

Behavioural and life history aspects of *Calliptamus plebeius* (Walker, 1870), an endemic grasshopper of the Canary Islands (Orthoptera: Acrididae, Calliptaminae)

Günter Köhler

Abstract

Two females and one male of *Calliptamus plebeius* (Walker, 1870) from Tenerife, Canary Islands were caged and the progeny reared for one generation. Observations on the resting, feeding and mating behaviour of this insect are described, including, for the first time in this species, its acoustic behaviour (assumed of the ♂) whilst an attracting mechanism (♀-pheromone?) was detected for the first time in Calliptaminae. Copulations were observed at an adult age of 27-56 days between 6.00 and 18.15 hrs. at temperatures of 18-35 °C. The median adult life-time amounted to about two months. The ovariole number varied from 10-20, with 10-11 eggs per pod. Pre-diapause eggs were able to absorb water in 100% relative air humidity. After 6 months of chilling, the first instar nymphs hatched after 29 days (at Ø 26.5 °C). Juvenile development over 4 instars in both sexes lasted an average of 41 days (at Ø 25-30.5 °C) with a considerable variation. Morphometric data from all juvenile stages (exuviae) and the adults are presented.

Zusammenfassung

Zwei Weibchen und ein Männchen von *Calliptamus plebeius* (Walker, 1870) von Teneriffa, Kanarische Inseln, wurden gekäfigt und deren Nachkommen bis zur F₁-Generation gehalten. Es werden Beobachtungen zum Ruhe-, Fraß- und Paarungsverhalten sowie erstmals für die Art Lautäußerungen (des ♂?) und erstmals für die Calliptaminae ein Anlockungsmechanismus (♀-Pheromon?) beschrieben. Kopulationen wurden zwischen 6.00 Uhr und 18.15 Uhr bei Temperaturen von 18-35 °C und im Imaginalalter von 27-56 Tagen beobachtet. Die imaginale Lebensdauer betrug etwa zwei Monate. Die Ovariolenzahl schwankte von 10-20, bei 10-11 Eiern je Gelege. Prädiapause-Eier konnten Wasser schon bei 100% rel. Luftfeuchte aufnehmen. Nach sechsmonatiger Kühle kam es nach 29 Tagen zum Schlupf (bei Ø 26,5 °C). Die Juvenilentwicklung über 4 Stadien in beiden Geschlechtern dauerte 41 Tage (bei Ø 25-30,5 °C), mit einer breiten individuellen Streuung. Morphometrische Daten aller Juvenilstadien (Exuvien) und der Imagines werden angegeben.

Introduction

The orthopteran fauna of the Canary Islands has been studied since the 1830s and is rather well-known, both in terms of its biodiversity and regional species distribution. Around 40 Acrididae species are known from the archipelago, of

which 17 (41%) are endemic, with about 25 species, including 7 endemics (30%) on Tenerife alone, the largest island of the archipelago (BLAND et al. 1996, BAÉZ et al. 2004 – both checklists are slightly different).

One of the most widespread endemic Canary acridids is *Calliptamus plebeius* (Walker, 1870), which is absent only on Fuerteventura. This ubiquitous species is characteristic for several xerophilic biotopes of different exposition and inclination and occurs on Tenerife from the sublitoral scrub zone (near the coastline) up to the subalpine scrub zone (> 2000 m a.s.l.) along the Cañadas de Teide (WILLEMSE 1949; GANGWERE et al. 1972, 1998; BLAND 2001). Ecologically, this calliptamine species has been studied primarily in relation to its phenology, food selection and feeding behaviour (GANGWERE et al. 1972, 1998), as well as in its morphometrical variation between the main islands (JAGO 1963, BLAND 2001). Referring to the trans-Palaeartic genus *Calliptamus* with 13 species (JAGO 1963), most of our knowledge is based on the potential pest species *C. barbarus* and *C. italicus* (summarized in UVAROV 1966, 1977; ANONYMOUS 1982). In contrast, for the non-pest species *C. plebeius*, very little is known about its behavioural ecology (except feeding preferences) and life-history. In light of this, some hitherto unpublished observations and biological characteristics of this species are described here, based on a study performed two decades ago.

Material and Methods

Origin

During a study trip through Tenerife two adult females (greenish and greyish-brown morph) and one adult male of *C. plebeius* (Walker, 1870) were sampled on 26.08.1991. The locality is situated south of Orotava along a path between Aguamansa and Portillo in the lower subalpine zone near the timberline (*Pinus canariensis*) on a NNW slope of the Cañadas de Teide, 2000-2100 m a.s.l. (Fig. 1; 28°20'19 N, 16°29'25 E). During a clear and sunny morning (about 25 °C), the grasshoppers were found sitting and climbing at 30-50 cm height in two dry shrubs, the endemic crucifere *Descurainia bourgaeana* (Hierba pajonera, Teide-Besenrauke) and the endemic legume *Spartocytisus supranubius* (syn. *S. nubigenus*; Retama del Teide, Echter Teide-Ginster) (HOHENESTER & WEIß 1993, SCHÖNFELDER & SCHÖNFELDER 1997), which formed patchy stands on the reddish-brown soil of Lapilli of varying size (Fig. 2), few of them still flowering (bright yellow). The grasshopper density was very low, and only few specimens were found within the shrubs. The insects were captured with a baseball cap and individually stored in plastic tubes with a foam stopper, later they were transferred to plastic bags with dry *Descurainia* twigs for air transport (27.08.91) to Germany.

