

IMPACT OF HABITAT MANAGEMENT ON GENERALIST PREDATORS OF THE SOYBEAN APHID, *APHIS GLYCINES* MATSUMURA

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INTRODUCTION

The soybean aphid, *Aphis glycines* Matsumura, is a newly introduced pest from Asia that was first discovered in the north central region of United States in 2000. In Asia *A. glycines* feeding causes significant direct damage, reducing seed yields by up to 28% (Wang *et al.*, 1996). Soybean aphids can also indirectly reduce soybean yield by excreting honeydew, which promotes the growth of sooty molds, and by vectoring plant viruses (Van den Berg *et al.*, 1997). In previous studies, generalist predators have been shown to play an important role in suppressing *A. glycines* populations in soybean fields in China (Han, 1997) and southeast Asia (Van den Berg *et al.*, 1997). However, little is known about their potential to affect soybean aphid populations in the United States.

Recently, the role of generalist predators in biological control has received increased attention (Symondson *et al.*, 2002). For example, it has been shown that ground beetles (Carabidae) can reduce populations of *Aphis fabae* Scopoli, a pest of sugar beet, *Beta vulgaris* L. (Hance, 1987). It has also been demonstrated that many species of carabid beetles in sugar beet fields in The Netherlands, along with spiders and a dominant cantharid beetle, aided in aphid control early in the season (Landis and van der Werf, 1997). While generalist predators are often not as effective *per capita* as are specialized predators, this defect is often compensated for by their being present earlier in the season (Chang and Kareiva, 1999), when pest densities are low and specialist predators scarce (Takagi, 1999). Furthermore, conservation of generalist predators through habitat management has been shown to have the potential to increase biological control (Landis *et al.*, 2000a, b; Lee *et al.*, 2001).

Our objectives in this study were to determine the abundance and effects of generalist predators on establishment of soybean aphid colonies in plots with and without predator refuge strips.

MATERIALS AND METHODS

All studies were conducted in 2001 at the Michigan State University Entomology Farm, Ingham County, Michigan. The site consisted of 30 x 30 m plots arranged in a randomized complete block design with four replications (Carmona and Landis, 1999). Refuge plots contained a central 3.2 m refuge strip consisting of a combination of orchard grass (*Dactylis glomerata* L.), white clover (*Trifolium repens* L.), and several flowering perennials. The control plots had no refuge strip and were planted to soybean. One half of each plot was randomly selected and used for either predation studies or predator sampling. The crop area was managed using reduced primary tillage (chisel plow then disc) followed by secondary tillage (field cultivator) after application of the herbicide metolachlor at a rate of 1.44 kg/ha. Potash was applied at a rate of 168 kg/ha to meet soil test requirements. Soybeans (Mycogen 5251RR) were planted on May 5, 2001, in 38.1 cm rows at a rate of 70,800 seeds/ha.

A colony of *A. glycines* was obtained from the USDA-APHIS-PPQ facility in Niles, Michigan and aphids were reared on greenhouse grown soybeans (Mycogen 5251RR) in growth chambers held at 25°C, 70 % RH, and a 16:8 (L:D) photoperiod.

To determine predator abundance and composition, six dry pitfall traps were placed in rows in each plot. Three pitfall traps each were placed at distances of 4 and 8 m from the refuge or control

strip, with 4 m between traps. Pitfall samples were checked daily during trials. In addition, a 30 cm x 1 m predator sampling area was defined in each plot to observe arrival and species composition of ground-dwelling and foliar-foraging predators in five-minute visual observations. Observations of predator abundance and composition were made immediately after aphids were put into cages, and again when aphids were sampled at 15 h, and at 24 h.

Aphid survival and reproduction was studied by confining aphids on soybeans in cages that selectively excluded predators to different degrees. Three treatments (open, exclusion, and leaky) of small 1 cm circumference clip cages constructed of 1.8 cm diameter Cresline® PVC pipe were used in three trials during 7-8 June, 14-15 June, and 24-25 June 2001. Adult female soybean aphids (three per cage during the first trial and four per cage during the second and third trials) were placed in clip cages. Four cages of each treatment were placed on soybean leaves in both refuge and control plots. Aphids were allowed six hours to settle, then all cages were equally disturbed by gently opening them. For the open treatment, cages were completely removed from leaves. In the exclusion treatment, cages were opened and then replaced on leaves, which prevented aphids from leaving and predators from entering. For the leaky treatment, cages were also opened and replaced but had 3 mm corks removed from holes in the sides of the cage. These holes allowed aphids to leave, but prevented entry by predators more than 3 mm in diameter. Cages were placed 4 m away from control or refuge strips on the uppermost fully expanded leaf of the selected plant.

At 8:00 AM (15 h) and 4:00 PM (24 h) of the following day, the number of adult aphids remaining alive and the number of nymphs produced in each cage were recorded. Data on the percentage of live adult aphids and the number of offspring produced were analyzed by logistic and Poisson regression, respectively, using the GLIMMIX Macro of SAS statistical program (SAS, 1999). Pitfall data were analyzed as the mean number of predators per trap per day in refuge versus control plots. Data from the foliar areas were analyzed as the mean number of predators per 5 minutes in refuge versus control plots. A type III *F*-test for overall treatment effect determined statistical significance of treatment effect of pitfall and direct observation data.

RESULTS

More than 20 species of potential soybean aphid predators were collected from our plots including ground beetles, rove beetles, ants, and spiders (Fox, 2002). In the last two trials, the ladybird beetles *Harmonia axyridis* Pallas and *Coccinella septempunctata* L. became increasingly abundant. The presence of a refuge habitat did not consistently alter the number of potential predators in the 30 cm x 1 m observation areas (Table 1).

