# IMPACT OF *HARMONIA AXYRIDIS* (COLEOPTERA: COCCINELLIDAE) ON NATIVE ARTHROPOD PREDATORS IN PECAN AND CRAPE MYRTLE

RUSSELL F. MIZELL III
NFREC-Quincy, University of Florida, 155 Research Road, Quincy, FL 32351

ABSTRACT

*Harmonia axyridis* (Pallas) was first detected in north Florida in 1993 feeding on crape myrtle aphids, *Sarucallis kahawaluokalani* (Kirkaldy) on crape myrtle, *Lagerstroemia indica* L. This lady beetle spread rapidly and was instrumental in reducing populations of the yellow pecan aphid complex, *Monellia caryella* (Fitch) and *Monelliopsis pecanis* Bissell, in pecan as well as crapemyrtle aphids. Prior to the arrival of *H. axyridis* to north Florida, the population dynamics of the yellow pecan aphid complex were compared to those of the crapemyrtle aphid and their common arthropod predators. The current study, conducted 8 and 9 years after the arrival of *H. axyridis*, sampled the same locations and some of the same trees reported previously. This research compares the current aphid and arthropod predator populations with the earlier results to determine the impact of *H. axyridis*. Prior to the addition of *H. axyridis*, aphid populations achieved high numbers and the lady beetles, *Hippodamia convergens* (Guerin-Meneville), *Olla v-nigrum* (Mulsant), *Coleomegilla maculata* (DeGeer), *Cycloneda sanguinea* L. and *C. munda* (Say) were the most frequently observed predators. In 1984-1985, other common predators included the green lacewing, *Chrysoperla rufilabris* (Burmeister), the brown lacewings, *Micromus posticus* (Walker), and *Hemerobius stigma* (Stephens), the mirid, *Deraeocorus nebulosus* (Uhler), the reduviids, *Zelus exsanguis* (Stahl) and *Sinea spinipes* (Herrich-Schaeffer), the hover flies, *Allograpta obliqua* (Say) and *Mesograpta* sp., the anthocorid, *Orius insidious* (Say), and spiders. A parasitoid of pecan aphids, *Aphelinus perpallidus* Gahan, was also common. Recent sampling showed *H. axyridis* to be the dominant predator of aphid populations. Populations of the aphids and the native predator and parasitoid species are dramatically reduced. Only spiders and the reduviids, species potentially involved in intraguild predation with *H. axyridis*, were detected.

Key Words: aphids, Coccinellidae, crape myrtle, *Harmonia axyridis*, lacewing, predator, pecan, intraguild predation, *Sarucallis kahawaluokalani*, *Monellia caryella*, *Monelliopsis pecanis*

RESUMEN

*Harmonia axyridis* (Pallas) fue detectado por primera vez en 1993 en el norte de la Florida alimentandose del áfido, *Sarucallis kahawaluokalani* (Kirkaldy) en mirto, *Lagerstroemia indica* L. Esta mariquita ha desparecido rapidamente y fue instrumental en la disminuación de poblaciones del complejo del áfido amarillo de pecan, *Monellia caryella* (Fitch), asi como de *Monelliopsis pecanis* Bissell, áfidos del pecan y mirto. Antes de la llegada de *H. axyridis* en el norte de la Florida, la dinámica poblacional complejo del áfido amarillo del pecan fue comparado con la dinámica poblacional del áfido del mirto y sus depredadores artrópodos comunes. El estudio actual, realizado 8 y 9 años después de la llegada de *H. axyridis*, mostrearon las mismas localidades y algunos de los árboles reportados anteriormente. Esta investigación comparó poblaciones actuales del áfido y los depredadores artrópodos con los resultados anteriores para determinar el impacto de *H. axyridis*. Antes de la llegada de *H. axyridis*, la población de los áfidos fue mas alta y las mariquitas, *Hippodamia convergens* (Guerin-Meneville), *Olla v-nigrum* (Mulsant), *Coleomegilla maculata* (DeGeer), *Cycloneda sanguinea* L. y *C. munda* (Say) fueron los depredadores mas frecuentemente observados. En 1984-1985, otros depredadores comunes incluyeron: los neurópteros, *Chrysoperla rufilabris* (Burmeister), *Micromus posticus* (Walker) y *Hemerobius stigma* (Stephens); el mírido, *Deraeocorus nebulosus* (Uhler); los reduvíidos, *Zelus exsanguis* (Stahl) y *Sinea spinipes* (Herrich-Schaeffer); las moscas, *Allograpta obliqua* (Say) y *Mesograpta* sp.; el antócorido, *Orius insidious* (Say); y arañas. El parasitoide del áfido del pecan, *Aphelinus perpallidus* Gahan, fue de los mas común. Un muestreo reciente mostro que *H. axyridis* es el depredador dominante en las poblaciones de áfidos. Las poblaciones de los áfidos, los depredadores nativos y los parasitoides fueron dramaticamente reducidas. Solamente fueron detectadas especies de arañas y de reduvíidos, que son potencialmente participes en depredación intracompetitiva con *H. axyridis*.

*Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), the multicolored Asian lady beetle, has become established in southern Canada (Coderre et al. 1995) and throughout much of the U.S. (Chapin & Brou 1991; Dreistadt et al. 1995; LaMana & Miller 1996) in arboreal and herbaceous habitats (Tedders & Schaefer 1994; Krafsur et al. 1997; Brown & Miller 1998). It is a voracious predator of aphids (Brown & Miller 1998), psyllids (Iablokoff-Khnzorian 1982), scales, mites (Cho et al. 1996), and the eggs and larvae of Lepidoptera and Coleoptera (Krafsur et al. 1997; Stuart et al. 2002). *Harmonia axyridis* has excellent searching ability and uses olfactory and visual cues from plants and prey to find food (Obata 1986). At many locations *H. axyridis* has become the dominant predator in arboreal habitats (LeMana & Miller 1996; Brown & Miller 1998) and in many agronomic crops (Colunga-Garcia & Gage 1998). Nault & Kennedy (2003) reported that *H. axyridis* was established in eastern North Carolina in wheat, potato, and corn but not soybeans.

Unfortunately, *H. axyridis* has become a major nuisance pest (Tangley 1999) and a public health pest (Yarbrough et al. 1999; Magnan et al. 2002) throughout its new range due to its gregarious overwintering behavior inside human dwellings. Additionally, it has become an important contaminant of wine grapes (Galvan et al. 2006) and pest of other fruits (Koch et al. 2004).

Koch (2003) and Pervez & Omkar (2006) discussed the extensive intraguild predation by *H. axyridis* on other lady beetles as well as on other predacious insects. Snyder et al. (2004) reported that larvae of 2 species of native coccinellids rarely survived encounters with *H. axyiridis* larvae. Michaud (2003) showed that *H. axyridis* larvae cannibalized siblings at lower rates than nonsiblings in contrast to 2 native coccinellids. Pervez & Omkar (2006) observed that *H. axyridis* relied on its larger size and more effective defensive behaviors to gain advantage over native coccinellids.

*Harmonia axyridis* has extended its range to include most of Florida and has been observed feeding on a variety of pests on pecan, *Carya illinoensis* [(Wangenh) K. Koch], ornamentals, citrus, agronomic crops, and vegetables (Mizell 1999, unpublished). Michaud (2002) reported the population dynamics of *H. axyridis* and the native coccinellid, *Cycloneda sanguinea* L., in citrus and found that *H. axyridis* is now the dominant predator in many citrus habitats where *C. sanguinea* had been previously.

The yellow pecan aphid complex (YPAC) consists of the yellow pecan aphid, *Monelliopsis pecanis* Bissell and the blackmargined aphid, *Monellia caryella* (Fitch). These aphids have similar life histories and in the southern U.S. east of the Mississippi River usually exhibit bimodal populations with peaks occurring in May-Jun and Aug-Oct (Tedders 1978; Dutcher & Payne 1983; Edelson & Estes 1983; Alverson & English 1990). The early population peak is usually much lower (<30 per compound leaf) than the late season peak which can reach >100 per compound leaf. A large number of predatory arthropods and a hymenopterous parasitoid, *Aphelinus perpallidus* Gahan, attack pecan aphids. However, prior to the arrival of *H. axyridis*, the YPAC reached high numbers consistently wherever pecan occurred in the pecan belt east of the Mississippi River (Tedders 1976; 1978; Dutcher & Payne 1983; Edelson & Estes 1987; Liao et al. 1984).

Crape myrtle, *Lagerstroemia indica* L., is one of the most common and important ornamental plant species in the Southeastern U.S. Like *H. axyridis*, crape myrtle is an exotic introduction from southeast Asia and is infested by the host-specific crapemyrtle aphid, *Sarucallis kahawaluokalani* (Kirkaldy) (Mizell & Schiffhauer 1987; Mizell & Knox 1993). *S. kahawaluokalani* is a preferred prey of *H. axyridis* in north Florida and is a very important mid-summer host for many native predators (Mizell & Schiffhauer 1987; Mizell & Knox 1993; Williamson & Dutcher 2007). It has no known common parasitoids (Mizell et al. 2002).

