Bionomics of *Scymnus* (*Pullus*) *louisianae* J. Chapin (Coleoptera: Coccinellidae) as a Predator of the Soybean Aphid, *Aphis glycines* Matsumura (Homoptera: Aphididae)

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ABSTRACT   A field population of *Scymnus louisianae* Chapin (Coccinellidae) was found attacking soybean aphids, *Aphis glycines* Matsumura (Aphidae), a pest recently introduced into Kentucky. This coccinellid had not previously been found in Kentucky. A greenhouse population of *S. louisianae* was established and its predation on *A. glycines* studied under laboratory conditions. Total time to develop from egg to adult was about 20 d. About 70% of immatures survived to adulthood and they consumed ≈100 aphid nymphs per beetle larva during the beetle's four larval instars. Adults lived for an average of 47 d (mated males) and 63 d (mated females) and, during their total adult lifetime, mated males consumed an average of 665 nymphs and mated females consumed 1261 nymphs. All developmental times and predation rates were comparable to those reported for other aphidophagous *Scymnus* spp. which, in conjunction with reports that *Scymnus* spp. are effective predators of cotton aphids, *Aphis gossypii* Glover, suggests that *S. louisianae* is a potentially important predator of *A. glycines* in the southern United States.

KEY WORDS   biological control, integrated pest management (IPM), life table

THE RECENT INTRODUCTION of the soybean aphid, *Aphis glycines* Matsumura, into North America poses a threat to the Canadian and United States soybean crop. In its native Asia, this insect can reduce soybean production by over 25% because of feeding injury and by over 50% because of its virus vectoring ability (Soernatiningsih et al. 1991). The development of sound IPM practices is thus a priority. One potential IPM tactic for the management of this pest is biological control.

The soybean aphid is a relatively small aphid, about the same size as the closely related cotton aphid, *Aphis gossypii* Glover. Cotton aphids often are attacked by *Scymnus* spp., lady beetles whose adults are very small, dark brown, and easily overlooked in the field (Wells et al. 2001). In contrast to the adults, however, larvae of the Scymninae are easily recognized by their hairy wax coating, which reportedly is a defense against aphid tending ants (Agarwala and Yasuda 2001). According to Roberts (2001), "*Scymnus* larvae are often numerous, sometimes the only predator observed, in [cotton] aphid infested fields with high numbers of fire ants foraging on plants." Among the *Scymnus* species, the Louisiana lady beetle, *Scymnus louisianae* J. Chapin, is considered particularly effective at reducing cotton aphid populations (Vinson and Scarborough 1989) and population fluctuations of *Scymnus* spp. appear to be closely tied to the fluctuations of cotton aphid density (Wells et al. 2001).

Relative to the larger and more obvious Coccinellinae, there have been few studies of aphidophagous *Scymnus* spp. Buntin and Tamaki (1980) conducted a detailed field and laboratory investigation of *S. marginicollis* Mannerheim, a predator of green peach aphids, *Myzus persicae* Sulzer. Naranjo et al. (1990) and Gibson et al. (1992) studied the effects of fluctuating temperatures and different prey on the development, survival, and reproduction of *S. frontalis* F. All of these authors concluded that the *Scymnus* spp. they studied were particularly well suited to surviving periods of low prey density. This is an important trait for a biological control agent and suggests that, whenever a *Scymnus* species is found attacking a significant aphid pest, it would be worthwhile to investigate its potential role in an IPM program.

During the summer of 2001, we conducted field experiments on soybean aphids and plant yield response. In these studies, wax-covered coccinellid larvae were found attacking *A. glycines* although adult beetles were not observed in the field. In an effort to better understand the beetle's potential as a predator of this important new soybean pest, we established a greenhouse colony and conducted a bionomic investigation, the results of which are reported herein.

