DISSERTATION

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The Graduate School

University of Kentucky

1998

FACTORS AFFECTING ABUNDANCE OF, AND PREDATION BY, *COLEOMEGILLA MACULATA* (DEGEER)(COLEOPTERA: COCCINELLIDAE) IN SWEET CORN

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Kentucky

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Director: Dr. Kenneth V. Yeargan, Professor of Entomology

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FACTORS AFFECTING ABUNDANCE OF, AND PREDATION BY, *COLEOMEGILLA MACULATA* (DEGEER)(COLEOPTERA: COCCINELLIDAE) IN SWEET CORN

Coleomegilla maculata (DeGeer) (Coleoptera: Coccinellidae) is a polyphagous predator that can develop and reproduce on a diet of corn pollen. Effect of corn pollen on *C. maculata* densities, predation on pest eggs, and egg cannibalism were examined over two years. Before and after anthesis, *C. maculata* density, pest predation, and egg cannibalism were not significantly different between pollen and no-pollen plots. During anthesis, *C. maculata* egg and larval densities were significantly higher in pollen than in no-pollen plots in one of two years, whereas predation on pest eggs was significantly lower in pollen than in no-pollen plots in one of two years. Egg cannibalism during anthesis was lower in pollen compared with no-pollen plots in both years.

Egg cannibalism by *C. maculata* on corn is common but less so when oviposition occurs on the weed hophornbeam copperleaf (*Acalypha ostryaefolia* Riddell [Euphorbiaceae]). Effect of hophornbeam copperleaf on *C. maculata* density and egg cannibalism in corn plots were examined over three years, whereas predation on pest eggs was examined during two of the three years. *Coleomegilla maculata* egg and larval densities were significantly higher in weedy plots during all three years. Pupal density was significantly higher in weedy plots during two of three years, whereas adult density was significantly higher in weedy plots in one of three years. More *C. maculata* eggs were on corn in weed-free plots than in weedy plots but the difference was not

significant; in weedy plots, most eggs were on the weed. However, more older larvae always were on corn in weedy than in weed-free plots. Predation of pest eggs was significantly higher on corn in weedy than in weed-free plots during both years, whereas cannibalism of *C. maculata* eggs was significantly higher on corn in weedy plots during one of the three years.

Ovipositional preference of *C. maculata* for hophornbeam copperleaf or corn, dispersal of larvae from hophornbeam copperleaf, capability for dispersal of larvae across soil, ability of larvae to climb hophornbeam copperleaf or corn, and effect of hophornbeam copperleaf borders near corn were examined. *Coleomegilla maculata* oviposited more on hophornbeam copperleaf than on corn. First-instars dispersed from hophornbeam copperleaf by falling because trichomes on this weed inhibited their movement. Some first instars traveled 8 m across bare soil and significantly more climbed corn than hophornbeam copperleaf. Larval densities were higher in corn plots bordered by hophornbeam copperleaf than in plots without such borders.

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Chapter I

Introduction

Lady beetles (Coleoptera: Coccinellidae) are easily recognized and commonly encountered insects. The striking color patterns of many coccinellid species tend to attract more attention than many other, just as common, insect species. There are more than 4,000 described species in this cosmopolitan insect family. Thus, the number of described coccinellid species is comparable with the number of described mammalian species worldwide (Hagen 1974). In America, north of Mexico, there are 47 genera and about 450 native species of Coccinellidae (Gordon 1985).

Generally, Coccinellidae are regarded as beneficial insects, and in temperate regions the vast majority are predaceous. However, in tropical habitats there are many phytophagous species of Coccinellidae, some of which are economically important. Four species of leaf-feeding coccinellids occur in the United States, all in the subfamily Epilachninae and the tribe Epilachnini. Two of these four species, the Mexican bean beetle (*Epilachna varivestis* Mulsant) and the squash beetle (*Epilachna borealis* (F.)), occur in Kentucky and feed on plants in the families Leguminaceae and Cucurbitaceae, respectively. The distribution of *Epilachna tredecimnotata* (Latreille) in the United States is from western Texas to Arizona. These three *Epilachna* species are native to North and Central America but the phytophagous lady beetle *Subcoccinella vigintiquatuorpunctata* (L.) was accidentally introduced into the United States from Europe. This species reportedly has been a major pest on alfalfa (*Medicago sativa* L.) in Europe but the principal host in the United States appears to be the weed 'bouncing bet', *Saponaria officinalis* L. (Caryophyllaceae), also from Europe (Gordon 1985). In addition to the herbivorous Coccinellidae in the United States, members of the tribe Psylloborini are reported to feed exclusively on fungal spores and hyphae (Gordon 1985).