Other workers have reported the dynamics of pecan aphids and their natural enemies in the southern U.S. (Tedders 1978; Dutcher & Payne 1983; Edelson & Estes 1983; Tedders et al. 1992). Mizell & Schiffhauer (1987) reported the population dynamics of predator species found on crape myrtle that were common on pecan in north Florida before the arrival of *H. axyridis*. This paper reports data from both crape myrtle and pecan in the same north Florida ecosystems from 8 and 9 years after the establishment of *H. axyridis*. The objectives were to quantify the abundance of crapemyrtle aphids and YPAC, their known predators and a parasitoid, and to determine the potential intraguild effects of *H. axyridis* by using before- and after-introduction comparisons.

## Materials and Methods

Locations for sampling were selected to maximize habitat variability and size, and ranged from plantings of single homogenous pecan and crape myrtle cultivars to sites with mixed cultivars in habitats surrounded with high host plant diversity. The main sample locations were within a <40-ha site, while supplemental samples within a 400-km radius were taken to determine if local populations reflected those over a larger geographical area.

Six locations within the 40-ha grounds of the North Florida Research and Education Center, Monticello, Florida (Table 1) were used for the main study and augmented with data from additional locations described below. The 3 crape myrtle plots are designated as locations I-III and the 3 pecan locations IV-VI.

Location I was in a 0.7-ha grassy field surrounded by forests of mixed hardwoods and pines and contained a 0.3-ha planting of mixed cultivars of crape myrtle and 2 smaller plantings of Japanese persimmon, *Diospyros khaki* L. Location I was 300 m northeast of location III and 250 m

TABLE 1. LOCATIONS AND COORDINATES (LONGITUDE OVER LATITUDE) OF MAIN STUDY LOCATIONS AND THE EXTRA LOCATIONS SAMPLED WITHIN 75 KM OF MONTICELLO TO AUGMENT THE OBSERVATIONS IN THE MAIN EXPERIMENTAL PLOTS IN 2001.

| City | State | Date | GIS Coordinates | Trees |
|---|---|---|---|---|
| Monticello I | FL | 31-V-1-XI | 30.53301-83.92084 | Pecan |
| Monticello II | FL | 31-V-1-XI | 30.53397-83.91907 | Crape myrtle |
| Monticello II/IV | FL | 31-V-1-XI | 30.53541-83.91698 | Pecan, Crape myrtle |
| Monticello V | FL | 31-V-1-XI | 30.53541-83.91698 | Pecan |
| Monticello VI | FL | 31-V-1-XI | 30.53934-83.91622 | Crape myrtle |
| Quincy | FL | 10-VIII | 30.55566-84.59262 | Pecan |
| Quincy | FL | 17-VIII | 30.55566-84.59262 | Pecan |
| Cairo | GA | 4-X | 30.90006-84.21459 | Pecan |
| Thomasville (Crocker) | GA | 12-XI | 30.73309-83.90079 | Crape myrtle |
| Monticello (Cheny) | FL | 18-XI | 30.64215-83.87448 | Pecan |

southwest of location IV. The crape myrtle trees were from 2-4 m in height and were mulched with coarse pine bark but received no other culture and management inputs. Eleven different cultivars of crape myrtle were sampled each week. Locations II and V were in the middle along the southern edge of a 30-ha field containing open pasture with several small plantings of blueberry, grape, various ornamentals, and pecan. Location II and V were separated from location I by 250 m of forest. The pecans were >20 years old, approximately 12 m in height. The crape myrtles were 10 years old and 2-3 m in height. Two 100-m rows of a single crape myrtle cultivar were planted between pecan rows and were location II. The crape myrtle was heavily pruned during the winter to a height of 1 m. The shoots were long, single stems as a result. Twenty crape myrtle trees were randomly chosen for sampling. Location II was destroyed in early 2002.

Location III was a 0.5-ha planting of mixed crape myrtle cultivars located approximately 50 m from location VI. The planting was 10 years old with trees 0.5 to 2 m in height and mulched with bark. Nine cultivars of crape myrtle were sampled.

Location IV contained 3 isolated pecan trees 15 years old and approximately 15 m in height in the northwest corner of a 3-ha field planted to peaches and surrounded by mixed pine and hardwood forests. The pecan trees received no culture or management inputs. Two of the 3 trees were sampled. This site was 300 m southwest of location I and was separated by a mixed hardwood forest.

Location V was a pecan orchard containing 23 cultivars with 1-4 replicates per cultivar planted unevenly within 5 rows running north to south with a 12 × 12-m spacing. In 2001 the pecan trees received 1 application of NPK 10:10:10 fertilizer and glyphosate herbicide within the rows and 2 applications of triphenyltin hydroxide, Supertin (Griffin Chemical Co., Valdosta, Georgia) fungicide in early season to control foliar pathogens. The trees received no inputs in 2002. Four pecans trees from the middle of the block and 4 pecan trees from the northwest edge of the block were sampled.

Location VI was in the same field as location II, III and V, but was 230 m north of locations II and V and 50 m south of III. This planting of 1.0 ha contained pecans 25 years old and <15 m in height. Five pecan trees on the east edge were used for the study. The trees received no culture and management inputs.

All sampling was completed in 1 d each week from 31 May-1 Nov 2001. Sampling during the second year, 2002, consisted of only 3 dates: 2 and 21 Sep and 19 Oct when the highest populations of pecan aphids are expected. The 5 main locations (location II had been removed) were sampled as in 2001and 5 terminals each from 10 additional pecan trees were sampled visually in location V to augment the main samples.

### Pecan Aphid Sampling

At all locations all life stages of the YPAC, *M. pecanis* and *M. caryella*, and mummies of their parasitoid, *Aphelinus perpallidus* Gahan, were quantified by visually examining and estimating the total aphids per terminal by counting aphids on all compound leaves of 5 terminals selected randomly around the circumference of the trees including samples from each cardinal direction. All foliage samples were selected by reaching from the ground (height <3 m) and aphid counts were estimated visually and recorded in the field. Aphid populations remained low in most plots throughout the season, thus facilitating the counts. Counts of YPAC were recorded in categories of 0, <5, <10, <25, <50, <75, >75 per terminal and averaged per terminal within trees and then by terminal over all trees. Counts are presented as mean aphids per terminal for each location.

### Crapemyrtle Aphid Sampling

Numbers of crapemyrtle aphids were estimated at all locations by visually examining 10 leaves on each of five 30-cm long terminal shoots per tree with shoots selected from around the circumference of the trees as above for YPAC. Crapemyrtle aphids reached high numbers on some trees and counts were estimated as described for pecan aphids. Counts were averaged per leaf within shoots, then per shoot within trees and finally, as mean aphids per shoot over all trees for each location.

Predator Sampling

Trees were sampled for predators with a small vacuum device powered by a portable generator. A vacuum cleaner was attached to either a 20-L bucket (pecan) or a 10 × 50-cm PVC pipe (crape myrtle). A series of funnels and additional PVC pipe allowed air to flow through the apparatus and a 250-mL collection vial inside the PVC attached to the bucket and pipe. Trees were sampled by moving around the bottom of the tree and randomly selecting terminals. Successive terminals around the tree were selected such that the next sample was not disturbed by the preceding sample. To complete a sample, a shoot was placed gently but quickly into the container (bucket or PVC pipe) and shaken vigorously into the vacuum stream. The terminal was removed and the sides of the container were rapped sharply to dislodge any insects from the walls into the collection vial. Previous work indicated the device was 98% efficient at removing motile stage of insects from leaves (Mizell 1988, unpublished). The vacuum device provided effective sampling of cryptic predators such as mirids and anthocorids often missed by visual inspections. After each sample, the apparatus was opened and the captured predators were identified, recorded and discarded in the field. On pecan, 10 terminals per tree were sampled. On crape myrtle, five 30-cm long stems or terminals representing 25-30 leaves each were sampled per tree except as noted in location II.

