THE BIONOMICS OF THE SPIDER *METAPHIDIPPUS GALATHEA* (WALCKENAER) AND ITS SIGNIFICANCE AS A BIOLOGICAL CONTROL AGENT IN SORGHUM

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PREFACE

My interest in the bionomics of spiders was aroused by Dr. Kenneth W. Stewart, Professor of Entomology at North Texas State University, while working with the brown recluse spider, Loxosceles reclusa Gertsch and Muliak. Since I knew Dr. Harvey L. Chada, Professor of Entomology at Oklahoma State University, was working with spiders as possible biological control agents in grain sorghum, I contacted him concerning the possibility of working on the problem.

I wish to express appreciation to Dr. Chada for making the study possible, for his guidance, encouragement, and assistance in the preparation of the manuscript.

I am indebted to my major adviser, Dr. Kenneth J. Starks, Professor of Entomology and Investigations Leader, Entomology Research Division, United States Department of Agriculture, for his guidance, helpful suggestions, generous encouragement, assistance in statistical analyses, and critical reading of this manuscript.

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INTRODUCTION

The economic importance of spiders on field crop pests has only recently been investigated by several workers in the United States, Canada, Europe and Japan. They showed that spiders play an important role in the control of many pests.

Bailey and Chada (1968) at Oklahoma State University reported that several species of spiders found in sorghum are important in the control of harmful insects. One of these spiders considered to be common was *Metaphidippus galathea* (Walckenaer) (Salticidae).

A review of the literature revealed that very little information was available on its life history and feeding habits. These data were needed before the spider could be considered an important biological control agent worthy of mass rearing which would be necessary for the development of an arthropod control program.

This study was designed to obtain information on the bionomics of *M. galathea* and to try to determine its feasibility as a biological control organism. Natural population, longevity, mating behavior, fecundity, incubation and hatching, growth and development, mortality, mass rearing, feeding habits, and aerial dispersal were studied. Prey studies were made using beneficial and harmful insects which are associated with grain sorghum. *M. galathea* was tested under caged conditions for the control of the tobacco budworm, *Helothis virescens* (Fabricius), and the greenbug, *Schizaphis graminum* (Rondani).

REVIEW OF LITERATURE

Spiders as Predators

Hobby (1940) prepared a list of some families of spiders with a list of the known insects taken as prey. Duckworth (1965) discussed the role of spiders in controlling insects. Clark and Grant (1968) showed that spider predation on centipedes and Collembola is a factor in checking their populations. Edgar (1969) in studying the predation of *Lycosa lugubris* (Walckenaer) found that 85% of the prey consisted of Diptera, Hemiptera, and Araneae.

Several workers have studied the predation of spiders on specific insect pests. Fluke (1929) observed several spider species feeding on the pea aphid, *Acyrthosiphon pisum* (Harris). Hukusima (1962) evaluated the feeding potential of spiders on aphids harmful to apple and pear orchards. Muniappan and Chada (1970) reported control of the greenbug, *Schizaphis graminum* (Rondani), by *Phidippus audax* (Hentz).

Spiders preying on the fall webworm, *Hyphantria cunea* (Drury), were observed by Riley (1887). Whitcomb and Tadic (1963) reported on the known spiders that are predators of the fall webworm. Warren et al. (1967) identified additional spiders that were associated with the fall webworm.

Eikenbary and Fox (1968) reported six species of spiders that prey upon the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock). Stultz (1955), Whitcomb (1967), and Lingren et al. (1968) have all made studies dealing with the predation of spiders upon the cotton bollworm, *Heliothis zea* (Boddie). Dabrowska et al. (1968) conducted field predation experiments on three species of forest mosquitoes by four species of spiders. Allen et al. (1970) reported several spider species predators of the Jack-Pine Budworm, *Choristoneura pinus* Freeman. Robinson (1969) and Gardner (1964) studied the predatory behavior of salticid and argiopid spiders, respectively.

Spider populations in several cultivated crops have been studied. The following references deal with spider populations in cotton: Kagan (1943) in Texas; Wene and Sheets (1962) in Arizona; Whitcomb et al. (1963) and Whitcomb and Bell (1964) in Arkansas; and Leigh and Hunter (1969) in California. Spiders associated with sweet corn were reported by Everly (1938). Chant (1956), studying spiders in orchards, was one of the first to recognize the value of their predatory habits. He showed that they may be of equal or greater importance than other predators because of their presence from early summer until late in the autumn. Putman (1967) showed the importance of spiders as predators in Ontario peach orchards. Dondale (1958) noted 2 population densities in Nova Scotia apple orchards, 1 in the spring and 1 in late summer. Specht and Dondale (1960) reported that the mean number of spiders in 3 unsprayed New Jersey apple orchards was higher than in 7 sprayed orchards and that chemical sprays affected hunting spiders more than web builders. Barnes (1953) found that each ecological community had a distinct spider population that was characterized by both the presence of certain species and by the relative density. The spider fauna of Finnish oat fields was reported by Raatikainen and Huhta (1968). They stated that the total number of spiders per sample depended on the distance of the field from the forest edge, the area of the field, weed coverage, and weed control. Bailey and Chada (1968) observed spiders on grain sorghum plants throughout the growing season. They concluded that spiders play an important role in controlling grain sorghum insect pests.

Distribution and Habitat of *M. galathea*

M. galathea was reported by Kaston (1948) to be common in the southern part of the United States. Fitch (1963) gave the range from southeastern Canada throughout most of the United States and south into Mexico and the Antilles. Dondale (1956) and Putman (1967) reported *M. galathea* in Nova Scotia and Ontario, Canada, respectively. Branson (1958) was the first to report *M. galathea* in Oklahoma. Whitcomb and Tadic (1963), Whitcomb et al. (1963), Whitcomb and Bell (1964) and Dorris (1969) mention its presence in Arkansas. Dorris and McGaha (1965) and Dorris (1970) list it among spiders collected in Mississippi. Eikenbary and Fox (1968) found it to be present in South Carolina. Studies conducted by Bailey and Chada (1968) in Oklahoma showed *M. galathea* to be numerous in sorghum, especially in the head.

Life History of Spiders

Several studies have been conducted on the life history of spiders. One of the early works was by Enock (1885) on a purse web spider, *Atypus piceus* Sulz. Due to the medical importance of the black widow spider, *Latrodectus mactans* Fab., it has been extensively studied by Rau (1924), Jellison and Phillips (1935), and Deevey (1949). In recent years spiders of the genus *Loxosceles* have been shown to be of medical importance and have been studied extensively. The biology of *Loxosceles laeta* (Nicolet), a native of South America, was studied by Levi and

Spielman (1964) and Bucherl (1969). Loxosceles reclusa (Gertsch and Mulaik) has been studied by Hite et al. (1966) and Horner and Stewart (1967).

Life history studies of spiders other than the preceding include the following: Teutana grossa Kock. (Branch 1943); Genus Corythalia from Venezuela (Crane 1948); Araniella displicata (Hentz), Philodromus rufus Walckenaer, P. cespiticolis Walckenaer, Metaphidippus protervus (Walck.), and Paraphidippus marginatus (Walck.) in Canada (Dondale 1961); Lycosa punctulata Hentz (Eason and Whitcomb 1965); Peucetia viridans (Hentz)(Whitcomb et al. 1966); Phidippus coccineus Peckham and Peckham (Gardner 1967); Oxyopes salticus Hentz (Whitcomb and Eason 1967); Philodromus praelustris Keyserling and P. cespiticolis Walck., in Ontario (Putman 1967); Phidippus audax (Hentz) (Bailey 1968); Agelena consociata Denis (Kraft 1969); Pardosa lapidicina Emerton (Eason 1969); Gea heptagon (Hentz) (Sabath 1969); Chiracanthium inclusum (Hentz) (Peck and Whitcomb 1970); Thomisus onustus Walck. (Levy 1970); and Misumenops celer (Hentz)(Muniappan and Chada 1970).

Mating Behavior

The majority of the mating behavior studies have been included in life history studies which were previously listed. The studies mentioned here deal primarily with the mating process.

Bristowe (1929, 1930 and 1931) was one of the earliest workers to describe courtship and the two basic mating positions. Alexander (1957) discussed the origin of mating behavior in spiders. Nappi (1965) studied the courtship of the wolf spider, Lycosa helluo Walckenaer. A detailed description of Peucetia viridans (Hentz) is given by Whitcomb and Eason (1965) and Exline and Whitcomb (1965). Rover (1966) demonstrated that courtship behavior is displayed by males independently of whether sperm induction had occurred following the final molt. Rover (1967) described the "pseudocopulation" of a palpless linyphiid spider.

The courtship of several species of salticids has been recorded. Gertsch (1949) credits Peckham and Peckham as first reporting the courtship antics of the American jumping spiders (salticids) in 1889. The Peckhams gave detailed descriptions of several species. The courtship activity of *Phidippus* sp. has been described by Gertsch (1949), Gardner (1965), and Bailey (1968). Gertsch (1949) stated that the *Metaphidippus capitatus* Peckham (= *galathea*) male approaches the female with legs extended upward, then stops and drops them exposing the highly marked and colored face.

Spider Feeding and Growth

Of the spider species studied by Bilsing (1920) none showed a particular food preference. Burkill (1922) found that an adult female spider (species unknown) fed for 2 or 3 days, fasted a day or 2 and then fed again. Deevey (1949) obtained variation in instar length due to the rate of feeding with the black widow *L. mactans*. Turnbull (1962) states in general the more prey supplied per day to *Linyphia triangularis* Clerck the more it would capture. Spiders in his test consumed virtually the same quantity of food at the completion of each developmental stage regardless of the rate at which prey was supplied. Turnbull (1965) working with *Agelenopsis potteri* (Blackwell), found mortality varied inversely with the feeding rate and that the rate of prey captured declined sharply in the adult. Haynes and Sisojevic (1966) showed that the male and female feeding rates of immature stages of *Philodromus rufus* Walckenaer were equal; however, the adult males were relatively inefficient predators when compared to the females. Miyashita (1968a) noted the changes of the daily food consumption during adult stages of *Lycosa pseudoannulata* Boes. et Str. Miyashita (1968b) described the growth and development of *Lycosa T-insignita* Boes. et Str. under different feeding conditions. Peck and Whitcomb (1966) made the first attempt at rearing spiders on artificial diets composed of egg yolk and powdered milk, crushed lepidopterous larvae, water and food coloring dye.

