BODY WEIGHTS AND EGG LOADS IN FIELD-COLLECTED *PODISUS MACULIVENTRIS* (HETEROPTERA: PENTATOMIDAE)

Jesusa Crisostomo Legaspi and Benjamin C. Legaspi, Jr.[1]
USDA-ARS-CMAVE, FAMU-Center for Biological Control, 6383 Mahan Drive, Tallahassee, FL 32308
[1]Employed by State of Florida, contact through senior author.

Abstract

Body weights and egg loads of field populations of the spined soldier bug, *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae) were studied from grape vineyards in Florida from April to November, 2003. Two main generation peaks were found in June and September. Mean female body weight throughout the year was similar to those obtained in various crops in Indiana. In both studies, body weights were comparable to those found in laboratory experiments where females were fed 1 prey item every 3 to 9 days. Egg loads in Florida were similar to those found in field populations in Indiana. The increase in numbers of immature eggs later in the Florida season may be an indication of continued egg production in older females. We interpret this as possible evidence of synovigeny in the field. This result is consistent with previous laboratory data showing that immature eggs are continuously produced throughout female lifetime. Larger females predictably had higher mean egg loads. The similarity in biological characteristics found in field populations in Indiana and Florida suggest that the predator has similar impacts on pest species by low feeding rates.

Key Words: ovigeny, predator, grape, vineyard, pheromone

Resumen

El peso del cuerpo y la carga de los huevos de poblaciones del chinche, *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae), fueron estudiados en viñas en la Florida desde abril hasta noviembre de 2003. Se encontró dos picos en las generaciones principales en junio y septiembre. El promedio del peso del cuerpo de las hembras atravéz del año fue similar al obtenido de hembras en varios cultivos en Indiana. En ambos estudios, el peso del cuerpo fue comparable al obtenido de los experimentos de laboratorio donde las hembras fueron alimentadas con 1 unidad de presa cada 3 a 9 dias. La carga de huevos en la Florida fue similar a las encontradas en poblaciones de campo en Indiana. El aumento en el número de huevos inmaduros mas tarde durante la estación en Florida puede ser una indicación de la producción continua por parte de hembras mas viejas. Nosotros interpretamos este como evidencia posible de sinovogenia (la producción de huevos atravéz de la vida de la hembra) en el campo. Este resultado es consistente con los datos del laboratorio previos demostrando que los huevos inmaduros continuamente producidos durante la vida de la hembra. Como esperamos, las hembras mas grandes tenian un promedio mayor de carga de huevos. La similitud en las características biológicas encontradas en las poblaciones en el campo en Indiana y Florida sugiere que el depredador tiene un impacto similar sobre las especies de plagas por las tasas bajas en alimentación.

The spined soldier bug, *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae), is found throughout North America and known to feed on >75 species of insect prey, primarily immature Coleoptera and Lepidoptera (McPherson 1980). Because the predator also plays a role in natural control of key pests and is available as a commercial control agent, much is known about its biology under laboratory conditions (e.g., Drummond et al. 1984; Legaspi & O'Neil 1993a, b, 1994; Wiedenmann & O'Neil 1991). In contrast, relatively few studies have investigated *P. maculiventris* in the field (see Evans 1982; O'Neil 1988; Wiedenmann & O'Neil 1992).

In field-cage experiments, the estimated attack rate of *P. maculiventris* on the Mexican bean beetle, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae) was ≈0.5 per day at low (sub-economic) prey densities of <10 prey/m^2 crop leaf area (Wiedenmann & O'Neil 1992; O'Neil 1997). At higher densities of ≈10-42 prey/m^2, representing economic pest levels, maximal attack rates were ≈2 per day. In spite of such low attack rates, *P. maculiventris* is able to persist in a variety of cropping systems through several adaptive mechanisms. Under conditions of food scarcity, *P. maculiventris* maintains longevity, but reduces its fecundity (Legaspi & O'Neil 1993a; Legaspi & Legaspi 1998). Starvation causes an increase in levels of lipid, which the predator uses as energy reserves (Legaspi & O'Neil 1994). Body mass also declines (O'Neil & Wiedenmann 1990; Legaspi & O'Neil 1993b). Furthermore, the predator may enhance its survival through phytophagy to provide water and possibly carbohydrates (Wiedenmann et al. 1996).

