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Postembryonic development and population parameters of *Alpaida veniliae* (Araneae, Araneidae), reared in the laboratory.

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Abstract. We studied postembryonic development from hatching to adult stage and determined life history traits and population parameters of *Alpaida veniliae*. It is one of the most abundant species of the orb weaving guild of the spider community of soybean crops in Buenos Aires province, Argentina. The first three instars occurred inside the egg sac, and nymph IV (spiderlings) started the dispersion from it. *Alpaida veniliae* female achieved greater adult size and larger adult longevity than the male. Mean fecundity, mean number of egg sacs per female, mean number of eggs per egg sac, as well as the net reproductive rate, the intrinsic rate of increase (r), the generation time (T), and the reproductive values (V_x) of three cohorts, were determined under laboratory conditions, indicating a relatively high capacity for growth. Their biological and ecological attributes indicate the importance of conservation this predator as a natural enemy of soybean crop pests.

Keywords: spiders; generalist predators; soybean; life history traits; population growth rates.

Introduction

Arthropod predators can be very effective in reducing the density of phytophagous arthropods in agroecosystems as well as in unmanaged habitats (Nyffeler et al. 1994; Wyss et al. 1995; Barbosa and Wratten 1998; Rypstra et al. 1999). Currently, there is a growing interest in the potential of generalist predators as biological control agents of pests (Riechert and Lockley 1984; Riechert and Bishop 1990; Symondson et al. 2002).

The reappraisal of conservation of natural enemies as biological control agents has started to change the current dogma and creating new management perspectives for pests (Nyrop et al. 1998). Accordingly, management practices to preserve predaceous arthropods in agro-ecosystems seem to be a sound alternative to pesticides (Ehler 1998).

Spiders are relevant components of the natural assemblages of predatory arthropods of most agroecosystems (Turnbull 1973; Young & Edwards 1990; Wise 1993; Sunderland *et al*., 1997; Sunderland & Greenstone 1999). Field and laboratory studies of spider predation rates indicate that the impact of the spider assemblages may contribute significantly to decrease pest population abundance in many crops (Wise 1993; Sunderland & Greenstone 1999; Nyffeler 1999; Maloney et al. 2003; Danişman et al. 2007). Normally, spider communities have high abundance, richness and diversity in agroecosystems throughout the crop growing season, (Riechert and Lockley 1984; Benamú and Aguilar 2001; Maloney et al. 2003; Beltramo et al. 2006). Another important feature of their life history, pointed out by Harwood and Obrycki (2005), is the advantage of spiders over specialist natural enemies due to their sit-and-wait strategy that allow them attack pests once they arrive, by surviving on alternative preys.

In transgenic soybean crops of Buenos Aires province, Argentina, the spider *Alpaida veniliae* (Keyserling 1865) (Araneae, Araneidae), is one of the most abundant species of the orb weaving guild of the spider community. Saavedra et al. (2007)

reported the importance of *A. veniliae* predation on herbivore insect populations on rice crops. However, to date, there is little information on the biology and the ecology of this species. In view of *A. veniliae* might be a potential natural enemy of some soybean pests that could be integrated in future pest management programs, basic studies of its biology and ecology are needed.

The objectives of this work were to study the postembryonic development and the population parameters of *Alpaida veniliae*, in laboratory.

Material and methods

A laboratory colony was reared, starting with 30 juvenile females, 10 adult gravid females and 10 adult males of *A. veniliae*, collected from two transgenic soybean crops located at Chivilcoy (35˚ 01' S, 60˚ 06' W) (Buenos Aires, Argentina). Spiderlings emerging from the egg-sacs were followed to obtain a mass-rearing population. In the laboratory, we individually reared juveniles and adult couples, to allow mating, in 500 ml glass jars. Juveniles and adults were provided with an *ad libitum* supply of *Drosophila melanogaster* and *Musca domestica* adults. Laboratory conditions were 25 ± 2 º C, 75 ± 5% RH, and a photoperiod of 16:8 (L: D) h. This colony provided the necessary individuals to study the different life traits and the population parameters.