Ecdysis in Spiders

Montgomery (1903) and Warren (1925) described the molting process in spiders. Montgomery stated that post-nuptial molts occur in *Atypus* and *Lycosa*. Dondale (1965) observed *Philodromus rufus* Walckenaer taking molting fluid from the exuvia. This was done by stripping the fluid to the end of the exuvia leg and biting the end from the leg.

Temperature Studies

Jones (1941) working with *Agelena naevia* Walckenaer reported that in low humidity (50%) mortality increased greatly with an increase of temperature (27^{o} C) but in high humidity (92%) mortality decreased slightly with an increase of temperature (27^{o} C). Kirchner (1969) found that *Araneus cornutus* Clerck could withstand lower winter temperature because of an increase of glycerol.

Ballooning of Spiders

One of the earliest reports of ballooning is by Blackwall (1827). He described how spiders became airborne and believed the purpose was to change quarters. McCook (1877) made some excellent observations giving a step by step procedure of the process of ballooning. In 1878 he showed a correlation between the distribution of Sarotes venatorius Linn. and the North Trade Winds. Emerton (1908) observed several spiders ballooning and noted that the maximum number was airborne about 10:00 a.m. after a fog, and at a temperature of 50° F. Ballooning stopped when the wind increased. Bristowe (1929) stated the ideal conditions to produce the urge to balloon were still, sunny days in spring, autumn, and early winter when humidity was high. Crosby and Bishop (1936) reported insect samples collected by airplanes at Tallulah, Louisiana, contained some argiopids at 5,000 ft. Glick (1939 and 1960) collected several spiders by airplane, some above 5,000 ft. The majority were collected in the day, but some were collected at night. Freeman (1946) found the largest number of spiders in the air when the temperature was above 64° F., the relative humidity below 60% and the wind velocity below 12 mph. Duffey (1956) reported immature spiders ballooning each month from December to May, except January. He stated that temperature had a more important influence on aerial dispersal than other microclimatic factors.

Parasites and Predators of Spiders

Cloudsley-Thomson (1953) listed the enemies of hunting spiders as cannibalism, toads, frogs, insectivorous birds, shrews, wasps, centipedes, and parasites. The parasites include Protozoa, nematodes, ichneumonids, and acrocerids which are egg parasites. Eason et al. (1967) found the incidence of parasitism was only 1.6% among 1,679 spiders (lycosids and oxyopids) examined. Dorris (1969 and 1970) listed spiders collected from mud-dauber nest in Arkansas and Mississippi, respectively.

METHODS AND MATERIALS

Collection of *Metaphidippus galathea* (Walckenaer)

The majority of the *M. galathea* colony was established by collecting adults and immature forms from the heads of forage type sorghum, *Sorghum bicolor* (Linn.) Moench. The sorghum was grown at the Oklahoma State University Agricultural Experiment Station at Perkins, Oklahoma. A small number of the colony members were collected from vegetation in the vicinity of the Oklahoma State University Insectary.

Spiders were collected by jarring plants over a white cloth supported by a metal ring (Fig. 1) and sweeping vegetation with insect nets. The specimens were captured in small medicine cups for transporting to the laboratory.

Laboratory Conditions

All field collected *M. galathea* immatures and adults except the breeding stock were cultured in a laboratory room at the Entomology Insectary. The ambient temperature ranged from 21 to 29^{o} with a mean of 28^{o} C. The relative humidity fluctuated from 10 to 60%. Artificial light was provided for 12 hours daily by means of four 40-watt fluorescent bulbs controlled by a time clock.

The breeding stock, eggs, and spiderlings were maintained in an incubator (Model 805, Precision Scientific Co., Chicago, Ill.) (Fig. 2). The temperature remained constant at 27^{o} C. with the relative humidity ranging from 60 - 80%. The photoperiod was identical to that of the

Fig. 1. Equipment for collecting M. galathea from vegetation.

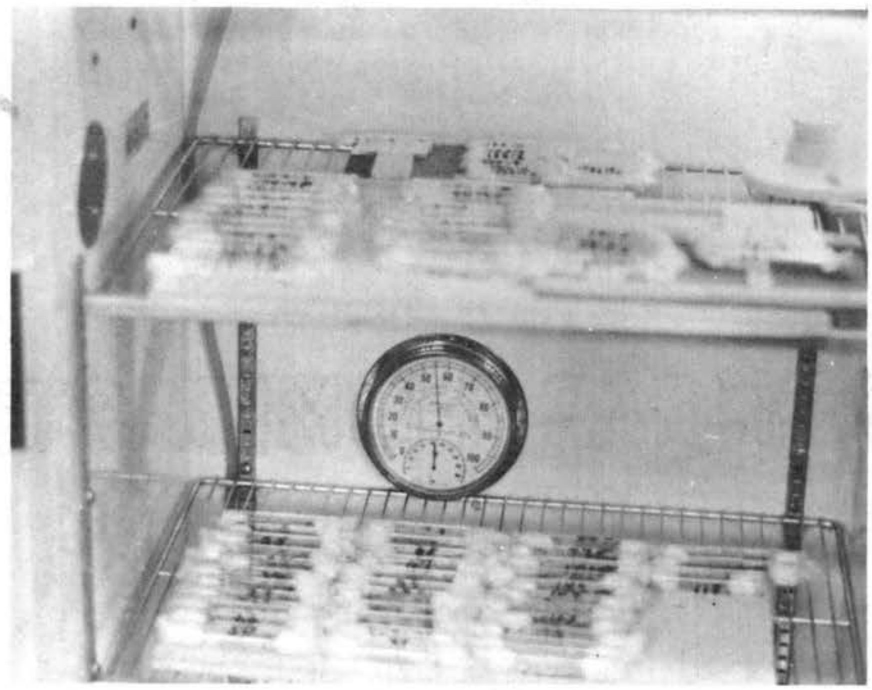

Fig. 2. Breeding stock, eggs, and spiderlings housed inside an incubator.

laboratory room except the light was produced by a 15-watt incandescent bulb.

Spider rearing

All spiders were reared in glass tubes patterned from those described by Peck and Whitcomb (1967). These consisted of three sizes, 17 mm x 10 cm for adults and 11 mm x 8 cm and 6 mm x 6 cm for immatures, depending upon the size of the spiderling. Each tube had a cotton stopper at each end and contained a small piece of filter paper approximately the diameter of the tube and one third its length. This provided a surface for the building of retreats, molting webs, sperm webs, and oviposition sites.

Two to 3 *Drosophila melanogaster* Meigen larvae were fed to 2nd and 3rd instar spiderlings every other day for the entire stadium. Five to 8 *D. melanogaster* adults or 1 corn earworm larva (2nd or 3rd instar), *Heliothis zea* (Boddie), were fed to 4th instar spiderlings through adults. Immatures were fed on the same schedule as 2nd and 3rd instar spiderlings, while the adults were fed 3 times weekly.

D. melanogaster larvae (1st and 2nd instar) were removed from the medium by means of a moist small artist's brush and placed directly into the glass tube. The adults were anesthetized with anhydrous ethyl ether and transferred to the rearing tubes where they recovered in the presence of the spider. The corn earworms were gently removed from the diet rearing medium with low tension forceps and placed on the filter paper in the spider rearing tube.

D. melanogaster were reared on a basic corn meal medium modified from the one used by Strickberger (1962). The corn earworms were reared on a bean diet described by Shorey (1964).

A spider rearing chamber (Fig. 3) was constructed from a gallon cardboard ice cream carton. The open top and two 2-inch square holes on opposite sides just above the bottom were covered with organdy cloth. An 8 dram shell vial containing a *D. melanogaster* culture (diet poured at a slant) was inserted 1 inch from the bottom. A 1 dram vial with water and plugged with cotton was inserted directly across the container from the culture. Spiders were introduced through one of the vial holes. In cages which housed 2nd instar spiderlings it was necessary to feed either introduced *D. melanogaster* larvae or greenbugs, *Shizaphis graminum* (Rondani), until they were large enough to feed on *D. melanogaster* adults from the culture. Observations on the spiders' feeding and behavior were recorded.

Mating

Laboratory matings were made in the rearing tube of the female since her retreat was the site of the mating. Matings were made during the day under normal laboratory conditions. Numerous mating sequences were observed and detailed observations were recorded.

Egg Sac Deposition and Incubation

Once laboratory or field-mated females deposited an egg sac it was carefully removed and placed on filter paper in a Petri dish which was kept in the incubator where the temperature was constant at 27^{o} C and relative humidity ranged from 60 - 80%. The egg development was observed daily and the eggs were measured with an ocular micrometer.

Spiderling Measurements

Records on the growth of spiderlings were made by measuring the cephalothoracic widths and body lengths at the beginning of each

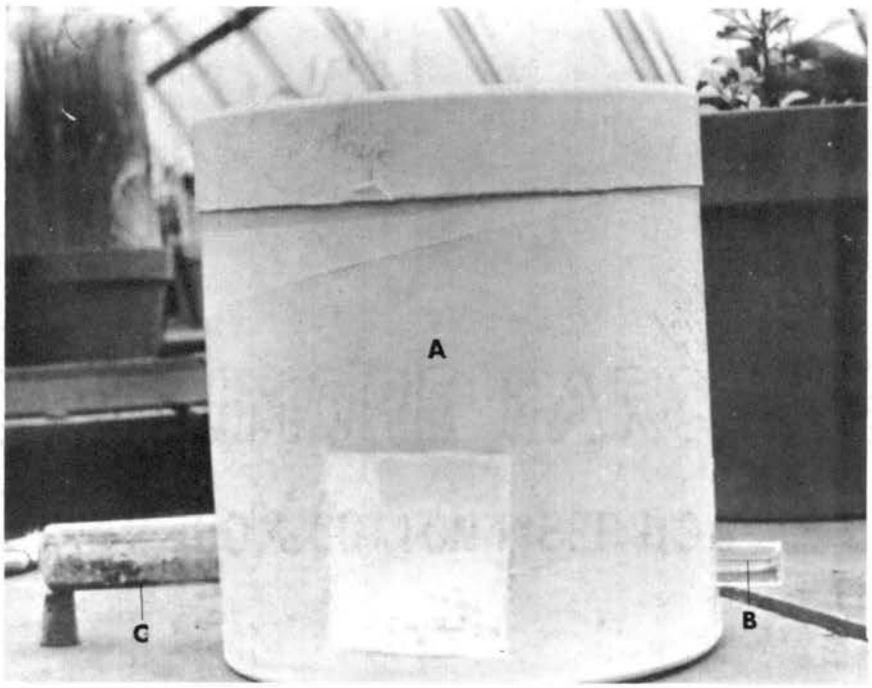

Fig. 3. Spider rearing chamber. A - One gallon ice cream carton. B - One dram water vial. C - Eight dram *Drosophila* culture vial.

stadium. The cephalothorax was measured at its greatest width, which was above the third pair of legs. The body length measurement was from the anterior median eyes to the tip of the abdomen above the spinnerets. The spiderlings were measured in their tubes. If excess activity was exhibited by the spiderlings, they were inhibited by small amounts of carbon dioxide. All measurements were made by use of an ocular micrometer.

