

OBSERVATIONS ON THE REPRODUCTIVE BIOLOGY AND LIFE HISTORY OF *MEGACORMUS GERTSCHI* DIAZ (SCORPIONES: CHACTIDAE; MEGACORMINAE)

Oscar F. Francke

Departments of Biological Sciences and Entomology, The Museum
Texas Tech University, Lubbock, Texas 79409

ABSTRACT

Four *Megacormus gertschi* Diaz females gave birth in the laboratory to 19, 25, 26 and 75 young. Laboratory-born specimens were raised to the fourth instar, and morphometric analysis of growth rates leads to the prediction that this species attains sexual maturity with the eighth instar. The mating behavior and the spermatophore are described, providing the only observations available for the subfamily Megacorminae.

INTRODUCTION

The chactid subfamily Megacorminae, endemic to México and Guatemala, is represented by two relatively rare genera: *Plesiochactas* Pocock, represented by two poorly known species; and *Megacormus* Karsch, represented by three species, of which only *Megacormus gertschi* Diaz is adequately represented in collections (Soleglad 1976). *M. gertschi* occurs on the eastern slopes of the Sierra Madre Oriental at elevations of 800-2000 m, and has been found in the Mexican states of Tamaulipas, Queretaro, San Luis Potosí, Hidalgo, and Veracruz (Soleglad 1976).

Nine specimens of *M. gertschi*, two adult males, five adult females, and two juveniles were taken near El Madroño (1800 m), Queretaro (27 km west of Xilitla, San Luis Potosí), on 10 March 1977. The specimens were returned to Lubbock, Texas alive, and the following brief observations are the first ever reported on the biology of any member of the subfamily Megacorminae.

MATERIALS AND METHODS

Specimens were kept, and the observations made, in an environmental chamber at $26.6 \pm 1^\circ\text{C}$. Darkness was interrupted only during maintenance activities, which occurred at various hours of the day. Field caught specimens were kept individually in 500 ml wide-mouth jars (85 mm internal diameter), with a 2 cm deep layer of soil and a small rock to provide shelter. Young scorpions born in the laboratory were kept individually in

75 ml wide-mouth jars (50 mm internal diameter), with a 1 cm deep layer of soil and no sheltering objects. Matings were staged in a plastic arena 26 cm in diameter, 9 cm deep, with a single layer of absorbent paper for substrate.

The specimens were checked and watered daily, prey was presented on alternate days. Adults were offered live immature cockroaches, *Nauphoeta cinerea* (Olivier). The rearing and maintenance of hundreds of scorpions in the laboratory over the past five years has led to the development of the following rule-of-thumb regarding "optimal" prey size: the prey should be about as long as the pedipalp chela of the scorpion (optimality in this case refers to the greatest success observed, but not quantified, in prey capture and prey consumption). Scorpions tend to retreat from larger prey, so that the capture rate is low. Smaller prey are readily captured and consumed, but very large numbers are needed if scorpion development is to proceed normally. Immature scorpions, especially the youngest instars, often pose a problem in this respect since most readily available prey items (e.g., small cockroaches, fruit flies, flour beetles) are too large to be taken. Mortality due to starvation in early instars had been very high in many of my studies (including the present one) until a solution was found: young scorpions readily accept dead prey. Cockroaches were cut into small pieces and offered to the young scorpions, which fed on them without having to subdue the prey or pierce its exoskeleton. Baerg (1961) reported that some scorpions accept raw red meat for food. Unconsumed prey remains decompose rapidly and favor the growth of fungi and mites in the rearing containers; this was prevented by the removal of prey remains each day.