Supplemental Sampling

Due to the extreme results accumulated during the weekly sampling in comparison to Mizell & Schiffhauer (1987), a large number of additional visual samples were completed on pecan and crape myrtle at the main locations on most sample dates (data not shown). In order to determine if the population trends were specific to the main sampling locations or indicative of populations throughout North Florida and South Georgia, supplemental sampling was done in other locations on a number of dates in 2001 within 75 km of Monticello (Table 1). Locations in the landscape or orchard containing pecan or crape myrtle were visited and the aphids and predators were sampled and recorded, respectively, as described above. Additionally, on 6-7 Oct 2001, 14 locations in Alabama and Georgia (Table 2) were assessed for aphids and predators present on pecan and crape myrtle. GIS coordinates were recorded for each location (Table 2). The locations were visited once and were approximately 120 km apart. At each location pecan and/or crape myrtle in the landscape in unsprayed habitats were sampled. Aphids were estimated as described above. The presence of sooty mold as an indicator of the occurrence of past aphid populations was noted. Predators were sampled with a 50 × 150-cm beat

TABLE 2. LOCATIONS AND COORDINATES (LONGITUDE OVER LATITUDE) OF THE EXTRA LOCATIONS SAMPLED WITHIN ALABAMA, GEORGIA, AND FLORIDA TO AUGMENT THE OBSERVATIONS OF THE MAIN EXPERIMENTAL LOCATIONS.

| City | State | GIS Coordinates | Trees | Aphids | Predators |
|---|---|---|---|---|---|
| Bainbridge | GA | 30.53770-83.91696 | Pecan | <1 | 3 Ba[1] |
| Dothan | AL | 31.28319-85.46417 | Pecan | 0 | S |
| Brundage | AL | 31.28319-85.46420 | Pecan | <5 | 4Za, Ba, S |
| Troy | AL | 31.78007-85.94390 | Crape myrtle | <25 | 2Ha, 2Hl, D, Zn, Ca |
| Montgomery | AL | 32.32639-86.30412 | Pecan; Crape myrtle | 5; 10 | Ha, 2S; Ha, S |
| Birmingham | AL | 33.54384-86.58516 | Pecan; Crape myrtle | 5; <5 | 5S, Zn; Ha, Hl, Syl |
| Villa Rica | GA | 33.72469-84.93820 | Pecan; Crape myrtle | 5; <25 | S,4Ha; Ha, 4Hl, D |
| Villa Rica (2) | GA | 33.72469-84.93820 | Pecan | <10 | 4Ha, Zn, 5S |
| Madison | GA | 33.54836-83.50438 | Pecan | 0 | Ha, 7Zn |
| Milledgeville | GA | 33.09055-83.25175 | Pecan | 0 | Ha, 4Zn |
| Dublin | GA | 32.51898-82.92040 | Pecan | <1 | Ha, Ca, S |
| Douglas | GA | 32.51896-82.02039 | Pecan | <1 | 3Ha, Hl, Ba, Oa, Ol, 8S |
| Valdosta | GA | 30.82778-83.28597 | Pecan | <1 | Ha, 3S |

[1]Ba = brown lacewing adult, Ca = *Cycloneda munda* adult, D = *Deraeocorus nebulosus*, S = spiders, Ha = *Harmonia axyridis* adult, Hl = *H. axyridis* larva, Oa = *Olla v-nigrum* adult, Ol = *Olla v-nigrum* larva, Syl = syrphid larva, Za = *Zelus exsanguis* adult, Zn = *Zelus exsanguis* nymph.

sheet. Five to 10 beat-sheet samples were made on 3-5 trees at each location. The species, life stage and number of each predator were recorded.

Sampling Method Comparisons

Sampling methods used by Mizell & Schiffhauer (1987) and in this study differed in the following manner. Pecan aphids were counted and recorded by Mizell & Schiffhauer (1987) on 10 compound leaves per tree rather than by counts on terminals. Pecan terminals average 10-15 compound leaves, thus the counts in the present study are based on 10-15 times more leaves per sample than in Mizell & Schiffhauer (1987). Pecan predator numbers were not reported by Mizell & Schiffhauer (1987); however, the current pecan aphid and predator counts are directly comparable to the weekly sampling methods and results of Tedders (1978) based on samples of 25 compound leaves per tree, Dutcher & Payne (1983) based on terminal sampling of aphid nymphs ($n$ = 5/tree, >10 trees/week), and Edelson and Estes (1983; 1987) based on sampling 3 compound leaves from 8 terminals per each of 7 trees.

Crapemyrtle aphids were reported as aphids per shoot by Mizell & Schiffhauer (1987) as was done in this study. Crapemyrtle aphid predators were sampled with a sweep net by Mizell & Schiffhauer (1987) while sampling in the present study was by terminals. These samples are not directly comparable but the vacuum device and large terminals used in this study were more efficient for detection of all arthropods present than sweep net samples. No statistical tests were deemed appropriate due to differences in sampling methods. Statistical tests were deemed unnecessary because sampling methods were more efficient, sampling intensity was equivalent or usually much greater herein than in Mizell & Schiffhauer (1987), and because of the large disparity between the higher counts in the "before" samples (Fig. 1) and the zero or very low counts in the present study (Figs. 2-7).

Monthly average temperature and rainfall data from Tallahassee, FL were obtained from NOAA from the years 1983-1985 and 2000-2002. I used $t$-tests to compare differences in monthly mean rainfall or temperature between years for the 3 years in each of the 2 data sets.

## RESULTS

The crapemyrtle aphid and predator counts in 1984 prior (before data) to the colonization by *H. axyridis* are provided (Fig. 1). Crapemyrtle aphid numbers in 2001 (after data) in the 3 locations differed by at least an order of magnitude. During 2001 in location I (Fig. 2), crapemyrtle aphid populations peaked at 40 per leaf in late season. Spiders were present in highest numbers

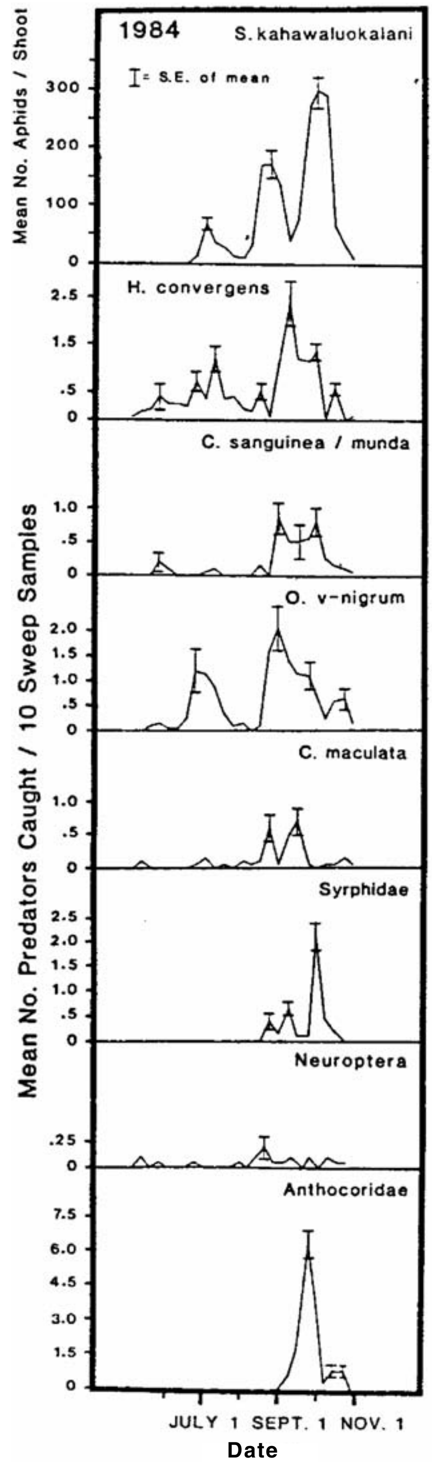


Fig. 1. Field data collected in 1984 from Mizell & Schiffhauer (1987, Fig. 3) showing relative predator numbers before the arrival of *Harmonia axyridis*. Used with permission of Biologische Bundesanstalt fur Land- und Forstwirtschaft Institut fur Biologischen Pflanzenschutz Heinrichstr.