Rearing

On 29.08.1991, the three adults were put into a cage with gauze walls (15 x 15 x 18 cm) and placed on the WSW balcony of our flat in Jena-Lobeda, Thuringia, Germany. For egg-laying, the bottom of the cage was filled with a 3 cm layer of fine, dry sand (see Fig. 4), and additionally a cup of dry sand was placed. As foodplants a few pieces of a wild *Descurainia* shrub, leaves and stems of *Lolium*, dry *Sphagnum* and a dry palm (*Areca* sp.) leaf were offered, but only *Lolium* was

slightly eaten. Two days later other plants were offered, from which *C. plebeius* preferred *Dactylis glomerata* (cocksfoot grass), which was subsequently used throughout the following rearing.

In the first two weeks following return (29.08.-15.09.1991), initial observations to foraging, mating and egg-laying were made. After one month, the two females had laid 6 eggpods. One female died on 27.10., surviving one pair. Of the eggpods one was broken open whilst the other 5 were again re-buried and stored in a refrigerator (at 5-7 °C) over 6 months (27.10.91–24.04.1992). Thereafter they were placed in a greenhouse, where the young hoppers hatched (22.-29.05.1992). On 03.06.92, the 5 eggpods were checked for eggs hatched and not hatched. Juveniles and adults were caged in the greenhouse during seasonally varying daily temperatures. All F₁-individuals moulted into adults until the 30.07., although the females didn't lay eggs up to 24.08. On 26.08., the surviving adults (8 ♀♀, 9 ♂♂), were separated in two cages: one under short-day (LD 8:16: 4 ♀♀, 4 ♂♂), and one under actual long-day conditions (LD 14/13:10/11, 4 ♀♀, 5 ♂♂), each cage containing 3 cups for egg-laying, with garden soil/sand-mixture, fine sand and gravel/sand, respectively. From the dead females the ovariole number and oocyte development were checked.

Weighing and measuring

On 17.09.91, from the broken eggpod all 10 eggs were separated, cleaned, stored in small Petri-dishes over fine sand, each 5 under contact with water and at 100% relative air humidity, and weighed every 3 days using a spring balance (tolerance 0.05 mg). This experiment was conducted from 17.09.-11.10. (in a bacteriological incubator, Ø 23,5 °C), but finally only 5 eggs (2 in contact with water and 3 in 100% r. h.) remained undamaged and could be analysed for water budget (see Fig. 5).

Over the complete rearing period, the air temperature near the cages was continuously recorded by a thermograph, and from the daily curves the means were determined. The eggs were measured under a stereomicroscope by means of an ocular micrometer. In the juvenile stages, the exuviae in the cages were successively sampled, and their post-femur lengths measured over an object micrometer under a stereomicroscope. The two females and one male from the wild, together with 7 females and 13 males from the F₁-generation were pinned with stretched right wings (coll. Köhler, one pair in coll. Hochkirch) and measured with an electronical vernier calliper (accuracy 0.01 mm).

Behaviour

Resting and eating

On 31.08.91, as observed at night, one female rested below the cage roof, whereas the other female and the male were hidden at the bottom between dry plant/moss material. The grasshoppers also rested in the afternoon at the same protected places during exposure to strong sunlight on the balcony, whereas the male often stayed invisible within the dry vegetation. On 13.09.91 at 7 hrs. in the morning (8°C) the male seemed to be sleeping laying on its side between *Sphagnum*, but completely recovered with rising temperatures.



Fig. 1: Habitat of *Calliptamus plebeius* on the NNW slope of the Cañadas de Teide, Tenerife. Subalpine scrub zone (2100-2200 m a.s.l.) below the observatory (2364 m a.s.l.). 26.08.1991. Photo: G. Köhler.



Fig. 2: Locality, where *C. plebeius* was sampled near the scattered timberline with shrubs of *Spartocytisus supranubius* (in the foreground) and *Descurainia bourgaeana* (in the background), at 2000-2100 m a.s.l.). 26.08.1991. Photo: G. Köhler.



Fig. 3:
Caged *C. plebeius* female feeding on the grass *Dactylis glomerata*. Note the orange-reddish and black colouration inside the postfemur, perhaps a visual signal for conspecifics. Sept. 1991. Photo: G. Köhler.



Fig. 4:
Caged *C. plebeius* females before egg-laying. Greyish-brown (left) and greenish colour morph. Sept. 1991. Photo: G. Köhler.