Legaspi et al. (1996) compared body weights, egg loads and lipid levels in female *P. maculiventris* collected in alfalfa, potato, soybeans, and fallow fields in Indiana from 1987 to 1989 against laboratory individuals under controlled feeding regimens. Field populations showed levels of these parameters comparable to laboratory specimens provided 1 prey item every 3-9 d, thus supporting the earlier finding of low field predation rates (Wiedenmann & O'Neil 1992). Furthermore, body lipid levels were higher during the drought year of 1988, suggesting conservation of energy reserves, as documented in the laboratory (Legaspi & Legaspi 1998). In this study, we compared body weights and egg loads in *P. maculiventris* collected by pheromone traps in Florida muscadine grape vineyards in 2003 against laboratory females under known feeding regimens.

Materials and Methods

From April 17 to November 14, 2003, *P. maculiventris* were collected from the FAMU-Center for Viticulture muscadine grape vineyard about 10 miles east of campus in Tallahassee, Florida (Leon County). Sampling methods were similar to those described in Legaspi et al. (2004). A glass vial filled with pheromone mixture (Aldrich 1988) and a cotton wick, as well as a vial of water inserted with a cotton wick, were placed inside each plastic covered trap. The trap was made from an inverted plastic food container. Insects entered through a wire screen funnel at the top and were removed through the screw cap lid at the bottom. The pheromone mixture and water were replaced bi-weekly or as needed. From April 17 to June 23, 11 traps were used (14 cm diameter × 24 cm height). The number of traps used was increased to 16 from June 24 to July 9 (14 cm diameter × 19 cm height), and to 27 from July 10 to November 14, 2004 (15 cm diameter × 21 cm height). Field collections were made mainly around 3:00 p.m., when most adults were observed to be caught. Samples were collected daily except the weekends. Some *P. maculiventris* adults were observed to feed on prey such as glassy-winged sharpshooter, flies, and spiders. Adult *P. maculiventris* collected from the traps were weighed individually in the laboratory on a Mettler PB 3002 analytical balance (Mettler Toledo, Hightstown, NJ) with a precision of ±0.0001 g.

All adults were kept in an ultra-low freezer at -80°C (Revco Model ULT 1786-3-A36, Kendro Laboratory Products, Asheville, NC) until dissections of female adults were done to measure the numbers of eggs in the ovaries. Methods of dissection and egg load measurements follow methods described in Legaspi et al. (2004). The dorsal and ventral abdominal body walls of the females were separated and the numbers of eggs in the ovaries were counted. Eggs were classified as mature (bigger, dark-colored, rough texture, and chorion prominent) and immature (light-colored, smooth texture, chorion not prominent).

Statistical Analysis

Linear regressions on egg loads and female body weights were performed with Systat (Systat Software, Inc., Point Richmond, CA).

Results and Discussion

Because the numbers of pheromone traps used increased during the season, numbers of predators sampled are presented as insects per trap (Fig. 1). The field population of *P. maculiventris* appeared to show two main peaks. The first, and more prominent peak was observed in June, followed by a less pronounced population peak in September. The two peaks probably correspond to two generations during the season. Adults that hibernated start field activity in March to April, and population numbers peak in June. The second peak in September indicates the second field generation.

