ratio was not exceeded at any release rate, but considerable variation in aphid control occurred with only 2 lacewing larvae per plant (ratio of 36:1). The individual plant values ranged from 5% to 100% aphid control. Pubescence on the lower stem and on flower buds reduced larva mobility. Cannibalism at the initial stage of introduction may have increased the aphid:chrysopid ratio above 50:1. At rates of 4-10 larvae per plant, the loss of a few larvae would not increase the ratio above 50:1. Four larvae per plant would appear to produce the most economically consistent results on snapdragons.

Table 1. Effectiveness of lacewing larvae on aphid populations released at rates of 0, 2, 4, 6, 8, and 10 larvae per plant.

Larvae released (No. per plant)	APHID POPULATION ^x						Mean aphid No.	Mean % control ^y
	Days after first instar larvae released							
	0	5	9	12	16	21		
0	108	147	160	162	170	170	152 A ^z	
2	72	66	56	55	62	56	61 B	63 B ^z
4	110	74	16	3	3	4	35 B	87 A
6	127	74	27	5	2	2	40 B	86 A
8	126	91	6	2	1	1	38 B	87 A
10	140	61	18	5	4	3	38 B	88 A
LSD (0.01)							53	16

x Average number of aphids for eight plants.

y $(1 - X_i/X_0^{-1}) \times 100$, where X_i = 2-10 larvae per plant, X_0 = the check.

z Values followed by the same letter in any one column are not statistically different at the 1% level.

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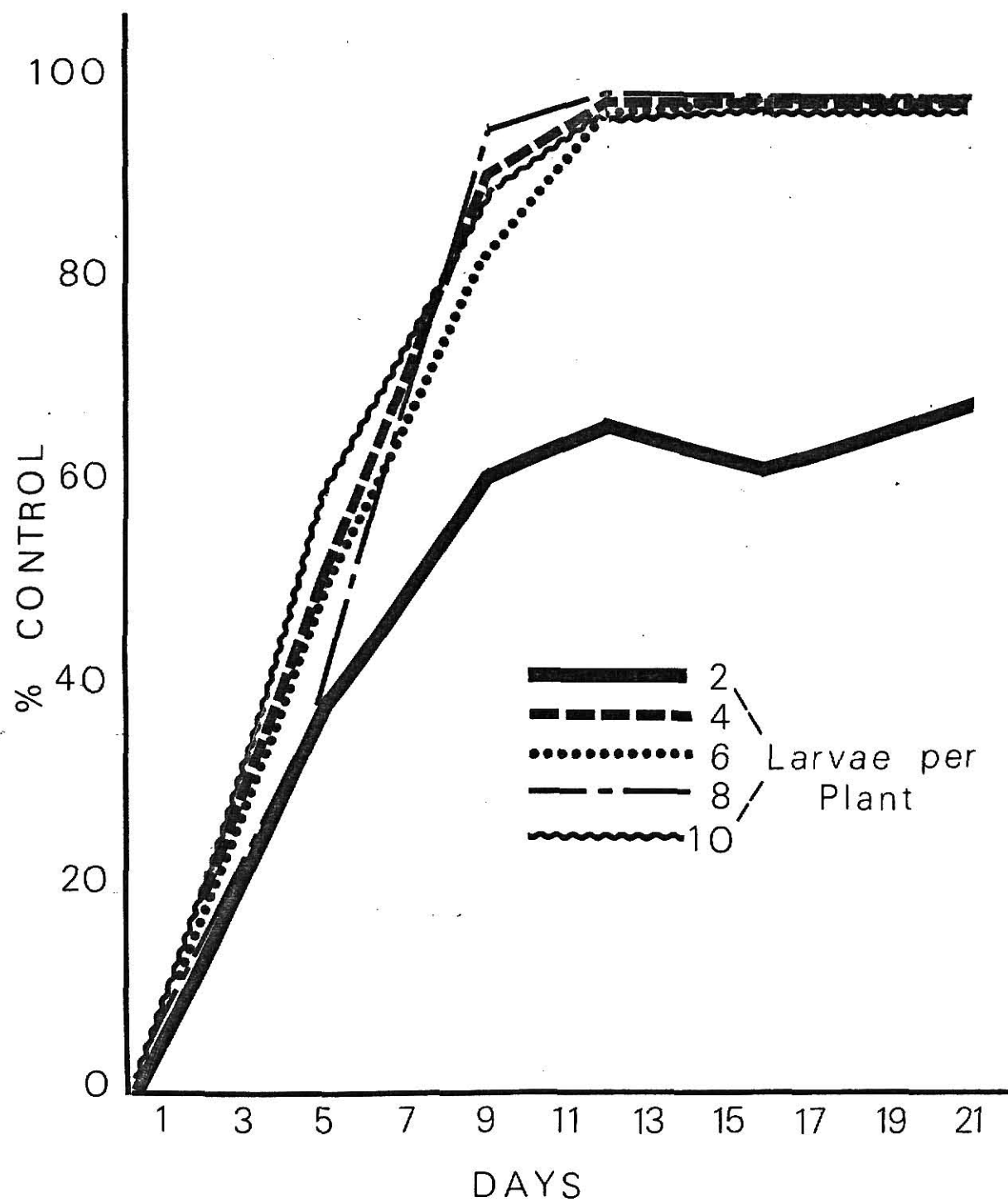


Fig. 1. Release of 4-10 first instar lacewing larvae per plant gave similar control of aphid populations, while 2 larvae per plant were not as effective.