On 30.08.91, the green female fed on a dry, rolled leaf of *Lolium*, holding it with its front tarsi and drawing it to the chewing mandibles. On 31.08./01.09.91 additional plant species (two shrub and one grass species) from the Leutratul were offered, of which *Rosa canina* later showed no signs of being chewed, *Cornus sanguinea* was only chewed on the stem, whereas *Dactylis glomerata* was clearly preferred and was eaten even as dry leaves (Fig. 3). In the manner of Gomphocerinae, *C. plebeius* nibbled grass leaves mostly from the margin (19x) to the central rib (Fig. 3), but sometimes the leaves were only perforated (5x).

Mating and singing

Between 1991 and 1992, a total of 6 copulation events were observed in the cages. They varied in the time of day (between 6.00 hrs. in the morning and 18.15 hrs. in the afternoon), the actual temperature (18-35 °C), and the adult age (27-56 days), resulting in a relatively long maturity phase (Table 1).

Table 1: Parameters of observed copulations in caged *Calliptamus plebeius*.

Date	Time of day	Temperature	Adult age	Observations
Wild specimens				
30.08.91	18.15 hrs.	-	-	with brown female
02.09.	17.30 hrs.	-	-	with the same brown female, after egg-laying
F₁-specimens				
06.08.92	6.00 hrs.	18 °C	27 days	final 10 minutes
26.08.	8.30 hrs.	27 °C	47 days	
29.08.	11.00 hrs.	35 °C	50 days	
04.09.	11.30 hrs.	22 °C	56 days	

A few interesting observations in the behaviour were made on the adults which sampled in the wild. On 30.08.91, around 18.15 hrs. (immediately after egg-laying!) a copulation was tried between the male and the greyish-brown female. The smaller male was sitting in an acute angle of about 30° on the abdomen of the female, bended his abdomen to the left below the female, fixed the cerci with the somewhat curved large dorsal apical lobes, and then enclosed her with its left hindleg. This procedure lasted about 10 min, which the female began to eat dry leaves of *Lolium*. Three days later, on 02.09. at 17.30 hrs., the end of a further copulation between the same (!) mating partners was observed, suggesting that the former copulation had been unsuccessful. The male supported itself with the left hindleg on the bottom, whereas the right hindleg was on the tegmina of the female. It held the female's body using its front and median legs. During the final minutes of the copulation a trembling (with 1-2 sec stops) was observed to pass through the male's body. Thereafter it parted from the female and began to eat, whereas the female violently moved her valvae (valvae gymnastics). On 29.09.92, at 11.00 hrs. an aroused male with sideward bended abdomen abruptly jumped from the right side diagonally on the female, a behaviour resembling a violation (rape).

In the afternoon of 14.09.91, about two weeks after caging the grasshoppers, a further rare observation was made, when a female was offered fresh *Dactylis* leaves which she immediately began to eat. Simultaneously she stretched her abdomen telescope-like, as seen during the beginning of egg-laying. The valvae were moved energetically up and down, and during this movement, a light-reddish pistil of 1-2 mm length was erected for a short time, situating ventrally behind or between the bases of the lower valvae. At the same time, from a distance of about 5 cm, the male moved straight to the female, waiting nearly parallel to her right side. He then bent his abdomen in an right angle to the left and tried to contact the female near the lower valvae, where shortly before the pistil had been erected. This procedure lasted about 1 min, but no copulation followed. This was clearly a pheromone-based behaviour, probably induced upon perceiving pheromone molecules with the antennae, on which the posterior segments seem to have many sensory hairs and pits (especially segments 12-21 in males, and 13/15-23/24 in females).

On 31.08./01.09.91, a very quiet monosyllabic song could sometimes be heard, similar to those of Gomphocerinae, and perhaps produced by the male, but without any related movement being observed.

Egg-laying

On 30.08.91, at 17.00 hrs. during sunshine, the successive egg-laying of the greyish-brown female (2 cm deep, 30 min) was observed, whilst after 15 min and at a distance of some 4 cm, the greenish female laid also her eggs (2 cm deep, 20-30 min, Fig. 4), indicating a synchronized egg-laying as described in *C. italicus* (UVAROV 1977). The telescope-like stretched and bend abdomen was progressively pressed into the dry sand, as seen in Gomphocerinae. After egg-laying and retraction of the abdomen, the posterior segments and the valvae were moved in an energetic fashion, supported by the spurs of the hindlegs, which roughly cleaned the outer valves. The hole was not actively closed by the female, but filled slowly by the dry sand. On 03.09. in the afternoon (4 days later only!), further egg-laying behaviour by a female was observed.

Life history

Adult lifetime

After caging in Jena the residual lifetime of the grasshoppers sampled at Tenerife on 26.08.91 lasted at least 62 days (greenish female), whereas the death dates of the other pair was not documented. Furthermore, the lifetime of 21 F₁-adults (9 ♀♀, 12 ♂♂) was registered: all of them moulted before 10.07.92. The median (min-max) lifetime reached 64 (35-80) days in females, and 55 (28-65) days in males, i.e. about 1-2 weeks longer in the females.