Materials and Methods

All aphids and predators used in this study were obtained from greenhouse colonies maintained at

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Table 1. Mean (±SEM) duration and head capsule width of immature stages of *Scymnus louisianae* reared on *Aphis glycines* in a growth chamber at 23 ± 2°C and 15:9 L:D. The initial cohort was 522 eggs and the successive decreases are because of mortality. To estimate adult lifespan, 50 adults of each sex were used

Immature stage	Number completing each stage	Duration (days)	Head capsule width (mm)
Egg	478	4.87 ± 0.24	—
Larva I	459	2.43 ± 0.17	0.21 ± 0.04
Larva II	437	2.01 ± 0.09	0.26 ± 0.04
Larva III	421	2.62 ± 0.07	0.32 ± 0.06
Larva IV	383	3.26 ± 0.10	0.37 ± 0.05
Pupa	367	4.89 ± 0.16	—
Adult Males	50	47.31 ± 1.11	—
Adult Females	50	63.23 ± 1.12	—

25 ± 5°C, 15:9 L:D (high-pressure sodium vapor illumination), and ambient humidity. Aphids were grown on soybean seedlings using 'AG5602' (Asgrow Corp., St. Louis, MO) planted in 10-cm peat pots and watered as needed with 0.02% 20:20:20 N:P:K. The original aphid colony was obtained from a greenhouse colony originally isolated from an Illinois field population (courtesy D. Voegtlin, IL, Nat. Hist. Survey). The coccinellid population was established from 26 field-collected larvae found feeding on soybean aphids on 19 June and 3 July 2001 in separate research plots located at the University of Kentucky Spindletop Research Farm, 15-km north of Lexington, KY. On those dates, the soybean plants were at V2 and V7 growth stages (Fehr and Caviness 1977), respectively. Larvae were transferred onto our greenhouse aphid colony and allowed to develop and mature.

Once the colony was established, ≈50 adults were examined by N. Vandenberg, Systematic Entomology Laboratory, National Museum of Natural History, Washington, DC. She determined the *Scymnus* specimens to be mostly *Scymnus* (*Pullus*) *louisianae* but there also was a single specimen of *S.* (*P.*) *lowei* Mulsant, a whitefly predator. Both *Scymnus* spp. are new records for Kentucky. Coloration was used to separate *S. lowei* from *S. louisianae; S. lowei* is brown with a black triangle on the elytra while *S. louisianae* is nearly all black. Voucher specimens were deposited with the National Entomological Collection, National Museum of Natural History, Washington, DC.

Table 2. Mean (± SEM) daily consumption rates of *Aphis glycines* by different life stages of *Scymnus louisianae* in a growth chamber at 23 ± 2°C and a photoperiod of 15:9 L:D (h)

Instar	n	Aphids consumed daily[a]	Cumulative stage total[b]
Larva I	459	1.32 ± 0.27	3.18 ± 0.19
Larva II	437	3.87 ± 0.21	7.89 ± 0.16
Larva III	421	9.23 ± 0.54	24.32 ± 1.41
Larva IV	383	19.51 ± 0.98	63.49 ± 2.87
Adult ♂	50	14.42 ± 0.57	665 ± 15.5
Adult ♀	50	20.84 ± 0.83	1261 ± 24.6

[a] Daily consumption rates corrected for nonpredation, aphid mortality using Abbott's (1925) formula.
[b] Mean cumulative prey consumed for each life stage was calculated over individuals and is not a simple product of mean aphids consumed per day and the mean instar duration from Table 1.

To collect *S. louisianae* eggs, the bottom of a 100 × 15 cm petri plate was lined with four layers of #1 qualitative filter paper which was moistened with 5 ml deionized water. A heavily infested (>100 aphids) soybean leaflet was then placed in the petri plate. A mating pair of *S. louisianae* adults was added to the plate which was then closed and placed in a growth chamber at 23 ± 2°C, 15:9 L:D. The leaflet was then examined daily for the presence of the singly laid eggs. When eggs were found, the leaflet was removed, the leaf tissue supporting the egg excised, and the eggs individually placed in a 28 ml clear plastic cup (Fill-Right Corp., Newark, NJ). Cups were housed in clear plastic crispers, 36 × 27 × 11 cm, containing moist paper towels (60 cups per crisper). These crispers were placed in a growth chamber at 23 ± 2°C, 15:9 L:D and each egg inspected twice per day until hatch. A total of 522 eggs were thus collected from 20 beetle pairs.