Biological vs. Chemical Control: Aphid populations were significantly reduced below the check with all treatments at 24° C and at 21° C (Table 2). Chemical treatments gave the most consistent high percentage control (significant at the 5% level in the 21° C greenhouse, but not in the 24° C greenhouse). There were occasional weeks of lower or inconsistent control, and rarely a chemical treatment area with no aphids recorded for the week. Thus, the potential for aphids to build up after a chemical treatment was evident (seen most clearly at weeks 3 and 4 in greenhouse I and II, Figs. 2 and 3).

The biological (lacewing) treatments gradually reduced aphid populations with peak control achieved 2-3 weeks after a release. Although the average number of aphids per plant appeared a little higher with biological treatments as compared with chemical treatments, these differences were not significant at the 5% level. Furthermore, the quality evaluation of harvested flowers showed no differences between chemically and biologically treated plants (Table 3). The control achieved utilizing lacewing larvae was satisfactory, or similar enough to chemical control, to produce quality snapdragons.

The check populations of aphids increased at a slower rate than would be expected (Table 2). Syrphid flies were observed in the research area and were thought to have reduced the aphid population in the check treatments. It was considered that the syrphid flies also would get into the biological treatment areas and introduce a variable to the degree of control that could be attributed to the lacewing larvae. However, only an average of one syrphid fly larva was observed in the treatment areas during a weekly count. In laboratory tests,

Table 2. Effect of five treatments on aphid populations in greenhouse I (24° C) and II (21° C).

APHID POPULATIONS ^x											Mean aphid no.	Mean ^y % control
Treatments	0	1	2	3	4	5	6	7	8			
<u>24° C</u>												
Check	44	94	114	183	283	253	303	216			186 a ^z	
Biological	43	21	15	16	34	30	14	21			25 b	86 a ^z
Bio-Chem	43	27	8	14	36	42	17	11			25 b	87 a
Chem-Bio	44	9	2	17	31	14	4	26			19 b	92 a
Chemical	43	19	2	2	1	1	5	5			10 b	95 a
LSD (0.05)											91	N.S.
<u>21° C</u>												
Check	31	46	45	61	36	48	73	135	169		72 a ^z	
Biological	31	40	15	4	1	3	5	5	5		12 b	77 b ^z
Bio-Chem	31	52	15	7	6	18	2	2	9		16 b	73 b
Chem-Bio	31	7	3	7	9	22	18	11	5		13 b	85 b
Chemical	31	5	2	1	1	1	1	2	8		6 b	97 a
LSD (0.05)											42	11

x Average number of aphids for two replications with nine plants to a treatment.

y $(1 - X_i X_0^{-1}) \times 100$, where X_i = all treatments excluding the check, and X_0 = the check.

z Values followed by the same letter in any one column are not statistically different at the 5% level.