Average body weights of female *P. maculiventris* were relatively constant during the sampling period (Fig. 2). Body weights are displayed together with four lines showing comparative weights of females reared in the laboratory under

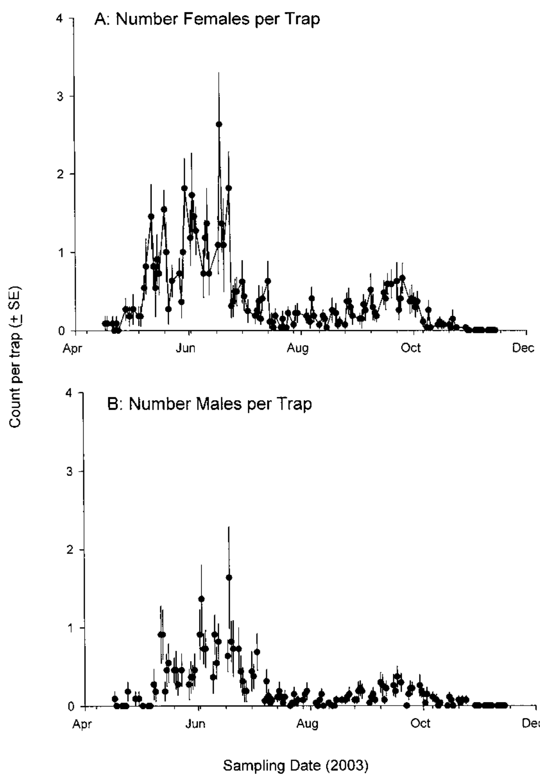

Fig. 1. Numbers of *Podisus maculiventris* collected per pheromone-baited trap ($\bar{x}$ ± SE) in muscadine grape vineyard, Leon Co., FL.

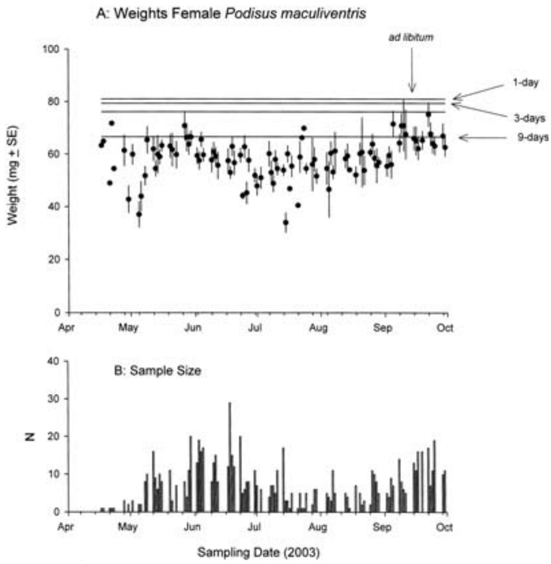

Fig. 2. Weights (mg) of female *Podisus maculiventris* ($\bar{x}$ ± SE) in grapes. A) Four lines indicate estimated mean laboratory weights of *P. maculiventris* in cultures fed *ad libitum*, and 1 prey item at intervals of 1, 3, and 9 days (Legaspi et al. 1996); B) Sample size obtained at sampling date, Leon Co., FL.

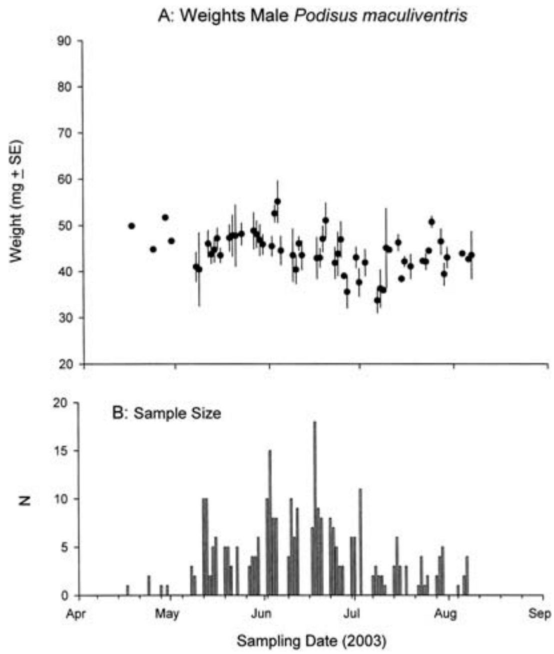

Fig. 3. Weights of male *Podisus maculiventris* (mg, $\bar{x}$ ± SE) in grapes, 2003, Leon Co., FL.