The morphometric analysis used to predict the number of instars required to attain sexual maturity has been modified from Francke (1976). Measurements of three structures (carapace length, metasomal segment V length, and pedipalp chela length) were obtained from exuvia or from preserved specimens representing known instars, at 20 X magnification. The growth factor (Dyar's constant) between succeeding instars was determined for each structure on each individual by dividing the dimension at one instar by the dimension at the previous instar. The average growth factor per molt for each structure was then calculated from the pooled data. Predicted dimensions for each structure on life stages not observed were calculated, as 95% Confidence Limits (C. L.), as follows: (a) 95% C. L. were calculated for each structure on the largest observed instar using the formula 'mean \pm 0.05 standard deviation'; (b) the upper and lower 95% C. L. for each structure on the largest observed instar were multiplied by the average growth factor of that structure to set the 95% C. L. of predicted dimensions for the following instar; (c) and so forth for dimension predictions on all structures for successive instars.

OBSERVATIONS AND DISCUSSION

Birth behavior.—Four of the five adult females gave birth in the laboratory on 5 and 6 May 1977, 56-57 days after they were captured. The apparent synchrony in births could be due to a number of reasons, among which (a) chance, (b) a highly synchronized mating season, and (c) simultaneous termination of embryonic diapause in the laboratory are distinct possibilities.

Females assume a stiling position to give birth similar to that described for other scorpions. The birth basket receives the first instars and is formed by the first pair of legs (Fig. 1). In *Euscorpius carpathicus* (L.) and *Euscorpius italicus* (Herbst), the only other chactids studied (Angermann 1957), the first two pairs of legs form the birth basket.

One of the females was observed for two hours while giving birth. In that time seven young were born, at an average interval of 17 minutes between births (range 11 to 29 min.). Three of the young emerged head first, and four emerged tail first. Soon after birth the newborns shed their birth membrane while still in the birth basket. While the origin of the birth membrane is not known, it is possible that it represents the partially fused embryonic membranes (serosa and amnion) observed in other apoikogenic scorpions (Johnson 1891). The first instars move anteriorly and pass over the female's chelicerae on their ascent to her dorsum (Figs. 1 and 2). They position themselves at random over the tergites and posterior region of the female's carapace. Similar behavior occurs in *Euscorpius* spp. (Angermann 1957).

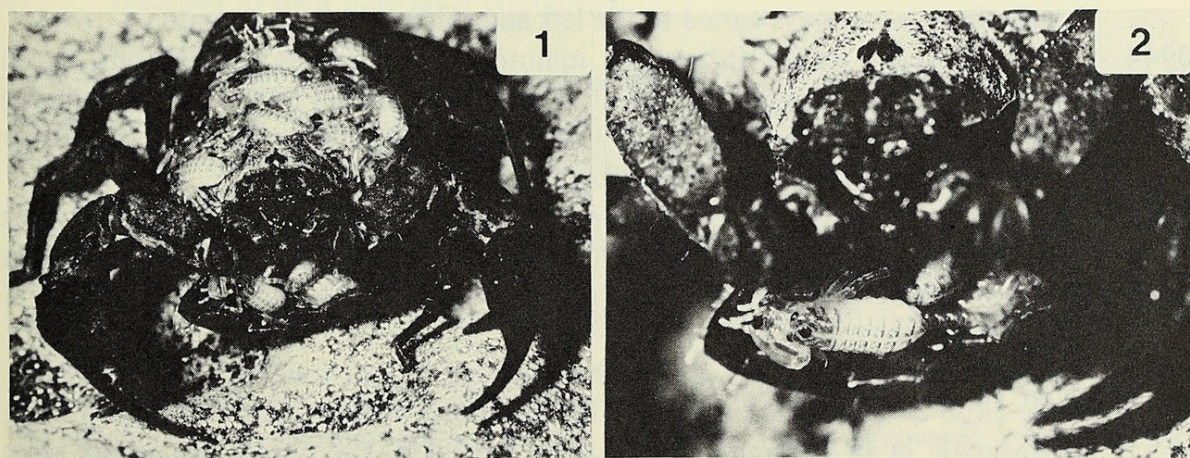
Litter sizes were as follows: 19, 25, 26 and 75 young. The female that had 75 young ranked second in size among the four that gave birth; it died of unknown causes two days after giving birth, and the first instars could not be saved.