Artificial Diet Tests

A preliminary study was conducted feeding second instar *M. galathea* spiderlings artificial diets. One diet was that developed for the greenbug, *S. graminum* (Cress 1969). The other was a saturated solution of "wheast" (yeast-cottage whey product). The diet was dispensed in cellulose sponge, a method described by Stoner and Bryan (1970). The test was conducted using four treatments of *D. melanogaster* larvae, wheast, aphid diet, and distilled water. Each treatment was replicated 6 times. New treatments were applied every 48 hours.

Feeding Tests

Feeding tests were conducted in the spider's rearing tube. The tests were conducted to determine if the adults would feed upon the insects supplied as food. Test insects included larvae of the tobacco budworm, *Heliothis virescens* (Fabricius), corn earworm, *H. zea* (Boddie), sorghum webworm, *Celema sorghiella* (Riley), and a lace-winged fly, *Chrysopa* sp. Adults of the latter two, the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville, and the false chinch bug, *Nysius ericae* (Schilling), were also used.

Aphid Control Studies

Forty-five 4-in plastic pots were planted with Rogers barley. When the plants were 2 inches high, they were thinned to 1 plant per pot. The plants were infested with greenbugs and female spiders, then covered with plastic cages. The 45 pots were divided into 9 treatments with 5 replications. The treatments were composed of plants infested with 5, 10, or 20 greenbugs. Each of these conditions had an old female (mature for at least 6 months), or a young female (mature less than 6 months), or was a control with no spiders. Records were kept on the total number of aphids, plant conditions, and spider activity for a 3 week period.

Tobacco Budworm Predation Study

Twenty 1st instar tobacco budworm larvae were placed in medicine cups with bean diet. Treatments consisted either of single adult *M. galathea* males, or adult females, or immatures. The control cups contained no spiders. Each treatment was replicated 5 times. At 24, 48, and 72 hr intervals the number of live budworms was recorded.

Aerial Dispersal of Spiders

The dispersal habits of *M. galathea* were studied by collecting immature and adult forms in 2 "Johnson-Taylor" suction traps. One was located on top of a 60 ft high building on the main campus at Oklahoma State University and the other on a 10 ft roof at the Insectary. Spiders were collected and stored in 80% ethyl alcohol. Samples were taken during 1970. They were removed daily during summer and early fall and once per week during colder months.

RESULTS AND DISCUSSION

Description of *M. galathea*

The spider, *M. galathea*, is a relatively small jumping spider of the family Salticidae. The adults show marked sexual dimorphism. The dark brown male (Fig. 4) exhibits a row of white scales on the dorso-lateral area of the cephalothorax and the dorso-lateral and anterio-dorsal area of the abdomen. The legs are annulated with alternate dark and light bands. Average cephalothoracic width and length of field collected males is 1.34 ± .11 mm and 4.27 ± .49 mm, respectively. The male palpi are much larger than those of the females and have a bulbous appearance. The palpi are the copulating organs of the male and function in sperm storage and transfer. Females (Fig. 5) are slightly larger than males. The average cephalothoracic width and total length of field collected females is 1.47 ± .14 mm and 5.03 ± .47 mm, respectively. Color of the female varies from light gray to light brown. Females possess an indistinct chevron pattern, or small spots on the abdomen. These spots are preceded by white areas. The caudal pair of white spots are transverse. The legs are conspicuously ringed as in the males.

Natural Populations of *M. galathea*

The majority of the specimens of *M. galathea* used in this study were collected from sorghum. The spiders were rare in grain sorghum during June, July, and August, but became more common in forage type

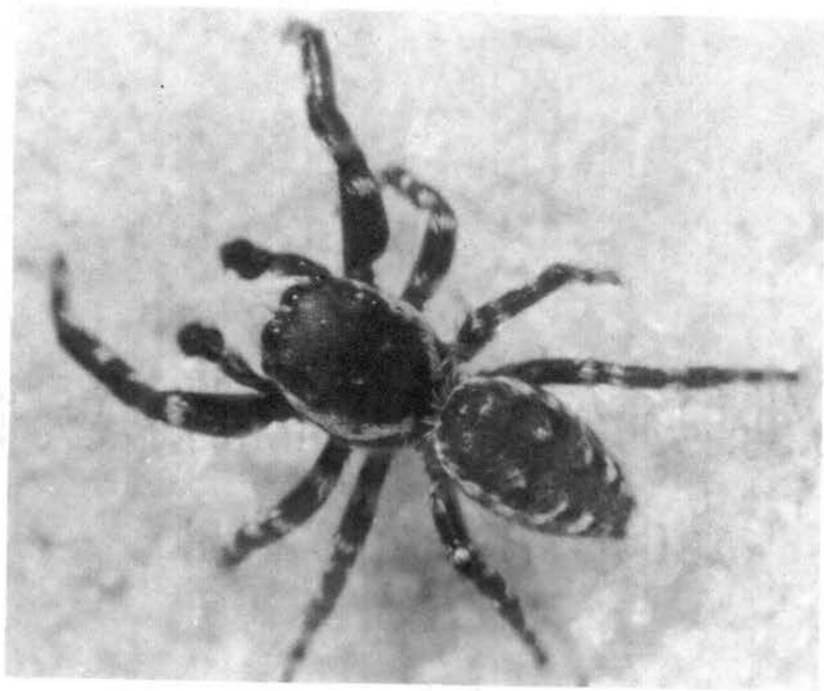

Fig. 4. Male M. galathea.

Fig. 5. Female M. galathea.

sorghum in September. From early October until late November it was one of the most common spider species in forage type sorghum heads. This fall population was largely immatures, but there were also some males and females. Adults and very early instars were commonly found in areas of heavy foliage cover during late spring and early summer. *M. galathea* was found under tree bark in its hibernaculum during winter months.

In the fall of 1969 and 1970, 83 adult and 142 immature specimens of *M. galathea* were collected at random from forage sorghum heads. The sex ratio was approximately 1:1 for the field collected adults and immatures (determined after reaching maturity in the laboratory).

Adult Longevity

Under laboratory conditions adult *M. galathea* lived a considerable length of time. Males lived an average of 184 ± 77.4 days with a range of 41 to 309 days. Females lived 222 ± 72.6 days with a range of 102 to 334 days. Both male and female averages were based on 20 observations of each sex.

Mating Behavior

Females were receptive to mating shortly after their final molt. The males had to charge their palpi with seminal fluid before mating could occur. This was not observed under laboratory conditions; however, it is assumed to be similar to that of other spiders which have been reported in the literature. Alexander and Ewer (1957) gave a good review on the techniques used by spiders to transfer seminal fluid into the female's genital openings by the palpi.

Several successful matings were observed under laboratory conditions. The success of the mating appeared to be due to the receptiveness of the female. All matings occurred in the silken tunnel (retreat) constructed prior to mating by the female. The majority of these silken tunnels had 3 entry ways, but some had 2, 1 at each end. If the female was out of the silken tunnel when the male was placed with her, she immediately went inside. Usually the male would make a rapid but cautious approach waving his first pair of legs in the air and vibrating his palpi. If the female was receptive, she would move to the entry way and vibrate her palpi while gradually moving back into the tunnel. Sometimes the male would be slow in entering the tunnel and the female would come out, approach the male vibrating her palpi, then return to the retreat with him following.

Pre-mating or courtship activity ranged from 2 to 10 min. The male usually used the entry that was directly in line with the eyes of the female. He would approach from the front and crawl over the cephalothorax of the female until he had moved 2/3 the total length of her body (Fig. 6). Using his 1st pair of legs, he would turn her abdomen approximately 160^{o} either to the right or left. If she was 1st turned to the left, his left palpus entered her left atrial opening. After approximately 25 min the male would move her abdomen to the right and use the right palpus in the other atrial opening about the same length of time. No switching back and forth from one atrial opening to the other was observed. The fundus of the palpi could be observed while pumping the seminal fluid into the female atrial openings. The male moved outside the tunnel after mating was completed. If he was allowed to remain inside the tube, he would construct himself a silken tunnel.