Table 1. Mean number of potential soybean aphid predators observed in refuge and control plots during five-minute observations, Trial One (7-8 June), Trial Two (14-15 June), and Trial Three (24-25 June).

Trial	Mean number of predators (+ SEM)		Statistics		
	Refuge	Control	<i>F</i>	<i>df</i>	<i>P</i> -value
One	8.0 + 2.5	11.8 + 1.5	2.03	1,18	0.2024
Two	2.5 + 1.0	3.0 + 1.2	0.11	1,18	0.8756
Three	5.5 + 1.4	7.3 + 3.5	0.34	1,18	0.5763

Similarly, the presence of refuge did not consistently alter the number of potential predators collected in pitfall traps. Means based on the number of predators per pitfall trap per day showed significantly more predators in control plots than in refuge plots in trial one, but no significant differences in trials two or three (Table 2).

Table 2. Mean (\pm SEM) number of potential soybean aphid predators collected in pitfall traps in refuge and control plots, Trial One (7-8 June), Trial Two (14-15 June), and Trial Three (24-25 June).

Trial	Mean number of predators (+ SEM)		Statistics		
	Refuge	Control	F	df	P-value
One	1.6 + 0.2	2.9 + 0.3	4.67	1,18	0.0444*
Two	1.5 + 0.2	1.6 + 0.2	0.08	1,18	0.9306
Three	0.3 + 0.1	0.4 + 0.1	0.40	1,18	0.5360

* Indicates significance at $P < 0.05$

Cage treatment significantly affected adult soybean aphid numbers in trials one and two, as did observation time (hour) in all trials. Predators significantly reduced adult soybean aphid survival in two out of three trials. During the first trial, significantly more aphids remained in exclusion versus open cages at 15 h (Table 3). Because leaky cages also contained significantly more aphids than open ones, it is very unlikely that emigration explains the loss of aphids in open cages. Thus, the evidence for predation in this trial is strong. In trial two, significantly more aphids remained in exclusion versus open cages at both 15 h and 24 h. However, because leaky and open cages contained similar numbers of aphids at 15 h and 24 h, we cannot discount that this may be explained by emigration alone.

For soybean aphid nymphs, there was a highly significant hour effect during all three trials with more nymphs produced at 24 h versus 15 h (Table 4). In trial two, significantly more nymphs were present in exclusion versus open cages at 24 h, however, this finding was not bolstered by a significant effect between leaky and open cages at 24 h (Table 4). Thus, we cannot discount that emigration may have contributed to these differences.

DISCUSSION

Overall, the addition of refuge habitats to experimental plots did not alter the abundance of foliar-foraging or ground-dwelling predators or alter predation of *A. glycines*. However, protecting aphids from predation by natural enemies significantly increased survival of adult aphids in two out of three trials and increased nymph production in one trial. This indicates that predation pressure on newly

Table 3. The probability of a greater *F*-statistic from GLIMMIX results of proportion of adult aphids remaining in refuge and control plots under different exclusion cage treatments.

Effect	Trial One (7-8 June)	Trial Two (14-15 June)	Trial Three (24-25 June)
Refuge	0.3681	0.5674	0.9966
Treatment	0.0391*	0.0108*	0.3849
Refuge x Treatment	0.4850	0.7528	0.7403
Hours	<0.0001*	<0.0001*	<0.0001*
Refuge x Hours	0.8781	0.4398	0.8300
Treatment x Hours	0.0898	0.3364	0.0875
Refuge x Treatment x Hours	0.8032	0.4652	0.0469*
E-O, 15	0.0274*	0.0138*	0.4300
E-O, 24	0.1210	0.0014*	0.0601
L-E, 15	0.6554	0.0409*	0.5377
L-E, 24	0.4273	0.0654	0.6488
L-O, 15	0.0155*	0.5943	0.8204
L-O, 24	0.4403	0.1278	0.1359

E-O = comparison of exclusion and open cages;

L-E = comparison of leaky and exclusion cages;

L-O comparison of open and leaky cages, all at the time indicated.

* Indicates significance at $P < 0.05$

establishing soybean aphids may be sufficient to slow population growth or in some cases eliminate colony establishment. The role of generalist predators in suppressing soybean aphid populations in the north central United States should be investigated in more detail to develop effective IPM programs to manage this invasive pest.

Table 4. The probability of a greater *F*-statistic from GLIMMIX results of number of soybean aphid nymphs produced in refuge and control plots under different exclusion cage treatments.

Effect	Trial One (7-8 June)	Trial Two (14-15 June)	Trial Three (24-25 June)
Refuge	0.5629	0.1724	0.7987
Treatment	0.1347	0.473	0.1992
Refuge x Treatment	0.9977	0.7993	0.4395
Hours	<0.0001*	<0.0001*	<0.0001*
Refuge x Hours	0.4189	0.1875	0.6929
Treatment x Hours	0.3314	<0.0001*	0.4288
Refuge x Treatment x Hours	0.1066	0.7817	0.2941
E-O, 15	0.5532	0.6072	0.1717
E-O, 24	0.0718	0.0083*	0.0798
L-E, 15	0.1646	0.6791	0.8732
L-E, 24	0.8781	0.1253	0.0801
L-O, 15	0.0785	0.3886	0.2028
L-O, 24	0.0984	0.1223	0.6085

E-O = comparison of exclusion and open cages;

L-E = comparison of leaky and exclusion cages;

L-O comparison of open and leaky cages, all at the time indicated.

* Indicates significance at $P < 0.05$

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