Eggpod production and ovariole number

According to the number of 8-11 oocytes (Table 2), a similar number of consecutive eggpods of a female are expected. The two wild Tenerife females produced a total of 6 eggpods within a month (29.-30.08.91: 2 eggpods, 31.08.-17.09.: 2, 18.-29.09.: 2). Because of the laying sequence, it may be surmised that after the first cage eggpods at the end of August (definitely from both females observed), each of the two females subsequently produced two further eggpods. In contrast, in the F₁-generation in 1992, the reproduction completely failed, one eggpod being empty (only foam) under short-day conditions along with two eggpods (1 empty, 1 deformed) produced under long-day conditions, laid in garden soil/sand and gravel/sand, which precluded any further rearing.

The ovariole number of 5 females was checked, 2 females had 10 and 14, and 3 females had 18(9+9) and 20(11+9) ovarioles, respectively (Table 2). The 6 eggpods in total contained 63 eggs, including hatched and residual eggs, and comprising 3 eggpods with 10 and 3 eggpods with 11 eggs each, respectively. This was only half of the potential number according the median ovariole number.

Normal eggpods were coated inside by a thin and glittering foamy layer, whilst outside were covered with fine sand particles according the substrate. Therefore, they easily decayed after being dug out, and presumably also did so in the substrate after hatching of the grasshoppers. In 1991, five complete eggpods were measured (median, min-max): length: 13.0 (11.1-15.0) mm, central diameter: 5.4

(5.0-6.2) mm. From one broken pod ten eggs were measured: length: 5.2 (4.9-5.3) mm, central diameter: 1.2 (1.1-1.3) mm. The egg with a distinctly settled pole cap was of a white-yellow colour and had irregular, light-brown stripes.

Table 2: Ovariole number and oocyte development in *Calliptamus plebeius*. Mature egg 1 = egg nearest to the oviduct and shortly before laid.

Date	Ovariole number	Oocyte development
28.10.91	10 (5+5)	5 mature eggs 1, 5 slender oocytes
01.09.92	18 (9+9)	1 mature egg 1, 3 nearly mature, 4 yellow and half of the length, the rest not developed, (5)-8-11 oocytes
02.09.	18 (9+9)	2 mature eggs 1 each, the other ovarioles not developed, 8-9 oocytes
16.09.	20 (11+9)	2+1 mature eggs 1
16.09.	14	6 mature eggs 1
30.09.	-	9 mature eggs 1

Water budget of pre-diapause eggs

A few days after laying, the eggs had a fresh weight of 5.84-7.13 mg (n=10, from one eggpod!). The water budget of these eggs was studied over 12 days during the pre-diapause period. Upon contact with water, the eggs rapidly increased in mass up to about one third of its initial mass during the first 9 days (Fig. 5). At 100% r. h. (on dry sand within a Petri dish) the eggs lost little water (about 3%) in the first week, but in the second week were able to absorb it, so that after 12 days, they increased between 8-12% of their initial mass (Fig. 5), and after 23 days, 17-20% of the initial mass (not drawn in Fig. 5).

In 3 eggs after 12 days in contact with water and another 3 eggs after 23 days at 100% r. h., the embryos were in the median anatrepsis, in effect still before blastokinesis, thereby revealing a rather slow embryonic development (at Ø 23.5 °C).

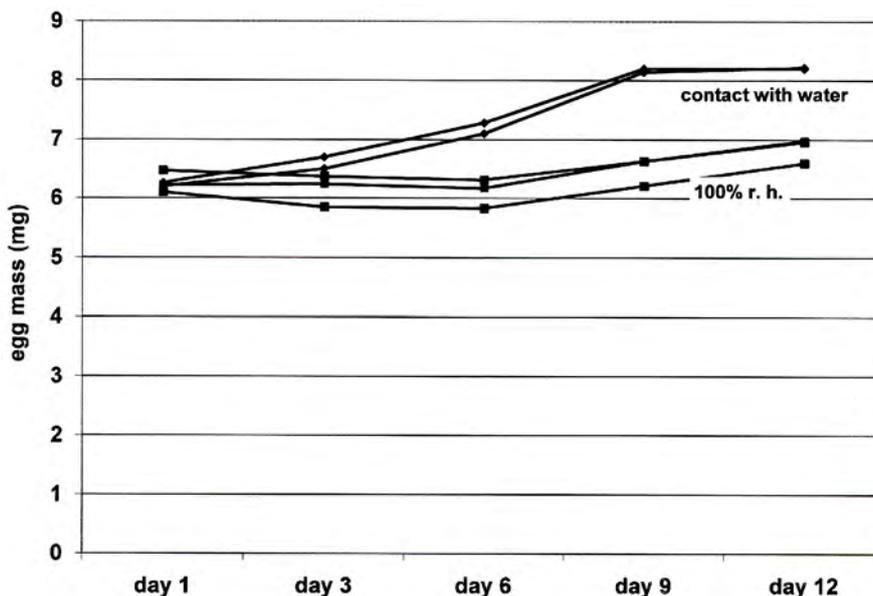


Fig. 5: Mass changes of single eggs of *C. plebeius* during pre-diapause under contact with water and 100% relative air humidity.