Postembryonic development

To determine postembryonic development, 16 egg masses were individually reared in 6 cm diameter plastic Petri® dishes. Dishes were disposed on trays of expanded polystyrene with pieces of moistened cotton to prevent the eggs from drying, and covered with plastic film to avoid contamination by fungi and mites. They were kept in an environmental chamber at 25 ± 0.5 ° C, 75 ± 5% R.H. and 16:8 L: D, h. Different postembryonic stages, from hatching to adult stage, were determined according to Galiano (1991), which considers that development begins with the rupture of the chorion (hatching), remaining the first instar inside it. The second instar appears after detaching the embryonic cuticle, which is considered the first molt, and the subsequent instars are numbered sequentially. At instar IV, individuals (spiderlings) abandon the egg-sac and start a free life.

As it was impossible to separate individual eggs from the egg mass, we determined the intrachorionic development by daily examination under binocular microscope of 978 eggs from different egg masses, but not separated from them. Spiderlings coming out the egg-sac, were individually kept in Petri dishes, and daily checked until reaching the adult stage. We measured the length and width of cephalothorax of 50 individuals of each instar, 50 adult males, and 50 adult females, immediately after the molt. To measure instar I and II we previously submerged some egg masses in liquid glycerin to transparent membranes, and randomly selected 50 individuals of each. Differences in development times and morphological measurements among juveniles, and in adult longevity, total life span, and in cephalothorax size between adult sexes were tested with ANOVA or Kruskal Wallis test. Means or medians were separated by the least significant differences (LSD) multiple range test or Box and Wisker plot method, respectively. A 0.05 significance level was chosen for all statistical analysis.

Life history traits

To assess male and female longevity, we followed the surviving individuals, used to study postembryonic development, until the end of their lives as adults. Additionally, 22 newly emerged male and female adults, randomly selected, were paired and placed in

500 ml plastic vials to determine the mean number of days from mating to the first oviposition (pre-reproductive period), the mean fecundity (mean number of eggs per female), the mean number of eggs per egg sac, and the mean percentage of egg hatching.

Population parameters

Three cohorts (i.e. a group of individuals born within the same short interval of time) selected from the laboratory colony were used to construct three age specific life tables and estimate the population parameters. Spiderlings of each cohort were placed individually in 6cm diameter Petri® dishes with a piece of moistened cotton on the bottom, and fed *ad libitum Drosophila melanogaster* up to the IV instar, and then fed *Musca domestica* to the adults. From a group of 100 eggs we measured the percentage of hatching and corrected the initial number of spiderlings of each cohort to perform the calculations of the population parameters starting from the eggs.

Thus, the initial number of eggs of each cohort was of 897, 429 and 483 eggs, respectively. Once a week we checked survival of each cohort until death of all individuals. Spiders were sexed in the fifth nymph. Cohort survival (proportion of the initial female cohort alive at age x) and fecundity (mean number of female offspring produced per female of age x) were estimated. From fifth instar to adult stage we calculated the mean sex ratio [(male / (male + female)] and used this value to correct age-stage specific survival values from birth, assuming that the sex ratio was similar from birth to fifth. Three of the surviving females of each cohort, chosen at random, were paired with males coming from the colony, and housed individually in 500 ml plastic vials to estimate age specific fecundity. We constructed age-specific survival (l_x)

and fecundity (m_x) curves at weekly intervals, and calculated the following demographic parameters:

Net reproductive rate (R_o), that is the mean number of female offspring produced per female per generation

$$R_o = \sum_{x=0}^{n} l_x m_x \qquad [1]$$

Intrinsic rate of increase (r), that is the mean number of female offspring produced per female per time unit.

$$r \approx \frac{\ln R_0}{T} \qquad [2]$$

Generation time (T) that is the mean age of the parents of all the offspring produced by a single cohort.

$$T = \frac{\sum_{x=0}^{n} x l_x m_x}{R_0} \qquad [3]$$

Reproductive values (V_x), that is the contribution to the future population that one female of age x will make. It is measured relative to that of the first age, which is considered equal to 1.

$$V_x = \frac{e^{rx}}{l_x} \sum_{y=x+1}^{n} e^{-ry} l_y m_y \qquad [4]$$

Where *x* is the age class and *n* the oldest age class.