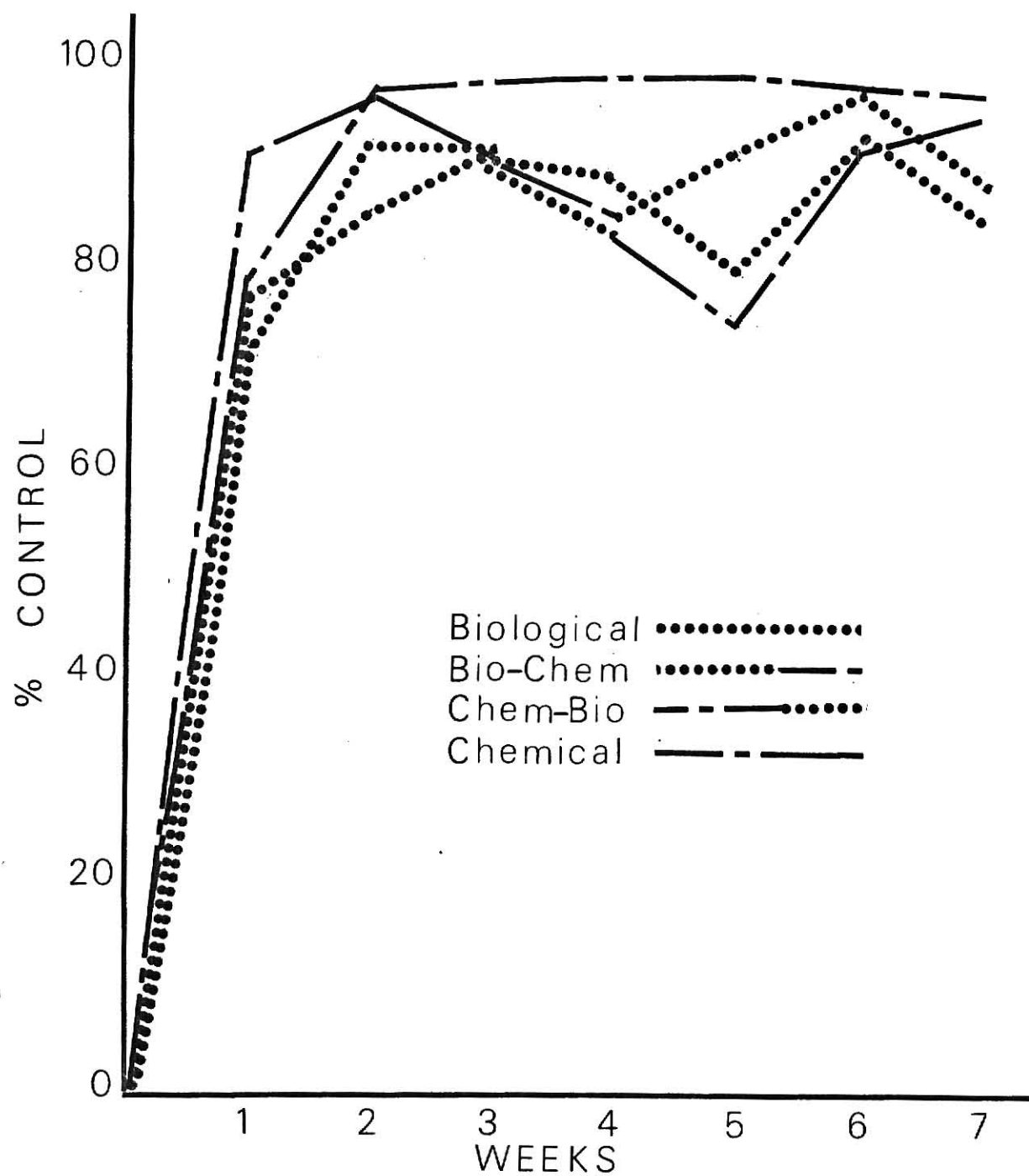


Fig. 2. Percent control achieved utilizing four treatments in greenhouse I (24° C).

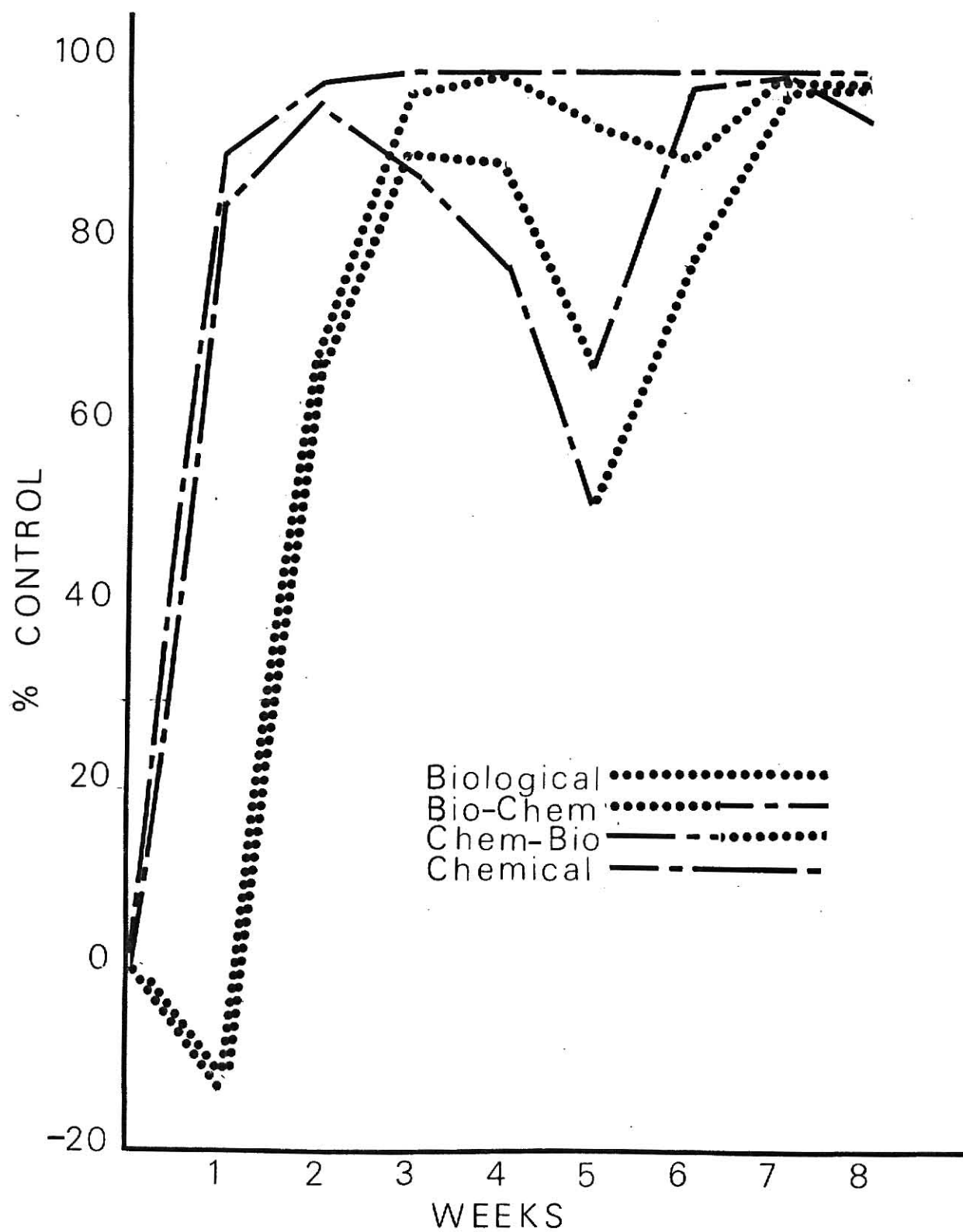


Fig. 3. Percent control achieved utilizing four treatments in greenhouse II (21° C).