Hatching and juvenile development

Following chilling for 6 months, the eggpods were placed under warm conditions (at $\bar{\theta}$ 26.5 °C), where upon the nymphs hatched after 29-34 days. Out of 5 eggpods with a total of 53 eggs 32 first instar nymphs hatched (60% hatching success). Of the residual eggs, 14 were found to be dried up whilst another 7 were unfertile. After hatching 6 nymphs died, resulting in 26 first instar nymphs for further rearing (Table 3 and 4).

Both sexes developed over 4 juvenile stages of 9-12 days each. The median juvenile development from hatching until the adult moult lasted 41 days ($\bar{\theta}$ 25-30,5 °C, Table 3), with a considerable scattering up to 3 nymphal stages at the same time (Table 4). The sex ratio was controlled first in the later nymphs, where it was male-dominated (14 : 9), but later became more balanced due to a slightly higher male-mortality (Table 4).

Table 3: Development (greenhouse) and post-femur length (exuviae) of the juvenile stages of *Calliptamus plebeius* (♂, ♀), 25.04.-03.07.1992.

Instar	Duration		Ø-temperature	Post-femur Median (min-max)
	n	days		
until hatch	26	29	26.5 °C	
1	26	12	29.0 °C	3.4 (3.3-3.6) mm
2	14	9	25.0 °C	4.8 (4.5-5.0) mm
3	22	9	28.5 °C	6.4 (6.0-6.8) mm
4	25	11	30.5 °C	8.2 (7.6-11.7) mm
1 to 4		41	25.0-30.5 °C	

Table 4: Development of the F₁-generation (greenhouse) of *Calliptamus plebeius*. Successive individual numbers (n) can vary because of exuviae and nymphs not detected.

Date (1992)	n	Stage					Sex ratio ♂ : ♀
		1	2	3	4	adult	
22./24.05.	22	22	-	-	-	-	
03.06.	26	25	1	-	-	-	
10.06.	26	-	12	14	-	-	
15.06.	26	-	10	11	5	-	
18.06.	26	-	9	7	10	-	
22.06.	23	-	-	6	17	-	14 : 9
03.07.	21	-	-	-	8	13	13 : 8
05./10.07.	22	-	-	-	-	22	13 : 9
20.07.	22					22	13 : 9
06.08.	21					21	12 : 9
13.08.	20					20	12 : 8
22.08.	18					18	10 : 8
23.08.	17					17	9 : 8
24.08.	17					17	9 : 8

Colouration and morphometry

Of the two wild females, one was greenish, the other greyish-brown, as was the male, too. In the F₁-generation, only one female was greenish, whereas 6 females and 12 males were of a grayish-brown colour. The first instar nymphs of *C. plebeius* were generally dark, with head, pronotum (here 4 darker patches), abdomen and legs of a ± dense brown-black dotting, the abdomen with a broad, black stripe dorsally, which also partly showed a thin, clear median line. The pronotum was partly light dorsally, with the distal part completely ivory-white laterally, and the proximal parts like the post-tibiae lac-black. The post-femora showed few light spots between the otherwise black colouration. All legs, mainly the hindlegs, had dorsally and ventrally distinctly long and white hairs, also found in the adults.

The 4 juvenile stages could readily be differentiated by their body size (post-femur length), without any overlap in the min-max values. Up to the third instar, and mainly in the fourth a broad variation occurred because of the developing sexual size dimorphism (Table 3). The marked sexual dimorphism of the genus is also well-known in *C. plebeius* with the males being a third smaller in body size (Table 5; also JAGO 1963, BLAND 2001). The body length of the adult male and female is on average nearly identical with those given by BLAND (2001) for specimens from Tenerife, with min-max values of our Cañadas specimen (F₁-generation!) in the middle of the range. The average cercus length is relatively large compared with those given by BLAND (2001), but because of the curved cercus form it is difficult to give an accurate measure (Table 5).

Table 5: Body measures (dried specimens) of *Calliptamus plebeius* from Tenerife, compared with literature data. F₁: Median (min–max), length in mm, [n]. BLAND (2001): mean (range) from Tenerife populations.

Sex	Body	Pronotum	Post-femur	Tegmen	Cercus
field					
♀	27.1	5.0/5.2	15.0/16.1	23.7	-
♂	16.1	3.0	11.0	16.1	3.22
F₁					
♀	28.0 (27.0-30.3) [6]	4.9 (4.4-5.0) [7]	15.0 (13.5-16.4) [7]	21.5/22.2	-
♂	17.2 (15.7-18.2) [12]	3.0 (2.3-3.4) [12]	11.0 (10.2-11.5) [12]	16.2 (15.1-17.6) [12]	3.27 (3.08-3.36) [11]
BLAND (2001)					
♀	27.5 (20.0-32.0) [20]	-	-	-	-
♂	17.1 (12.5-20.0) [24]	-	-	-	3.1 (2.7-3.3) [24]

Discussion

The genus *Calliptamus* was divided by JAGO (1963) in a northern temperate group with 4 species (including *C. italicus*) and a southern temperate group with 9 species (including *C. barbarus*); for Spain the subfamily is summarized by LLORENTE (1982). Within the latter group, *C. barbarus* seems to have given rise to several isolated species, including the two island species *C. madeirae* from Madeira and *C. plebeius* from the Canary Islands (JAGO 1963). Both *C. italicus* and *C. barbarus* are the most widespread and because of its pest status, best-known species within the subfamily (summarized by UVAROV 1977, ANONYMOUS 1982), and so far suitable for comparisons with *C. plebeius*.