After hatching, each coccinellid larva was inspected for exuvia twice per day, when exuvia were found an instar transition was assumed to have occurred. At each inspection, each larva was provided with a fresh leaflet containing 15 small soybean aphids (first and second instars). Immature aphids were used to avoid the confusing effects of aphid reproduction. Inspection for exuvia and provisioning was performed at 0800 hours and at 1600 hours each day, when the old leaflet was removed along with any live aphids, and all live aphids counted. Finally, the larva, along with its fresh aphid supply, was returned to the growth chamber. This procedure iterated until each larva pupated. A total of 383 larvae were individually reared.

The larvae did not consume the entire aphid but, instead, sucked body fluids from their prey. The resulting cadaver could not be decisively distinguished from aphids dying from potentially other causes. To obtain the intrinsic mortality of aphids in this system, three fresh leaves with 15 aphids were prepared daily as above and individually placed in a cup without predators. Cups were stored in the same crispers as those containing predators and the controls were run concurrent with the predator study. Aphids were inspected every 24 h and those that did not move after stimulation with a camel hair brush were considered dead. Predator consumption rates were corrected for this "control" mortality using Abbott's (1925) formula.

Pupae were allowed to remain in the cups until eclosion. At that time, the adults were sexed and randomly paired until 50 mating pairs had been obtained. Mating pairs were allowed to remain *in copulo* for up to 4 h after which they were separated and individually provisioned with 50 aphids per day per beetle as described above. In those cups containing females, the cup sides, lids, and leaves were inspected daily and all eggs were counted and then removed or destroyed.

Results and Discussion

Newly laid eggs were almost transparent, measured 0.2 × 0.5 mm, and were predominately laid on the leaf undersurface, nestled among the leaf hairs. Eggs were
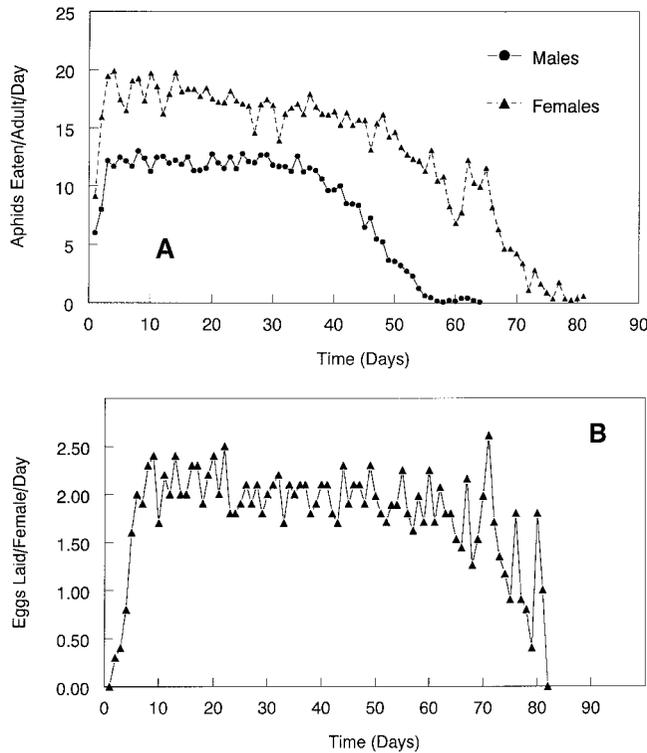
Fig. 1.   Performance of 50 male and female *Scymnus louisianae* Mulsant adults. (A) Mean aphids eaten per beetle each day posteclosion throughout the lifespan of both sexes and (B) the mean eggs laid per day by the females over their entire adult life.

rarely found to be laid off the leaf (9% of the total eggs). Neonate larvae were initially devoid of wax but usually the wax coating began to appear the following day. A few larvae (actual number not recorded but we estimate the frequency to be <5%) did not develop visible wax until the second instar.

Total time in each immature stage is shown in Table 1. Four larval instars were found and the total time required to go from egg to adult was about 20 d. This duration is about the same as that reported for several *Scymnus* spp. (Davidson 1923, Tawfik et al. 1973, Buntin and Tamaki 1980, Naranjo et al. 1990, Gibson et al. 1992), which vary from 17–22 d depending on species, rearing temperature, and prey species. From Table 1, the egg-adult survivorship was 70.3% (367 adults obtained from 522 eggs) which is similar to the 69% immature survivorship reported by Buntin and Tamaki (1980) for *S. marginicollis.*

Adult male longevity was ≈75% of that observed for females (Table 1). In both sexes, this longevity is about 20 d shorter than that reported for *S. interruptus* Goez (Tawfik et al. 1973), about half that for *S. frontalis* (Gibson et al. 1992) but about 15 d longer than that reported for *S. hoffmani* Weise (Kawauchi 1991).