Table 3. Arbitrary ratings of harvested flowers showed no differences in quality between chemically and biologically controlled plants.

Judge	TREATMENTS				
	Biological	Bio-Chem	Chem-Bio	Chemical	Check
A	40	46	42	34	22
B	38	38	36	42	18
Mean points ^x	39 A ^y	42 A	39 A	38 A	20 B

x Average number of points from four replications of an arbitrary rating of two flower judges (54 points possible for the nine plants in a treatment).

y Values followed by the same letter in any one row are not statistically different at the 1% level. LSD (0.01) = 9.

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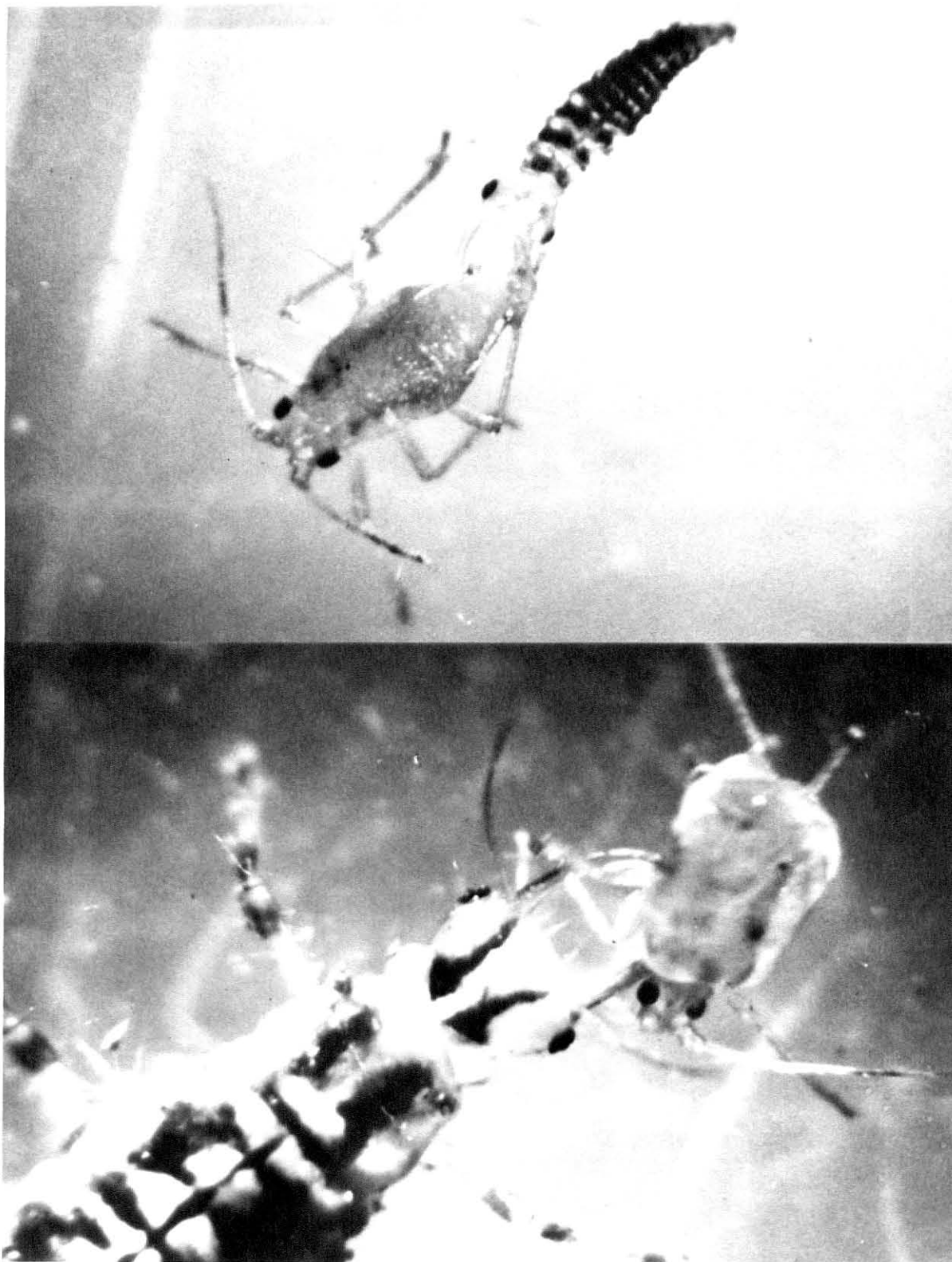
Plate 1 Upper: First instar larva attacking aphid. Lacewing larvae at this stage are not very effective in suppressing aphid populations due to relative size of predator and prey.

Lower: Third instar larva devouring aphid. Lacewing larvae are very effective at this stage, and the time in this instar is the greatest.

The magnification was approximately 30-40x.

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lacewing larvae were found to be capable of feeding on both small and large syrphid fly larvae. Since percent control is dependent on the check population, percent control was less as the check population was proportionately reduced by syrphid fly larvae.

More work needs to be done on the timing of second releases of lacewing larvae and the number of aphids needed to support the larvae through the first two instars. It is thought that the larvae, when introduced at such high numbers per plant, would feed upon themselves when aphid populations were low. Thus, the lacewing larvae could sustain themselves for a longer period of time than would be possible with no food, and some of the larvae would reach the effective third instar stage (Plate 1) to feed upon the growing aphid populations. Lacewing larvae occasionally feed upon themselves when aphid populations are still abundant. But, the results of both experiments indicated 4 larvae per plant were efficient at variable aphid populations. In greenhouse II (21° C), for example, there was an average of only 5 aphids per plant when the second release of lacewing larvae was made, as compared to 31 aphids per plant at the first release. Third instar larvae were observed three weeks later, while the aphid population was held relatively stable.