Behavioural aspects

The calliptamine *C. plebeius* is known as a phytophilous, euryphagous grasshopper feeding on coarse herbs and shrubs in arid localities all over the Canary islands (GANGWERE 1973). In his preliminary study, which considers only Cañadas populations of Tenerife, a nearly monophagous feeding on the leguminous shrub *Spartocytisus nubigenus* (syn *S. supranubius*) was observed, a widespread shrub used also by the insects for resting (see Fig. 1 and 2). But despite this preference, a differential feeding test showed that also the forbs *Pterocephalus lasiospermus* and *Descurainia (Sisymbrium) bourgaeana* (where *C. plebeius* seldom rested) were also occasionally eaten or at least nibbled (GANGWERE 1973). Summarizing several feeding tests on La Palma and Lanzarote, 16 dicot (e.g. *Daucus*, *Echium*, *Euphorbia*), and 1 grass species were readily consumed with changing preferences according to the local spectrum, in accordance with its forbivorous-type mandibles (GANGWERE et al. 1998). In our cages in Jena, far away from the Canary vegetation, the cocksfoot grass (*Dactylis glomerata*) was consumed, but clearly this diet is nutritionally inadequate as a food-plant since the F₁-generation later failed to reproduce.

The ephemeral observations of mating behaviour here described for *C. plebeius* correspond at least in the male with the very detailed descriptions both for *C. italicus* (e.g. FABER 1949; JACOBS 1949a,b) and *C. barbarus* (e.g. LARROSA et al. 2004, 2008). The males of both species normally prepare their mating events carefully, but also cases of violation rape-like matings were described (*C. italicus*, JACOBS 1949a). It has also been reported from Milkweed butterflies *Danaus p. plexippus*, suggesting that pyrrolizidine alkaloids (from the host plants) have a direct aphrodisiac effect (ROTHSCHILD & MARSH 1978).

Already FABER (1949) and JACOBS (1949a,b) detected two different types of bioacoustic behaviour in *C. italicus*, but perhaps playing a subordinate role in mating. On the one hand, stridulation is created by rubbing the apical parts of the mandibles together, whilst the post-femur movements stay silent (FABER 1949), on the other hand, rough parts of the groin (where internally muscles are fixed) inside the post-femur are rubbed on somewhat projecting forewing veins, what was described as a new (*Calliptamus*-)type of grasshopper stridulation (JACOBS 1949a,b). Recently, bioacoustic behaviour was detected in *C. barbarus* mainly in males, but to a lesser extent in females also, and studied intensively in the context with the post-femur colour polymorphism (LARROSA et al. 2004, 2008), sug-

gesting that here no chemical signals are involved. In *C. plebeius*, which hence is the third *Calliptamus* species to be shown to have a sound producing behaviour, and this heard without seeing any movements of the hind legs, is probably produced by the mandibles. Otherwise, in both sexes of *C. plebeius* the morphological situation leads one to assume that the somewhat protruding lower inner carina of the post-femur is also able to produce stridulation rubbing over the anterior central part of the tegmen, perhaps over the strong costa and the diverging intercalata (which is reduced basally), which can have a more or less rough structure. Summarizing that, it is neither clear from the ephemeral present observations (1) if mandibles or post-femur stridulation occurred nor (2) whether male or female singing was heard.

A really surprising observation was the erection of a pistil-like structure between the ventral valvae of the female, which I interpret as a behaviour for attracting males (as observed), if so, probably involving pheromon emission. Hitherto, there are no indications in the recent reviews consulted (WHITMAN 1990, REINHARDT 2000), therefore it is believed to be a new phenomenon in the Calliptaminae.

Life-history aspects

It was stated by GANGWERE et al. (1972) that on Tenerife nearly all Acridoidea occur as adults throughout the year, except *C. plebeius*, which is described as a univoltine species which hibernates as a diapausing egg (in the upper soil layer). This seems to be true at least for populations in the subalpine zone selected for hibernation, where nymphs appear again in the spring and adults in the summer months (GANGWERE et al. 1972). Accordingly, the three adults sampled at the end of August 1991 represented the phenological peak of *C. plebeius*, whose adults occur mainly from June till October (GANGWERE et al. 1972). This phenology also accords with our findings in greenhouse rearing for at least two months of adult lifetime of *C. plebeius*. In the field, during a November excursion (13.-28.11.2005) to ten localities in Tenerife and Gomera this species was found only in Valle Gran Rey (Gomera) on 22.11. (leg. K. Reinhardt, coll. Köhler). The phenology is also supported by JOHNSEN (1974), who found no *C. plebeius* during January excursions in 1966 and 1971, whereas he mentioned a sampled male from Gran Canaria from the end of December, 1972. Adults and nymphs have been mentioned from the Valle Hermosa (Gomera) also around Christmas time 2008 (W. Wagner, unpubl. in www.pyrgus.de). Only in GANGWERE et al. (1972) is January mentioned as an ephemeral month for adults. In spring, at the beginning of March 2010 no *C. plebeius* were found at 5 localities in Tenerife (E. Friedrich, pers. comm.), whereas HOCHKIRCH (1997) on 21.3.1996 found only one specimen on one study plot (of 5) in SE Gomera.