known feeding regiments. Legaspi et al. (1996) estimated that adult, unmated *P. maculiventris* females fed *ad libitum* (0 days between meals), and 1 prey item every 1-, 3-, and 5-days would weigh an estimated mean of 80.9, 79.3, 76.1, and 66.6 mg, respectively. These lines are superimposed on the field data. With few exceptions between 3- and 9-day feeding lines, the vast majority of the field population weighed less than the benchmark level of 66.6 mg, indicating low field predation rates. The present results are comparable to those obtained by Legaspi et al. (1996) for *P. maculiventris* in various crop systems in Indiana where female body weights were similar to laboratory females reared on a feeding regimen of 1 prey item every 3 to 9 days. Legaspi et al. (2004) used the same procedure to study field populations of *P. maculiventris* collected by pheromone traps from May to August 2003 in a muscadine grape vineyard at the Florida A&M University Center for Viticulture in Tallahassee, Florida. Field-collected females were found to have live body weights comparable to females fed less than one prey item every 9 days in the laboratory.

Body weights of males are shown for comparison (Fig. 3), although no similar studies have been performed on the effects of feeding regimens on body weights in the laboratory. Male body weights are known to be less than those of females under both laboratory and field conditions (Legaspi et al. 1996). These studies support the finding of low field predation rates in *Podisus maculiventris* (Wiedenmann & O'Neil 1992; and others).

Egg load dissections during the season are shown for mature, immature, and total eggs (Fig. 4). The numbers of immature eggs (Fig. 4b) indicate low numbers early in the season, followed by a subsequent increase, possibly due to ovigenesis in the field population. Insects that produce eggs after emergence are termed "synovigenic". The terminology was originally developed for parasitic Hymenoptera, but is applicable to other insects (Jervis & Kidd 1996; Jervis et al. 2001), although it had not been studied in predators previous to Legaspi & Legaspi (2004) (M. Jervis, Univ. Cardiff, personal communication). Recent laboratory data suggest that *P. maculiventris* is strongly synovigenic (Legaspi & Legaspi 2004). The present study may be interpreted as evidence for synovigeny in a field population of *P. maculiventris*. However, this conclusion is made with caution because of the presence of females without eggs (Fig. 4) and because the ages and individual histories of the specimens are unknown.

Legaspi & O'Neil (1994) determined that laboratory females with egg loads ≥25 corresponded to 15-d-old predators fed *ad libitum* to 1 prey item every 3 days. Conversely, predators with <25 eggs corresponded to 15-d-old females fed 1 prey item at intervals >3 days. Mean egg load of 25 was used as a benchmark by Legaspi et al. (1996) to characterize field populations and is superimposed on field egg loads in Fig. 4c. With the exception of a