Results

Postembryonic development

The egg sac of A. *veniliae* is yellow and shaped like a dome. It has three layers of fibers surrounding the mass of eggs, which is pink, darkening as it develops and it measures 3.82 ± 1.1 mm (mean ± SD; n=16) in length, and 3.23 ± 0.7 mm (mean ± SD; n= 16) in width. Hatching occurred in two steps within the egg sac. During the first, the individual broke the chorionic membrane. This is considered the instar I, which is intrachorionic, still wrapped in the embryonic cuticle, the body bent at right angle with the legs folded under the cephalothorax and no visible segmentation of the legs. The rupture of chorionic membrane took place 6.33 ± 0.5 days after oviposition (Table 1). During the second step, at approximately 24 h from breaking the chorionic membrane, the embryonic cuticle is detached, dragging the egg membranes, resulting in the freeing of the legs from the cephalothorax and the emergence of instar II. The instar III had the cephalothorax and legs free and extended parallel to each side of the body, with little sketches of segmentation at the level of the trochanter-femoral joint. They had no hair nor pigmentation, only a slight red pigmentation in their eyes, and fed on the chorion, which dries and become increasingly crumpled inside the ootheca. Instar IV (spiderlings) had hair, tarsal nails and eyes, and started the dispersion from the egg sac. At this point, spiderlings were also able to spin a simple type of silk for capture prey. Cannibalism was not observed inside the egg sac. It was possible to discriminate sex in instar V, because it was easy to see the palp of the male. Females had nine instars, while males had only eight.

Developmental time of juveniles and adults and cephalothorax size of *A. veniliae* is shown in Table 1 and 2, respectively. Earlier instars, particularly from the first to the third, had shorter developmental time than later ones (Kruskal-Wallis, H = 5212.62; P =0.001, n= 3164). Adult male longevity was much shorter than that of female, as well as the total male life span.

Cephalothorax length was similar until instar VI, and then successively increased to adult (H= 475.90; P = 0.001). Cephalothorax width differed between instar II to III and remained similar until instar VII when it increased with age (H= 466.84; P = 0.001). Adult females had a longer and wider cephalothorax than adult males (length: H = 24.75; P = 0.001; width: H= 78.24; P= 0.001).

Life history traits

Females had a longer total life span than males, living approximately 62 days longer (F= 105; df =1, 78; P< 0.001). Adult female longevity was approximately 42 d longer than that of the male (H= 57.43; P= 0.001) (Table 1). After 6.7 ± 2.6 (mean ± SD) d from copulation, females laid the first egg sac. Mean (± SD) female fecundity was 740.91 ± 329.16 eggs. The mean (± SD) number of egg sacs deposited by a female was 4.59 ± 2.04, and the mean (± SD) number of eggs per egg sac was 161.39 ± 32.17. The percentage of egg hatching was 95.02%.

Population parameters

The age-specific survival curves showed some variations at initial ages between cohorts (Fig. 1). In cohort 1 survival sharply decreased during the first four weeks of life, indicating a high mortality at the first instars. Survival in cohorts 2 and 3 remained very high during the first six weeks, after which it suffered a pronounced reduction. From this moment on, patterns of survival were rather similar, declining gradually to reach zero between the 28th and 29th week of cohort life span. Cohort survival had values ranging from 10 to 15 % when females started oviposition. Fecundity curves exhibited two or three peaks, reaching the maximum fecundity from week 21 to week 23.