Such a univoltine development with egg overwintering in diapause over several months has also been reported from *C. barbarus*, *C. italicus* (ANONYMOUS 1982), and *C. b. palaestinensis* (SHULOV & PENER 1968). This manner of development as also seen in *C. plebeius* fits well the climatic conditions of the geographic region. On Tenerife, the temperature differences on the north side between Orotava and the Cañadas amount to about 10 °C, with monthly mean temperatures from January until April in the Cañadas, ranging from around 3-8 °C. The mean yearly rainfall amounts to ~400 mm in Orotava and ~330 mm in the Cañadas,

with only 6.7% and 15.2% of this amount, respectively, for the period April until September (FICKER 1930, with detailed meteorological data). Referring to *C. plebeius*, the eggs laid in August-October develop and hibernate in a relatively humid period, whereas hatching occurs at the beginning of a very dry period of several months. The slow pre-diapause and post-diapause embryonic development also favour a univoltine life cycle, but because of a prolonged life time single adults can also occur still in November/December. Comparing reproduction parameters, for *C. barbarus* 20-40 eggs/pod and 100-200 eggs/female, and for *C. italicus* 20-50 eggs/pod, about 150 eggs/female and 4-6 pods/female (summarized in ANONYMOUS 1982), 40/43 (13-59) eggs/pod (JANNONE 1934), and 22 (16-32) eggs/pod (REINHARDT & JENTZSCH 1999) are known, respectively. Following, observation of 10-11 eggs/pod in *C. plebeius*, the species is seen to have only half of the potential compared with the two other species mentioned. It is also of interest that in contrast to the 4 juvenile instars in *C. plebeius* (at least in caged individuals), 5 instars in both sexes are reported from *C. barbarus*, and 5 (♂) resp. 6 instars (♀) in *C. italicus* (ANONYMOUS 1982).

Morphological aspects

As with all other species in the genus, *C. plebeius* also shows a marked sexual dimorphism and colour polymorphism (GANGWERE 1973). The Cañadas population (Tenerife) morphologically resembles specimens from Gran Canaria, which JAGO (1963) used for a detailed species description. The inner post-femora were orange-red (like the tibiae) mainly in females, whereas in males they were more or less darkened, with fused femoral spots in both sexes. The colourless hind wings were slightly fumated in the anterior third of the wings. The observed colour polymorphism in the Cañadas specimens was not distinct either in the few adults from the wild and in the caged progeny, where only single greenish individuals between normally greyish-brown ones occurred. One female from Valle Gran Rey (Gomera, 22.11.2005, leg. K. Reinhardt) showed yellow dorsal stripes (f. *marginellus*), as to be seen on a photo in HOCHKIRCH (1997) from a Gomera specimen, too. In comparing populations of *C. plebeius* from the Canary islands, BLAND (2001) found significantly longer body size parameters in both sexes at Gran Canaria (supported by JAGO 1963) and intermediate ones in Tenerife, thereby concluding that the populations from Gran Canaria are the oldest ones, whereas smaller individuals were more likely transported by the prevailing NE wind and colonizing by founder events the westernmost islands following selection for smaller body size (BLAND 2001).

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Author:
Günter Köhler
Friedrich-Schiller-Universität Jena
Institut für Ökologie
Dornburger Str. 159
D-07743 Jena
E-Mail: Guenter.Koehler@uni-jena.de

