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DEVELOPMENT OF THREE SAC SPIDERS OCCURRING ON LIME ORCHARDS AT HOMESTEAD, FLORIDA

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Abstract. The development of three species of sac spiders known to prey on citrus leafminer was studied under laboratory condition. Females and males Chiracanthium inclusum had mean life spans of 215 ± 6 and 177 ± 6 days, respectively. The mean life span of females and males of Hibana velox was 311 ± 4 and 240 ± 9, respectively. Trachelas volutus females and males had mean life spans of 253 ± 8 and 212 ± 19, respectively. Females of all species that matured and were fertilized in captivity produced 1-3 egg masses. Oviposition took place 2-7 days after mating for all species. Chiracanthium inclusum had an average of 57 ± 10 eggs per egg mass, whereas H. velox and T. volutus had averages of 110 ± 5 and 56 ± 4 eggs per egg mass, respectively.

Spiders are one of the ubiquitous groups of predatory organisms in the animal kingdom (Dondale et al., 1970; Greenstone and Sunderland, 1999; Nyffeler and Benz, 1987; Turnbull, 1973). They are considered to have an important influence in the dynamics of arthropod pest populations in natural and agricultural landscapes. In agriculture, experimental evidence is available showing the important contribution of spiders in pest suppression (Greenstone and Sunderland, 1999) particularly when assembled into groups of species (Riechert and Bishop, 1990; Sunderland et al., 1997). For instance in citrus orchards, sac spiders and other related species have been reported among the dominant spiders (Breene et al., 1993; Carroll, 1980; Mansour et al., 1982; Platnick, 1974). According to Carroll (1980), various species of sac spiders (i.e., Chiracanthium sp., Hibana sp., and Trachelas sp.) contribute to the control of lepidopterous pests, mites, and thrips in California citrus orchards.

In Homestead, Florida, survey results also showed that this group of spiders is a dominant component of the community of predatory spiders in lime orchards. Among this group of spiders, three species: Chiracanthium inclusum Hentz [family Clubionidae], Hibana velox (Becker) [family Anyphaenidae], and Trachelas volutus (Gertsch) [family Corinnidae], were confirmed to feed on the larvae and prepupae of citrus leafminer, Phyllocnistis citrella Stainton. This moth is a major insect pest of lime Citrus aurantifolia (Christm.) in south Florida (Amalin, 1999). Regardless of the known predation potential of this group of spiders, knowledge of their development is fragmentary. The aim of this study was to examine the life cycle, habits, and other biological aspects of three species of sac spiders, C. inclusum, H. velox, and T. volutus in order to better understand their role, as natural enemies of arthropod pests in lime (Citrus aurantifolia) orchards.

Materials and Methods

Initial source of spider population. Egg sacs of C. inclusum, H. velox, and T. volutus were collected in an experimental lime orchard at the Tropical Research and Education Center at Homestead, Fla. The egg sacs were brought to the laboratory and held inside an incubator at 27 °C and 80% RH until the spiderlings emerged. First-instar spiderlings from the same egg mass for each spider species were used for all rearings.

Laboratory rearing. Hibana velox was reared using artificial diet, whereas C. inclusum and T. volutus were reared on 2nd-instar P. citrella. The choice of diet for each spider species was based on results of a previous experiment on rearing spiders under laboratory conditions (Amalin et al., 1999). Chiracanthium inclusum and T. volutus reared on P. citrella larvae were able to develop into adult stage, but H. velox did not. However, H. velox was able to develop into adult stage on artificial diet.

Spiders were reared on artificial diet in laboratory glass vials (15 mm diameter x 60 mm long) (Amalin et al., 1999). The diet was a mixture of 230 mL soybean beverage, 230 mL homogenized whole milk, two fresh chicken egg yolks, and 5 mL honey. A single spiderling was placed in each laboratory glass vial. The mouth of the vial was closed with a cotton swab saturated with artificial diet. A one-inch long stick was impaled in the vial, and the stick supported the spider as it fed on the artificial diet.

The spiders reared on 2nd-instar P. citrella larvae were placed inside a plastic Petri dish (10 cm diameter x 1 cm high) lined with moistened filter paper. The P. citrella were collected in the field or from a greenhouse culture, depending on the availability of the larvae. Portions of leaf containing 2nd-instar P. citrella were placed in each Petri dish. A total of 10 P. citrella larvae were exposed to each spiderling.