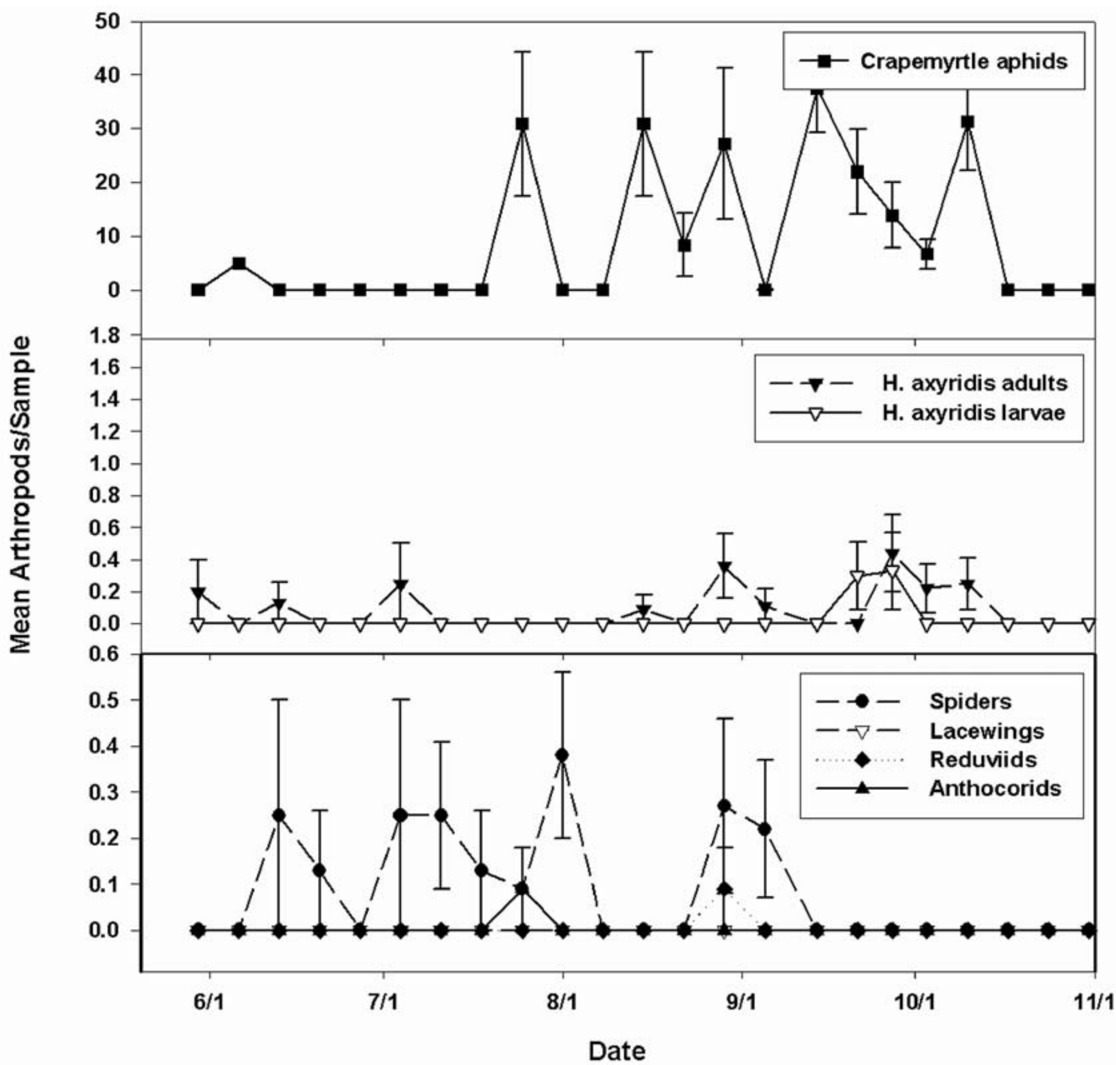


Fig. 2. Seasonal occurrence of crapemyrtle aphids and predators sampled in crape myrtle in location I.

in early and mid season, and *H. axyridis* adults were present for much of the season while larvae peaked in late season. Reduviids were detected in late season. No other predators were detected.

Crapemyrtle aphids were much lower in location II (Fig. 3). The crape myrtles in location II were heavily shaded by pecan, which adversely affects susceptibility to crapemyrtle aphids. In location II crapemyrtle aphids and predator populations remained low. However, spiders were present for much of the season, while *H. axyridis* was detected intermittently over the season. No other predators were detected.

In location III (Fig. 4) crapemyrtle aphid populations achieved relatively higher numbers and peaked twice in mid and late season. Spiders were present intermittently over the season peaking early and between the aphid peaks. *Harmonia axyridis* adults were detected from mid to the end of the season and remained higher over the entire period when aphids were present, but *H. axyridis* larvae were observed only in late season. No other predators were detected.

Predator species composition and relative numbers of predators were the same in all locations. Adults and larvae of *H. axyridis*, spiders, reduviids, and an occasional brown or green lacewing were the only predators sampled. Other coccinellid species, syrphids, mirids, anthocorids and the aphid parasitoid were not detected. On the 3 sample dates in 2002, crape myrtle aphids averaged <5 per leaf at both locations. Predator numbers were again low and represented the limited species diversity as in 2001 (data not shown).

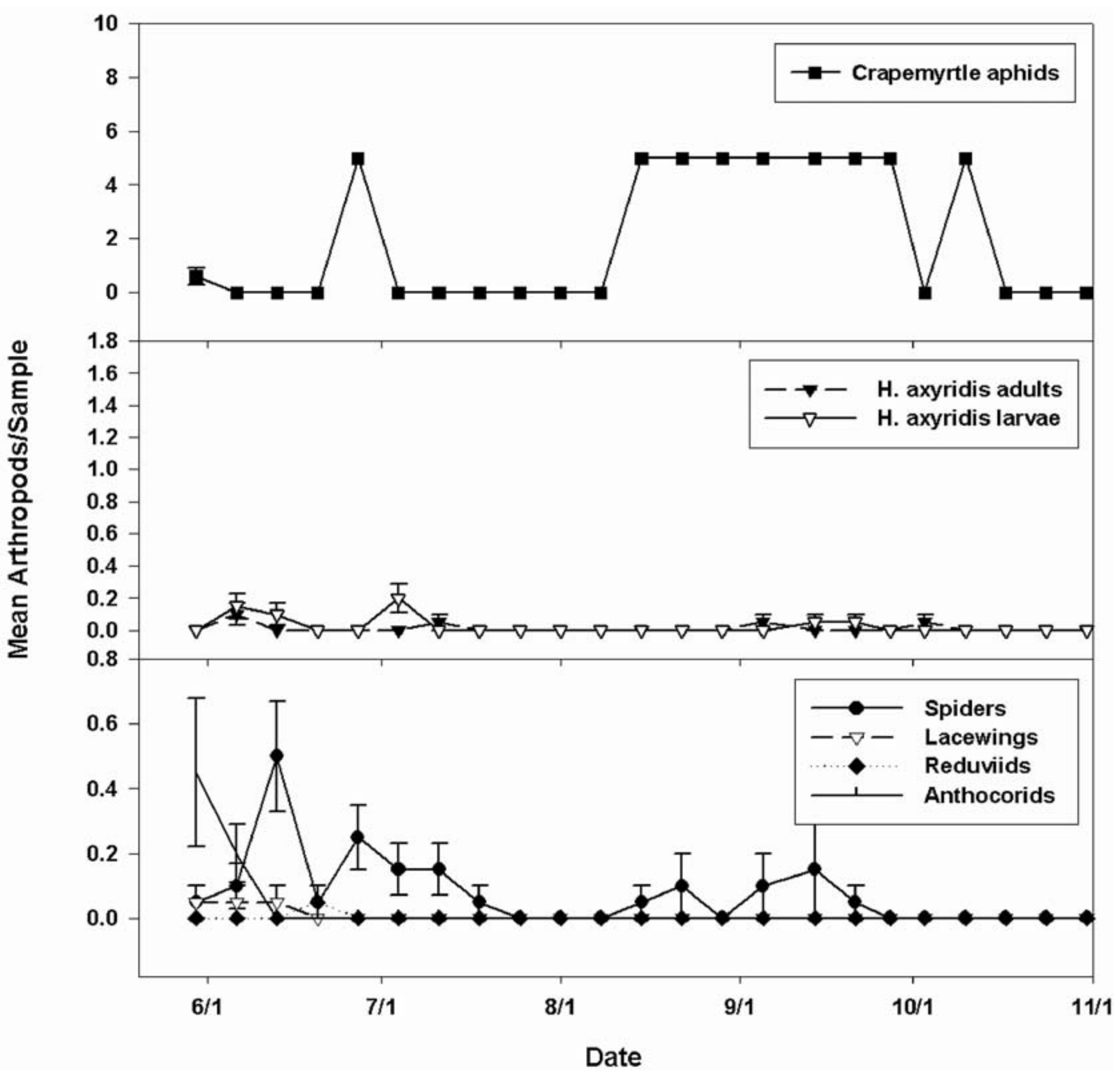


Fig. 3. Seasonal occurrence of crapemyrtle aphids and predators sampled in crape myrtle in location II.

In location IV, the expected early season peak during May-Jun 2001 was not observed, but the YPAC peaked in late season below 40 aphids per terminal (Fig. 5). Spiders were present throughout the season as were adult *H. axyridis*, with *H. axyridis* larvae peaking in early and late season. Green lacewings were detected at low numbers in mid season on 9 Aug and 21 Aug. Trees in location IV defoliated a few weeks earlier than trees in location V. No other predators or the parasitoid were detected. Similar results on pecan predators were found in 2002 for the 3 pecan locations on the 3 sample dates, whereas pecan aphids averaged <10 per terminal (data not shown).