Bibliography

- ANONYMOUS (1982): The locust and grasshopper agricultural manual. – Centre for Overseas Pest Research, London, 690 pp.
- BAÉZ, M.; OROMI, P.; GARCÍA, A.; MARTÍN, E. & E. ZURITA (2004): Isoptera, Orthoptera, Embioptera, Phasmatodea, Dermaptera, Mallophaga, Anoplura. In: IZQUIERDO, I.; MARTIN, J.L.; ZURITA, N. & M. ARECHAVALTA (eds.): Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). – Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias, 499 pp. [pp.186-187 Orden Orthoptera].
- BLAND, R.G. (2001): Additions to the Orthoptera (sens. lat.) of the Canary Islands. – Journal of Orthoptera Research 10 (1): 113-119.
- BLAND, R.G.; GANGWERE, S.K. & M. MORALES MARTÍN (1996): An annotated list of the Orthoptera (sens. lat.) of the Canary Islands. – Journal of Orthoptera Research 5: 159-173.
- FABER, A. (1949): Eine bisher unbekannte Art der Lauterzeugung europäischer Orthopteren: Mandibellaut von *Calliptamus italicus* L. – Zeitschrift für Naturforschung 4 (6): 367-369.
- FICKER, H. V. (1930): Die meteorologischen Verhältnisse der Insel Teneriffa. – Abhandlungen der preussischen Akademie der Wissenschaften, Jg. 1930, Physikalisch-mathematische Klasse, Nr.1: 1-105.
- GANGWERE, S.K. (1973): Notes on food-habits and behavior in selected Orthopteroidea of Tenerife, Canary Islands, Spain. – Miscelánea Zoológica, Barcelona 3 (3): 19-31.
- GANGWERE, S.K.; MCKINNEY, J.C.; ERNEMANN, M.A. & R.G. BLAND (1998): Food selection and feeding behavior in selected Acridoidea (Insecta: Orthoptera) of the Canary Islands, Spain. – Journal of Orthoptera Research 7: 1-21.
- GANGWERE, S.K.; MORALES MARTÍN, M. & E. MORALES AGACINO (1972): The distribution of the Orthopteroidea in Tenerife, Canary Islands, Spain. – Contributions of the American Entomological Institute 8 (1): 1-40.
- HOCHKIRCH, A. (1997): Notizen zur Heuschreckenfauna von La Gomera (Kanarische Inseln, Spanien). – Articulata 12 (2): 187-200.
- HOHENESTER, A. & W. WEIß (1993): Exkursionsflora für die Kanarischen Inseln mit Ausblicken auf ganz Makaronesien. – Verlag Eugen Ulmer, Stuttgart, 374 S.
- JACOBS, W. (1949a): Vergleichende Verhaltensforschung bei Feldheuschrecken. – Zoologischer Anzeiger, Suppl. 13: 257-262.
- JACOBS, W. (1949b): Beobachtungen an der Heuschrecke *Calliptamus italicus*. – Natur und Volk 79 (1/2): 89-92.

- JAGO, N.D. (1963): A revision of the genus *Calliptamus* Serville (Orthoptera: Acrididae). – Bulletin of the British Museum (Natural History), Entomology 13: 289-350.
- JANNONE, G. (1934): Osservazioni ecologiche e biologiche sul *Dociostaurus maroccanus*, Thunb., *Calliptamus italicus* L. e loro parassiti in Provincia di Napoli. (Primo contributo). – Bolletino Lab. Zool. gen. agr. Portici 28: 75-151.
- JOHNSEN, P. (1974): Contributions to the knowledge of the Dermaptera, Orthoptera and Dictyoptera of the Canary Islands. – Natura Jutlandica 17: 25-57.
- LARROSA, E.; GARCIA, M.-D.; CLEMENTE, M.E. & J.J. PRESA (2004): El comportamiento en cautividad de *Calliptamus barbarus* (Orthoptera Acrididae). – Memorie de la Società entomologica italiana 82 (2): 615-630.
- LARROSA, E.; GARCIA, M.-D.; CLEMENTE, M.E. & J.J. PRESA (2008): Sound production in *Calliptamus barbarus* Costa 1836 (Orthoptera: Acrididae: Catantopinae). – Annales de la Société Entomologique de France 44 (2): 129-138.
- LLORENTE, V. (1982): La subfamilia Calliptaminae en España. – Eos 58: 171-192.
- REINHARDT, K. (2000): Mating biology and sexual selection in the short-horned grasshoppers (Caelifera).[Review] In: Mating biology of the Meadow grasshopper, *Chorthippus parallelus* (Zetterstedt), and its influence on population processes. – Ph.D. thesis, University of Jena, Institute of Ecology: 9-64.
- REINHARDT, K. & A. JENTZSCH (1999): Lebensdauer, Eizahl und Dauer der Speicherung lebensfähiger Spermien bei Weibchen der Italienischen Schönschrecke, *Calliptamus italicus* (L.). – Articulata 14 (2): 199-204.
- ROTHSCHILD, M. & N. MARSH (1978): Some peculiar aspects of danaid/plant relationships. – Ent. exp. & appl. 24: 437-450.
- SCHÖNFELDER, P. & I. SCHÖNFELDER (1997): Die Kosmos-Kanarenflora. – Franck-Kosmos Verlags-GmbH & Co., Stuttgart, 319 pp.
- SHULOV, A.S. & M.P. PENER (1968): Environmental factors in interruption of development of Acrididae eggs. In: GROSSOWICZ, N. (ed.): Cryptobiontic stages in biological systems. – Elsevier Publishing Company, Amsterdam: 144-153.
- UVAROV, B. (1966): Grasshoppers and locusts. A Handbook of General Acridology, Vol. 1. – At the University Press, Cambridge, 481 pp.
- UVAROV, B. (1977): Grasshoppers and locusts. A Handbook of General Acridology, Vol. 2. - Centre for Overseas Pest Research, London, 613 pp.
- WHITMAN, D.W. (1990): Grasshopper chemical communication. In: CHAPMAN, R.F. & A. JOERN (eds.): Biology of grasshoppers. – John Wiley & Sons, New York et al.: 357-391.
- WILLEMSE, C. (1949): Second addition to the knowledge of the Dermaptera and Orthoptera of the Canary Islands. – Tijdschrift Entomologie 92: 248-250.

