Predation by *Coccinella septempunctata* and *Harmonia axyridis* (Coleoptera: Coccinellidae) on *Aphis glycines* (Homoptera: Aphididae)

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Predation by Coccinella septempunctata and Harmonia axyridis (Coleoptera: Coccinellidae) on Aphis glycines (Homoptera: Aphididae)

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ABSTRACT Coccinella septempunctata L. and Harmonia axyridis Pallas are key natural enemies of soybean aphid, Aphis glycines Matsumura, in North America. Third instars, adult females, and adult males of both C. septempunctata and H. axyridis exhibited a type II functional response for predation toward adult soybean aphids at 26 ± 1°C. In C. septempunctata, the functional response curve of adult males differed from those of third instars and adult females, but there was no difference between third instars and adult females. In H. axyridis, the functional response curves of larvae, adult females, and adult males all differed significantly. Third instars and adult females consumed significantly more soybean aphids than did adult males at prey densities of 150 and 180 aphids per arena for C. septempunctata and at prey densities of 60, 90, 120, 150, and 180 aphids per arena for H. axyridis. The theoretical maximum daily predation rate of adult aphids by C. septempunctata was predicted to be 204 per third instar, 277 per adult female, and 166 per adult male, and 244, 156, and 73, respectively, for H. axyridis. Third instars and adult females of both species consumed significantly more aphids than did adult males on soybean plants with the recommended action threshold of 250 soybean aphids per plant. Both C. septempunctata and H. axyridis have high predation capacities and are important in suppressing soybean aphid populations.

KEY WORDS functional response, biological control, seven-spotted lady beetle, multicolored Asian lady beetle, soybean aphid

Soybean aphid, Aphis glycines Matsumura (Homoptera: Aphididae), is native to Asia and has become a severe pest of soybean, Glycine max (L.) Merril, since its discovery in North America in 2000 (Rutledge 2004, Venette and Ragsdale 2004). Natural enemies are important to the regulation of soybean aphid populations in Asia (Quinio and Callilung 1993, Chang et al. 1994, van den Berg et al. 1997, Heimpel et al. 2004, Liu et al. 2004, Wu et al. 2004, Miao et al. 2007) and in North America (Fox et al. 2004, 2005; Rutledge et al. 2004; Rutledge and O'Neil 2005; Costamagna and Landis 2006, 2007; Costamagna et al. 2007). In North America, predators commonly dominate the natural enemy community (Rutledge et al. 2004, Costamagna and Landis 2007). Generalist predators such as the seven-spotted lady beetle, Coccinella septempunctata L., and the multicolored Asian lady beetle, Harmonia axyridis Pallas (Coleoptera: Coccinellidae), account for most of the observed mortality and are very effective at reducing aphid numbers on a per capita basis (Costamagna and Landis 2007).

The current action threshold of 250 soybean aphids per plant (NCSRP 2006, Baute 2007) was validated by determination of an economic threshold of 273 aphids per plant (Ragsdale et al. 2007); although natural enemies would have been present in study fields, natural enemy numbers were not explicitly taken into account in development of either threshold. To incorporate predator effects into the action threshold, it is necessary to determine the functional response for each predator species. Functional response is defined as the relationship between the number of prey consumed per predator and the prey density (Solomon 1949) and is a valuable tool for assessing the potential impact of a natural enemy on pest population growth and predicting the potential for success of biological control agents (Hassell 1978, Houck and Strauss 1985, Tully et al. 2005). Holling (1959a) categorized functional responses into three basic types. The type I response is characterized by a linear rise with a constant attack rate over all prey densities until satiation is reached. In the type II response, the attack rate decreases as prey density increases. Type III is represented by a sigmoid curve where the attack rate increases with increasing prey density and decreases toward satiation. Most studies are confined to type II and III responses because these are the most commonly observed in nature (Juliano 2001).