Life history.—The data pertain to early instars. This is sufficient, however, to make some predictions on the entire life history of *M. gertschi*.

FIRST INSTAR—The first instars spent 10 to 12 days on the female's dorsum prior to molting. In *Euscorpius* spp. this stage lasts six to ten days (Angermann 1957).

SECOND INSTAR—The second instars spent an additional 3 to 7 days on the female's dorsum prior to dispersing. After dispersion each young scorpion was sorted into an individual container on 25 May 1977. Mortality due to starvation was very high: of the 70 individuals alive on 25 May, four died during May, 49 during June, and six during the first two weeks in July. Mortality was about equal among the three litters. The eleven surviving individuals entered the second molt at an age of 116 ± 20.7 days (mean \pm standard deviation) (range 81-158 days). Four of the second instars were unable to completely free themselves from their exuvium and died during the molting process.

THIRD INSTAR—There were no deaths during this stage. However, five of the seven specimens died from complications during, or shortly after, the molt to fourth instar. This stadium lasted 84.0 ± 46.5 days (range 36-143), and the molt to fourth instar occurred at an age of 200.6 ± 48.8 days (range 136-250).



Figs. 1-2.—Frontal view of female *Megacormus gertschi* Diaz giving birth in the laboratory: 1, note the randomly positioned young on her dorsum, and those in the birth basket which is formed by the first pair of legs only; 2, close-up showing the tail-first emergence of one young, and the anterior movement of the first instars on their ascent to the female's dorsum.

FOURTH INSTAR—The two specimens that entered this stage died of unknown causes 2 and 3½ months after the successful molt. The duration of this and subsequent stages are unknown.

Morphometrics, growth factors, and instar predictions (see Materials and Methods) on the life history of *M. gertschi* appear in Table 1. Measurements of seven specimens of various sizes, including three females from this study (known to be sexually mature), and published data (Soleglad 1976) from two adult females from other populations are also given in Table 1. A male and female from the same population on which this study is based correspond very well with the predicted dimensions for sixth and seventh instars respectively (Table 1). The values observed in adult females fall within the predicted 95% confidence interval for eighth instars in the case of metasomal segment V length and pedipalp chela length. The observed upper range for carapace length exceeds the predicted upper limit for eighth instars, but does not reach the predicted lower limit for ninth instars. Three of the five adult females, however, have carapace lengths that fall within the predicted range for eighth instars; and the two females that do not, correspond to eighth instars in the two other structures measured. Therefore, I consider that *M. gertschi* attains sexual maturity with the eighth instar.

Mating behavior.—Two matings were staged using the same male. The first female was mated on 27 November 1977, 205 days after giving birth. The proceedings were not observed, but a post-insemination spermatophore was recovered (Francke 1979). This female died seven days after mating.

The second female was mated on 26 February 1978, 297 days after giving birth. This mating took place 91 days after the male's previous mating. The following notes, with time of day at the left, summarize the observations on courtship and mating:

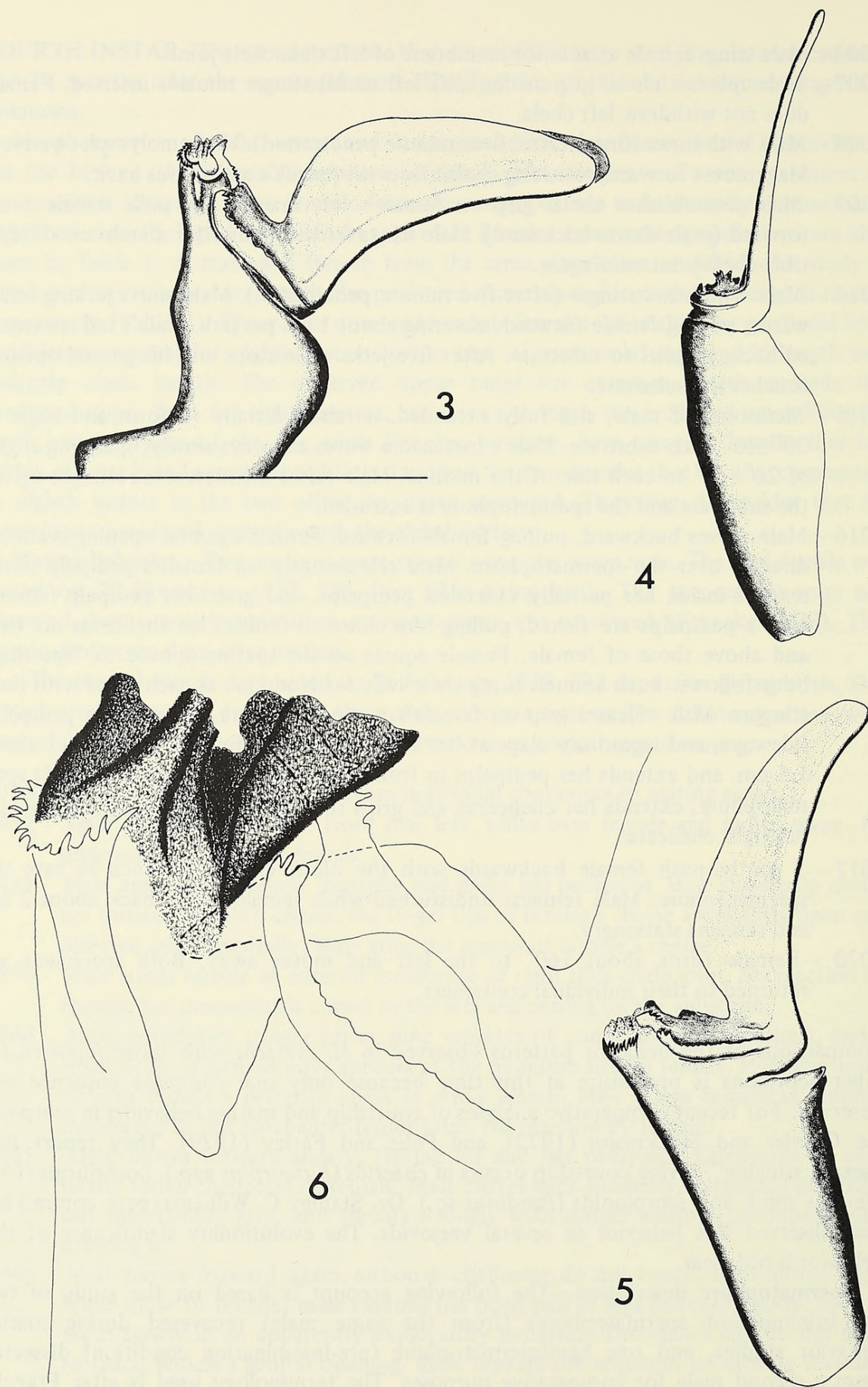
- 0930 - Male and female transferred from individual containers to mating arena.
- 0932 - Male approaches female from rear left, walks over female and moves away. No observable reaction by female.
- 0935 - Male approaches female frontally and grabs her pedipalps. Male's pedipalp chelae are outside female's chelae; the finger tips of female's chelae are slightly open and directed anteromedially. Male grips the manus of female's chelae.
- 0936 - Male stings female at anterior membrane of right tibia-chela joint. No reaction by female, her metasoma is curled to the left and resting on the substrate.
- 0944 - Male withdraws stinger (after nine minutes of continuous penetration), and a small drop of hemolymph appears at the puncture site on female. Male continues to grip female's pedipalp chela at arm's length. Male stings female at anterior membrane of left trochanter-femur joint. No reaction by female.
- 0945 - Male moves forward slowly, flexing his and her pedipalps. Chelicerae of male nearly touch chelicerae of female. Male moves back suddenly, extending pedipalps but maintaining grip, and thrusts strongly with stinger without previously withdrawing it.
- 0946 - Male moves forward again, although chelicerae do not touch, then moves back. While close to female, male extends the front pair of legs under her body, moving them slowly in an apparently exploratory behavior. The male's legs do not seem to reach female's genital opening. Male repeats the sequence of moving forward, extending the legs and moving back several times.
- 1003 - Male withdraws stinger (after nine minute penetration). No hemolymph seen at puncture site. Male moves forward, his chelicerae touch female's chelicerae, and then moves back. Female remains passive.