Predaceous lady beetles occur in various habitats, including agricultural systems and have long been thought of as predators of aphids (Homoptera: Aphididae). Even though some coccinellid species are, indeed, aphid specialists, the dietary range of many predaceous coccinellid species is quite diverse and may include a variety of arthropod prey, pollen, nectar, and fungal spores (Forbes 1880, Balduf 1935, Putman 1960, Hagen 1962, Harris 1969, Nalepa et al. 1992, Pemberton and Vandenberg 1993, Hodek and Honěk 1996).

Different species of lady beetles have been instrumental as biological control agents of arthropod pests in the United States. In 1888, the vedalia beetle (*Rodolia cardinalis* (Mulsant) [Coleoptera: Coccinellidae]) was imported from Australia and released in California for control of the cottony cushion scale (*Icerya purchasi* Maskell [Homoptera: Margarodidae]) on citrus (Hagen 1974, DeBach and Rosen 1991). This has been one of the most successful examples in all of classical biological control. In fact, the stunning success achieved by the vedalia beetle against the cottony cushion scale was the impetus for further importation and release of coccinellids into the U. S. in what was the beginning of the 'ladybird beetle era' which lasted until the early 1900's. Between 1891 and 1892 alone, 46 coccinellid species from Australia were released into the United States (Hagen 1974). Gordon (1985) reports that through 1983, 179 species of coccinellids had been introduced into North America and approximately 26 foreign coccinellid species are now established in North America. More recently, the multicolored Asian lady beetle (*Harmonia axyridis* Pallas) was successfully established for control of arboreal homopteran pests in the United States. Many releases of *H. axyridis* were made at various sites in the United States beginning with the first recorded release in 1916 continuing with periodic releases through 1987 (Tedders and Schaefer 1994).

Use of coccinellid species as biological control agents of insect pests in the United States, however, does not exclude native species. Species within the genus *Hippodamia* are recognized as aphid specialists. *Hippodamia convergens* Guerin , a native species, is found throughout the United States and is recognized as an important aphid predator in various agricultural systems. This species probably is best known as the lady beetle that aggregates and overwinters in very large masses at high elevations in western parts of the United States. From these overwintering sites, *H. convergens* adults have been collected, shipped to various points within the United States, and released as biological control agents of aphid pests in various crops. Although *H. convergens* is an effective aphid predator, released adults tended to disperse away from specific target areas. Other native species in the genus *Hippodamia,* in addition to species of *Coccinella*, *Cycloneda*, and *Adalia*, also tend to specialize on aphid prey in various habitats (Gordon 1985).

Lady beetles in the genus *Stethorus* are found throughout the United States and feed almost exclusively on spider mites (Acari: Tetranychidae) (Gordon 1985). *Scymnus* is a speciose genus within the United States and its predominant food source is aphids on shrubs and grasses (Hodek and Honěk 1996). *Hyperaspidus* and *Hyperaspis* also are speciose genera in the United States. *Hyperaspidus* prey records are limited but most recorded prey are Homoptera. *Hyperaspis* species also are recorded as feeding on Homoptera, specifically the families Pseudococcidae and Coccidae (Gordon 1985).

Another native lady beetle that is well known from various habitats, including many agricultural habitats, across the eastern United States and southern Canada is *Coleomegilla maculata* (DeGeer). This lady beetle feeds on aphids but many studies and observations have revealed that *C. maculata* is omnivorous; its food includes a variety of arthropod prey, pollen, fungal spores, and even plant tissue.

Distribution and Description of *Coleomegilla maculata*

Although *C. maculata* is quite common in the eastern United States and southern Canada, Gordon (1985) lists one species, *maculata*, within the genus *Coleomegilla* in America north of Mexico. *Coleomegilla maculata* also occurs throughout Central America and at least in parts of South America. In the United States, three subspecies are recognized by Gordon (1985): *lengi*, *strenua*, and *fuscilabris*. The distribution of *C. maculata* subspecies *lengi* is across the eastern United States and southeastern Canada from Ontario to Georgia and west to Minnesota and Texas. *Coleomegilla maculata* subspecies *fuscilabris* is distributed along the Atlantic and Gulf of Mexico coasts of the southeastern United States, including Florida, whereas *C. maculata* subspecies *strenua* is found in the southwestern United States along the United States - Mexico border from Texas to California. The subspecies found in Kentucky is *lengi*. Gordon (1985) notes that *Naemia seriata* (Coleoptera: Coccinellidae) may be confused with *C. maculata* due to similar dorsal color patterns between the two species; however, *N. seriata* mainly is distributed along the eastern coast of the United States.