Many studies have been conducted on the functional responses of C. septempunctata and H. axyridis to aphids, including the pea aphid, Acyrthosiphon pisum (Harris) (Carter et al. 1984). Aphis citricola van der Goot (Wang et al. 1999, Chen et al. 2005), cotton
aphid, *Aphis gossypii* Glover (Xia et al. 2003, Lee and Kang 2004), *Aphis robiniae* Macchiati (Wang et al. 1999), *Chaitophorus populeti* (Panzer) (Zhang and Liu 2006), *Hyalopterus axyridis* (Blanchard) (Zhang et al. 2004), turnip aphid, *Lipaphis erysimi* (Kaltenbach) (Sinha et al. 1982, Xue et al. 1996, Kumar et al. 1999, Omkar and Srivastava 2003, Zhang and Liu 2006), tobacco aphid, *Myzus nicotianae* (Blackman) (Liu et al. 2002), green peach aphid, *Myzus persicae* (Sulzer) (Xue et al. 1996, Ma et al. 2000, Hao and Hao 2005), waterlily aphid, *Rhopalosiphum padi* L. (Ge et al. 2006), bird cherry-oat aphid, *Rhopalosiphum padi* L. (Lou 1987, Zhang and Liu 2006), greenbug, *Schizaphis graminum* (Rondani) (Hu 1992), English grain aphid, *Sitobion avenae* (F.) (Skirvin et al. 1997), and yellow clover aphid, *Thrioaphis trifolii* (Monell) (Zhang et al. 2007). However, the functional responses of *C. septempunctata* and *H. axyridis* to the soybean aphid have not been described. Xue et al. (1996) reported that the predation capacity of *C. septempunctata* on *M. persicae* was greater than on *L. erysimi*, which might be caused by the physical structures and wax on the body of *L. erysimi*. These results suggest that predation data collected from other aphid species may not apply to the soybean aphid, although studies with very similar species such as cotton aphid may be more useful.

The purpose of this study was to better understand the interaction between these two generalist predators and soybean aphids and their potential to suppress soybean aphid populations by determining the functional responses of third instars, adult females, and adult males to soybean aphids. We also examined predation by these species on aphids on soybean plants at the current action threshold of 250 aphids per plant under laboratory conditions.

### Materials and Methods

#### Insect Culture

Soybean aphids were collected from a soybean field near Guelph, Ontario, Canada. Aphids were reared on soybean cultivar Colby in a growth room held at 24 ± 2°C and 16:8 L:D with fluorescent bulbs (Cool White; Sylvania, Mississauga, Ontario, Canada). Soybean seeds were soaked in Cell-Tech Bradyrhizobium *japonicum* inoculant (EMD Crop Bioscience Canada, Belgrave, Ontario, Canada) before planting and were watered using 20–20–20 fertilizer water *ad libitum*.

Adult beetles were obtained from 10 soybean fields in Kent and Lambton counties, Ontario, Canada, where soybean aphid populations were present. Beetles were held in 10 by 20 by 25-cm nylon mesh cages in a growth room at 24 ± 2°C and 16:8 L:D and fed a mixed diet of both soybean aphid reared on soybean (as above) and bird cherry-oat aphid. Bird cherry-oat aphid starter colonies (Aphid Banker System; Plant Products, Brampton, Ontario, Canada) were reared on barley grown in 14 cm diameter by 14 cm high pots and held within a large mesh enclosure in a greenhouse at 23 ± 3°C and 16:8 L:D. Even-age cohorts of lady beetles from eggs laid on the same day were reared in separate cages, with new aphid-infested plants introduced twice weekly. All beetle eggs found in adult cages were moved to separate cages and given a fresh supply of aphids.

#### Functional Responses

To examine the functional response of third instar, adult female and adult male lady beetles, V1 soybean plants, 15–18 cm high with two fully expanded trifoliates, were each cut above the cotyledon. Stems of individual excised plants were inserted through holes in the lids of bottles containing 20 ml water. Adult soybean aphids selected on the basis of body size were transferred to these plants at densities of 30, 60, 90, 120, 150, and 150 per plant. Each plant unit was placed in a clear plastic container (10 cm diameter by 8 cm height; Shortreed Paper, Guelph, Ontario, Canada). Mesh-covered holes in the lid provided ventilation. Predation of first instars produced during the experimental period was ignored because of the small biomass this life stage represented.

