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Full Length Research Paper

Studies on the immature stages and burrow excavating behavior of *Schizodactylus monstrosus* (Drury) (Grylloptera: Gryllodea: Schizodactylidae) from Sindh, Pakistan

Sabir Ali Channa, Riffat Sultana* and Muhammad Saeed Wagan

Department of Zoology, University of Sindh, Jamshoro, Pakistan.

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The biology of nymphal stages and life habits of the *Schizodactylus monstrosus* (Drury) were investigated in this study that was carried out between 2004 and 2007 in the left bank of River Indus Sindh province. The study showed that *S. monstrosus* which is a nocturnal and voracious carnivorous insect, passed through 9 nymphal stages, took 1 year to complete its developmental period, though the female laid a total of 23.10 ± 3.66 eggs at 14.05 ± 1.85 cm depth of the soil. The burrow habit and food preferences of the cannibalistic species of S. *monstrosus* were also investigated.

Key words: *Schizodactylus monstrosus*, biology, life-habits, immature stages, behavior.

INTRODUCTION

The genus *Schizodactylus* represents distinctive features regarding their morphology. It comprises seven species. Of these *S. monstrosus* (Drury) and *Schizodactylus minor* (Ander) occur along the shores of River Indus in Pakistan and River Ganga (India). *S. monstrosus* is a large, robustly built, ferocious looking, burrow maker and nocturnal insect (Khattar, 1972). Usually, it lives singly in burrows and comes out at night, thereby constituting an important part of the food of many arthropods and vertebrates and they also play a signi-ficant role in maintaining the local food chain that prevents certain insect population increasing in the field.

Taxonomy of *S. monstrosus* has been studied by Snodgrass (1937, 1957), Ragge (1957), Imms (1957), Khattar (1958, 1959, 1972), Khattar and Srivastava (1962), Randell (1964) and Uvarov (1952); however, the external genitalia (proximal plate of epiphalus and epiproct) in the postgenital segments when compared between the epiproct and paraprocts of both males and females and the key components of the alimentary canal (that is, stomodaeum, crop, proventriculus, mesenteron and proctodaeum), were studied in detail by Crampton (1929), Ramme (1931), Hubbell (1936) and Khattar (1972). The morphology of various sclerites of the head, mouth parts, cervix and prothrox, and the interrelationship of this insect with others was studied by Khattar and Srivastava (1962). Its distribution and habitat preferences were studied by Khattar (1972) and Aydin (2005); whereas the population ecology of *Schizodactylus* was studied by Hazra et al. (1983). However, there has been no further information available on the biology, life habit and burrowing behavior of *S. monstrosus* from this region.

This insect appears to be exclusively carnivorous in habits and feed mainly on different types of ground darkling, dung beetles and grasshoppers found in its vicinity, but while in the laboratory, it accepted a piece of raw meat and fish when its natural food was not available. This study was, therefore, confined to establish the numbers of nymphal instars in *S. monstrosus* to describe and illustrate the morphological differences between these instars and to report information on the life-cycle and burrow excavating behavior of this species. Further, the record collection of *Schizodactylus* represents the first comprehensive record of the entomological fauna of Sindh.

*Corresponding author. E-mail: riffatumer@hotmail.com.

Figure 1. Eggs of *S. monstrosus*.

MATERIALS AND METHODS

Collection of specimens

Specimens of *S. monstrosus* were collected 4 km away from the Jamshoro bypass on the left bank of River Indus near Hussainabad, Hyderabad, Sindh, during the years 2004 to 2007. The material was collected on moderate slopes or level in deep layers of loess and fine sand, with or without thin semi-desert vegetation or in places to which layers of this fine soil were deposited by wind.

Preservation of specimens

From the field, the collected material was transferred into polythene bags and brought to the laboratory where they were put in small glass jars containing 70% alcohol and then a label showing locality, date of collection and collector name was pasted on each jar. After a couple of weeks, fresh 70% alcohol was added in the glass jars and the old one was replaced in order to perverse the insects longer.