Adult *C. maculata lengi* vary in length from about 4.2 to 6.6 mm. The pronotum and elytra typically are pink with a total of twelve black spots (two on the pronotum, six on each elytron [two spots on each elytron combine when the elytra are closed]).

Coleomegilla maculata strenua is similarly colored and patterned but is reported to be "noticeably" larger than *C. maculata lengi*. *Coleomegilla maculata fuscilabris* has spots that are not the same size as found on *C. maculata lengi* and the pronotum and elytra are usually a pale yellow and never pink in contrast to subspecies *lengi* and *strenua*. Currently, the Entomological Society of America (Lanham, MD) does not recognize a common name for this species of lady beetle. Nonetheless, *C. maculata* generally has been called the twelve-spotted lady beetle (e.g., Obrycki 1995). Larval descriptions were provided by Rees et al. (1994), and Rhoades (1996) has provided a key to first and second instars of several coccinellid species that occur on alfalfa, including *C. maculata*.

Habitat Preference of *Coleomegilla maculata*

Coleomegilla maculata is common in many habitats including old fields, areas dominated by trees and shrubs, and agricultural habitats. Some crops in which it is found are corn (*Zea mays* L.) (Riley 1893, Everly 1938, Smith 1971, Benton and Crump 1981, Coderre et al. 1987, Hoffmann et al. 1997), alfalfa (Kieckhefer et al. 1992, Giles et al. 1994), potatoes (*Solanum tuberosum* L.) (Groden et al. 1990, Hazzard and Ferro 1991, Hazzard et al. 1991), and cotton (*Gossypium hirsutum* L.) (Bell and Whitcomb 1964, Cosper et al. 1983).

Intraplant distribution of *C. maculata* typically has been reported as the lower portions of plants. Putman (1964) states that *C. maculata*, in addition to *Hippodamia* species, are adapted to plants that grow low and are easily reascended by the larvae. Although that author did not define low-growing plants, many agricultural crops are low-growing habitats compared with arboreal habitats. *Coleomegilla maculata*, however, may be found at different heights on different crop species. On corn, Foott (1973) reported that *C. maculata* always was the dominant coccinellid species on lower portions of the plants. Ewert and Chiang (1966) showed that adult *C. maculata* predominantly was found on the lower one-half of corn plants whereas *Hippodamia convergens* and *Hippodamia tredecimpunctata* occupied the upper one-half of the corn plants. In addition, Coderre et al. (1987) examined oviposition site selection by *C. maculata* on corn and found that 96.5% of *C. maculata* eggs occurred on the lower one-third of the corn plants, specifically on the undersides of leaves. On barley and sorghum, Ewert and Chiang (1966) reported that *C. maculata* adults predominantly occurred on the lower one-half of the plants whereas on alfalfa, adult *C. maculata* were on the upper one-half of plants. Adult and larval *C. maculata* also were observed on the seed heads of orchard grass (*Dactylis glomerata* L.) and fescue (*Festuca* spp.) (T. E. Cottrell, personal observation). *Coleomegilla maculata* adults and larvae each were found to be significantly more abundant on sweet corn than on soybeans (*Glycine max* (L.) Merrill [Fabaceae]), tomatoes (*Lycopersicum esculentum* Miller [Solanaceae]) or tobacco (*Nicotiana tabacum* L. [Solanaceae]) (Pfannenstiel 1995). However, intraplant distribution of *C. maculata* on tobacco was examined by Pfannenstiel (1995), and it was reported that adults occurred predominantly on the lower one-third of the plants whereas larvae occurred on the lower one-fifth of tobacco plants. Over 40% of *C. maculata* larvae on lower portions of tobacco plants were found on dead and senescing leaves. Cosper et al. (1983), however, reported that *C. maculata* (stages not reported) predominantly was found on upper portions of cotton plants throughout the season. Apparently, *C. maculata*'s preferred stratum varies among different plant species.

Biology of *Coleomegilla maculata*

Life cycle and development. The life cycle of *C. maculata*, as with other coccinellids, consists of the egg stage, four instars during the larval stage, a pupal stage, and the adult (Hodek and Honěk 1996). Warren and Tadic (1967), however, reported that a fifth instar sometimes occurred when *C. maculata* was reared under laboratory conditions. *Coleomegilla maculata* generally has been reported to complete from two to three generations per year (Obrycki and Tauber 1979) in New York.