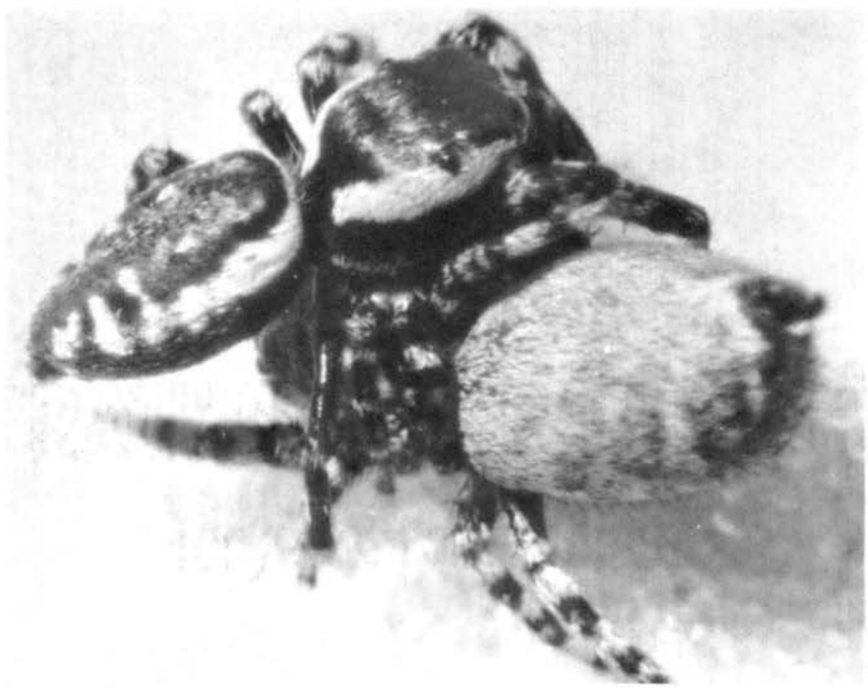

Fig. 6. Copulatory position of M. galathea with the male on the left and the female partly on her side.

The male and female remained compatible as long as food was available, but she killed and ate the male when there was no food.

Several attempts were made to remate a female, but they were unsuccessful. She would take a defensive position by holding up her 1st pair of legs, and this show of hostility caused the male to retreat to the opposite end of the tube. However, males would mate numerous times with virgin females.

Egg Deposition, Incubation and Hatching

Egg sac construction in all cases took place inside the silken tunnel. Just prior to egg deposition the female laid down a base web about 10 mm in diam. Eggs were deposited on this base web starting in the center and working to the sides. A dense covering web was used to cover the eggs and hold them in place. In general, the sacs were oval measuring about 8 x 15 mm and approximately 3 mm thick. Many of the females deposited more than 1 sac in the same tunnel. The size of the tunnel depended upon the number of egg sacs present. As the number of egg sacs increased the female would increase the overall area of the silken tunnel in length and width. Oviposition usually took place at night and was not observed. The female protected her sac continually by taking a position over it. The only time she was observed leaving it was for feeding. When the female was teased, she would attack the object being very reluctant to give up the sac.

Two females that were collected late in October 1969 produced viable eggs the next spring (March) under laboratory conditions. The number and percent hatch was very similar to those mated in the laboratory. One produced 4 and the other 6 egg sacs. This indicates that females under natural conditions are probably capable of mating late in the season, overwintering and producing viable eggs the following spring.

Data on M. galathea oviposition are presented in Table 1, and a viable egg sac is shown in Fig. 7. Thirty-four females deposited egg sacs during the study; however, only 6 of these were mated in the laboratory during the early spring at the approximate time of natural field matings. An average of 8.3 egg sacs was deposited by 6 females. All mated females produced more than 1 viable sac. The number of viable sacs depended upon what time of the season mating was allowed to occur. If a female became gravid but was not allowed to mate, she would construct an egg sac and deposit infertile yolk-like material in which the individual "eggs" appear to run together (Fig. 8). The "eggs" were golden yellow and became very hard within 24 hours. No chorion was believed to be present in the material. The female treated this material as a normal sac. These infertile masses were deposited continually at approximately the same intervals that other females deposited fertile egg sacs until the female mated or died. Once mating occurred the females started producing normal, viable eggs. The 6 females that were mated early in the season started producing infertile yolk material after several viable egg sacs were produced (Table 2). As indicated by the table, the pattern of oviposition for each female was similar; however, female number 3 did produce an egg sac (the 10th) which had 1 viable egg. This sac was preceded by 2 sacs which had no hatch and 2 which had only yolk material.

This deposition of yolk material from non-mated females has been difficult to explain. Several workers have reported a decrease in number and percent hatch with succeeding sacs and this pattern seems to be

Table 1. *M. galathea* oviposition data in the laboratory.[a]

Item	No.			
	Observations	Minimum	Maximum	Mean
Egg sacs/female/year	6	7	11	8.3 ± 1.6
Days between egg sacs	55	5	40	14.6 ± 6.5
Eggs/egg sac	55	9	31	19.0 ± 4.3
Eggs/female/year	6	97	233	158 ± 53.7

[a]Viable eggs - yolk deposits excluded.

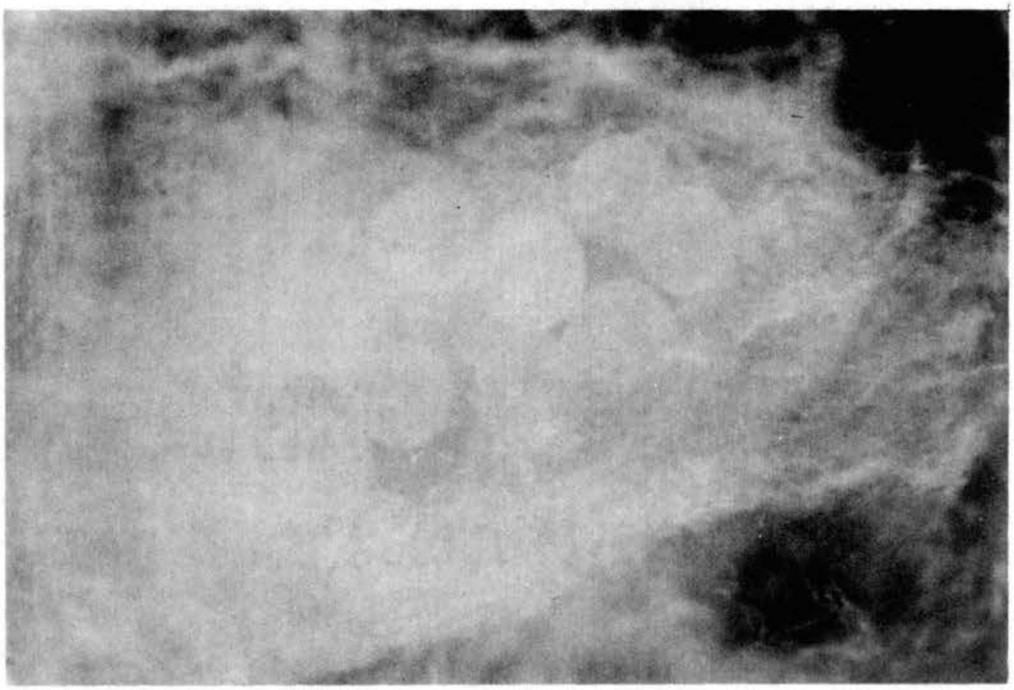

Fig. 7. M. galathea viable eggs within the egg sac.

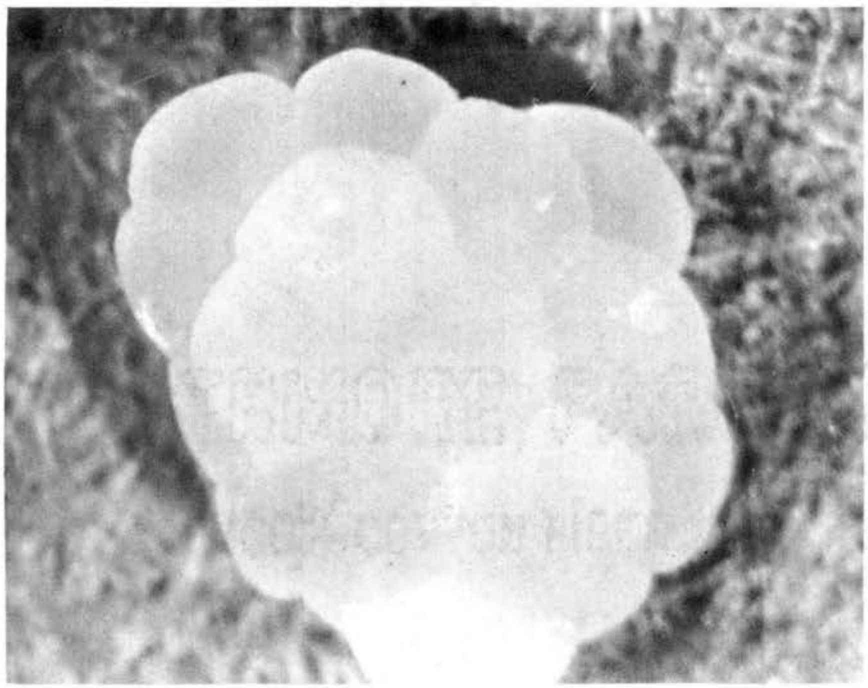

Fig. 8. Non-viable egg mass containing yolk-like material.

Table 2. Fate of egg sacs deposited by 6 *M. galathea* females.

Female identification No.	No. of viable sacs	No. with no hatch	No. with yolk	Total
1	3	8	1	12
2	7	0	1	8
3	5	2	4	11
4	6	1	3	10
5	7	2	3	12
6	6	3	3	12

normal for the majority of spiders. Putman (1967) found a similar problem with Philodromus praelustris Keyserling in that the later eggs did not hatch. Putman states, "A few of the first nonviable eggs may have undergone some embryonic development for they darkened before they dried up, but most solidified without change of colour within a few days after they were laid, probably indicating that no development had taken place." He believed lack of egg development was due to unavailability of sperm for fertilization. This may be the reason for non-viable eggs in M. galathea; however, it still does not explain the yolk material. In spiders, fertilization is believed to occur soon after the eggs are deposited (Gertsch 1949). He states, "They issue one by one from the genital opening beneath the base of the abdomen, and are bathed with a syrupy fluid in which quantities of sperm from the stores in the spermathecae have been discharged. At this time the eggs have a very soft chorion, which is easily penetrated by the sperm at any point."

It is conjecture on the part of the author, but it seems possible that this semen or "syrupy fluid" has at least a dual function. It is believed the fluid carries sperm which fertilizes the egg and also carries another substance which hardens the chorion and gives rigidity to the egg. If this is true, it could explain why the non-mated females produce the yolk-like mass, since no seminal fluid would be present to harden the chorion. This could also explain why early egg masses of mated females are fertile (both fluid and sperm present), later masses are non-fertile (no sperm present), and then still later the production of yolk material (neither sperm nor fluid present).