Lacewing larvae were observed continually searching the wooden flats and clay pots. The larvae would search from the bottom to top of these surfaces, and when reaching the top, continue searching the top for long periods of time. It may be that larvae would be more efficient if the plants were grown directly in the bench. This method would eliminate many square inches of "non-plant" surface area. However, lacewing larvae would either scare or knock aphids from the plants.

The aphids would also wander around the top of the flat and pots where the lacewing larvae would find them.

Snapdragons are normally staked or wired. This aids lacewing larvae to overcome reduced mobility caused by pubescence on the lower stem and flower buds. Also, if timed correctly, the aphid populations could be suppressed before the buds develop hairs.

The temperatures maintained were $24 \pm 14^{\circ} \text{C}$ and $21 \pm 14^{\circ} \text{C}$ in greenhouse I and II, respectively. Lacewing larvae were less effective at 21°C than at 24°C for the first two weeks following a release, but effective control was reached by the third week (Fig. 4). At cooler temperatures, larvae developed into the third instar stage several days after the larvae in the 24°C greenhouse. Also, the general searching activity of the larvae appeared slower with cooler temperatures. Although the lacewing larvae responded faster at 24°C temperatures, this is not a recommended growing temperature for high quality snapdragons. During vegetative growth stages, higher temperatures may be maintained to increase larvae effectiveness; however, temperatures should be reduced during flower initiation and development.

In summary, promise is indicated in the use of lacewing larvae to suppress aphid populations below a level at which significant damage occurs to the quality of snapdragons. The use of an integrated insecticide spray program also appears possible. Effects of temperature and perhaps other controllable environmental factors on lacewing activity needs to be studied more conclusively. Also, the economics of different treatment methods, especially utilization of sequential sampling techniques, needs to be assessed to aid in the efficiency of production of greenhouse snapdragons.