Population parameters were similar between cohorts and indicated a relatively high capacity for growth (Table 3). Generation time ranged approximately from 19 to 24 weeks, and the maximum reproductive values (Fig. 2) were at the ages of 20, 23 and 24 weeks of the female life span, in cohort one, two, and three, respectively. The sex ratio differed between cohorts and was biased towards females in the three cohorts.

Discussion

The aforementioned research has increased the knowledge of some basic biological and ecological attributes of *A. veniliae,* an abundant species of the orb weaving guild of the spider community in soybean agroecosystem.

The major web types (e.g., scattered, sheet, and orbs) are reported to be specifically adapted to particular habitat structures and to the capture of specific prey, being the orb-web capable of capturing a wider range of taxa than other web types (Turnbull, 1973).

Web-building spiders are, directly or indirectly, important mortality factors of pests. According to Greenstone (1999), pests are an important part of the diet of web-building spiders. Moreover, Harwood et al. (2001, 2003) have reported that cereal spiders have a non-random web location strategy, which is directly related to prey density. This strategy allows the spiders to increase the frequency with which the insects fall into his web when prey density is high, although not feed directly on them.

Saavedra et al. (2007) studied the predation rate of *A. veniliae* in rice crops, concluding that the predatory behaviour of this spider could have strong implications on the regulation of two phytophagous species inhabiting this crop. Moreover the high prey capture capacity, *A. veniliae* exhibits many attributes that are considered desirable for natural enemies and make them relevant predators of pests MARCO QUIEN DICE ESTO!!!. Among them, temporal synchronization with preys, high fecundity, high population growth potential, predation at juvenile and adult stages, and the orbicular web (Bellows and Fisher, 1999).

Flórez et al. (2002) also reported one more nymphal instar in the female than in the male of the related species *A. variabilis*, under both greenhouse and field conditions, but a smaller female and male longevity than that of *A. veniliae* determined in this study. However, the greater longevity of *A. veniliae* females compared to males registered in the present study is coincident with findings of other authors in phylogenetically unrelated species (Gardner 1965; Bailey 1968; Jackson 1978; Mansour et al. 1980).

Fecundity curves indicated that *A. veniliae* is iteroparous, which means that the female reproduces repeatedly during its lifetime. The mean female fecundity coincided with that found for other spiders (Foelix 1996), but it was considerably higher than that of other *Alpaida* species, such as *A. variabilis* (76.5 ± 34 eggs per female) (Flórez et al. 2002). However, fecundity comparisons are difficult to make because there are not data on female size or biomass, only cephalothorax width, and female size, among other factors, is very related to fecundity.

The mean number of days from mating to the first oviposition of *A. veniliae* was much shorter than that of other species of the same genus, e.g. *A. variabilis* (15.25 ± 2.6

d) (Flórez et al. 2002). A short prereproductive period is an important trait for a natural enemy of pests, because it contributes to population growth.

Since the three studied cohorts came from the same colony and were reared under identical conditions of food, temperature, humidity and photoperiod, we assumed that variations among survival curves registered at initial ages, revealed the natural inter- population variations.

Seeing as males may copulate several times with different females through their lives, the highest proportion of females found in the studied cohorts (sex ratio biased towards females) would indicate another positive feature that would promote population increase. But, whether this potential would be expressed in field conditions is difficult to predict and deserves more research.

Unfortunately, there is very little information about population parameters from others spiders to compare with this study. Boulton & Polis (1999) have calculated some life history parameters of *Diguetia mojavea* (Diguetidae) under field conditions in southern California. However, results are not easy to compare since that family is not closely related to Araneidae, and conditions like food, temperature and photoperiod that greatly affect development and growth rate were different.

In addition to the high abundance of *A. veniliae* in the soybean spider community, their biological and ecological attributes indicate the importance of conservation this predator as a natural enemy of soybean crop pests. However, more research to elucidate the significance of their predator role in pest suppression of soybean crops is needed.

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