Coleomegilla maculata requires a total of 236 degree days to complete development from the egg to adult stage with a calculated developmental threshold of 11.3°C (Obrycki and Tauber 1978). A similar study by Wright and Laing (1978) reported that 199 degree days were required to complete development with a calculated developmental threshold of 13.8°C. These authors noted, however, that when *C. maculata* eggs were held at 14°C, embryonic development occurred but the eggs did not hatch. Nonetheless they still used the calculated value of 13.8°C as the developmental threshold with no further explanation.

At 21.1°C, Obrycki and Tauber (1978) reported that total developmental time for *C. maculata* was 23.7 days, whereas Wright and Laing (1978) reported total developmental time was 27.3 days at 21°C. It is possible that the food provided to *C. maculata* in each study served as a source of variation. When Warren and Tadic (1967) reared *C. maculata* on pork liver or *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae) eggs at 26.7°C, total time for development was 20.6 and 18.2 days, respectively. Obrycki and Tauber (1978) provided *C. maculata* with water, a Wheast-protein food mixture, pea aphids (*Acyrthosiphon pisum* [Harris]), and green peach aphids (*Myzus persicae*

[Sulzer]), whereas Wright and Laing (1978) provided tobacco leaves infested with green peach aphids as a food source. Glandular trichomes on tobacco leaves, in addition to tritrophic effects, could have affected consumption and/or physiological utilization of aphids thereby increasing total development time of *C. maculata* as reported by Wright and Laing (1978). Glandular trichomes on tobacco can affect coccinellid larvae as discussed by Elsey (1974), Belcher and Thurston (1982), and Pfannenstiel (1995).

The duration of each developmental stage (as well as time spent in each instar) varies with temperature. The optimal rearing temperature for *C. maculata* appears to be between 24 and 27°C (Obrycki and Tauber 1978, Wright and Laing 1978). Obrycki and Tauber (1978) reported that the duration of the egg, first instar, second instar, third instar, fourth instar, and pupa at 24°C was 3.22, 3.10, 2.02, 2.54, 4.81, and 3.66 days, respectively, whereas at temperatures below and above 24°C, more and less time, respectively, was required to complete development.

At a constant temperature of 21 ± 3°C, an average of 272 ± 15 green peach aphids (*M. persicae*) per *C. maculata* larva were required to complete development. When cotton aphids (*Aphis gossypii* Glover [Homoptera: Aphididae]) were fed to *C. maculata* larvae at a constant temperature of 21 ± 3°C, an average of 486 ± 18 aphids per larva were required to complete development. Relative masses of the two aphid species were not reported (Gurney and Hussey 1970). From laboratory feeding trials with *C. maculata* on lepidopteran eggs, average consumption by first-instar *C. maculata* was 19 *Heliothis* (Lepidoptera: Noctuidae) eggs per larva over a 48 hour interval. Average consumption by individual *C. maculata* third-instars, adult females, and adult males over 48 hours was 262, 357, and 291 eggs, respectively. When the test was done using first-instar *Heliothis* larvae, average consumption by *C. maculata* first instars, third instars, adult females, and adult males was 6, 208, 81, and 87 *Heliothis* larvae, respectively (Lopez et al. 1976).

The adult stage of *C. maculata* is more long-lived than the combined duration of individual immature stages. Warren and Tadic (1967) reported that adult *C. maculata* collected from overwintering sites and fed pork liver and a vitamin mixture lived an average of 61.9 days (range = 4 - 139 days) in the laboratory at 26.7°C (exclusive of time before entering the overwintering site and time spent in the overwintering site) and laid an average of 49.8 eggs (range = 10 - 226). Wright and Laing (1979) showed that *C. maculata* adults collected from overwintering sites and fed aphids (*M. persicae*) lived an average of 79.7 days (range = 52 - 133) at 27°C and the females produced an average of 349.5 eggs (range = 106 - 857).

Overwintering behavior. Adult *C. maculata* beetles overwinter in aggregations and commonly are found at the bases of dominant trees at or near agricultural habitats, under tree bark, under leaves on well-drained slopes, and sometimes in clumps of broomsedge (*Andropogon virginicum* L.) (Landis 1936, Warren and Tadic 1967, Benton and Crump 1981, Jean et al. 1990, Roach and Thomas 1991). Park (1930) reported that more than 9,800 *C. maculata* (= *Ceratomegilla fusilabris*) adults were recovered from one-square yard of moist earth located at the base of a *Crataegus* (hawthorn) bush in an oak-elm-hickory forest in Illinois. Few beetles were found in the leaf litter that was above the layer of soil containing the beetles.

Weiss (1913) suggested that adult *C. maculata* (= *Megilla maculata*) aggregated at overwintering sites because of the 'peculiar odors' emitted by Coccinellidae and that as