Maximum number of viable egg masses for a given female in 1 season was 7 (Table 2). Totals of 12 sacs (including viable, infertile, and yolk material deposits) were deposited by 3 different females mated early in the spring. Table 1 shows an average of 158 eggs were deposited per female per year with a minimum of 97 and a maximum of 233. Minimum number of days between egg sacs was 5 and the maximum was 30 with a mean of 14.6. Number of eggs per egg sac ranged from 9 to 31 with a mean of 19.

Laboratory mated females deposited their 1st egg sac within 10 days of mating. Forty-six percent of all observed eggs deposited during the study hatched at 27^{o} C (Table 3). Early egg sacs had the highest percent hatch. First and 2nd had 92 and 97 percent hatch, respectively, but hatching decreased to 0% in the later sacs.

Growth, Development and Ecdysis

The terminology used to describe the various stages of embryonic development in spiders is not consistent among authorities in the field. Peck and Whitcomb (1970) described the difficulty in delineating eclosion and discussed postembryological development in spiders. The 1st instar (deutovum of Gertsch 1949) is the stage from rupture of the chorion to the 1st true molt. The deutovum has been subdivided into the 1st and 2nd post embryo (used by Hite et al. 1966, Eason and Whitcomb 1965, Horner and Stewart 1967, and Peck and Whitcomb 1970). The 1st post embryo is from eclosion (hatching from the chorion or outer egg membrane) to the beginning of the break from the vitelline membrane (inner egg membrane). After the spiderling breaks from the vitelline membrane to the 1st true molt, it is known as the 2nd post

Table 3. Regression in percent hatch from a composite of the 1st through 11th egg sacs of *M. galathea*.

Egg sac number	Total number of eggs	Number hatched	Percent hatched
1	126	116	92
2	127	123	97
3	107	85	80
4	109	29	27
5	109	36	33
6	89	21	24
7	96	14	15
8	66	0	0
9	59	0	0
10	33	1	3
11	21	0	0
Total	942	425	-
Avg.	86	39	46

embryo. In this paper the 1st instar (deutovum) is divided into the 1st and 2nd post embryos.

Development of the eggs was determined by daily examination of 30 egg sacs under a dissecting microscope. The silk covering had to be removed in order to observe development within the egg sac. Observations were made and then the covering was carefully replaced. If the covering was not replaced the developing embryos appeared to dehydrate and die. Eggs were creamy-white and spherical at the time of deposition, but as hatching neared the eggs became more oval. The average diam of 100 eggs was 0.81 mm. A mean of 6.8 days at 27^{0} C was required for incubation with a range from 5 to 9 days (Table 4). After approximately 7 days the eggs hatched and were then in the 1st post embryo stage. This stage in M. galathea seems to be very similar to that reported for other spiders. It had no striking characteristics. The cephalothorax had the legs, chelicerae, and palpi confined by the vitelline membrane. The entire organism was translucent with the abdomen somewhat yellow because of the stored yolk. The vitelline membrane was shed in 1 to 2 days. With this shedding, the spiderling became a 2nd post embryo and developed typical spider characteristics. This 2nd post embryo (Fig. 9) had functional legs and moved within the egg sac. The only pigmentation present was that of the eyes. The mean cephalothoracic width of the stage was 0.50 mm (Table 5). An average of 10 days (range 6-13) was required for completion of the 2nd post embryo stage.

After the 1st true molt the spiderlings were in their 2nd instar. This molt occurred inside the egg sac. Upon completion of this molt the spiderlings usually emerged from the sac within 24 hr. The

Table 4. Number of days in various developmental stages of laboratory reared *M. galathea* at 27° C.

Stage of development	Number of observations	No. of days in stage: Minimum	Maximum	Mean
Egg - Hatch (Incubation)	30 sacs	5	9	6.8
1st post embryo (1st stadium)	120	1	2	1.6
2nd post embryo (1st stadium)	120	6	13	10.0
1st molt - 2nd (2nd stadium)	114	18	103	43.8
2nd molt - 3rd (3rd stadium)	88	11	75	29.9
3rd molt - 4th (4th stadium)	63	16	61	34.4
4th molt - 5th (5th stadium)	52	11	52	28.0
5th molt - 6th (6th stadium)	30	11	47	26.1
6th molt - 7th (7th stadium)	12	14	53	25.5
7th molt - death (8th stadium)	Adults			
Hatch to Adult ♀	12	162	249	193.2
Hatch to Adult ♂	18	161	239	180.5

Fig. 9. Second post embryo of M. galathea.

Table 5. Growth in cephalothoracic width and body length of M. galathea spiderlings at 27^{o} C.

Instar	No. measured	Cephalothoracic width (mm) Range	Cephalothoracic width (mm) Mean	No. measured	Body length (mm) Range	Body length (mm) Mean
First	6	-	.50	0	-	-
Second	65	-	.53	0	-	-
Third	103	.63-.73	.66	18	1.16-1.85	1.68
Fourth	78	.70-.90	.80	16	1.85-2.44	2.39
Fifth	49	.83-1.00	.92	11	2.35-3.33	2.68
Sixth	37	.90-1.26	1.05	16	2.59-3.48	3.10
Seventh	27	.93-1.37	1.21	24	2.81-4.61	3.59
Eighth (adults)	5	1.33-1.42	1.37	5	3.33-4.61	4.15
	7	1.20-1.67	1.50	7	4.31-5.67	5.37

cephalothoracic width was .53 mm (Table 5), only .03 mm larger than that of the 2nd post embryo. Further development, from the 2nd instar through adult stage took place in individual rearing tubes. Table 5 shows the increase in the mean size of the cephalothoracic width and body length for each instar through the 8th.

Second instar spiderlings were offered 2nd instar D. melanogaster larvae as food the 1st day after emergence. Some fed the 1st day, but the majority waited until the 2nd and 3rd day to feed. Second instar spiderlings did not construct a retreat, but just prior to making their 2nd molt a molting web was constructed. All other succeeding instars constructed a silken tunnel at the beginning of the stadium.

The actual process of molting was difficult to observe from onset to completion because of the dense molting web. Twenty-four to 48 hr prior to each molt the spiderlings would enter their silken retreat and become quiescent. The general coloration became much darker and food was refused.

As the molting process began, the spiderling was observed undergoing a twitching of the body. Soon afterwards the old cuticle split around the carapace at the junction of the legs and the lower part of the clypeus. Rhythmic expansion of the cephalothorax caused the old carapace to rupture and be shed. The process continued with the shedding of the chelicerae, palpi, legs and abdomen in the order given. Time required for this process ranged from about 10 min for the early instars to 20 or 30 for the later instars. Upon completion of ecdysis the spiderling would remain inside the molting web for several hours. Usually within a day after the completion of a molt the spiderling was actively seeking food.

Molting is a very critical time in the life of a spider, and a great number do not successfully complete a molt. In general, if a spider failed to withdraw its legs from the old exuvia, it struggled for hours and finally died. Figure 10 illustrates how M. galathea (4th instar) would get entangled trying to remove the legs from the old skin. Peck and Whitcomb (1970) state that this problem could be due to a premature loss of molting fluid. M. galathea was observed undergoing autotomy. This was usually successful if only 1 leg was involved. Regeneration of new appendages occurred in early instars, but did not in the later ones. Field collected adults have been observed with as few as 5 legs.

The duration in days between molts (2nd - 8th stadia) is given in Table 4. In general, the early stadia required more time than the later ones.

Mortality

Mortality was a major problem in rearing M. galathea spiders, as shown in Table 6. Of the original 215 spiderlings, 185 died before reaching maturity. Thirty-four were known to have died from the molting process. Many of the 101 2nd instar spiderling deaths are believed to have been due to the molting process. However, only 8 were classified as deaths due to molting because the old exuvia could be seen pulled away from these spiderlings. The 2nd instar spiderlings that died withstood rearing conditions for several weeks before dying and fed readily on 2nd instar D. melanogaster larvae.

Mortality among broods (progeny from a single egg sac) varied considerably. The 215 2nd instar spiderlings came from 12 different broods involving 8 female spiders. Two of the broods showed no

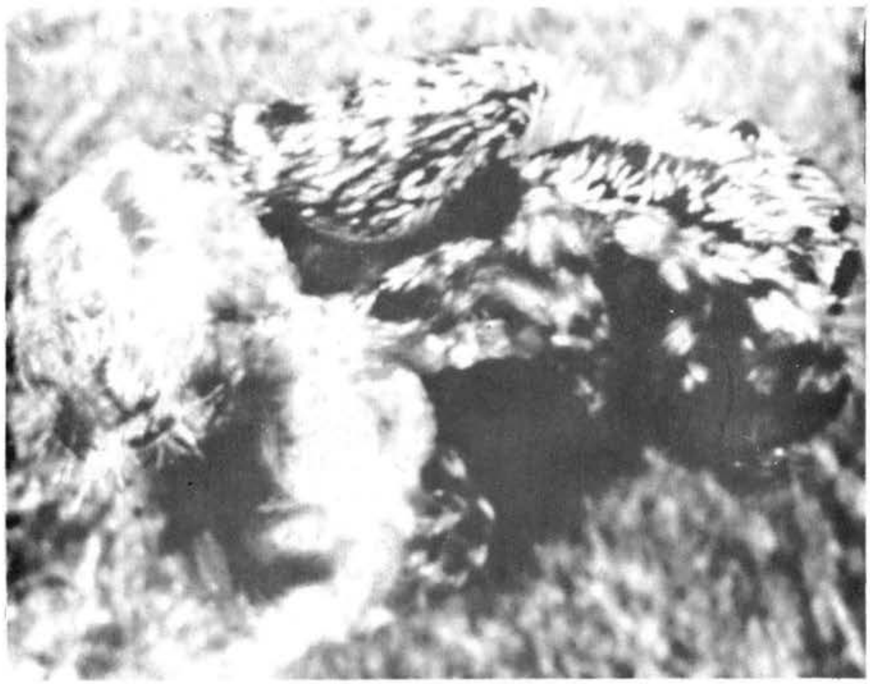

Fig. 10. Death of M. galathea due to failure to complete ecdysis.

