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Some behavioral and biological traits under rearing conditions of *Bryophyma debilis* (Karsch) (Orthoptera, Acrididae, Cyrtacanthacridinae), a grasshopper from Burkina Faso

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Abstract

Bryophyma debilis, a poorly known grasshopper from the wooded savanna of West Africa, was reared for the first time under laboratory conditions. Morphological descriptions of adults and nymphs were made previously. We describe some behavioral traits (aggressiveness, stridulation, egg-laying), and record data on nymphal development and reproductive biology.

Résumé

Bryophyma debilis, un criquet peu connu des savannes arbustives d'Afrique de l'Ouest, a été élevé pour la première fois en laboratoire. Des descriptions morphologiques et anatomiques ont été faites sur les larves et les imagos. Nous décrivons dans cet article quelques aspects de son comportement (agressivité, stridulation, ponte) ainsi que le développement larvaire et l'activité génésique des reproductrices.

Key words

Reproduction, behavior, hopper, oocyte, resorption, ovary, rearing

Introduction

Bryophyma debilis (Karsch) is widely distributed in Eastern and Southern Africa. The type originates from Zanzibar and four subspecies have been described: *B.d. debilis* (Karsch), *B.d. picta* Uvarov, *B.d. robusta* Miller and *B.d. sigillata* (Bolivar). For West Africa, Dirsh (1966) synonymized these subspecies in one species named *B. debilis* (Luong-Skovmand & Foucart 1999). The western edge of the known distribution of this species just reaches Burkina Faso which could explain its rarity in this country. However it is not in high abundance anywhere in its huge range. There are almost no bioecological data available on the species which is not harmful to crops and is hard to locate and approach in the field.

Materials and Methods

In October 1997, *B. debilis* was collected in a wooded savanna with shea trees (*Butyrospermum parkii*, Sapotaceae) at Yagma, close to Ouagadougou (lat 12°20'N, long 1°40'W), Burkina Faso, and brought to the laboratory in France to investigate some of its morphological and biological traits

(Luong-Skovmand & Balança 1999, Launois-Luong *et al.* 1999, Luong-Skovmand & Foucart 1999). We present here some behavioral, reproductive biology and nymphal development data for this laboratory-reared grasshopper.

B. debilis was reared in a cage of clear plexiglass and wire screen (40 X 40 X 50 cm) where their activities could be fully monitored. The cage had a removable floor, flush-fit with four egg-pod tubes (6.5 cm diameter, 10 cm high). Three of the four sides of the cage were almost completely screened to promote air circulation; two round openings, on the front and top of the cage, provided access to the grasshoppers and permitted insertion of the daily food ration. Two 40-W lamps were placed against the screens to provide light and heat 12 h daily. This cycle, 12L:12D, corresponds to the photo-period at the latitude of Ouagadougou where the grasshoppers were collected. The temperature was almost constant at 30°C, which is considered optimal for the development of many grasshopper species (Hink & Erlandson 1994); nevertheless the insects were able to modify their internal temperature by moving closer to or further from, the lamps. The humidity level was maintained at 50%, with moistened cotton-mesh (a piece of cotton in a small petri dish) which also provided a drinking source.

In rearing this arboreal grasshopper for the first time, we had to find a suitable food plant enabling them to survive and breed in caged conditions. Tested with grasses and clover (*Trifolium* sp.) they consumed little and so these foods could only be offered as a nutritional stop-gap. *Rosa-ceous* species such as bramble (*Rubus* sp.), rose (*Rosa* sp.) and wild rose (*Crateagus* sp.), which are relatively rare in *B. debilis* habitat, were found to provide acceptable food as indicated by the resulting volume and quantity of feces. Brambles were used to fulfil the insect's daily food requirements. Wheat bran was given as a dietary protein and lipid health supplement (MacMasters *et al.* 1972, McKinlay 1981).

Individual grasshoppers were monitored under these group-rearing conditions. For identification purposes, the sides or the top of the pronotum of each female were marked with glyptal color paint. Observations of behavioral traits took place three times a day, at 8:00, 12:00 and 16:30 and lasted 5-10 min each time. Reproductive activity was monitored in the laboratory as weight change, number of layings, inter-clutch intervals (the latter is the time between two

egg-layings) and longevity. The prereproductive period, from fledging to 1st laying, was observed in 12 females and reproductive performance recorded for the whole colony of 22 females. This is a univoltine species with an embryonic resting stage; nymphal development was followed for one subsequent year, with hoppers pooled in groups of 10 males or 10 females, in cages similar to the one in which the adults had been reared and under the same conditions.