In location V (Fig. 6) YPAC never reached high numbers but several peaks were detected from mid to late season. Again, the expected early season peak during May-Jun was not observed. Adults of *H. axyridis* were present throughout the season but reached highest numbers at the end of the season. These trees were treated with fungicides and retained their leaves along with associated arthropods until the first frost. This enabled the higher numbers of *H. axyridis* adults at the end of the season in this location. Larvae of *H. axyridis* occurred in late season but did not appear related to the timing of increases in aphid populations. As in the other locations, spiders, although in low numbers, were present throughout the season. Lacewings were also detected over much of the season in this location. No other predators or the parasitoid were detected.

In location VI (Fig. 7) YPAC peaked in moderate numbers in late season. Aphid numbers were

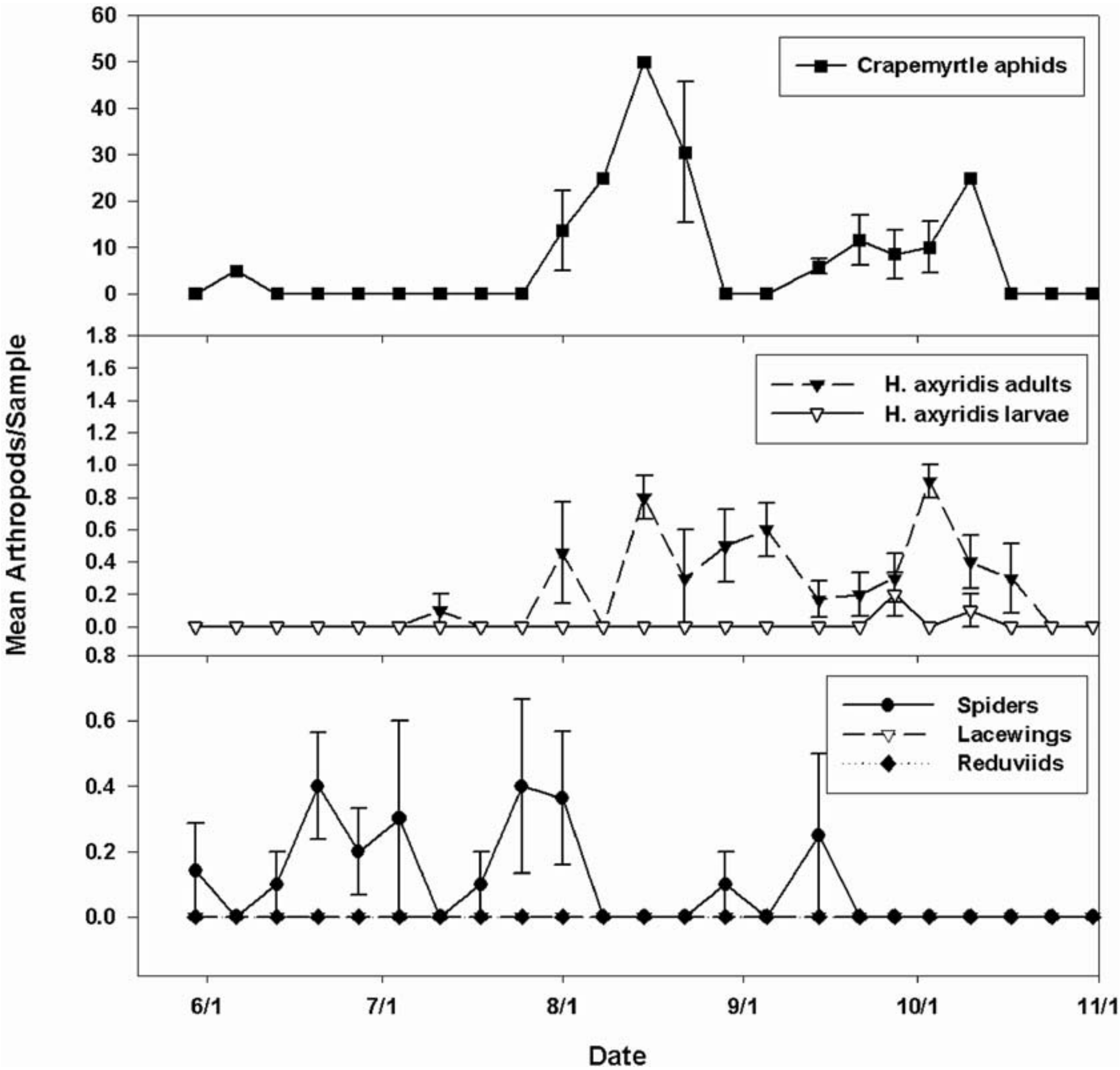


Fig. 4. Seasonal occurrence of crapemyrtle aphids and predators sampled in crape myrtle in location III.

much lower (50 per terminal) in comparison to average aphid numbers prior to the arrival of *H. axyridis.* Again, the expected early season peak during May-Jun was not observed. *Harmonia axyridis* adults were present throughout the season but reached highest numbers at the end of the season, and *H. axyridis* larvae occurred in late season following the peak in YPAC. Spiders were present throughout the season with 1 peak early before the YPAC peaked. Reduviids peaked in late season when YPAC peaked. No other predators or the parasitoid were detected

Results from the 14 locations visited (Table 2) in Alabama and Georgia mirrored the population trends found at other sites. YPAC were low and they should have been high when the trees were visited. Trees also lacked sooty mold on the leaves indicating that YPAC numbers had likely remained low over the season. No parasitoid mummies that usually stick to the leaves for sometime were observed on any trees. Most of the crape myrtles sampled were covered with heavy sooty mold indicating crapemyrtle aphids were or had been present in high numbers. Several adults of the mirid, *Deraeocorus nebulosus* (Uhler), were captured on crape myrtle at Troy, Alabama and Villa Rica-2, Georgia and represent the only specimens of this cryptic predator captured in this study. This is a dramatic contrast to the "before" data (Fig. 1).

The population trends found for the aphids and predators in all the samples from supplemental locations and dates were similar to those found in the 6 main locations in Monticello from

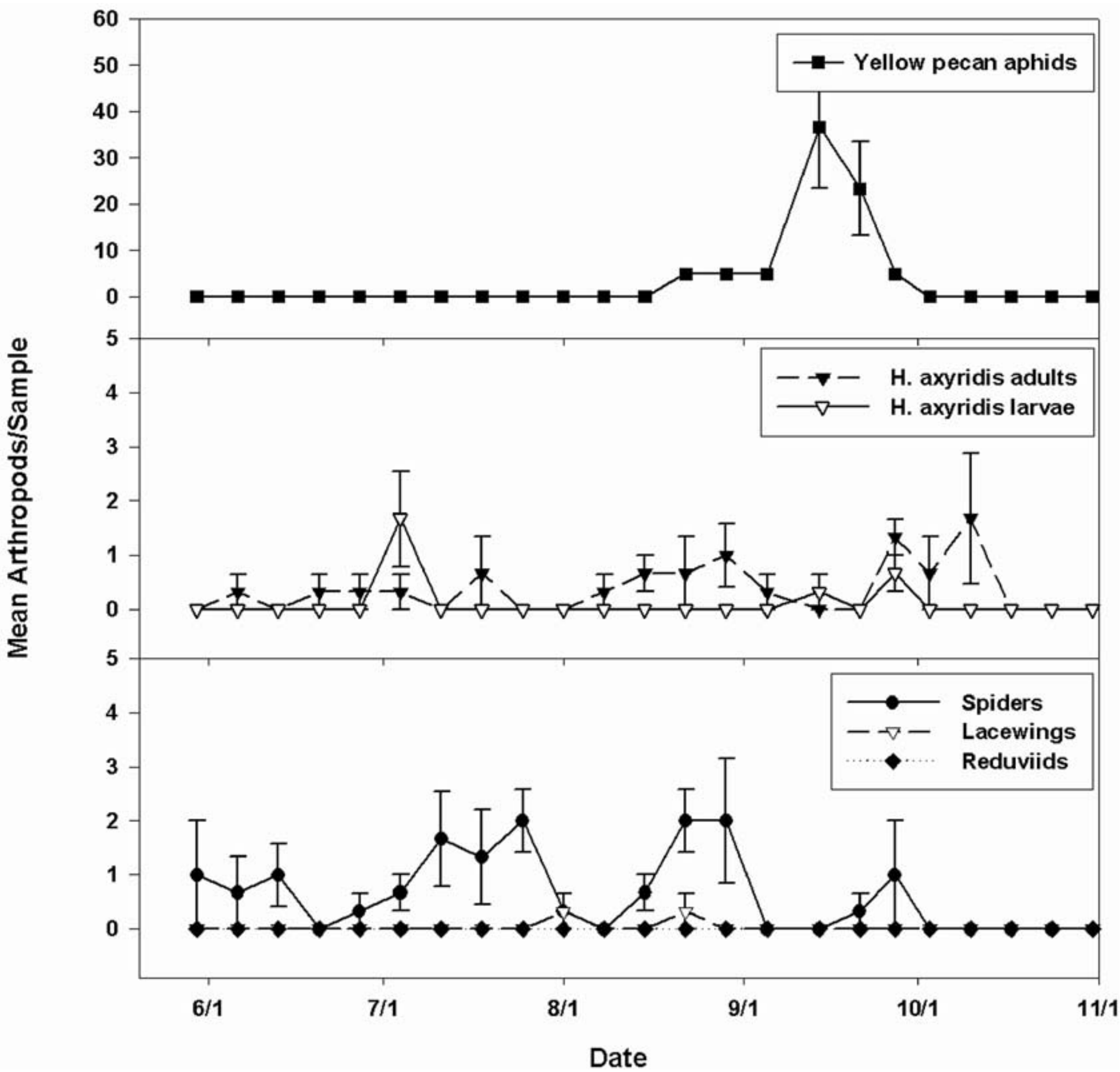


Fig. 5. Seasonal occurrence of the yellow pecan aphid complex and predators sampled in pecan in location IV.