A study of the life-cycle and burrow excavating behavior

Fundamentally, to study the life cycle of insects, monthly visits were made to the study sites in order to collect as many specimens as possible. The burrows of insects were dug out with a single long stick. The stick was put inside each burrow until it touched the end of it. Then the digging started caringly with the upper part of the stick while being directed towards the end of each burrow, in order to avoid any insect injuries. Burrows were identified for excavation by locating the talus piles left at the entrance. In order to determine the contents of burrows, excavations of 421 burrows were conducted in 2004 and 2007. A soda straw (trimmed to 20 cm length and with a diameter less than that of an average adult burrow) was placed in the hole to prevent cave in the burrow during digging, after which sand was carefully removed around it with a garden trowel. The sand removed was inspected for the presence of eggs, nymphs and insects parts such as elytrae and wings in order to determine the food preference of *S. monstrosus*. The variances between body length of nymphs and adults were compared using one-way analysis of variance (ANOVA) (SPSS 10.0), and the variation was tested using LSD (1%) (Cochran and Cox, 1957).

The terminology regarding the different body regions adopted here was that of Khattar (1972). All the measurements were taken in millimeter with the help of the 'ocular square reticule' in one ocular of the stereoscopic dissecting binocular microscope.

RESULTS

S. monstrosus laid a total of 23.10 ± 3.66 eggs (Figure 1) at the depth of 14.05 ± 1.85 cm, and the eggs were expended throughout the burrow. These eggs were hatched out in tiny nymphs. Mostly, females preferred to lay eggs where food resources are available so that new hatching nymphs can get the food without any difficulty. The life cycle took more than one year for its completion and passed through nine nymphal instars.

Morphological description of nymphal instars

First nymph

Minute tegmina and wing rudiments were present in small triangular lobes on the lateral sides of the meso and meta thorax. These lobes were indistinct in this stage (Figure 2a).

Second nymph

Triangular tegmina and wings rudiments became slightly larger and separated from the meso and meta thoracic segments by forming distinct ridges. These lobes are slightly anterior and were pointed downwards (Figure 2b).

Third nymph

The size of the tegmina and wing rudiments increased slightly, but they remain as triangular lateral flaps of the meso and meta thorax and were separated by distinct ridges (Figure 2c).

Fourth nymph

The tegmina and wing rudiments become large, but remained laterally downwards on the side of the meso and meta thorax. Longitudinal striations also appeared in this stage and their traces were visible on both rudiments (Figure 2d).

Fifth nymph

Tegmina and wing rudiments increase further in size when they became conical pads and were directed laterally downwards. Longitudinal striations became more prominent, while the anal areas became distinct and separated on both rudiments (Figure 2e).