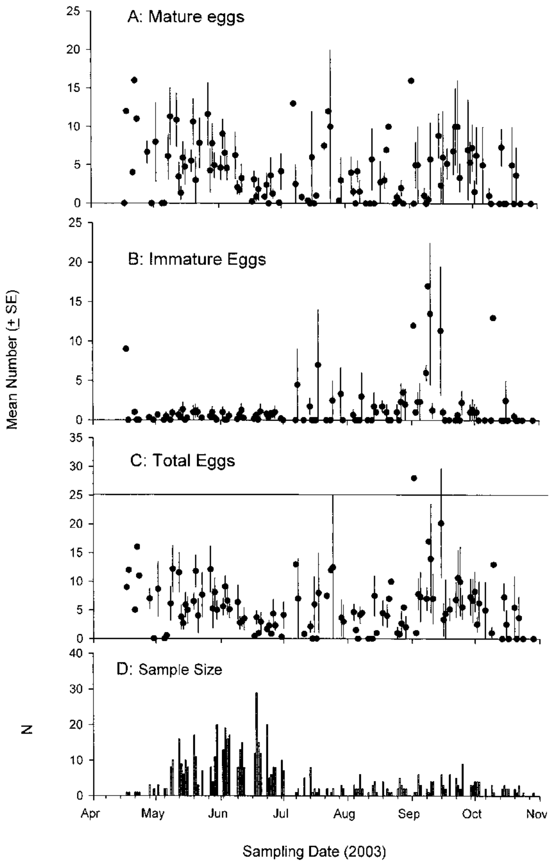

Fig. 4. Mean egg loads of female *Podisus maculiventris* (mg, $\bar{x}$ ± SE) in grapes. A) Mature eggs; B) Immature eggs, showing increasing numbers later in the season; C) Total eggs, line indicates 25 eggs which is the egg load of laboratory females fed 1 prey item every 3 days (Legaspi et al. 1996); D) Sample size obtained at sampling date, 2003, Leon Co., FL.

single observation, all egg loads were found below the benchmark line, possibly indicating low field predation rates. The sample sizes upon which all egg counts were based roughly correspond to the June and September peaks found for the field population (Figs. 4c and 1). Unlike body weights, it is more difficult to make inferences based on mean egg loads because of the confounding effects of feeding regimen and predator age. Age tends to increase egg load; food scarcity to decrease it. Both factors are largely unmeasured in our field populations. Legaspi & O'Neil (1994) also concluded that *P. maculiventris* exhibits continued egg development and storage until deposition, thereby suggesting a synovigenic predator.

Linear regressions of egg loads on female body weights gave the expected result that larger females had higher total numbers of mature and immature eggs (Fig. 5) (*TOTAL EGGS* = -10.92 + 0.277 *WEIGHT*; F = 170.9; $df = 1, 580$; $P < 0.01$; R^2 = 0.23). Regressions on numbers of mature eggs (*MATURE* = -9.2 + 0.23 *WEIGHT*), and immature eggs (*IMMATURE* = -1.79 + 0.045 *WEIGHT*;) were similarly significant ($F = 145.1$; $df = 1, 577$; $P < 0.01$; $R^2 = 0.2$; and $F = 38.1$; $df = 1, 577$; $P < 0.01$; $R^2 = 0.06$, respectively). The positive relationship we found between egg loads and female body weights has been amply documented. Jervis & Kidd (1996) cite numerous examples in the literature of positive relationships between female body size or weight and the following measures of reproduction: ovariole number (two references); egg load (18 references); and lifetime fecundity (nine references).

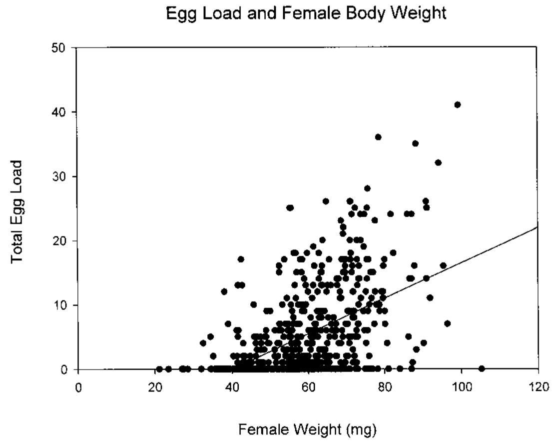

Fig. 5. Total egg load as a function of female body weight (mg). Line indicates linear regression: *TOTAL EGGS* = -10.92 + 0.277 *WEIGHT* ($P < 0.01$).

In conclusion, *P. maculiventris* probably has two field generations in Florida, which are not discrete due to the largely mild year-long climate and absence of severe winters. Mean female body weight in the field was similar to those obtained in various crops in Indiana, indicating low predation rates in both cases. Egg loads of field-collected females were comparable to those found in Indiana. The increase in numbers of immature eggs later in the season may be an indication of continued egg production in older females. This finding is expected given previous laboratory data showing that immature eggs are continuously produced throughout female lifetime. Larger females predictably had higher mean egg loads. The similarity in biological characteristics found in field populations of Indiana and Florida suggest that *P. maculiventris* plays similar roles in the suppression of pest insects by feeding on prey in low rates, despite the differences in crop and climate.

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