both years (data not shown). YPAC were found in low numbers and the predators observed were *H. axyridis* larvae and adults, spiders, reduviids and an occasional brown or green lacewing. Crapemyrtle aphid populations were quite variable. Predator species were similar to those found in pecan. A single *O. v-nigrum* (Mulsant) larva and 1 adult were captured on the crape myrtle in Quincy, Florida on 10 Aug 2001.

No significant differences in mean monthly rainfall or temperature were found between any 2 years in either the before or after datasets (data not shown). Therefore, weather differences were likely not a factor in mediating the changes in insect numbers observed during the years sampled in this and Mizell and Schiffhauer (1987).

## Discussion

Mizell & Schiffhauer (their Figs. 3 and 4) (1987) (Fig. 1 is 1984) provides the before baseline numbers of crapemyrtle aphids, YPAC, and the predator species present in crape myrtle before *H. axyridis* arrival. *Harmonia axyridis* suppressed crapemyrtle aphids on individual trees to levels much lower (Figs. 2-4) than those observed on average prior (Fig. 1) to its 1993 arrival. At many locations and dates crape myrtles which are more widely distributed in higher numbers than pecan across the region were found with high numbers of crapemyrtle aphids but without *H. axyridis*. Moreover, in the absence of *H. axyridis*, the native predators were not present on these trees like

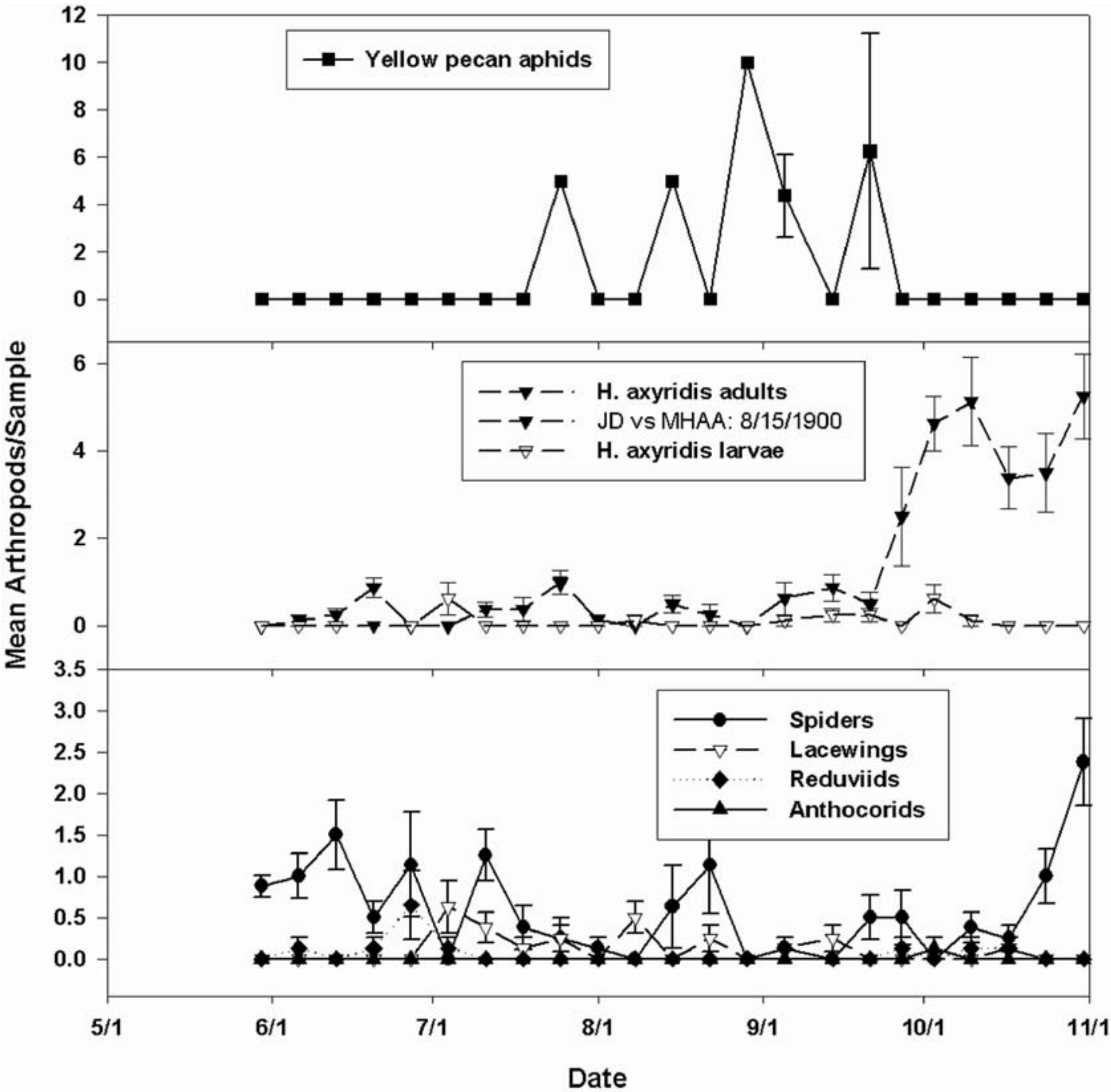


Fig. 6. Seasonal occurrence of the yellow pecan aphid complex and predators sampled in pecan in location V.

they were in the previous study. This suggests an impact on the native fauna from *H. axyridis* at the habitat level in addition to those likely occurring on individual plants (Hironori & Katsuhiro 1997; Cottrell & Yeargan 1998; Phoofolo & Obrycki 1998; Kajita et al. 2000; Michaud 2002; Koch 2003).

These same native predator species in crape myrtle are common on the native pecan throughout its range (Tedders 1976; Liao et al. 1984; Edelson & Estes 1987; Tedders et al 1990; Dutcher et al. 1999; Mizell, unpublished 1985-1988). Common predators included the green lacewing, *Chrysoperla rufilabris* (Burmeister), the brown lacewings, *Micromus posticus* (Walker), and *Hemerobius* sp., the mirid, *D. nebulosus*, the reduviids, *Zelus exsanguis* (Stal) and *Sinea spinipes* (Herrich-Schaeffer), the syrphids, *Allograpta obliqua* (Say) and *Mesograpta* sp., the anthocorid, *Orius insidious* (Say); the lady beetles, *Hippodamia convergens* (Guerin-Meneville), *O. v-nigrum*, *Coleomegilla maculata* (DeGeer), *Cycloneda sanguinea* and *C. munda* (Say). Bumroongsook et al. (1992) reported the predation by spiders on pecan aphids and estimated spider populations in pecan at 1 spider per 10-100 leaves. The numbers of spiders recorded in the samples in this study fall within the range reported by Bumroongsook et al. (1992). To augment this predator complex, crape myrtle was touted as a potential plant to enhance pecan aphid biological control (Mizell & Schiffhauer 1987).