Table 6. Mortality and percent survival of laboratory reared *M. galathea* at 27° C and 60 - 80% relative humidity.

Instar	Number: Beginning	Died molting	Total mortality	Surviving	Maturing	Percent mortality
First	-					
Second	215	8	101	114	-	47
Third	114	2	26	88	-	59
Fourth	88	10	25	63	-	71
Fifth	63	4	8	55*	3♂	73
Sixth	52	7	18	34*	4♂	83
Seventh	30	3	7	23*	6♂, 5♀	86
Eighth	12	0	0	24*	5♂, 7♀	-

*Includes the number maturing in each instar.

development past the 2nd instar; both of these were from the 2nd egg mass deposited by the female. The highest percentage of survival (58%) was a sac from which 7 out of 12 spiderlings reached adulthood.

Effects of Starving

A group of 60 spiders including adult males and females and immatures were placed in an incubator at 27^{o} C and 60 to 80% relative humidity. One half (30) were deprived of food and water while the other half (30) were fed on a normal diet. Those deprived of food and water lived 43 ± 15 days. (One male lived 14 days while one immature lived 70 days.) In the group fed a normal diet only one male died during the test period of 75 days. This information indicates that under normal conditions these spiders can probably live for long periods without food and water. This would be advantageous in their use as biological control agents, since prey would not need to be continually present.

Communal Rearing

Twenty 2nd instar spiderlings were placed in a self-contained rearing chamber (Fig. 3). These spiderlings were offered greenbugs for 2 weeks and then forced to feed on D. melanogaster from the culture. The chamber was examined 3 times at 60 day intervals so development could be observed. Five spiderlings were alive at the end of 60 days; 3 were in the 3rd, and 1 each in the 4th and 5th instar. After 120 days the 5 spiderlings were still alive with 2 in the 3rd, 2 in the 4th and 1 in the 5th instar. At the final examination, after 180 days, only 3 spiderlings were alive--1 in the 4th and 2 in the 5th instar; The rate of growth of these spiderlings was comparable to those reared in single tubes. However, at the end of 60 days 1 spiderling had already reached the mean cephalothoracic width for the 5th instar (Table 5). This required 136 days under single tube rearing conditions. This rapid rate of growth did not continue, as none of these spiderlings were above the 5th instar when the test was discontinued after 180 days.

Two other self-contained chambers were established with late instars and adults. One had 14 spiders of which 5 were males, 1 was a female and 8 were late instar spiderlings. The males were placed in the chamber first, and they immediately took fighting positions by facing each other and raising their 1st pair of legs in the air. This activity was observed for several minutes before one would yield and move to another part of the cage. Of the 8 immatures, 4 were immediately killed and eaten by 3 of the males and the female, leaving a total of 10 in the cage. Probably a reason for the fast killing action was that the spiders were field collected 3 days prior and had not been fed since capturing. The cage was broken down and examined 115 days after it was established, and 2 females and 3 males were found. Both females were gravid and 1 was with an egg sac that had developed because the 1st exuvia were present. However, no young spiderlings were found, since they were probably eaten by the other adults.

The 2nd chamber was established with 2 females, 3 males and 5 immature spiders. Upon examination 135 days after being established 4 of the 10 were alive. All were females and 2 were gravid.

This rearing procedure is a good method for studying the spider behavior. By observing the spiders in the cages, it seemed evident that they were establishing a territory and the retreats were about equally spaced. In the chambers which housed the adults 1 had 5 and the other 4. Four or 5 adults may be all that can live in this close communal contact.

Parasitism and Predation

Of the more than 250 M. galathea collected, none were observed to be parasitized. Field observations revealed M. galathea to be cannibalistic and prey for the spiders of the families Oxyopidae, Salticidae and Thomisidae. Dorris (1969 and 1970) found that M. galathea was used by some sphecids as food for their larvae. No egg parasites were observed for M. galathea; however, not enough egg sacs were examined to make any conclusions.

Artificial Diet

Attempts were made to rear spiders on two artificial diets, the greenbug diet (Cress 1969) and a concentrated suspension of "wheast." The treatment consisted of individual groups of 5 which were fed D. melanogaster larvae, "wheast," aphid diet or only water; these lived an average of 85.8, 6.5, 45.8 and 5.5 days, respectively. Duncan's multiple range test showed there was no difference between the "wheast" and water, but there was a significant difference between the other treatments. The group on the aphid diet lived a mean of 45.8 days, which is about the same (43.8 days) as the mean duration of the 2nd stadium (Table 4). The diet was probably insufficient for the spiders to synthesize necessary material for the molting process, because none of them molted. Spiderlings in the group fed D. melanogaster larvae were completing their molt at the time the aphid diet group was dying. Peck and Whitcomb (1968) reported that C. inclusum and Lycosa gulosa

Walckenaer were maintained 36 and 90 days, respectively, on a diet of homogenized milk and egg yolk with most of the specimens molting 1 or more times while on the diet.

Insects Offered as Food

Several species of harmful and beneficial insects were offered to adult *M. galathea* as food. Table 7 reveals the insects and the developmental stage offered as food to the spiders. If the insect was not taken as food within 48 hours, the spider was considered to have rejected it as prey. The spiders appeared to avoid lace-wing larvae, the last larval instars of both *Heliothis* species, and adult convergent lady beetle. None of the predaceous insects fed upon the spider.

Several insects have been reported as prey for *M. galathea*. These include: eyespotted bud moth, *Spilonota ocellana* (Denis and Schiffermuller), Dondale (1956); corn earworm larvae, *H. zea*, Whitcomb et al. (1963), Whitcomb (1967) and Whitcomb and Bell (1964); fall webworm larva, *Hyphantria cunea* (Drury), Warren et al. (1967); larvae and adults of Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), Eikenbary and Fox (1968); and sorghum midge, *Contarinia sorghicola* (Coquillett), Bailey and Chada.

Tobacco Budworm Predation

A total of twenty 1st instar tobacco budworm larvae, *Heliothis virescens* (Fabricius), were offered as food to males, females and immature *M. galathea*. Within 24 hours the males had eaten an average of 11, females 14, and immatures 7.2 larvae. The control, which had no spiders, had an average mortality of 2 larvae. The analysis of variance revealed the treatments to be significant at the 1% level.

Table 7. Insects offered *M. galathea* as food.

Scientific name	Common name	Develop-mental stage	Accepted	Rejected
Nysius ericae (Schilling)	false chinch bug	adult	X	
Heliothis virescens (Fabricius)	tobacco budworm	larva	X[a]	X[b]
H. zea (Boddie)	corn earworm	"	"	"
Celema sorghiella (Riley)	sorghum webworm	larva[c]		X
"	"	adult	X	
Chrysopa sp.	a lace-wing	larva		X
"	"	adult	X	
Hippodamia convergens Guerin-Meneville	convergent lady beetle	adult		X

[a]1st - 3rd instars.

[b]3rd - 6th instars.

[c]late instars.

Duncan's multiple range test showed that the consumption of tobacco budworm larvae by males and females was significantly different at the 5% level when compared to the control.

Greenbug Control by *M. galathea*

Control of insect pests by spiders has been reported by Muniappan and Chada (1970) and Kayashima (1961). Muniappan and Chada found *P. audax* to be effective in controlling the greenbug, *S. graminum*, under caged conditions. Kayashima (1961) reported that the release of 45,000 lynx spiders, *Oxyopes sertatus* L. Koch., gave good control of cryptomerian leaf flies, *Contarinia inouyei* Mani. These results tend to show the biological control capabilities of spiders. This study was established to test the possibility of using *M. galathea* as an effective biological control agent against the greenbug.

Forty-five 4-in plastic pots were planted with Rogers barley and covered with plastic cages. After 2 weeks the plants were thinned to 1 per pot and then infested with various treatments. The test consisted of 9 treatments, each with 5 replications. Three of the treatments were controls infested with 5, 10 or 20 greenbugs per pot but with no spiders. The other treatments consisted of the 3 levels of infestation of greenbugs with old female spiders (mature for at least 6 months) and the 3 levels with young female spiders (mature less than 6 months).

Greenbug numbers and the condition of the plants were recorded daily. Data on the effectiveness of the spiders in controlling the greenbug are presented in Table 8. Duncan's multiple range test was used to determine differences among treatments. Greenbug populations in treatment 7 (control with 5 greenbugs/pot) did not develop normally, possibly because of the intervention of an aphid parasite, *Lysiphlebus*

Table 8. Effectiveness of *M. galathea* spiders in control of the greenbug.

Treatment No.	Treatment Spider	No. of greenbugs At start of test	No. of greenbugs After seven days	No. uninjured plants	Avg. No. days to plant death
1	old female	5	4 a*	5	-
2	old female	10	18 a	2	25
3	old female	20	126 b	0	15
4	young female	5	13 a	2	25
5	young female	10	16 a	2	22
6	young female	20	85 b	0	19
7	none	5	8 a	3	23
8	none	10	352 c	0	11
9	none	20	394 c	0	10

*Means followed by the same letter are not significantly different by Duncan's multiple range test at the 5% level of probability.

testaceipes (Cresson), the adults of which were later found in some of the cages. For this reason there was no significant difference at $P = 0.05$ between the average number of greenbugs after 7 days in this treatment and either treatment 1 (5 greenbugs/pot and an old female spider) or treatment 4 (5 greenbugs/pot and a young female). However, the average number of aphids after 7 days in the other 2 levels of greenbug infestation in the controls (10 aphids/pot and 20 aphids/pot) was significantly different from the corresponding levels caged with both old and young female spiders. Furthermore, both old and young spiders more effectively suppressed the greenbug population when the initial infestation was 10 aphids/pot than when the infestation was 20 aphids/pot. The old and young female spiders were about equal in effectiveness.

Data on the numbers of uninjured plants and the numbers of days before the plants were killed by greenbugs are presented in Table 8. The treatment of old female spiders with 5 greenbugs per plant was the only treatment that prevented plant injury by the greenbug. None of the treatments that had 10 or 20 greenbugs entirely prevented plant damage. The old and young female spiders did prolong life of the plants by several days in comparison to the corresponding controls.