Sixth nymph

In this stage, tegminal rudiments were slightly directed

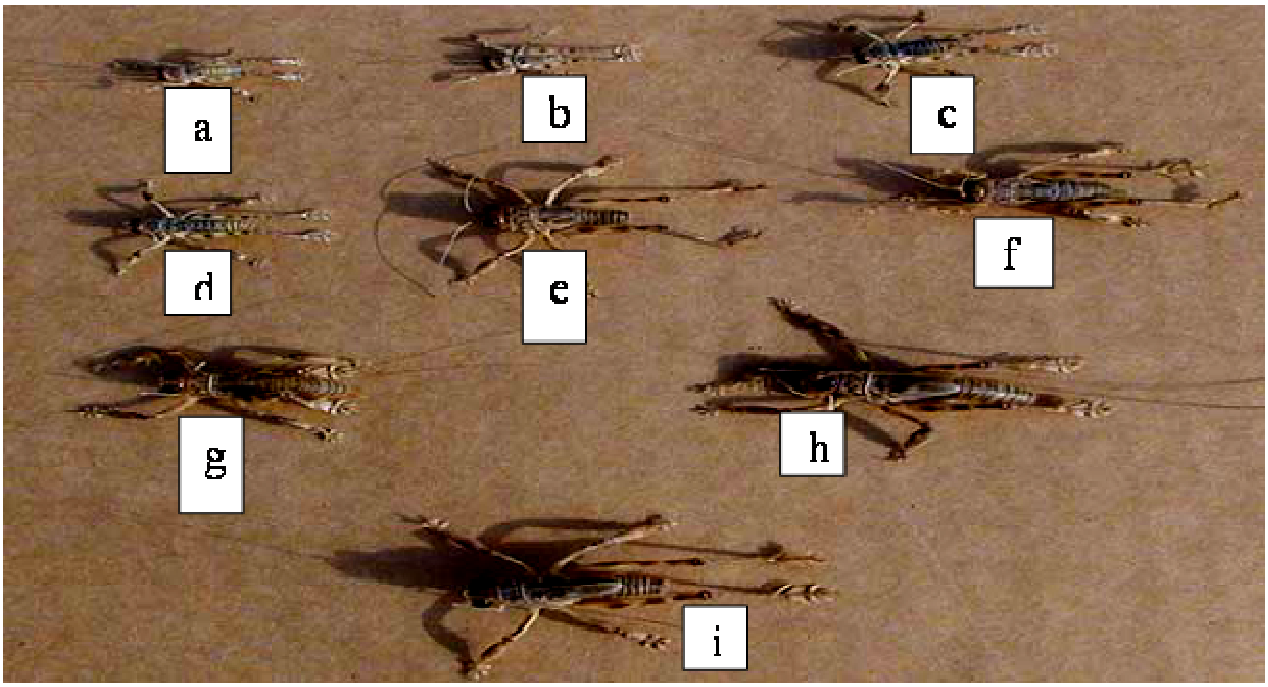

Figure 2. 1st to 9th nymphal stage of *S. monstrosus* (a to i).

backwards, while the wings turned laterally downwards. As a consequence, the ridge completely separated the anal area that became more diverse at this stage (Figure 2f).

Seventh nymph

The tegmina and wing pads turned over to the back of the segment. The wing pads reached the first abdominal segment, while tegmina extended to the posterior margin of the meta thoracic segment. However, the wing rudiments overlapped the basal posterior margin of the tegminal rudiments (Figure 2g).

Eight nymph

Tegmina and wing pads were reflected over the back and they further increased in size. In this stage, tegmina reached the first abdominal segment, while the wings extended to the second abdominal segment. In this stage also, tracheation was more prominent in both rudiments (Figure 2h).

Ninth nymph

The tegmina and wing pads became larger and they almost covered the dorsal as well as the lateral sides of the first fourth abdominal segments. The wing pads covered the fifth abdominal segment, while the tegmina reached the fourth abdominal segment, and so, both rudiments became darker in color (Figure 3).

Measurement of *S. monstrosus*

The comparison of the body length of the various nymhal instars of *S. monstrosus* is shown in Table 1. This indicated that there was significant difference in the measurement of male and female nymphal instars from the first instar to the adult instar. The total body length slightly increased in the first instar onwards, but it was significantly increased in the adult's stage (43.96 ± 1.04 mm for male and 50.55 ± 2.19 mm for female).

Burrowing behavior

For habitation, the young and adult made isolated slanting tunnels which they rarely leave except at night. They preferred to live in moist sandy places, because they could not survive in dry, hard or water-logged soil. Like the *S. minor,* once they came out of their burrows, they dug fresh ones for further activations (that is, reproduction and preying). The tunnels entered the soil at an angle of 45 to 60° and turned slightly to the left in a majority of cases. The diameter of the tunnel varied from 0.635 to 0.6985 cm. Adults could go as deep as 66.81 ± 7.73 cm. Moreover, no side tunnels branching from the main tunnel was observed. Digging was done by the