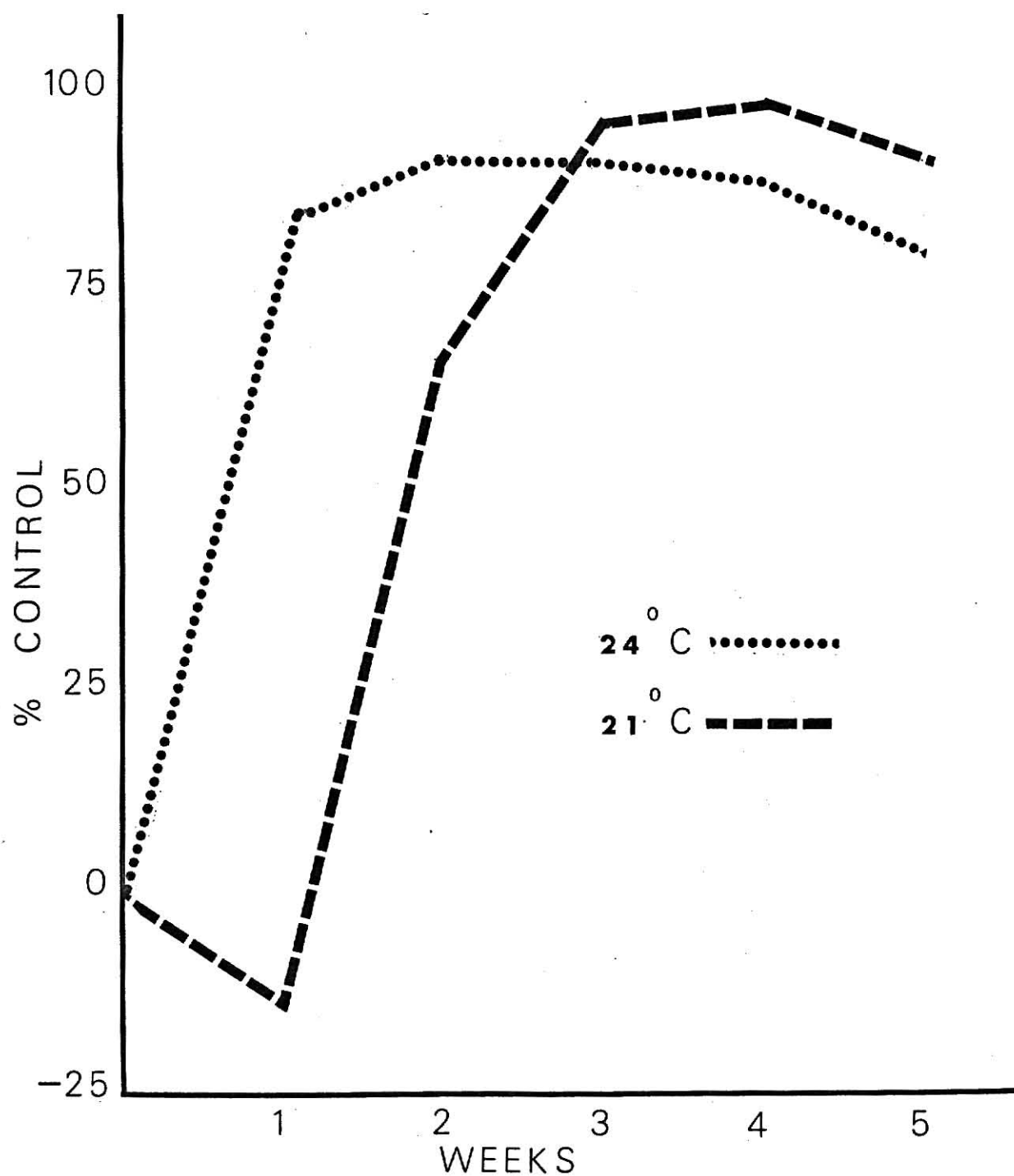


Fig. 4. Effect of $24 \pm 14^{\circ}\text{C}$ and $21 \pm 14^{\circ}\text{C}$ temperatures on lacewing larvae effectiveness. Cooler temperatures slowed larvae effectiveness, but similar control to the warmer greenhouse was achieved by the end of three weeks.

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APPENDIX

EXPERIMENTAL PROCEDURES AND PROBLEMS

Lacewings: The lacewing eggs were hatched in Petri dishes due to the lack of viable eggs received. Chrysopa carnea stalked eggs were obtained from the Rincon-Vitova Insectaries approximately 4 days before placement in the greenhouse. Strips were cut from the brown paper bag containing the stalked eggs and placed in Petri dishes. The eggs would hatch in 2-3 days and a known number of larvae were placed in an area. Hatching the eggs and counting the larvae was necessary for as few as 10% of the eggs sent hatched in some instances.

Photographs were made of lacewing larvae at various stages of development (Plate 1). Magnification was between 30 and 40 times actual size. The film used was Kodak Ektachrome-X, daylight or tungston, high speed or regular speed depending on the situation.

Aphid counts: Aphids of all sizes were counted on both upper and under leaf surfaces. Weekly counts gave excellent indications of aphid population changes.

Cages: One of the first problems encountered was caging the larvae as they would not stay in the area where they were placed. They consistently found their way into the check areas. Lumite screen was used as cage material for the experiment to determine release rates, but was not very satisfactory. The screen shaded the

snapdragons and did not allow proper growth due to cage size. Teflon coated flat fiberglass proved to be a much more effective and usable cage. The plants could be removed and aphids counted without disturbing the lacewing larvae, or risking loss of larvae. Care had to be taken so as not to get soil on the Teflon surfaces when watering.

Other natural enemies: Photographs were taken of syrphid flies at various stages of development (Plates 2-4). Syrphid flies were observed in the research area and were thought to have reduced the aphid population in the check treatments.

A few parasitized aphids were observed (Plate 5). They were not considered significant due to the few mummies found.

Statistics: Analysis of variance for the release rate study is found in Tables 1 and 2. Analysis of variance for the five different treatments is found in Tables 3-6. Analysis of variance for the arbitrary ratings of harvested flowers is presented in Table 7.

Plate 1. Upper Left: First instar lacewing larva attacking an aphid.

Upper Right: Third instar larva attacking an aphid. It is essential that some of the released larvae reach this stage if good control is to be achieved.

Lower left: Lacewing larva feeding on another lacewing larva.

Lower right: Lacewing larvae working its way up an aphid infested stem. Lacewing larvae characteristically grab an aphid, shake it vigorously in the air, and then suck the body fluids from the captured aphid, leaving only a lifeless shell. Some of the aphids escape for a period of time by falling off or running down the stem.

The magnification was approximately 20-30x.