A single newly molted third instar or a 1- to 3-wk-old adult lady beetle was introduced into each arena. Newly molted third instars were obtained by collecting second instars, which had ceased feeding and were preparing to molt, from the stock colony and holding them individually in small containers without food. After 24 h, newly molted third instars were selected for experimentation. Adults were starved for 24 h before being introduced to arenas. Arenas were kept in a controlled environment chamber at 26 ± 1°C and a 16:8-h L:D period. After 24 h, the number of prey consumed was recorded. Each aphid density was replicated 10 times. In addition, controls for each aphid density were conducted without predators to control for other sources of aphid mortality and replicated three times.

#### Predation on Soybean Plants

To examine predation of aphids on whole plants, 250 aphid adults were transferred with a paintbrush to V3 soybean plants with three unfolded trifoliates. Each plant was held in a plastic cage (9 cm diameter by 30 cm high) with a mesh top to provide ventilation. A single third instar, adult female, or adult male lady beetle was introduced into each cage. Cages were kept in a controlled environment chamber, as above, and after 24 h, the number of prey consumed was recorded. The experiment was replicated 12 times for the larval stage of *C. septempunctata* and 10 times each for the larval stage of *H. axyridis* and adults of both species. Predation of first instars produced during the experimental period was ignored because of the small biomass this life stage represented. Three replications of aphids in the absence of predators were conducted as controls.

#### Statistical Analyses

Functional responses were described using two-stage analysis (Juliano 2001). A cubic logistic regression (equation 1) between proportion of prey consumed and initial prey density was first performed to determine the type of functional response curve (Juliano 2001):

\[
N_o = \frac{\exp(P_0 + P_1N_0 + P_2N_0^2 + P_3N_0^3)}{1 + \exp(P_0 + P_1N_0 + P_2N_0^2 + P_3N_0^3)}
\]
where \( N_a \) is the number of prey consumed, \( N_0 \) is the initial prey density, and \( P_0, P_1, P_2, \) and \( P_3 \) are the intercept, linear, quadratic, and cubic coefficients, respectively. If the linear coefficient, \( P_1 \), is significantly negative, the predator is displaying a type II functional response; if positive, there is a type III functional response (Juliano 2001). If a cubic equation yields a nonsignificant cubic coefficient, it is desirable to reduce the model by eliminating the cubic coefficient from equation 1 and to retest the other parameters (Juliano 2001).

Because the logistic regression analysis indicated that our data fit type II in each case, further analyses were restricted to the type II functional response. The Holling’s disc (equation 2) (Holling 1959b) and the random predator (equation 3) (Royama 1971, Rogers 1972) were used to model the relationship between the number of prey consumed (\( N_a \)) and initial prey density (\( N_0 \):

Holling’s disc equation:

\[
N_a = \frac{a N_0}{1 + a T_h N_0}
\]  

Random predator equation:

\[
N_a = N_0 \left[1 - \exp(a T_h N_a - a)\right]
\]

where \( a \) is the instantaneous searching rate and \( T_h \) is the handling time per prey item. A nonlinear regression procedure (NLR) based on the Levenberg-Marquardt method (SPSS 2006) was performed to estimate the parameters \( a \) and \( T_h \). The starting values of \( a \) and \( T_h \) required by the NLR procedure were found by linearly regressing \( 1/N_a \) against \( 1/N_0 \). The resultant \( y \)-intercept is the initial estimate of \( T_h \) and the reciprocal of the regression coefficient (slope) is an estimate of \( a \) (Livdahl and Stiven 1983, Watson et al. 2000). These initial estimates were refined by NLR. Data did not fit the model if the asymptotic 95% confidence intervals (CIs) of \( a \) and \( T_h \) estimates included zero (i.e., the estimates did not differ significantly from zero) (Watson et al. 2000, SPSS 2006). If the data fit both models, the best model was selected based on the value of the coefficient of determination (\( R^2 \)).