Aerial Dispersal of *M. galathea*

Aerial dispersal of *M. galathea* was studied by collecting immature and adult forms in 2 "Johnson-Taylor" suction traps. One was located 60 and the other 10 ft above ground level. A total of 22 specimens of *M. galathea* were collected from June 1970 through January 1971. Of the 22, 8 were males, 4 were females and 10 were immatures. Data on *M.*

galathea collected in the suction traps during the 8 month period are shown in Table 9.

Table 9. Number of *M. galathea* collected monthly in Johnson-Taylor suction traps. Stillwater, Oklahoma 1970-71.

	Number of spiders collected		
Month	Trap 1[a]	Trap 2[b]	Total
June	0	1	1
July	1	0	1
August	4	4	8
Sept.	1	0	1
Oct.	1	0	1
Nov.	4	3	7
Dec.	1	0	1
Jan.	2	0	2
Total	14	8	22

[a]Trap 10 ft above ground.

[b]Trap 60 ft above ground.

SUMMARY AND CONCLUSIONS

Bionomics of a small jumping spider, Metaphidippus galathea (Walckenaer) (Salticidae), was studied under laboratory conditions. These data included information of longevity, mating behavior, oviposition, incubation, development, and feeding. M. galathea was found to have two population peaks, one in late spring and the other in the fall. It is widely distributed in the southeastern United States and is common on vegetation in north central Oklahoma.

Adult males are readily distinguished from females by different scale patterns. Females are a little larger than males. Palpi of adult males are much larger than those of the female and they have a bulbous appearance.

Longevity under laboratory conditions was 184 ± 77.4 and 222 ± 72.6 days, respectively, for males and females. Individuals of M. galathea were receptive to mating shortly after the final molt. The mating approach was "head-on" with the male crawling over the cephalothorax of the female. Courtship and copulation took approximately 1 hr. Females would mate only once, but males would mate numerous times with virgin females.

Oviposition averaged 19 eggs measuring 0.81 mm in diam per egg sac. The number of egg sacs per season ranged from 7 to 11 with an average of 8.3. When a female became gravid but was not allowed to mate, she would void a yolk-like material. This same material was also observed being deposited after producing several sacs containing viable eggs.

A mean of 6.8 days at 27^{o} C was required for incubation of the eggs. The hatching (rupture of chorion) produced a stage known as the 1st post embryo. In 1 to 2 days this stage shed its vitelline membrane and became a 2nd post embryo which had functional legs and moved within the egg sac. After 10 days the 1st molt was completed and it became a 2nd instar spiderling.

The average time required for males and females to attain adulthood was 180.5 and 193.2 days, respectively. Males attained maturity in the 5th, 6th, 7th or 8th instars with the females maturing in only the 7th or 8th.

Size of prey seemed to be an important factor in the feeding of *M. galathea*. The spider would not feed upon dead insects and the more activity exhibited by the prey the more likely it was to be fed upon.

Female *M. galathea* were effective in suppressing greenbug, *Schizaphis graminum* (Rond.), populations on caged barley plants. Male, female, and immature *M. galathea* were each offered 20 1st instar tobacco budworms, *Heliothis virescens* (Fabricius). Within 24 hr the male, female, and immature spiders had eaten an average of 11, 14, and 7.2 tobacco budworm larvae, respectively.

A total of 22 *M. galathea* were collected in "Johnson-Taylor" suction traps. There were 8 males, 4 females and 10 immatures.

The information collected in this study indicates that *M. galathea* has an important part in the natural control of insect pests, but it is impractical to rear with present knowledge and techniques. The technique of rearing is the critical part of any spider life history study.

More information is needed before mass rearing of spiders for biological control can be possible.

LITERATURE CITED

Alexander, A. J., and D. W. Ewer. 1957. On the origin of mating behavior in spiders. Amer. Nat. 91:311-317.

Allen, D. C., F. B. Knight and J. L. Foltz. 1970. Invertebrate predators of the jack-pine budworm, Choristoneura pinus in Michigan. Ann. Entomol. Soc. Amer. 63(1):59-64.

Bailey, C. L. 1968. Life history of the spider, Phidippus audax (Hentz), in relation to biological control of grain sorghum insects. Unpublished Ph.D. thesis. Okla. State Univ. 59 p.

Bailey, C. L., and H. L. Chada. 1968. Spider populations in grain sorghums. Ann. Entomol. Soc. Amer. 61(3):567-571.

Barnes, R. D. 1953. The ecological distribution of spiders in non-forest maritime communities at Beaufort, North Carolina. Ecol. Monogr. 23:315-337.

Bilsing, S. W. 1920. Quantitative studies in the food of spiders. Ohio J. Sci. 20(7):215-260.

Blackwall, J. 1827. Observations and experiments made with a view to ascertain the means by which the spiders that produce gossamer effect their aerial excursions. Trans. Linn. Soc. Lond. 15:449-459.

Branch, J. H. 1943. On the life history and progressive factor in growth of Teutana grossa Koch. (Theridiidae). Bull. Southern Calif. Acad. Sci. 42(1):34-38.

Branson, B. A. 1958. Further additions to the known spider fauna of Oklahoma. Proc. Okla. Acad. Sci. 38:60-62.

Bristowe, W. S. 1929a. The mating habits of spiders, with special reference to the problems surrounding sex dimorphism. Proc. Zool. Soc. Lond. 99:309-358.

Bristowe, W. S. 1929b. The distribution and dispersal of spiders. Proc. Zool. Soc. Lond. 99:633-657.

Bristowe, W. S. 1930. A supplementary note on the mating habits of spiders. Proc. Zool. Soc. Lond. 100:395-413.

Bristowe, W. S. 1931. The mating habits of spiders: a second supplement with the description of a new thomisid from Krakatau. Proc. Zool. Soc. Lond. 101:1401.

Bucherl, W. 1969. Biology and venoms of the most important South American spiders of the genera Phoneutria, Loxosceles, Lycosa and Latrodectus. Amer. Zool. 9(1):157-159.

Burkill, I. H. 1922. The irregularity of a spider's feeding. J. Straits Asiatic Soc. 86:270.

Chant, D. A. 1956. Predacious spiders in orchards in Southeastern England. J. Hort. Sci. 31(1):35-46.

Clark, R. D., and P. R. Grant. 1968. An experimental study of the role of spiders as predators in a forest litter community. Ecology. 49(6):1152-1154.

Cloudsley-Thomson, J. L. 1953. The biology of hunting spiders. Discovery. 14:286-289.

Crane, J. 1948. Comparative biology of salticid spiders at Rancho Grande, Venezuela. Pt. 1. Systematics and life histories in Corythalia. Zoologica. 33(1):1-38.

Cress, D. C. 1969. Development and utilization of a synthetic diet for the greenbug, Schizaphis graminum (Rond.), for use in determining the factor or factors responsible for resistance in barley and wheat. Unpublished Ph.D. thesis. Okla. State Univ. 146 p.

Crosby, C. R., and S. C. Bishop. 1936. Aeronautic spiders with a description of a new species. J. New York Entomol. Soc. 44:43-49.

Dabrowska, P. E., J. Luczak and K. Tarwid. 1968. The predation of spiders on forest mosquitoes in field experiments. J. Med. Entomol. 5(2):252-256.

Deevy, G. B. 1949. The developmental history of Latrodectus mactans (Fabr.) at different rates of feeding. Amer. Midland Natur. 42(1):189-219.

Dondale, C. D. 1956. Annotated list of spiders (Araneae) from apple trees in Nova Scotia. Can. Entomol. 88(12):697-700.

Dondale, C. D. 1958. Notes on population densities of spiders (Araneae) in Nova Scotia apple orchards. Can. Entomol. 90(2): 111-113.

Dondale, C. D. 1961. Life histories of some common spiders from trees and shrubs in Nova Scotia. Can. J. Zool. 39(6):777-787.

Dondale, C. D. 1965. A spider's (Philodromus rufus Walck.) first meal after molting. Can. Entomol. 97(4):446.

Dorris, P. R. 1969. Spiders collected from mud-dauber nests in Clark Co. Arkansas. Ark. Acad. Sci. Proc. 23:88-90.

Dorris, P. R. 1970. Spiders collected from mud-dauber nest in Mississippi. J. Kan. Entomol. Soc. 43:10-11.

Dorris, P. R., and Y. J. McGaha. 1965. A list of spiders collected in Northern Mississippi. Trans. Amer. Microscop. Soc. 84(3):407-408.

Duckworth, J. C. 1965. Spiders controlling insects. Sci. J. 1(4):20-21.

Duffey, E. 1956. Aerial dispersal in a known spider population. J. Anim. Ecol. 25:85-111.

Eason, R. R. 1969. Life history and behavior of Pardosa lapidicina Emerton (Araneae:Lycosidae). J. Kan. Entomol. Soc. 42(3):339-360.

Eason, R. R., and W. H. Whitcomb. 1965. Life history of the dotted wolf spider, Lycosa punctulata Hentz (Araneida:Lycosidae). Ark. Acad. Sci. Proc. 19:11-20.

Eason, R. R., W. B. Peck and W. H. Whitcomb. 1967. Notes on spider parasites, including a reference list. J. Kan. Entomol. Soc. 40(3):422-434.

Edgar, W. D. 1969. Prey and predators of the wolf spider Lycosa lugubris. J. Zool. 159(4):405-411.

Eikenbary, R. D., and R. C. Fox. 1968. Arthropod predators of the nantucket pine tip moth, Rhyacionia frustrana. Ann. Entomol. Soc. Amer. 61(5):1218-1221.

Emerton, J. H. 1908. Autumn flight of spiders. Psyche. 15:121.

Enock, F. 1885. The life history of Atypus piceus Sulz. Trans. Entomol. Soc. London. 33:389-420.

Everly, R. T. 1938. Spiders and insects found associated with sweet corn with notes on the food and habits of some species I. Arachnida and Coleoptera. Ohio J. Sci. 38(3):136-140.

Exline, H., and W. H. Whitcomb. 1965. Clarification of the mating procedure of Peucetia viridans (Araneida:Oxyopidae) by a microscopic examination of the epigynal plug. Fla. Entomol. 48(3): 169-171.