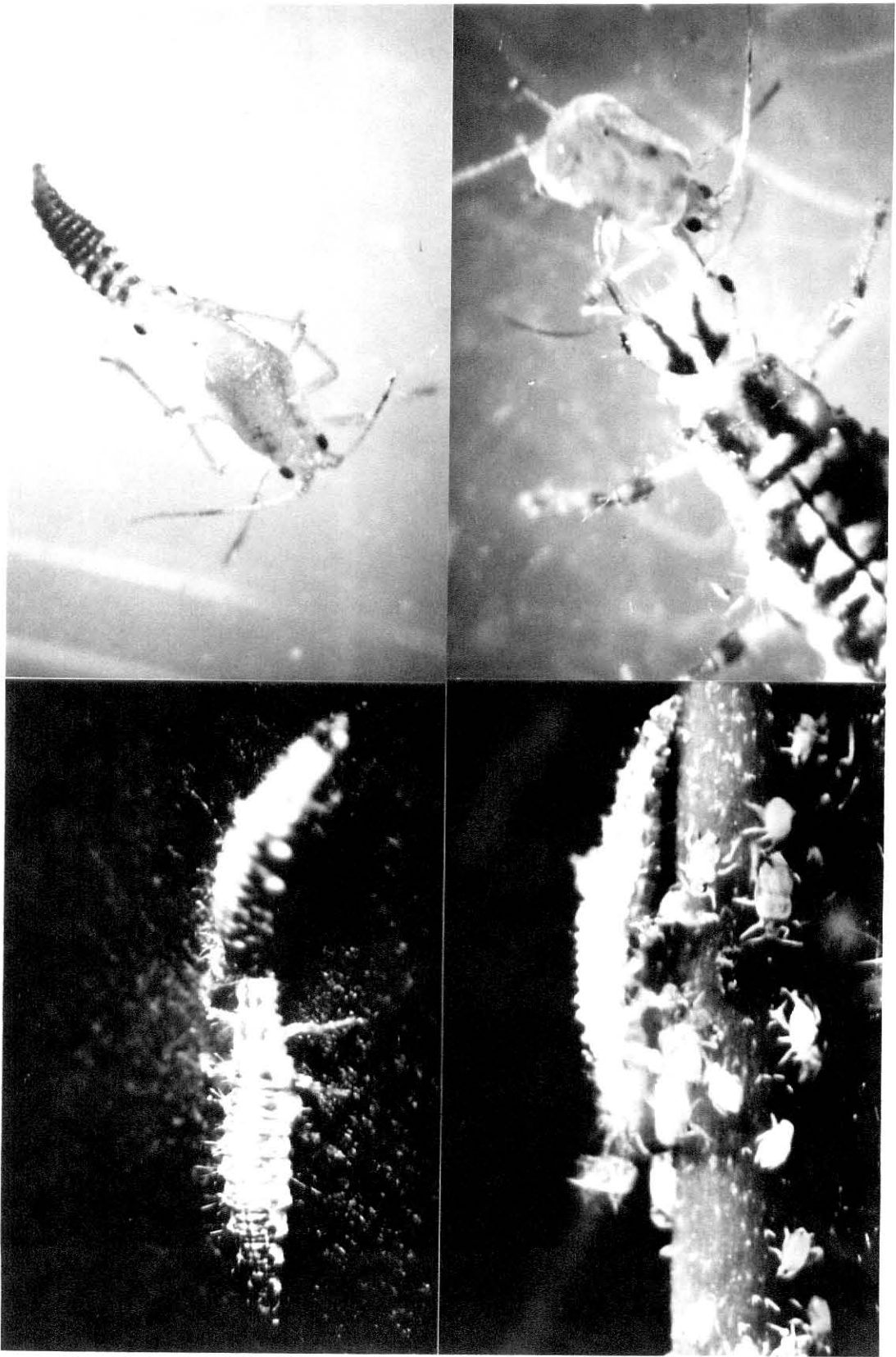


Plate 2. Syrphid fly attacking an aphid. The larvae characteristically lift the aphid into the air and then suck out the body contents.

The magnification was approximately 40x.



Plate 3. Life stages of the syrphid fly, (eggs, larva, pupa, and adult).

The magnification was approximately 15x.



Plate 4. Lacewing larva attacking a syrphid fly larva. Syrphid fly larvae of equal size or larger than lacewing larvae have a defense mechanism that hinders the lacewing larvae for a moment. The flies spit a tobacco like juice on the lacewing larvae as the lacewing pierces the syrphid fly with its pinchers. However, the lacewing rubs off the juice and soon returns to finish its meal. With smaller syrphid flies, the lacewing lifts the fly into the air where the fly larva has no chance for any defense.

The magnification was approximately 20x.