Differences between the functional response curves in different stages and sexes of lady beetles (referred to as “stages” throughout for simplicity) were analyzed using a nonparametric rank sum test. To apply the test, a single functional response curve was fitted to the pooled samples, and regression residuals were computed, keeping track of which residuals were from the third instars and which were from the adult female or male stages. The residuals from each stage were tested using the Kruskal-Wallis test (Holander and Wolfe 1973, Gibbons 1976, Houck and Strauss 1985). The Kruskal-Wallis test was also used to determine differences in prey consumption among third instars, adult females, and adult males for a given prey density. When there was a significant difference among the treatments, the Mann-Whitney test was used for pairwise comparisons with the Bonferroni correction (\( P = 0.05/3 = 0.0167 \)) (Siegel and Castellan 1988, SPSS 2006). All analyses were performed using SPSS software (SPSS 2006).

### Results

**Functional Response.** The cubic equation for third instars, adult females, and adult males of \( C. septempunctata \) and \( H. axyridis \) yielded nonsignificant cubic parameters; therefore, these terms were eliminated and the remaining parameters were retested. The linear coefficient, \( P_1 \), in the reduced logistic model was significantly negative for third instars, adult females, and adult males for both \( C. septempunctata \) and \( H. axyridis \) (Table 1), indicating that all stages tested of both species exhibited a type II response to soybean aphids.

The parameter estimates of the instantaneous searching rate (\( a \)) and the handling time per prey item (\( T_h \)) for both the Holling’s disc equation and the random predator equation for \( C. septempunctata \) and \( H. axyridis \) are presented in Table 2. Data for all three stages of both lady beetles fit the Holling’s disc model well, but not the random predator model for which the asymptotic 95% CIs of \( T_h \) estimates included zero.

The Holling’s disc equation with corresponding \( a \) and \( T_h \) for \( C. septempunctata \) (Table 2) predicts theoretical maximum predation rates of 204, 277, and 166 adult aphids per day for third instars, female adults, and male adults, respectively.

### Table 1. Estimates of the linear coefficient, \( P_1 \pm SE \), and the probability (\( P \)) that \( P_1 \neq 0 \) in the reduced logistic model of equation 1 used to determine the type of functional response exhibited by \( C. septempunctata \) and \( H. axyridis \) when preying on soybean aphid, \( A. glycines \), at \( 26 \pm 1^\circ C \) in a 24-h prey exposure period

<table>
<thead>
<tr>
<th>Predator</th>
<th>Stage</th>
<th>( P_1 \pm SE )</th>
<th>( P (P_1 \neq 0) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C. septempunctata )</td>
<td>Third instars</td>
<td>-0.0430 ± 0.0099</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>-0.0228 ± 0.0100</td>
<td>0.0262</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>-0.0371 ± 0.0107</td>
<td>0.0010</td>
</tr>
<tr>
<td>( H. axyridis )</td>
<td>Third instars</td>
<td>-0.0351 ± 0.0071</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>-0.0358 ± 0.0092</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>-0.0411 ± 0.0078</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Estimates were obtained by rewriting the reduced logistic model to a quadratic, followed by quadratic curve estimation regression.
There were no significant differences in prey consumed between third instars and females at any prey density.

The functional response curves of larvae, adult females, and adult males of *H. axyridis* were significantly different from each other (Mann-Whitney test: $Z = -4.393$, $P < 0.001$ between larvae and adult females; $Z = -7.988$, $P < 0.001$ between larvae and adult males; $Z = -5.811$, $P < 0.001$ between adult females and males; Fig. 1).

The *Holling’s disc* equation with corresponding $a$ and $T_h$ for *H. axyridis* (Table 2) predicts theoretical maximum predation rates of 244, 156, and 73 adult aphids per day for third instars, adult females, and adult males, respectively.

Third instars of *H. axyridis* consumed significantly more aphids than did adult males at all prey densities (Table 3). Females consumed significantly more prey than did males at all prey densities except at 30 aphids/plant. There were no significant differences in prey consumed between third instars and females at all prey densities, except at 150 aphids/plant.

When functional response curves of *C. septempunctata* and *H. axyridis* were compared between the same stage or same sex, they were significantly different for larvae (Mann-Whitney test: $Z = 2.715$, $P = 0.007$) and adult females ($Z = 2.473$, $P = 0.013$). There was no significant difference between the shapes of the functional response curves of adult males of each species ($Z = 1.793$, $P = 0.073$).