Fitch, H. S. 1963. Spiders of the University of Kansas Natural History Reservation and Rockefeller Experimental Tract. Univ. Kan. Museum Natur. Hist. Misc. Pub. No. 33 202 p.

Fluke, C. L. 1929. The known predacious and parasitic enemies of the pea aphid in North America. Res. Bull. Wis. Agr. Exp. Sta. 93. 47 p.

Freeman, J. A. 1946. The distribution of spiders and mites up to 300 feet in the air. J. Anim. Ecol. 15:69-74.

Gardner, B. T. 1964. Hunger and sequential responses in the hunting behavior of salticid spiders. J. Comp. Physiol. Psychol. 58(2): 167-173.

Gardner, B. T. 1965. Observations on three species of *Phidippus* jumping spiders (Araneae:Salticidae). Psyche. 72:133-147.

Gardner, B. T. 1967. The life cycle of the spider, *Phidippus coccineus* (Salticidae) under laboratory conditions. Psyche. 74(2):104-106.

Gertsch, W. J. 1949. American spiders. D. Van Nostrand Co., New York. 285 p.

Glick, P. A. 1939. The distribution of insects, spiders, and mites in the air. U. S. Dep. Agr. Tech. Bull. 673. 150 p.

Glick, P. A. 1960. Collecting insects by airplane with special reference to dispersal of the potato leafhopper. U. S. Dept. Agr. Tech. Bull. 1222. 16 p.

Haynes, D. L., and P. Sesojevic. 1966. Predatory behavior of *Philodromus rufus* Walckenaer (Araneae:Thomisidae). Can. Entomol. 98: 113-133.

Hite, M., W. J. Gladney, J. L. Lancaster, Jr., and W. H. Whitcomb. 1966. Biology of the brown recluse spider. Univ. Ark. Agr. Exp. Sta. Bull. 711. 26 p.

Hobby, B. M. 1940. Spiders and their prey. Entomol. Monthly Mag. 76 (11):258-259.

Horner, N. V., and K. W. Stewart. 1967. Life history of the brown spider, *Loxosceles reclusa* (Gertsch and Mulaik). Tex. J. Sci. 19(4):333-347.

Hukusima, S., and K. Kondo. 1962. Further evaluation in the feeding potential of the predaceous insects and spiders in association with aphids harmful to apple and pears growing and the effect of pesticides on predators. Jap. J. Appl. Entomol. Zool. 6(4):274-280.

Jellison, W. L., and C. B. Philip. 1935. The biology of the black widow spider *Latrodectus mactans*. Science. 81(2090):71-72.

Jones, S. E. 1941. Influence of temperature and humidity on the life history of the spider, *Agelena naevia* Walckenaer. Ann. Entomol. Soc. Amer. 34(3):557-571.

Kagan, M. 1943. The Araneidae found on cotton in Central Texas. Ann. Entomol. Soc. Amer. 36(2):257-258.

Kaston, B. J. 1948. Spiders of Connecticut. Connecticut State Geol. and Nat. Hist. Surv. Bull. 70. 874 p.

Kirchner, W., and P. Kestler. 1969. Investigations on the resistance to cold of Araneus cornutus (Araneidae). J. Insect Physiol. 15 (1):41-53.

Kraft, B. 1969. Various aspects of the biology of Agelena consociata Denis when bred in the laboratory. Amer. Zool. 9(1):201-210.

Leigh, T. P., and R. E. Hunter. 1969. Predacious spiders in California cotton. Calif. Agr. 23(1):4-5.

Levi, H. W., and A. Spielman. 1964. The biology and control of the South American brown spider, Loxosceles laeta in a North American focus. Amer. J. Trop. Med. Hyg. 13:132-136.

Levy, G. 1970. The life cycle of Thomisus onustus (Thomisidae:Araneae) and outlines for the classification of the life histories of spiders. J. Zool. 160(4):523-536.

Lingren, P. D., R. L. Ridgway and S. L. Jones. 1968. Consumption by several common arthropod predators of eggs and larvae of two Heliothis spp. that attack cotton. Ann. Entomol. Soc. Amer. 61(3):613-618.

McCook, H. C. 1877. The aeronautic flight of spiders. Phila. Acad. Natur. Sci. Proc. 29:308-312.

McCook, H. C. 1878. Notes on the probable geographical distribution of a spider by the trade winds. Phila. Acad. Natur. Sci. Proc. 30:136-147.

Miyashita, K. 1968a. Growth and development of Lycosa T-insignita Boes. et Str. (Araneae:Lycosidae) under different feeding conditions. Appl. Entomol. Zool. 3(2):81-88.

Miyashita, K. 1968b. Changes of the daily food consumption during adult stages of Lycosa pseudoannulata Boes et Str. (Araneae: Lycosidae). Appl. Entomol. Zool. 3(4):203-204.

Montgomery, T. H., Jr. 1903. Studies on the habits of spiders, particularly those of the mating period. Phila. Acad. Natur. Sci. Proc. 55:59-149.

Muniappan, R., and H. L. Chada. 1970a. Biology of the crab spider, Misumenops celer. Ann. Entomol. Soc. Amer. 63(6):1718-1722.

Muniappan, R., and H. L. Chada. 1970b. Biological control of the greenbug by the spider Phidippus audax. J. Eco. Entomol. 63(5): 1712.

Nappi, A. J. 1965. Notes on the courtship and mating habits of the wolf spider Lycosa helluo Walck. Amer. Midland Natur. 74(2):368-378.

Peck, W. B., and W. H. Whitcomb. 1966. Feeding spiders on artificial diet. Entomol. News. 79(9):322-236.

Peck, W. B., and W. H. Whitcomb. 1967. An adaptable method for rearing spiders and cannibalistic insects. Turtox News. 45(10):242-244.

Peck, W. B., and W. H. Whitcomb. 1970. Studies on the biology of a spider, Chiracanthium inclusum (Hentz). Univ. Ark. Agr. Exp. Sta. Bull. 773. 76 p.

Putman, W. L. 1967a. Prevalence of spiders and their importance as predators in Ontario peach orchards. Can. Entomol. 99:160-170.

Putman, W. L. 1967b. Life histories and habits of two species of Philodromus (Araneida:Thomisidae) in Ontario. Can. Entomol. 99(6): 622-631.

Raatikainen, M., and V. Huhta. 1968. On the spider fauna of Finnish oat fields. Ann. Zool. Fennici. 5(3):254-261. (Biol. Abstr. 1969. No. 106660).

Rau, P. 1924. Some life history notes on the black widow spider, Latrodectus mactans. Psyche. 31(3-4):162-166.

Riley, C. V. 1887. Our shade trees and their insect defoliators. U. S. Dept. Agr. Entomol. Bull. 10. 69 p.

Robinson, M. H. 1969. Predatory behavior of Argiope argentata (Fab.) Amer. Zool. 9(1):161-173.

Rovner, J. S. 1966. Courtship in spiders without prior sperm induction. Science. 152:543.

Rovner, J. S. 1967. Copulation and sperm induction by normal and palpless male linyphiid spiders. Science. 157(3790):835.

Sabath, L. E. 1969. Color change and life history observations of the spider Gea heptagon. Psyche. 76(3):367-374.

Shorey, H. H. 1965. Mass rearing of the larvae of nine noctuid species on a simple artificial medium. J. Econ. Entomol. 58:522-524.

Specht, H. B., and C. D. Dondale. 1960. Spider population in New Jersey apple orchards. J. Econ. Entomol. 53(5):810-814.

Stoner, A., and D. E. Bryan. 1970. Wicks of compressed cellulose sponge to water or feed insects. J. Econ. Entomol. 63(3):1021.

Strickberger, M. W. 1962. Experiments in genetics with Drosophila. John Wiley and Sons, Inc., New York. 144 p.

Stultz, H. T. 1955. The influence of spray programs on the fauna of apple orchards in Nova Scotia. VIII. Natural enemies of the eye-spotted bud moth, Spilonota ocellana (D. & S.) (Lepidoptera: Olethreutidae). Can. Entomol. 87(2):79-85.

Turnbull, A. L. 1962. Quantitative studies of the food of Linyphia triangularis Clerck (Araneae:Linyphiidae). Can. Entomol. 94: 1233-1249.

Turnbull, A. L. 1965. Effects of prey abundance on the development of the spider, Agelenopsis potteri (Blackwell) (Araneae:Agelenidae) Can. Entomol. 97(2):141-147.

Warren, E. 1925. Notes on the ecdysis of a spider. Ann. Natal Mus. 5(2):231.

Warren, L. O., W. B. Peck and M. Tadic. 1967. Spiders associated with the fall webworm, Hyphantria cunea (Lepidoptera:Arctiidae) J. Kan. Entomol. Soc. 40(3):382-395.

Wene, G. P., and L. W. Sheets. 1962. Relationship of predatory and injurious insects in cotton fields in the salt river valley area of Arizona. J. Econ. Entomol. 55(3):395-398.

Whitcomb, W. H. 1967. Field studies on predators of the second instar bollworm, Heliothis zea (Boddie) (Lepidoptera:Noctuidae). J. Ga. Entomol. 2(4):113-118.

Whitcomb, W. H., and M. Tadic. 1963. Araneida as predators of the fall webworm. J. Kan. Entomol. Soc. 36(3):186-190.

Whitcomb, W. H., and K. Bell. 1964. Predaceous insects, spiders and mites of Arkansas cotton fields. Univ. Ark. Agr. Exp. Sta. Bull. 690. 84 p.

Whitcomb, W. H., and R. Eason. 1965. The mating behavior of Peucetia viridans (Araneida:Oxyopidae). Fla. Entomol. 48(3):163-167.

Whitcomb, W. H., and R. Eason. 1967. Life history and predatory importance of the striped lynx spider (Araneida:Oxyopidae). Ark. Acad. Sci. Proc. 21:54-58.

Whitcomb, W. H., H. Exline and R. C. Hunter. 1963. Spiders of the Arkansas cotton fields. Ann. Entomol. Soc. Amer. 56(5):653-659.

Whitcomb, W. H., M. Hite and R. Eason. 1966. Life history of the green lynx spider Peucetia viridans (Araneida:Oxyopidae). J. Kan. Entomol. Soc. 39(2):259-267.

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