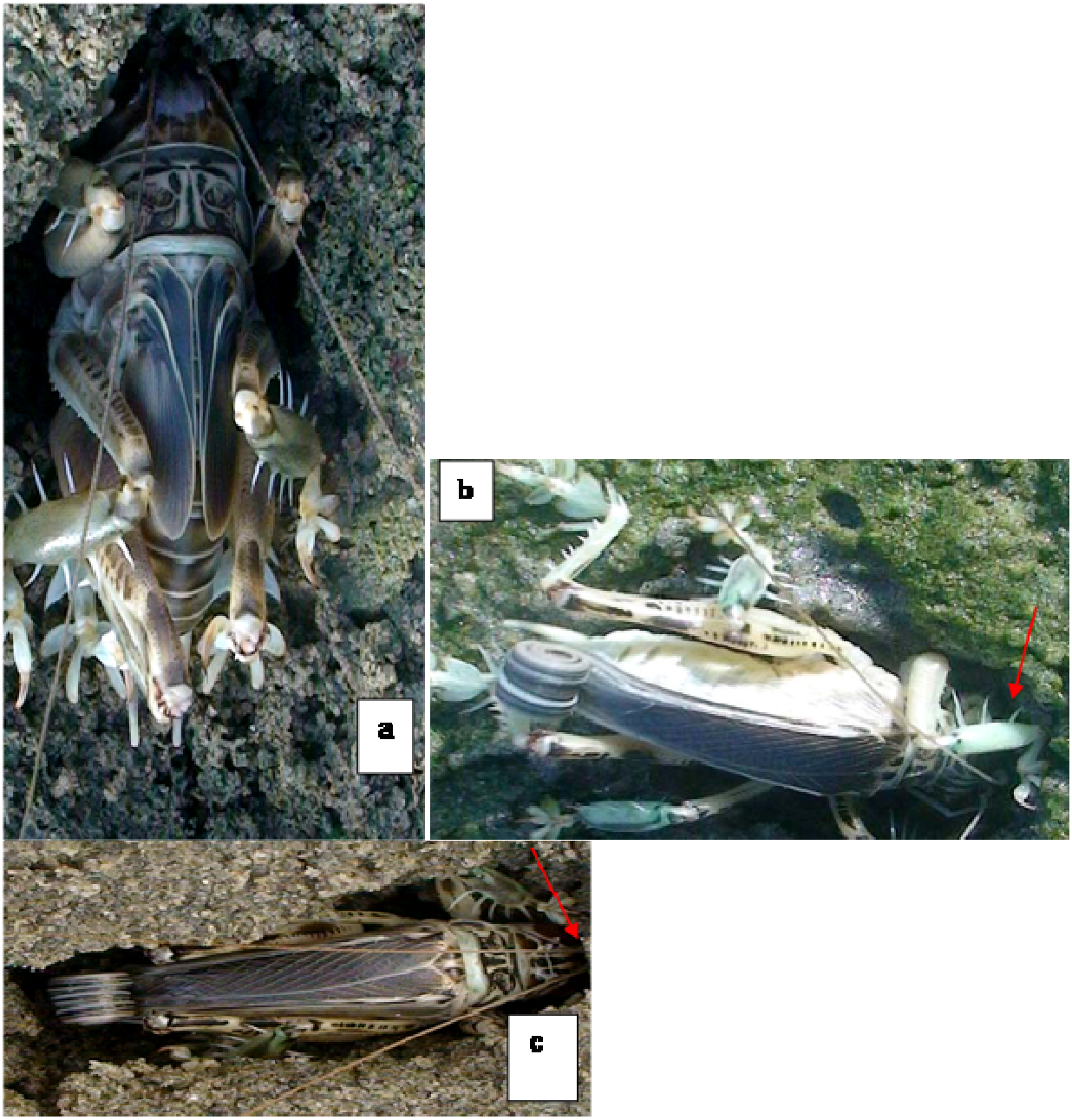

Figure 3. Insect (a to c) engaged in digging the burrow with its jaws.

mouth parts and the heap of sand was thrown out with force by the large spurs of hind tibia (Figure 3a to c).

This species was virtually found from large areas of sterile sand, but it was hardly found in edaphically suitable places other than too densely grown places. During the study, it was observed that several nymphs and adults were outside the tunnels trying to escape, but they hid back into the tunnel immediately they were discovered by means of strong light. This indicates that *S. monstrosus* is strictly night-active which is supported by its coloration, and that it uses its tunnels as a protection and hiding place. However, they were strongly carnivorous and they just compromise during mating with each other for a short period. Their burrows were situated in sparsely grown dry loess zone between the edges of the field and foot of the slope. The intervals between individual burrows varied from 6 to 10 cm on an area, some of which were 50 to 80 ft wide and about 2500 ft long.

Table 2 shows that a total of 421 burrows were examined at the study sites between 2004 and 2007. These burrows were occupied with a single male and female. The total number of the male's solitary burrows was examined to be 181 with 43%, while the solitary burrows of

Table 1. The average body size (mm) of nymphal stages and adult of *S. monstrosus*.

Stage	Number	Male	LSD	Minimum to maximum	n	Female	LSD	Minimum to maximum
Ist nymphal stage	10	7.46±0.050	A**	7.40 - 7.50	10	8.72±0.182	A**	8.5 - 9.10
2nd nymphal stage	10	11.28±0.09	B	11.23 - 11.46	10	13.44±0.25	B	12.45 - 13.55
3rd nymphal stage	10	14.54±0.05	C	14.50 - 14.60	10	16.38±0.11	C	16.34 - 16.55
4th nymphal stage	10	18.46±0.10	D	18.30 - 18.60	10	19.44±0.09	D	19.3 - 19.60
5th nymphal stage	10	20.42±0.05	E	20.10 - 20.20	10	22.25±0.100	E	21.80 - 22.56
6th nymphal stage	10	26.42±0.24	F	26.0 - 26.70	10	27.85±0.32	F	27.3 - 28.4
7th nymphal stage	10	27.25±0.84	G	26.4 - 28.70	10	30.54±1.88	G	28.0 - 33.2
8th nymphal stage	10	30.25±0.04	H	30 - 23 - 30 - 34	10	35.93±0.97	H	35.5 - 37.6
9th nymphal stage	10	38.46±0.11	I	38.30 - 38.60	10	43.05±2.87	I	39.0 - 46.5
Adult	10	43.96±1.04	J	42.44 - 45.65	10	50.55±2.19	J	47.80 - 53.70

*Mean ± standard deviation; **the letter indicates a significant difference ($P < 0.01$) according to LSD test.