**Predation of C. septempunctata and H. axyridis on Soybean Plants at V3 Stage.** Whereas third instars and adult females consumed significantly more prey than did adult males for both *C. septempunctata* and *H. axyridis* (Fig. 2), there were no significant differences in number of prey consumed by third instars and adult females. Comparisons of predation between the same stages of *C. septempunctata* and *H. axyridis* showed that there were no significant differences between species for a given stage: larvae (Mann-Whitney test: $Z = -0.958$, $P = 0.338$), adult females ($Z = -0.303$, $P = 0.762$), and adult males ($Z = -0.454$, $P = 0.650$).

**Table 2.** Estimates of the instantaneous searching rate ($a$) and handling time ($T_h$) of *C. septempunctata* and *H. axyridis* when preying on soybean aphid, *A. glycines*, at 26 ± 1°C in a 24-h prey exposure period with asymptotic 95% confidence intervals using the *Holling’s disc* and random predator models.

<table>
<thead>
<tr>
<th>Predator</th>
<th>Stage</th>
<th>Equation</th>
<th>$R^2$</th>
<th>$a$</th>
<th>95% CI of $a$</th>
<th>$T_h$</th>
<th>95% CI of $T_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. septempunctata</em></td>
<td>Third instars</td>
<td><em>Holling’s disc</em></td>
<td>0.7192</td>
<td>1.1578</td>
<td>0.5440–1.4715</td>
<td>0.0009</td>
<td>0.0032–0.0067</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Random predator</td>
<td>0.6456</td>
<td>0.5574</td>
<td>0.1731–0.9418</td>
<td>−0.0006</td>
<td>−0.0029–0.0047</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td><em>Holling’s disc</em></td>
<td>0.8210</td>
<td>1.0536</td>
<td>0.5337–1.2735</td>
<td>0.0036</td>
<td>0.0021–0.0051</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Random predator</td>
<td>0.7692</td>
<td>0.8210</td>
<td>0.4005–1.2415</td>
<td>−0.0043</td>
<td>−0.0015–0.0032</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td><em>Holling’s disc</em></td>
<td>0.5884</td>
<td>0.7722</td>
<td>0.5009–1.0436</td>
<td>0.0060</td>
<td>0.0025–0.0094</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Random predator</td>
<td>0.6065</td>
<td>0.2420</td>
<td>0.0578–0.4261</td>
<td>−0.0248</td>
<td>−0.0551–0.0055</td>
</tr>
<tr>
<td><em>H. axyridis</em></td>
<td>Third instars</td>
<td><em>Holling’s disc</em></td>
<td>0.8343</td>
<td>1.2079</td>
<td>0.9702–1.4457</td>
<td>0.0041</td>
<td>0.0025–0.0053</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Random predator</td>
<td>0.7334</td>
<td>1.0185</td>
<td>0.4861–1.5509</td>
<td>−0.0023</td>
<td>−0.0068–0.0041</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td><em>Holling’s disc</em></td>
<td>0.7671</td>
<td>1.3231</td>
<td>1.0132–1.6330</td>
<td>0.0064</td>
<td>0.0050–0.0078</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Random predator</td>
<td>0.5257</td>
<td>0.7810</td>
<td>0.3383–1.2238</td>
<td>−0.0023</td>
<td>−0.1027–0.0056</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td><em>Holling’s disc</em></td>
<td>0.5767</td>
<td>1.4400</td>
<td>0.9744–1.9176</td>
<td>0.0136</td>
<td>0.0114–0.0157</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Random predator</td>
<td>−0.1699</td>
<td>0.3135</td>
<td>0.0392–0.5879</td>
<td>0.0111</td>
<td>0.0031–0.0149</td>
</tr>
</tbody>
</table>

**Fig. 1.** Functional responses of third instars (L3), adult females, and adult males of *C. septempunctata* and *H. axyridis* to adult *A. glycines* in a 24-h prey exposure period at 26 ± 1°C.

**Table 3.** Mean ± SE numbers of adult soybean aphid, *A. glycines*, consumed by *C. septempunctata* and *H. axyridis* third instars, adult females, and adult males at different prey densities on excised soybean plants at the V1 stage at 26 ± 1°C in a 24-h prey exposure period.