- 1004 - Male stings female at anterior membrane of left tibia-chela joint.
- 1007 - Male releases chelal grip on female's left chela; stinger remains inserted. Female does not withdraw left chela.
- 1008 - Male withdraws stinger (after four minute penetration). No hemolymph observed. Male moves forward, touching chelicerae with female's and moves back.
- 1009 - Male reestablishes chelal grip on female's left manus, and pulls female 5 cm forward (male moves backward). Male stings female at anterior membrane of right tibia-chela joint once again.
- 1014 - Male withdraws stinger (after five minute penetration). Male starts jerking backwards, pulling female forward, covering about 1 cm per jerk. Male's tail is extended back, parallel to substrate. After five jerks male stops and his genital opening touches the substrate.
- 1015 - Metasoma of male, still fully extended, is raised distally to form an angle of 30° – 40° with substrate. Male's metasoma waves sideways slowly, spanning angles of 20° – 30° to each side of the midline. Male raises the mesosoma straight up off the substrate and the spermatophore is extruded.
- 1016 - Male moves backward, pulling female forward. Female's genital opening is almost directly over the spermatophore. Male releases grip on female's pedipalp chela; reaches inside her partially extended pedipalps, and grabs her pedipalp femora. Male's pedipalps are flexed, pulling him closer to female; his chelicerae are over and above those of female. Female squats on the spermatophore. A "sparring" bout follows: both animals bring their tails forth and jab at each other with their stingers. Male releases grip on female's pedipalp femora, extends his pedipalps sideways, and vigorously claps at her sides with them. Female moves back about 1.5 cm, and extends her pedipalps in front. Female moves forward towards spermatophore, extends her chelicerae and grips the base of the spermatophore with her right chelicera.
- 1017 - I gently push female backwards with the blunt end of a pencil to save the spermatophore. Male remains undisturbed while female moves back about 2 cm and remains stationary.
- 1020 - Female turns about 160° to the left and moves away. Both specimens are returned to their individual containers.

Comparisons of the behavior patterns observed in *M. gertschi* with those reported for other scorpions is premature at this time because only one complete sequence was observed. For recent comparative analyses of courtship and mating behaviors in scorpions see Garnier and Stockmann (1972), and Polis and Farley (1979). They report that "sexual stinging" during courtship occurs in chactids (*Euscorpius* spp.), bothriurids (*Urophonius* spp.), and scorpionids (*Pandinus* sp.). Dr. Stanley C. Williams (pers. comm.) has also observed this behavior in several vaejovids. The evolutionary significance of this behavior is not clear.

Spermatophore description.—The following account is based on the study of two post-insemination spermatophores (from the same male) recovered during mating behavior studies, and one hemispermaphore (pre-insemination condition) dissected from a second male for comparative purposes. The terminology used is after Francke (1979).

Lamelliform (Figs. 3-5). Pedicel 1.20-1.30 mm long, 0.75-0.85 mm wide; pedal flexure conspicuous in post-insemination condition only (Fig. 3). Trunk 1.50-1.60 mm long,



Figs. 3-6.—Male reproductive structures of *Megacormus gertschi* Diaz: 3, lateral view of post-insemination spermatophore; 4, ventral view of hemispermatotheca; 5, lateral view of hemispermatotheca; 6, detail lateral view of capsular region of hemispermatotheca.

Table 1.—Morphometrics, growth factors, and instar predictions on the life history of *Megacormus gertschi* Diaz. Measurements (in millimeters) represent the length of the structures indicated (mean \pm standard deviation). Data from Soleglad (1976) indicated by an asterisk.