One hundred spiders of each species were reared from egg to maturity on different diets. All spiders were placed in an incubator kept at 27 °C, 80% RH, and L:D 12:12 photoperiod. The artificial diet and P. citrella larvae were replaced every 2 d. Daily observations were made on the life history of C. inclusum, H. velox, and T. volutus in order to obtain a com-

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complete picture of development. Ten pairs of adult male and female spiders for each species were included to observe courtship, mating, oviposition, and maternal care. Each pair was kept in a separate container to avoid cannibalism.

Data gathered. Data about egg mass size, number of molts, days to maturity, adult life span, and total life span for each species were taken, and the mean and standard error for each parameter were calculated. The mean number of eggs laid by females for each species was also calculated.

Results and Discussion

Spiderling. The period between oviposition and the first true molt, in which a skin with extremities is shed, was 17 to 20 d for C. inclusum, 19 to 22 d for H. velox, and 22 to 25 d for T. volutus. The duration of all subsequent stages varied widely even for individuals of the same parentage and reared under the same conditions. For all species, the active feeding stage includes the period from the first true molt until adult stage.

About 2 d before molting, the spiderlings of the three sac spider species slow their movement and reject food. Nevertheless, they remain capable of normal movement and they attack and kill any prey that disturbs them. During this period the spider normally becomes enclosed in a silken nest. A successful molt takes place after about 15 to 20 min. If the molting process goes awry, the spider may struggle for 1 h or more, and sometimes the struggle ends with death. In this study, mortality rates during each molt varied by developmental stage and species. For C. inclusum, an average of 47.5 ± 7.4% died during molts and from the surviving 7th-instar, 45.5% developed into male adults and 54.5% developed into female adults. Hibana velox had an average mortality rate of 23.7 ± 5.1% during molting and from the surviving spiders in the 6th and 7th instars, 28.2% and 71.8% developed into male and female adults, respectively. Trachelas volutus had an average mortality rate of 46.2 ± 7.5% during molting and from the surviving 6th- and 7th-instar 57.1% developed into female adults and 42.8% developed into male adults.

Both female and male Chiracanthium inclusum were found to mature with fully developed genitalia after the 7th molt. Female and male H. velox mature after the 7th molt and 6th molt, respectively. Trachelas volutus females may mature at any instar after the 6th molt and the males mature after the 7th molt. The number of immature instars varied with gender and among individuals within the same gender. Male C. inclusum underwent 7-8 molts, which required an average of 98 d, whereas the females underwent 7-9 molts, which required an average of 102 d. Females required an average of 22 d and males required an average of 13 d to develop to full maturity after having molted to the last immature instar. For H. velox, the female underwent 7-12 molts, which required an average of 171 d and the males underwent 6-9 molts, which required an average of 131 d. Hibana velox females required an average of 31 d and males required an average of 15 d to reach full maturity during the penultimate instar. In T. volutus, the females underwent 6-9 molts, which required an average of 111 d, and the males underwent 7-8 instars, which required an average of 106 d. Females reached full maturity at an average of 8 d and males at an average of 6 d as subadults.

Adult. Table 1 presents the major life history parameters of the three sac spider species. Under standard laboratory conditions, adult females of C. inclusum lived an average of 95 d; adult males, on the other hand, lived an average of only 58 d. When the immature stages are included, the total life span in C. inclusum was an average of 215 d and 177 d for females and males, respectively. Adult H. velox females lived an average of 121 d, and males for an average of 90 d. The total life span averaged 311 d for females and 240 d for males. On the other hand, T. volutus females lived for an average of 120 d and the males lived an average of only 82 d. The total life span of T. volutus was an average of 253 d and 212 d for females and males, respectively.

Egg and Postembryo. The egg masses of the three species of sac spiders included in this study differ in size and shape. The egg mass of C. inclusum is generally an oblate spheroid. The individual eggs are spherical, non-agglutinate, and egg mass size (5.0 ± 1.0 mm) varies with number of eggs produced. The eggs are pale yellow, with a translucent, frosty appearance and are clearly visible through the silken covering sheath. The thin, finely spun egg sac in which they are contained is suspended within a much more tightly woven brood nest in which the female encloses herself with the egg mass. The egg mass of H. velox is flat oblong with the longest dimension being an average of 8.0 ± 1.2 mm. The eggs are creamy in color and spherical. The egg mass is laid inside the retreat or egg nest, where the female encloses herself. The egg mass of T. volutus is contained inside a circular papery cocoon fastened on a flattened surface. In the field, the egg cocoon is usually located on the surface of leaves, branches, trunks, and fruits. The female stays on top of the cocoon to guard the egg mass. The egg mass has an average diameter of 4.5 ± 0.9 mm. The eggs are round and pale yellow in color.