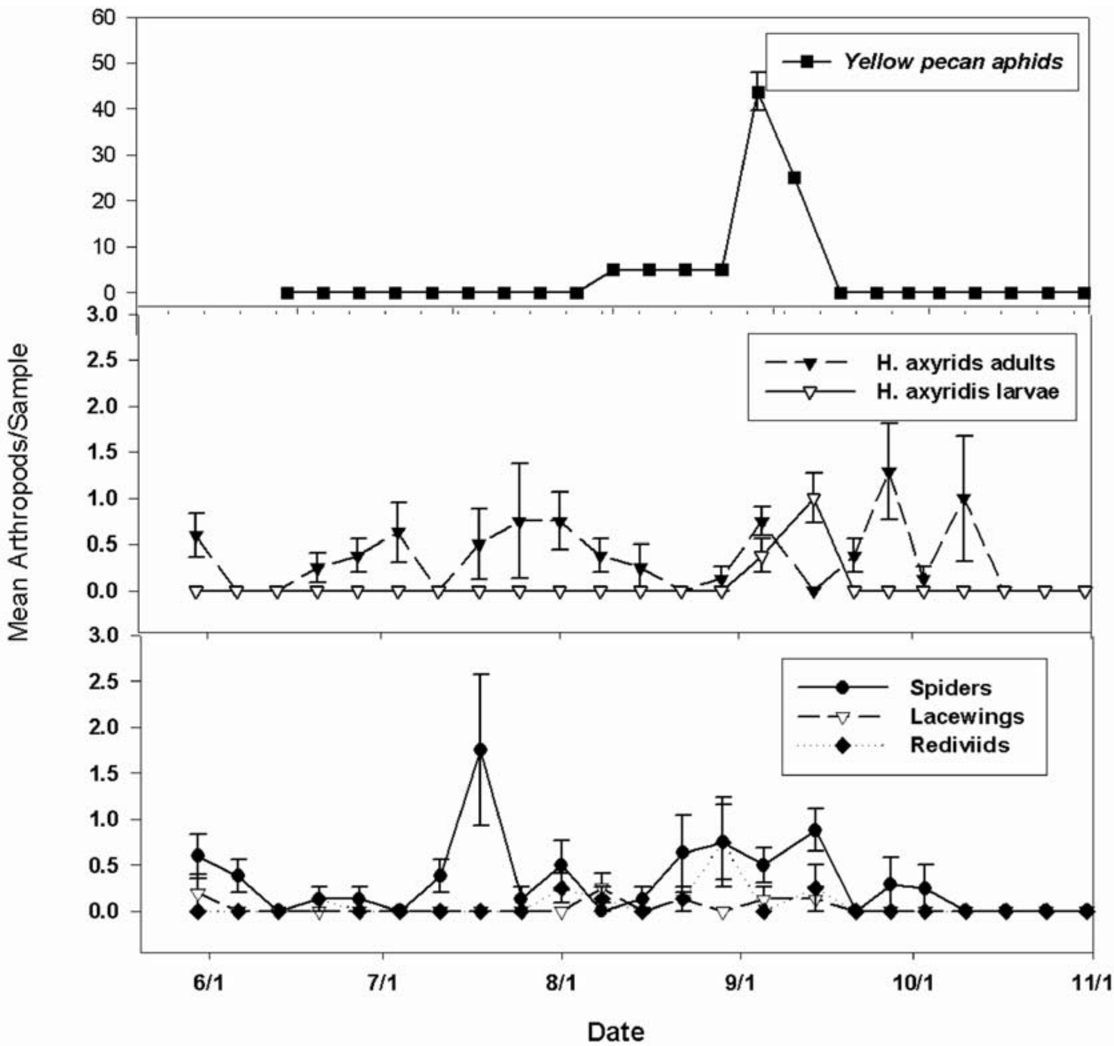


Fig. 7. Seasonal occurrence of the yellow pecan aphid complex and predators sampled in pecan in location VI.

Following its arrival, *H. axyridis* appears to have become the dominant predator and populations of the YPAC and native predator species were dramatically reduced. No native coccinellids, syrphids, mirids, or anthocorids were detected in these "after" samples. Brown or green lacewing larvae or adults were rarely recorded in pecan. Only spiders and reduviids, some species of which likely engage in intraguild predation on *H. axyridis* (Eubanks 2001), were present in any detectable numbers.

Populations of the YPAC in all locations were well below the aphid numbers observed prior to the arrival of *H. axyridis*. Before *H. axyridis*, yellow pecan aphids exhibited 2 population peaks and commonly reached numbers from 100-1000 per terminal (Tedders 1978; Edelson & Estes 1983; Dutcher & Payne 1983; Mizell & Schiffhauer 1987). *Harmonia axyridis* likely impacted the pecan aphid parasitoid, *A. perpallidus*, since the parasitoid was common on pecan aphids across the pecan belt prior to *H. axyridis* arrival (Tedders 1978; Edelson & Estes 1983; Dutcher & Payne 1983; Mizell, personnel observation). No parasitized aphid mummies were observed during this study. Edelson & Estes (1987) reported that *A. perpallidus* reached peak numbers in Alabama in response to peak aphid numbers in early and late season. Based on samples of 25 compound pecan leaves, Tedders (1978) reported that *A. perpallidus* reached numbers in middle Georgia as high as 120 parasitoids per sample. The suppression of pecan aphids and the likely consumption of parasitized aphids by *H. axyridis* (Takaziwa et al. 2000) probably led to the dramatic suppression of the parasitoid from the studied habitats.

Uniformly lower populations of the YPAC have been reported on pecan throughout the Southeast following the colonization of *H. axyridis*. Florida pecan growers (unpublished informal survey of 10-30 growers at 2002-2005 Florida Pecan Growers Association meeting) and growers in other states in the Southeast where YPAC were a primary pest (GA, MS, LA, minutes of the regional pecan project SDC306), indicate that the number of applications per year of insecticides targeted for the YPAC have decreased markedly from 5-8 before to 0-3 applications following the arrival of *H. axyridis*. The typical early season May-Jun peak in YPAC numbers has been greatly suppressed or eliminated.

## SUMMARY

This study reports intensive sampling data from 1 year and data for a second year from 3 dates in late season when high YPAC populations historically occurred, supplemented by data from additional locations in Alabama and Georgia. The additional data were gathered with 1 sample in early Oct, a date when prior to the arrival of *H. axyridis*, YPAC were commonly found in high numbers across most of the pecan belt (Tedders 1978; Edelson & Estes 1983; Dutcher & Payne 1983; Mizell & Schiffhauer 1987). Before and after the introduction of *H. axyridis*, dramatic changes were observed in the number of YPAC and crapemyrtle aphid and natural enemy populations as follows. No specimens of a previously-common pecan aphid parasitoid were detected, only an occasional green or brown lacewing was captured and no specimens were detected of several species of coccinellids, a mirid, syrphids, and an anthocorid that previously had been important predators in both pecan and crape myrtle. Therefore, the putative impact of *H. axyridis* observed in this study affects a myriad of predacious species in 6 families representing a range of behaviors, biologies and life histories. These generalist predators are very important and widely distributed in other habitats (Eubanks 2001). With such a broad array of species apparently affected, it is likely that many community food web associations could be disrupted based on the ecological concept of trophic cascades (Polis & Strong 1996; Moran & Hurd 1998; McPeek 1998; Pace et al. 1999; Polis et al. 2000).

The significant reduction of arthropod pests in pecan, the concomitant reduction in pesticide use and the documented impact on other crop and landscape pests, indicate that *H. axyridis* provides a great deal of benefit from the perspective of pest management. However, the putative negative effects of *H. axyridis* on native beneficials combined with the tremendous nuisance (Tangley 1999) and concomitant public health effects (Yarbrough et al. 1999; Magnan et al. 2002), cast doubt on the net benefit of the addition of *H. axyridis* to the U.S. fauna.

## ACKNOWLEDGMENTS

I thank B. Brodbeck, J. Dutcher, J. Funderburk, P. Stiling, T. Cottrell, C. Tipping, and anonymous reviewers for helpful comments on earlier drafts of the manuscript.

## REFERENCES CITED

ALVERSON, D. R., AND W. ENGLISH. 1990. Dynamics of pecan aphids, *Monelliopsis pecanis* and *Monellia caryella*, on field-isolated single leaves of pecan. J. Agric. Entomol. 7: 29-38.

BROWN, M. W., AND S. S. MILLER. 1998. Coccinellidae (Coleoptera) in apple orchards of eastern West Virginia and the impact of invasions by *Harmonia axyridis*. Entomol. News 109: 136-142.

BUMROONGSOOK, S., M. K. HARRIS, AND D. DEAN. 1992. Predation on blackmargined aphids (Homoptera: Aphididae) by spiders in pecan. Biol Cont. 2: 15-18.

CHAPIN, J. B., AND V. A. BROU. 1991. *Harmonia axyridis* (Pallas), the third species of the genus to be found in the United States (Coleoptera: Coccinellidae). Proc. Entomol. Soc. Wash. 93: 630-635.

CHO, J., K, HONG, G. LEE, B. CHOI, J. YOO, AND J. LEE. 1996. Selection of the acaricides selective to *Harmonia axyridis* and effects of their application on phytophagous mites and natural enemies. Korean J. Appl. Entomol. 35: 243-248.

CODERRE, D., E. LUCAS, AND I. GAGNE. 1995. The occurrence of *Harmonia axyridis* (Coleoptera: Coccinellidae) in Canada. Can. Entomol. 127: 609-611.

COLUNGA-GARCIA, M., AND S. H. GAGE. 1998. Arrival, establishment, and habitat use of the multicolored Asian lady beetle (Coleoptera: Coccinellidae) in a Michigan landscape. Environ. Entomol. 27: 1574-1580.