Table 2. Showing the percentage of solitary male and female *S. monstrosus* burrow examined during the year 2004 to 2007.

Burrow content	Number of burrows examined	Percentage of burrow (%)
Solitary male	181	43.0
Solitary female	240	57.0
Total	421	100.0

the female was recorded as 240 with 57%. During the study, it was also observed that their population never attained such density, as in this locality; *S. monstrosus,* in general may inhabit the deep layers of fine loess sand. It was also recorded that the insect used its sharp strong jaws for digging the burrow.

DISCUSSION

Various stages of Lepidoptera were studied for the first time by Dyar (1890). He recommended that, the head capsule of these larvae can grow in geometrical succession, thereby increasing in width at each ecdysis; but this is not pertinent for all other species, and the ratio may not be constant for the different structures of the body in the same species. Criddle (1926) reported that a number of antennal segments, development of wings rudiments and modification of pronotum are crucial for the study of the immature stages of Orthoptera, whereas (Riffat, 2007; Riffat and Wagan, 2010) stated that antennal segments, length of antennae, pronotum and total body length of nymphal instars have significant importance to distinguish the various stages of *Hieroglyphus* spp. Cowan (1929), on the contrary, recommended that development of ovipositor in females and subgenital plate in males is a fundamental character to determine the immature stages of *Anabrus simplex,* but this character is not much reliable in *Schizodactylus*.

However, this study suggests that the length of the body, the antennae, the hind femur, the development of the genitalia, the size of the pronotum and the length and position of wings rudiments is particularly very important for determination of the various stages of *Schizodactylus.* Both the tegmina and wings of *S. monstrosus* are long, while tapering posteriorly and rolling into a spiral that lies over the cerci. The tegmina sides turn down abruptly and cover the lateral side of the abdomen although this is not present in *S. inexpectatus.* Choudhuri and Bagh (1974) also found that the female of *S. monstrosus* lays eggs towards the end of the burrow; moreover, this was not reported in this study The females laid eggs at the bottom of the burrow, but these eggs never reached the last end of the burrow.

Details of burrowing habits of *S. monstrosus* are given in this study. Carpentier (1953) stated that the depth of the burrow would depend on the depth of the insect research water, while Khattar (1972) did not find a single instance of a burrow going down to the level of water. During the study, it was observed that the burrows were never directed towards the sea, as Guichard (1961) reported. They appeared on soil surface at night when preying on insects or perhaps, when they had mating desires. Furthermore, the coloration of these insects indicated that they were typical soil or nocturnal insects. All burrows with mounds were invariably occupied by each species containing a solitary individual of *S. monstrosus*. The species is apparently carnivorous consuming small insects (beetles, grasshopper and cricket) that go into its burrow or preying on them on the

soil surface in the environs of its burrow at night. During increase in the water level of river Indus, not a single individual was found other than those buried in the soil (Aydin and Khomutov, 2008).

Khatkar (1972) also reported that the burrow of both adults and immature stages of *S. monstrosus* were closed after they were completed; nevertheless, during the study, some opened burrows were also observed, but the exact cause of these open burrows are yet unknown. Khattar (1972) reported a distinct correlation between the depth of the burrow and the condition of the soil. The drier the sand, the deeper the burrow becomes, and vice versa. However, this study is in agreement with this. Ramme (1931) had reported that *S. monstrosus* used their spurs of hind tarsi for digging, while Carpentier (1953) observed that digging was done by jaws. This study supports the view of Carpentier, because the results obtained are valuable in acquiring a better understanding of the economic importance of this rare genus.

Conclusion

This species does not seem to produce more than one generation a year. It comprises nine nymphal stages, and the insect is a predatory species. As its activity never could have been observed in the day during which the insects could only be detected in their burrow, they were observed in the night while performing mating and searching of prey.

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