Egg eclosion starts when the contours of the embryo, especially those of the appendages, become imprinted upon the chorion. The process required 11 ± 2.1 d for C. inclusum, 12 ± 1.2 d for H. velox, and 15 ± 2.3 d for T. volutus. For all the species, the first postembryo emerged after 24 h. Initially the first postembryo is immobile with appendages appressed to its body and still enveloped by the very thin, transparent vitelline membrane. Within 2 d after the chorion is cast, the vitelline membrane recedes from all of the appendages of the first postembryo. By the time the membrane has been shed com-

<table>
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<th>Species</th>
<th>Days to maturity (mean ± SEM)</th>
<th>No. of instars (mean ± SEM)</th>
<th>Adult life span (mean ± SEM in days)</th>
<th>Total life span (mean ± SEM in days)</th>
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<tr>
<td>C. inclusum</td>
<td>120 ± 18</td>
<td>8 ± 0.5</td>
<td>95 ± 9</td>
<td>215 ± 6</td>
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<tr>
<td>H. velox</td>
<td>190 ± 35</td>
<td>9 ± 0.8</td>
<td>121 ± 5</td>
<td>311 ± 4</td>
</tr>
<tr>
<td>T. volutus</td>
<td>133 ± 21</td>
<td>7 ± 0.6</td>
<td>120 ± 4</td>
<td>253 ± 8</td>
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completely, the second postembryo begins to move and walks around the brood nest, within half an hour after its emergence. Almost invariably the second postembryo climbs to the top of the inside of the brood nest where it clings and moves slowly for approximately 7 d. The newly emerged, active second postembryo of *C. inclusum* and *H. velox* are pale yellow and devoid of markings and other pigmentation; whereas, the second postembryo of *T. volutus* is light gray and also devoid of any body ornamentation. Within 6 d, the appendages acquire a dark pigmentation caused by the developing hairs and spines on the forming cuticle. The postembryonic stage of each species lasted 7 to 10 d. The first molt occurs about 24 h after the pigmentation is evident to produce the first instar spiderling.

**Fecundity and Maternal Care.** Females that matured and were fertilized in captivity produced 1-3 egg masses. The ovi-position in all species took place 2 to 7 d after mating. The number of eggs per egg mass of *C. inclusum* reared in the laboratory varied from 36 to 86 with an average of 57 eggs. Edwards (1958) reported 112 eggs in a single egg mass, and Peck and Whitcomb (1970) reported a range of 17 to 86 eggs per egg mass. Female *H. velox* laid 96 to 120 eggs per egg mass with an average of 110 eggs. Female *T. volutus* produced 47 to 66 eggs per egg mass with an average of 56 eggs.

Our findings and observations on the behavior of *C. inclusum* are similar to those of Peck and Whitcomb (1970) regarding the distinctly different construction of the brood nest and the egg sac. The female and male pair spends much of their time in the brood nest. In nature, both kinds of enclosures are constructed in protected places such as curled leaves, or formed between the fruit and its pedicel. In the laboratory, these enclosures are constructed in various corners of the spider’s container. The resting nest is cylindrical, 5 mm in diameter and 20-25 mm in length. The nest may be open one side or on 2 sides, or completely enclosed and more finely woven. The egg sac is larger than the resting nest and almost spherical; it is woven more tightly and densely and is always sealed completely from the outside environment. The female remains in close contact with the eggs during the entire period of their development. Periodically, she moves around the eggs and touches them with her palpi. Subsequently, the female extends her care for the first instar spiderlings. The maternal care behavior of the other two species, *H. velox* and *T. volutus*, was similar to that of *C. inclusum*. Moreover, the spiderlings of these three sac spider species depend on their mothers, who tear the fabric of the brood nest so that the spiderlings can emerge from the egg sac.

All the information gathered from this study is instrumental in evaluating the potential of the three spider species as biological control agents of important arthropod pests of lime in south Florida. From the first true molt, spiderlings, or the second instar spiderlings to the adult stage of *C. inclusum* and *T. volutus* and the immature stages of *H. velox*, actively fed on CLM larvae, which suggests that a high number of spiders are potentially able to attack CLM in the field. All of these spiders can search the CLM larvae even inside the mine. This specialized feeding behavior in which they can search and extract cryptic food source may merit their consideration as important predators of CLM in lime orchards. Thus, they should be fostered by orchard care practices.

**Literature Cited**