Results

Aggressiveness and stridulation.— *B. debilis* is a sturdy, sluggish and silent grasshopper. Females do not stridulate, whereas the males occasionally do so, briefly, if attacked by another male when mounting a female. Twice we noted that during a male-male confrontation, the copulating male stridulated by rubbing its hind tibia spines against its forewings, part of its abdominal wall, and the upper part of the female's forewing underneath. No special stridulatory organs were detected on the males' fore-wings or abdominal pleura. This primitive limb-on-body stridulation without specialized sound-producing structures is seen in other Acrididae (Golding 1934; Laub-Drost 1960, in Uvarov 1966). In a few cases *B. debilis* male aggressiveness induced them to bite an opponent's labium during furious, very short combats, prompting the attacked male to produce shrill stridulations in protest. We did not notice sound production under any other circumstances, e.g. when males were courting females.

Copulation and oviposition.— Though some inter-male aggressiveness was observed between males competing to mount the same female, these grasshoppers always copulate only as separate couples. There were no situations with several males sitting on the back of the same female, as seen in *Schistocerca gregaria* (Forskål), *Locusta migratoria* (L.), *Dociostaurus maroccanus* (Thunberg) and others. Some pairs remained in copula for a full day (5 of 18 observations).

At Yagma, where *B. debilis* were collected, the soil was sandy or sandy-clay, with considerable herbaceous cover under the trees. In the laboratory, six times eggs were left on the surface of the soil and 67 clutches were found in egg-tubes. Only egg-tubes filled with heavy soil were chosen for egg-laying: those filled with river sand were abandoned after a few probing attempts. Exploratory soil-probing can take place 2-3 d before laying. Oviposition lasted 3-4 h, then the female quickly covered the foam plug with soil by a rapid hind limb movement. When a female was disturbed, the foam was spread over the surface of the ground. In a few cases, the male was allowed to remain perched on the back of the female during laying.

Senescence.— Young *B. debilis* exhibit a green shade (Fig. 1), then turn saffron yellow during the last half of their reproductive life (Fig. 2). This chromatic change with aging was markedly abated when the grasshoppers were reared in a more humid environment, i.e. 70% compared to 50% humidity (Fig. 3). Color change occurs in gregarious *S. gregaria* and *L. migratoria*, which turn lemon yellow at sexual maturity as the result of the migration of dietary β -carotenes to

the outer cuticle layer (Goodwin 1949, 1950).

Most of the senescent grasshoppers showed necrotic blackening around forelimb coxae, at the tergosternal junctions of the 1st-2nd and 7th-8th abdominal segments, thus stiffening the tip of the body. Analysis of sections of melanoma in the cuticle indicated a fungal origin involving many spores and mycelia (R. Kleespies, personal communication). Black nodules containing bacteria were also found (rarely) in the underlying tissues. It should also be pointed out that dead grasshoppers were never attacked by congeners: no necrophagy or cannibalism were noted.

Ovary morphology and oocyte resorption.— The ovaries of *B. debilis* females are composed of 80 ovarioles on average ($n=10$, $s=5.88$), generally distributed in a pectinate pattern along the calyx. This is close to the number of ovarioles in *Acridoderes strenuus* (Walker), i.e., 72, but much less than the 140 ovarioles noted on average in *Kraussaria angulifera* (Krauss), two Cyrtacanthacridine species about the same size as *B. debilis* (Launois-Luong unpublished).

Ovarial function can be assessed by observing residual oocyte structures, i.e., follicle resorption bodies (FRBs) following an ovulation, and oocyte resorption bodies (ORBs) following ovogenesis failure. In *B. debilis*, the FRBs are whitish when recent and translucent yellow when old. Oocyte resorption is clearly indicated by the presence of reddish orange or bright red ORBs with yolk pigments (Fig. 4). It is possible, up to the third laying, to determine the number of layings and eggs/clutch for females collected in the field, by counting the number of FRBs within the same oocyte row. After three ovipositions, FRBs and ORBs can no longer be clearly identified, as they have usually been altered by the growth and successive development of subsequent oocytes (Launois 1972; Launois-Luong 1978, 1979).

Female reproductive activity.— *B. debilis* develop one generation a year with an embryonic resting stage. Under our rearing conditions (Table 1, 2) the lifetime from fledging to death lasts nearly 3 mo (84.2 days, $s=18.4$, $n=12$). The first copulation was noticed 19 d after fledging and the first egg-pod was deposited 2 wk later. The inter-clutch period does not seem to be affected by aging and the female lays every 2 wk. On average 3.3 clutches are produced per female during the 6-wk reproductive period. Seven of 22 females laid four times; only three succeeded in laying five times and two, six times. The loss of weight after each laying was not affected by age, i.e., the egg row suggested a stable egg production throughout the reproductive period. At their death, the females weighed on average 2.4 g (range 2.7-2.1 g), i.e., close to their weight after laying. The number of eggs/clutch was calculated in 11 cases when the eggs were left on the floor of the cage or when the female died with ripe oocytes in her oviducts. On average there were 52 eggs/pod ($s=13.8$), i.e., 65 % of ovarioles were functional.