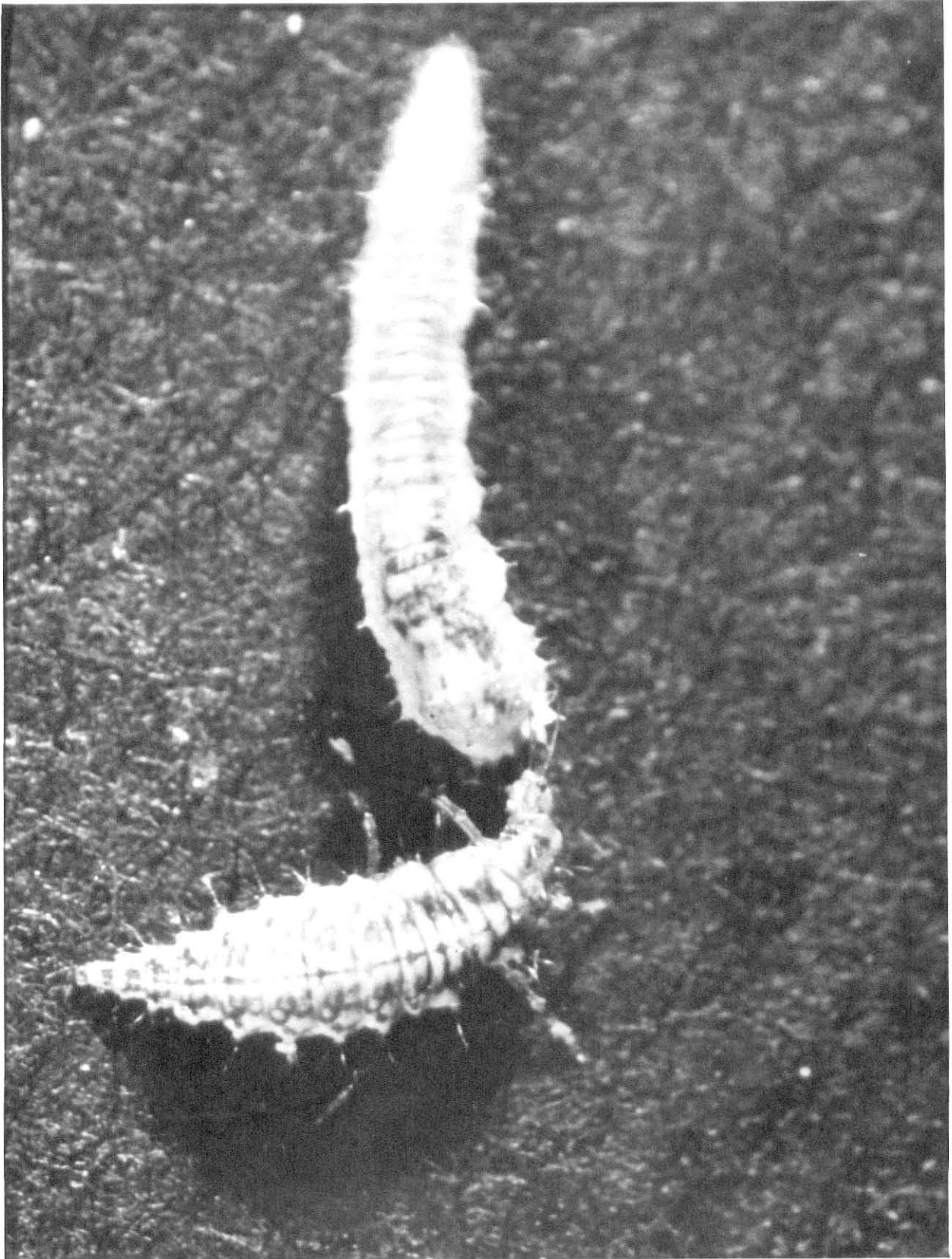


Plate 5. A family of aphids (species unknown) with at least one parasitized aphid. The parasite is a tiny wasp.

The magnification was approximately 20x.



Table 1. Analysis of variance of aphid populations, release rate study.

Source of variance	Degrees of Freedom	Mean Square	F Value
Total	35	-	
Treatment	5	12,737	11.76**
Date	5	5,974	5.52**
Error	25	1,083	

**Significant at the 1% level. $F(0.01) = 3.86$

Table 2. Analysis of variance of percent control, release rate study.

Source of variance	Degrees of Freedom	Mean Square	F Value
Total	24	-	
Treatment	4	548	7.41**
Date	4	1,612	21.82**
Error	16	74	

**Significant at the 1% level. $F(0.01) = 4.22$

Table 3. Analysis of variance of aphid populations, biological vs. chemical control study, greenhouse I (24° C).

Source of variance	Degrees of Freedom	Mean Square	F Value
Total	69	-	
Reps.	1	720	0.08
Treatments	4	102,278	11.97*
Reps. x Trts.	4	8,545	2.60
Date	6	3,460	1.05
Date x Trts.	24	2,608	0.79
Error	30	3,291	

*Significant at the 5% level. $F(0.05) = 6.39$

Table 4. Analysis of variance of percent control, biological vs. chemical control study, greenhouse I (24° C).

Source of variance	Degrees of Freedom	Mean Square	F Value
Total	55	-	
Reps.	1	810	3.25
Treatments	3	288	1.12
Reps. x Trts.	3	249	4.90**
Date	6	227	4.45**
Date x Trts.	18	49	0.96
Error	24	51	

**Significant at the 1% level. $F(0.01) = 4.72$.

Table 5. Analysis of variance of aphid populations, biological vs. chemical control study, greenhouse II (21° C).

Source of variance	Degrees of Freedom	Mean Square	F Value
Total	79	-	
Reps.	1	3,176	1.58
Treatments	4	14,654	7.27*
Reps. x Trts.	4	2,016	7.30**
Date	7	948	3.43**
Date x Trts.	28	1,249	4.53**
Error	35	276	

* Significant at the 5% level. $F(0.05) = 6.39$

** Significant at the 1% level.

Table 6. Analysis of variance of percent control, biological vs. chemical control study, greenhouse II (21° C).

Source of variance	Degrees of Freedom	Mean Square	F Value
Total	63	-	
Reps.	1	1	0.01
Treatments	3	1,782	18.18*
Reps. x Trts.	3	98	1.56
Date	7	3,141	49.86**
Date x Trts.	21	949	15.06**
Error	28	63	

* Significant at the 5% level. $F(0.05) = 9.28$

** Significant at the 1% level.

Table 7. Analysis of variance of the arbitrary ratings of harvested snapdragons.

Source of variance	Degrees of Freedom	Mean Square	F Value
Total	19	-	
Reps.	1	2	0.06
Judge	1	36	0.94
Rep x Judge	1	39	2.27
Treatments	4	305	17.76**
Error	12	17	

**Significant at the 1% level. $F(0.01) = 5.41$

THE EFFECT OF LACEWING LARVAE ON APHID POPULATIONS
ON GREENHOUSE SNAPDRAGONS

by

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B.S., Washburn University, 1970

AN ABSTRACT OF A MASTER'S THESIS

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Aphid (Myzus persicae) populations on greenhouse snapdragons (Antirrhinum majus) were effectively controlled by utilizing green lacewing (Chrysopa carnea) larvae as biological control agents. With 4, 6, 8, or 10 larvae per plant, 92-97% control was achieved under caged conditions during a three week period. Consistent results were not obtained with 2 larvae per plant.

Biological treatments using 4 lacewing larvae per plant gave similar control to chemical treatments consisting of weekly spray applications. Arbitrary ratings of the harvested flowers showed no differences in quality between chemically and biologically controlled plants.

Lacewing larvae were less effective at average temperatures of 21° C than at 24° C for the first two weeks following release, but effective control was reached by the third week. At cooler temperatures, larvae developed into the third instar stage several days after the larvae in the warmer house. The general searching activity of the larvae appeared to be much slower with cooler temperatures.