COTTRELL, T. E., AND K. V. YEARGAN. 1998. Intraguild predation between an introduced *Harmonia axyridis* (Coleoptera: Coccinellidae), and a native lady beetle, *Coleomegilla maculata* (Coleoptera: Coccinellidae). J. Kansas Entomol. Soc. 71: 159-163.

DREISTADT, S. H., K. S. HAGAN, AND L. BEZARK. 1995. *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), first western United States record for this Asiatic lady beetle. Pan Pac. Entomol. 7: 135-136.

DUTCHER, J. D., AND J. A. PAYNE. 1983. Impact assessment of carbaryl, dimethoate, and dialifor on foliar and nut pests of pecan orchards. J. Georgia Entomol. Soc. 18: 495-507.

DUTCHER, J. D., P. M. ESTES, AND M. J. DUTCHER. 1999. Interactions in entomology: aphids, aphidophaga and ants in pecan orchards. J. Entomol. Sci. 34: 40-50.

EDELSON. J. V., AND P. M. ESTES. 1983. Intracanopy distribution and seasonal abundance of the yellow pecan aphids *Monellia caryella* (Fitch) and *Monelliopsis nigropunctata* (Homoptera: Aphidae). Environ. Entomol. 12: 862-867.

EDELSON. J. V., AND P. M. ESTES. 1987. Seasonal abundance and distribution of predators and parasites associated with *Monelliopsis pecanis* Bissell and *Monellia caryella* (Fitch) (Homoptera: Aphidae). J. Entomol. Sci. 22: 336-347.

EUBANKS, M. 2001. Estimates of the direct and indirect effects of red imported fire ants on biological control in field crops. Biol. Control. 21: 35-43.

GALVAN, T. L., E. C. BURKNESS, AND W. D. HUTCHINSON. 2006. Efficacy of selected insecticides for management on wine grapes near harvest. Online, Plant Health Prog doi: 10.1094/PHP-2006-1003-01-RS.

HIRONORI, Y., AND S. KATSUHIRO. 1997. Cannibalism and interspecific predation in two predatory ladybirds in relation to prey abundance in the field. Entomophaga 42: 153-163.

IABLOKOFF-KHNZORIAN, S. M. 1982. Les coccinelles: Coleopteres- Coccinellidae. Societe nouvelle des editions. Boubee, Paris. 568 pp.

SNYDER, W. E., G. CLEVENGER, AND S. EIGENBRODE. 2004. Intraguild predation and successful invasion by introduced ladybird beetles. Oecologia 140: 550-565.

KAJITA, Y., F. TAKANO, H. YASUDA, AND B. AGARWALA. 2000. Effects of indigenous ladybird species (Coleoptera: Coccinellidae) on the survival of an exotic species in relation to prey abundance. Appl. Entomol. Zool. 35: 473-479.

KRAFSUR, E. S., T. KRING, J. MILLER, P. NARIBOL, J. OBRYCKI, J. RUBERSON, AND P. SCHAEFER. 1997. Gene flow in the exotic colonizing ladybeetle *Harmonia axyridis* in North America. Biol. Cont. 8: 207-214.

KOCH, R. 2003. The multicolored Asian lady beetle, *Harmonia axyridis*: A review of its biology, uses in biological control, and non-target impacts. J. Insect Sci. Online: insectscience.org/3.32

KOCH, R., E., BURKNESS, S. BURKNESS, AND W. HUTCHINSON. 2004. Phytophagous preferences of the multicolored Asian lady beetle (Coleoptera: Coccinellidae) for autumn-ripening fruit. J. Econ. Entomol. 97: 539-544.

LAMANA, M. L., AND J. C MILLER. 1996. Field observations on *Harmonia axyridis* Pallas (Coleoptera, Coccinellidae) in Oregon. Biol. Control 6: 232-237.

LIAO, H-T., M. K. HARRIS, F. GILSTRAP, D. DEAN, C. AGNEW, G. MICHELS, AND F. MANSOUR. 1984. Natural enemies and other factors affecting the seasonal abundance of the blackmargined aphid in pecan. Southwest. Entomol. 9: 404-420.

MAGNAN, E. M., H. SANCHEZ, A. LUSKIN, AND R. BUSH. 2002. Multicolored Asian ladybeetle (*Harmonia axyridis*) sensitivity. J. Allergy Clin Immunol. Abstract 205.

MCPEEK, M. A. 1998. The consequences of changing the top predator in a food web: a comparative experimental approach. Ecol. Monogr. 68: 1-23.

MICHAUD, J. P. 2002. Invasion of the Florida citrus ecosystem by *Harmonia axyridis* (Coleoptera: Coccinellidae) and asymmetric competition with a native species, *Cycloneda sanguinea*. Environ. Entomol. 31: 827-835.

MICHAUD, J. P. 2003. A comparative study of larval cannibalism in 3 species of ladybird. Ecol. Entomol. 28: 92-101.

MIZELL, R. F., AND D. E. SCHIFFHAUER. 1987. Seasonal abundance of the crapemyrtle aphid *Sarucallis kahawaluokalani* (Kirkaldy) in relation to the pecan aphids *Monellia caryella* (Fitch) and *Monelliopsis pecanis* (Bissell) and their common predators. Entomophaga 32: 511-20.

MIZELL, R. F. III, AND G. W. KNOX. 1993. Susceptibility of crape myrtle, *Lagerstroemia indica* L., to the crapemyrtle aphid, *Sarucallis kahawaluokalani* (Kirkaldy) in North Florida. J. Entomol. Sci. 28: 1-7.

MIZELL, R. F., F. D. BENNETT, AND D. REED. 2002. Unsuccessful classical biological control search for parasites of the crapemyrtle aphid, *Tinocallis kahawaluokalani*. Florida Entomol. 85: 521-523.

MORAN, M. D., AND L. E. HURD. 1998. A trophic cascade in a diverse arthropod community caused by a generalist arthropod predator. Oecologia. 113: 126-132.

NAULT, B., AND G. KENNEDY. 2003. Establishment of multicolored Asian lady beetle in Eastern North Carolina: seasonal abundance and crop exploitation within an agricultural landscape. BioControl. 48: 362-378.

OBATA, S. 1986. Mechanisms of prey finding in the aphidophagous ladybird beetle, *Harmonia axyridis* (Coleoptera: Coccinellidae). Entomophaga. 31: 303-311.

PACE, M. L., J. COLE, S. CARPENTER, AND J. KITCHELL. 1999. Trophic cascades revealed in diverse ecosystems. Trends in Ecol. and Evol. 14: 483-488.

PERVEZ, A., AND A. OMKAR. 2006. Ecology and biological control application of multicolored Asian ladybird, *Harmonia axyridis*: a review. Biocontrol Sci. and Tech. 16: 111-128.

PHOOFOLO, M. W., AND J. OBRYCKI. 1998. Potential for intraguild predation and comp1etition among predatory Coccinellidae and Chrysopidae. Entomol. Expt. & Appl. 89: 47-55.

POLIS, G. A., AND D. R. STRONG. 1996. Food web complexity and community dynamics. Am. Naturalist 147: 813-846.

POLIS, G. A., A. L. SEARS, G. HUXE, D. R. STRONG, AND J. MARON. 2000. When is a trophic cascade a trophic cascade? Trends in Ecol. and Evol. 15: 473-475.

STUART, R., J. MICHAUD, L. OLSEN, AND C. MCCOY. 2002. Lady beetles as potential predators of the root weevil *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in Florida citrus. Florida Entomol. 85: 409-416.

TANGLEY, L. 1999. Ladybug, fly outta my home. U.S. News & World Report (Science & Ideas). p. 58.

TAKIZAWA, T., H. A. YASUDA, AND B. AGARWALA. 2000. Effects of parasitized aphids (Homoptera: Aphididae) as food on larval performance of 3 ladybirds (Coleoptera: Coccinellidae). Appl. Entomol. Zool. 35: 467-472.

TEDDERS, W. L. 1976. Beneficial insects of pecan. Pecan South. 3: 400-402.

TEDDERS, W. L. 1978. Important biological and morphological characteristics of the foliar-feeding aphids on pecan. USDA, ARS Tech. Bull. 1579. 29 pp.

TEDDERS, W. L., AND P. SCHAEFER. 1994. Release and establishment of *Harmonia axyridis* (Coleoptera: Coccinellidae) in the Southeastern U.S. Entomol. News. 105: 228-243.

YARBROUGH, J., A. ARMSTRONG, J. BLUMBERG, M. PHILLIPS, A. E. MCGAHEE, AND W. DOLEN. 1999. Allergic rhinoconjunctivitis caused by *Harmonia axyridis* (Asian lady beetle, Japanese lady beetle, or lady bug). J. Allergy Clin. Immunol. 104: 704-705.