Nymphal development.— This was monitored in 20 males and 20 females pooled into groups of 10. Sexing of hatchlings caused the death of a few nymphs within the first 2 d. Then 17 males and 15 females were monitored and all survived until fledging. Durations of instars were calculated



Fig 1. Male *Bryophyma debilis* fledgling.



Fig. 2. Senescent adults.



Fig. 3. Mature males reared under different moisture.



Fig. 4. Oocyte resorption bodies in ovarioles of a female that has just laid. Early orange and red oocyte resorption bodies (ORBs) in rows 1 and 2. Old yellow translucent follicle resorption body in row 1 and recent whitish FRBs.

according to mean development time of the cohort, as shown in Table 3. Under our rearing conditions, nymphal development took 2 mo for males and 80 d for females, similar to some univoltine grasshopper species such as *K. angulifera* (Bindra & Amatobi 1981), with a mean of 62 d. The males had five instars, females had six, thus explaining the gap in the total development time. All but the last instars showed the same development rate in both males and females.

Discussion

Behavioral and biological traits of *B. debilis*, apparent under laboratory conditions, could explain its rarity and the reason it is so difficult to find and approach in the field. In addition to their low densities, this grasshopper species is silent: males rarely stridulate even during courtship, so sound can provide no guide to their detection.

This arboreal grasshopper lives in wooded savanna, and changes its color with age, turning from bright green when younger to saffron yellow when mature. While green they perch in the canopy. When ready to oviposit in the grass cover, they assume its saffron yellow color.

B. debilis exhibits a long embryonic resting stage of 7 mo which corresponds to the dry season in the Sahel, then a 2-mo nymphal stage and 3-mo adult lifetime. These biological features (number of hopper stages, larval and adult development durations) are similar to those of *K. angulifera* Krauss (Bindra & Amatobi 1981). However this latter species can easily pullulate because of its reproductive potentialities (140 ovarioles vs 80 for *B. debilis*) and laying females aggregate in small egg-beds, producing bunches of egg-clutches giving rise to hopper bands at the onset of the rainy season (G.B. Popov c.p.). This is not the case with *B. debilis* which, like most grasshoppers, lay their eggs in isolated clutches. Under rearing conditions, the mean egg production/female during her lifespan is 170 eggs, corresponding to only 65% ovarioles functional; but this figure should be confirmed by further studies under field conditions by observing residual oocyte structures.

Many scientists (Phipps 1950, 1966; Singh 1958; Launois 1972; Launois-Luong 1978; Bellinger & Pienkowski 1985; Launois-Luong & Lecoq 1996, Sundberg, Luong-Skovmand & Whitman 2001) have investigated ovarian function by assessing residual oocyte structures. For acridids with a pale yolk such as *Acorypha glaucopsis* (Walker) and *Aiolopus thalassinus* (Fabricius), the lack of a distinction between old FRBs and ORBs often confuses interpretations. On the other hand, species with accessory glands that produce white secretion as occurs in *K. angulifera*, *Acanthacris ruficornis citrina* (Serville) and *Metaxymecus gracilipes* (Brancsik), make opaque dissections and hamper analysis of oocyte structures (Launois-Luong 1978). *B. debilis*, like most Eyprepocnemidinae, Oedipodinae and Catantopinae species, do not have any of these drawbacks.

The necrotic blackening associated with senescence which was observed may be the result of a bacterial infection initiated following the abrading of the cuticle after a biting

attack, a bramble thorn injury, or during exuviation. A hypothesis is put forward by R. Kleespies: the initial infection was halted by the host's immune reaction, leading to the formation of nodules in the body cavity and melanization. Such infections would then be conducive to fungal development. However the situation could also be explained by development of a fungal infection followed by a bacterial infection. A more in-depth study is needed to assess the origin of the observed nodules and melanomas.

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Table 1. Weights (mg) of reared females during the reproductive period.

	Weight of soft female at D1	Mean weight loss after each laying				Mean weight loss after each laying
		1 st laying	2 nd laying	3 rd laying	4 th laying	
MEAN	1521.0	74.4	58.0	79.3	89.7	77.8
s	0.08	20.8	20.5	19.3	18.8	22.3
n	12	22	20	13	7	66

'Soft female' means fledglings when the cuticle is still soft the day after the moult.

Table 2. Duration of main reproductive stages (days).

	Days from fledging to		Inter-clutch period			Reproductive period	Post-reproductive period
	1 st mating	1 st laying	1 st -2 nd laying	2 nd -3 rd laying	3 rd -4 th laying		
MEAN	18.7	36.5	18.6	14.5	17.0	45.4	8.8
s	4.6	9.9	11.6	4.4	9.1	21	7.6
n	12	12	20	13	7	22	22

Table 3. Mean length of nymphal instar stages in *B. debilis* (days).

	N1	N2	N3	N4	N5	N6	Total length
Male	11.1	11.2	11.6	12.6	15.9		62.5
Female	12.1	11.3	11.7	12.1	14.1	19	80.5

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