	Carapace	Metasoma V	Pedipalp chela
OBSERVED			
Second instar (n=7)	1.58 \pm 0.06	1.06 \pm 0.05	2.54 \pm 0.08
Growth factor	1.30 \pm 0.06	1.35 \pm 0.06	1.30 \pm 0.05
Third instar (n=7)	2.06 \pm 0.15	1.44 \pm 0.13	3.31 \pm 0.19
Growth factor	1.23 \pm 0.08	1.27 \pm 0.08	1.29 \pm 0.04
Fourth instar (n=5)	2.51 \pm 0.08	1.84 \pm 0.17	4.25 \pm 0.22
Average growth factor (n=12)	1.27 \pm 0.08	1.32 \pm 0.08	1.30 \pm 0.04
PREDICTED 95% CONFIDENCE LIMITS			
Fifth instar	2.91–3.47	1.81–3.05	4.73–6.32
Sixth instar	3.69–4.40	2.39–4.02	6.15–8.21
Seventh instar	4.69–5.59	3.15–5.31	8.00–10.68
Eighth instar	5.96–7.10	4.16–7.01	10.40–13.88
Ninth instar	7.56–9.02	5.49–9.75	13.52–18.04
FIELD CAUGHT SPECIMENS (RANGE)			
Adult females (n=3)	6.60–7.30	5.80–6.50	11.40–12.20
Adult females (n=2)*	6.65–7.30	5.80–6.40	11.65–12.75
Subadult female	5.60	5.00	9.20
Juvenile male	4.00	3.30	6.50

0.55-0.65 mm wide, depth could not be accurately determined. Truncal flexure marked by strongly sclerotized transverse lateral ridges that prolong ventrally into blunt edge of lamellae. “Capsule” strongly developed, everted in both the pre-insemination (Fig. 5) and post-insemination (Fig. 3) states. Capsular region roughly resembles a truncated tetrahedron: the plane area between the paired transverse ridges that mark the truncal flexure represent one face of the tetrahedron, and the planes between the transverse ridges and the dorsal seam of the spermatophore (where the two hemispermatoophores come together) form the other two faces. The base (=fourth face) of the tetrahedron is imaginary and lies inside the trunk. The truncated “peak” of the tetrahedron is the opening of the sperm tube. Submedially along the dorsal seam are two heavily sclerotized bands that culminate each in a half-crown of sharp, curved spines (Figs. 3, 5, 6). The “V-shaped” areas between these submedian bands and the transverse lateral ridges (Figs. 5 and 6), are membranous and transparent, extend beyond the sclerotized portions of the capsular region, and distally their external surface is densely covered with minute, slightly to moderately curved spines (Fig. 6). Lamellae 2.00-2.30 mm long, 0.25-0.35 mm wide, 0.75-0.90 mm deep; thickened ventrally but not curled into an inverted “T-beam”, with dorsal margin slightly notched basally (Figs. 3, 5).

Among chactids only the spermatophores of *Euscorpius* spp. (Euscorpioninae) and *Superstitionia donensis* Stahnke (Superstitioninae) have been previously described (Angermann 1955, 1957, Angermann and Schaller 1956, Francke 1979). The spermatophores of *Megacormus gertschi* Diaz (Megacorminae) resemble those of *Euscorpius* spp. more closely than either of them resembles the spermatophores of *Superstitionia*. Based on the disposition of the ventral carinae on the metasoma, Birula (1917) suggested that

Euscorpioninae and Megacorminae are sister-groups within the Chactidae. More recently, Sologlad (1976) arrived at a similar conclusion based largely on a comparison of trichobothrial patterns between representatives of various chactid subfamilies. The spermatophore data available seem to lend further support to this phylogenetic interpretation. However, spermatophore information is needed for other subfamilies and genera before reasonable phylogenetic hypotheses can be developed.

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