Mean corrected predation rates (aphids eaten per individual per day) by life stage are shown in Table 2. Over the entire experimental period, daily mortality on the leaves without predators was 1.21 ± 0.13 aphids per leaflet per day or ≈8% although it ranged from a daily 3-leaflet mean of 0–2.3 over the ≈4 mo in the experiment.

The results in Table 2 indicate that, after correction for experimental aphid mortality, the larval instars of *S. louisianae* consume a total of ≈100 *A. glycines* nymphs. Compared with *Scymnus* spp., this is intermediate among reported prey consumption rates which vary from 16 *M. persicae* (Buntin and Tamaki 1980) to over 200 *A. punicae* Passerini (Tawfik et al. 1973) consumed during the larval stages. This wide reported range is likely a result of experimental details as well as prey size. For example, we used small nymphs of a small aphid species whereas Buntin and Tamaki (1980) used adult apterae of a medium-sized aphid. Perhaps a better way of expressing total consumption would be in terms of prey and predator biomass. In our study, mature larvae weighed ≈3.4 mg while the *A. glycines* nymphs that we used weighed 0.13 mg. Thus, 100 nymphs represent ≈3.8 times the body weight of a fourth instar. We do not have comparable results for the other *Scymnus* species.

Adults consumed many more aphids than did immatures. Males ate about half as many aphids as did females (Table 2), about the same ratio as that reported for *S. marginicollis* (Buntin and Tamaki 1980). The mean total number of aphids eaten per adult each day by both males and females is shown on Fig. 1A. For both sexes, aphid consumption was lower in the first

few days posteclosion but thereafter remained relatively constant over ≈70% of the adult life span.

Adults began mating about a day after eclosion and females began producing eggs on the third day posteclosion (Fig. 1B). This was the same preovipositional period reported by Buntin and Tamaki (1980) for *S. marginicollis* but much shorter than the 10–11 d preovipositional period observed by Gibson et al. (1992) for *S. frontalis.*

After the preoviposition period, the oviposition rate increased rapidly until around day 10 after which it gradually decreased throughout most of the population's life (Fig. 1B). The overall mean lifetime egg production was 122.04 ± 2.63 eggs per female. This is generally comparable to total egg production in other aphidophagous *Scymnus* spp. For example, Kawauchi (1985) found that *S. hoffmanni* produced an average 126.9 eggs per female at 25°C; Gibson et al. (1992) reported that *S. frontalis* averaged 151.3 eggs per female at 22°C; Buntin and Tamaki (1980) observed *S. marginicollis* to produce 75 eggs per female at 20–25°C.

An overall conclusion of this study is that *S. louisianae,* when provided with *A. glycines* as the sole prey source, exhibits developmental times, survivorship, oviposition and predation rates which are fairly typical of other aphidophagous *Scymnus* spp. This is important because, in the few studies comparing *Scymnus* spp. bionomics on different prey, survival, development time, and oviposition can all be affected by the host aphid species (Gibson et al. 1992). That this population of *S. louisianae* can attack a new aphid species (with which it has no history) and still have "typical" bionomics is indeed encouraging for its potential use as a biological control agent.

Certainly these results are not directly applicable to actual field management of *A. glycines.* They do, however, indicate that this beetle is potentially an important biological control agent for soybean aphid management. Because of its small size and dark coloration, the beetle is easily overlooked, especially relative to other coccinellids, yet each consumes roughly 750 aphids (males) to 1350 aphids (females) in its lifetime. The beetle can evidently also use other prey as well and other aphidophagous *Scymnus* species are considered especially well adapted to persist under low prey densities (Buntin and Tamaki 1980, Naranjo et al. 1990, Gibson et al. 1992). The ability of the beetle to survive and reproduce using *A. glycines,* its high prey consumption rate, and its prevalence in southern states make it a species worth further study for its biological control potential of this important aphid pest.

Acknowledgments

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