<table>
<thead>
<tr>
<th>Predator</th>
<th>Mean ± SE numbers of aphids consumed</th>
<th>Prey density</th>
<th>Aphid density</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. septempunctata</em></td>
<td></td>
<td>Third instars</td>
<td>Females</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>51.6 ± 2.0a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>71.9 ± 4.0a</td>
</tr>
<tr>
<td><em>H. axyridis</em></td>
<td></td>
<td>120</td>
<td>82.3 ± 7.2ab</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150</td>
<td>98.8 ± 7.9a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
<td>105.4 ± 6.4a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>28.9 ± 0.2a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>55.3 ± 0.8a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>74.7 ± 1.7a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>95.8 ± 3.5a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150</td>
<td>105.4 ± 6.6a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
<td>112.4 ± 6.8a</td>
</tr>
</tbody>
</table>

*For a specific predator, means within the same prey density followed by the same letter are not significantly different (Kruskal-Wallis test followed by Mann-Whitney test with Bonferroni correction, $P > 0.05/3 = 0.0167$).*
The random predator equation has been considered more appropriate than Holling’s disc equation in studies where consumed prey are not replaced and trial duration is relatively long and leads to a significant reduction in prey density over time (Houck and Strauss 1985). However, our data fit Holling’s disc equation well, but not the random predator equation. Similar results have been found in other studies. The instantaneous searching rate \((a)\) of first instars of \(H.\ axyridis\) attacking the cotton aphid was 0.0037 \pm 0.00617 (Lee and Kang 2004), indicating the data did not fit the random predator model. Zamani et al. (2006) reported that the type II functional responses of two aphid parasitoids, \(Aphidius colemani\) and \(A.\ matricariae\), to the cotton aphid were best described using Holling’s disc equation rather than the random predator equation. Fan and Petitt (1994, 1997) found that the Holling’s disc equation has been used most commonly to describe the type II functional response, although it has been criticized by Royama (1971) and Rogers (1972). Rogers (1972) acknowledged that both equations can be used to describe the same results but that the resultant estimates of instantaneous searching rate and handling time will be different because of different assumptions made in each. The random predator equation assumes a random search pattern, whereas the disc equation assumes a systematic search pattern with no area searched more than once. Consequently, the instantaneous searching rate \((a)\) calculated from the random predator equation is greater than that calculated from the disc equation. Our results and the results above indicate that searching behavior of \(C.\ septumpunctata\) and \(H.\ axyridis\) is not random, but systematic, probably because of the use of semiochemical cues (Magro et al. 2007).

The predation capacity of a specific coccinellid varies with the prey species. We predicted theoretical maximum values of predation of 204 and 277 adult soybean aphids per third instar and female adult per day, respectively. Xia et al. (2003) reported that \(C.\ septumpunctata\) had a handling rate of 120 adult cotton aphids per third instar per day and 206 per adult female per day at similar temperatures to our study. When evaluating the potential for a particular predator as a biological control agent, it is critical to assess its predation capacity (Lucas et al. 1997). Quantitative models of interactions between predator and prey can be used to predict prey–predator dynamics (Hassell 1978). \(H.\ axyridis\) and \(C.\ septumpunctata\) are known predators of soybean aphid throughout its North American range (Rutledge et al. 2004, Costamagna and Landis 2007); assuming no great genetic differences among populations that impact predation capacity, our results have the potential to help quantify impact of these predators on soybean aphid populations outside our study area. These predators have high predation capacity and great potential to suppress soybean populations, which suggests that the development of dynamic action thresholds that incorporate natural enemy numbers is warranted. Dynamic action thresholds could be developed based on functional response curves and predation capacities of key predators.
predators in conjunction with projections of aphid population growth under given environmental conditions. However, field studies will be needed to validate the dynamic action threshold, because laboratory studies may not accurately reflect field predation rates. Giving consideration to field observations of both aphid and lady beetle populations before making an insecticide application has the potential to reduce insecticide use against the soybean aphid, as well as to help preserve natural enemy populations.

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