Study on the Biology of Sorghum Chafer, *Pachnoda interrupta* (Coleoptera: Scarabaeidae) Under Laboratory Condition

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Abstract

The duration of egg, larvae, pupae and adults stages of *Pachnoda interrupta* was studied under laboratory condition (28 ± 2°C), and the life history explained following field observation during 1999 and 2001. Beetles became sexually mature after about ten months in June. Females oviposited singly in the soil and oviposition rate by a single female was 1.75 eggs per day on average and this lasted for more than two months. The peak oviposition took place in July. The hatching period for eggs was 6 to 16 days with a mean of 11.3 days. The duration of the three larval instars was roughly estimated using measurements of the width of head capsule and body length measurements. The larval stage lasted between 41 and 71 days with a mean of 55.7 days. Pupal stages took 11 to 26 days, the average being 18.9 days. Newly emerged beetles activity overlapped with flowering stage of sorghum and other host plants. The adult beetles could live up to 17 months under laboratory condition.

Introduction

The genus *Pachnoda* belongs to the subfamily Cetoniinae and comprises over 130 species (Krikken 1984). Its distribution is restricted to the African continent, although a few species were recorded in Arabia and Madagascar (Grunshaw 1992). In Ethiopia, survey conducted about 20 years ago revealed the presence of nine species of *Pachnoda*, one represented by two subspecies (Clark & Crowe 1977). Except the two species, *P. stehelini* Sch. and *P. abyssinica* Blan. that were often observed above 2000 masl, the remaining species are mainly found in the *Acacia* woodlands distributed between 800-1800 masl (Clark & Crowe 1977).

Among the nine species, the sorghum chafer, *Pachnoda interrupta*, has become a well-established regular pest since the last eight years attacking wide range (over 35 types) of crops, tree plants and fruits, sorghum being the major one. According to the local farmers *P. interrupta,* although was recognized three decades ago, only sporadically damaged sorghum. Since 1993, however, it has been noted to increase both in number and geographic distribution. The area infested has increased from 1375 ha in 1993 to over 112,000 ha of land in year 2001 (Hiwot 2001). It is now the dominant pest of sorghum, causing losses up to 80% in the Amhara, Afar and Oromiya regions (Hawariat & Hiwot 2000).

Successful management of *P. interrupta* requires detailed knowledge of its biology and many aspects of the beetle's life history and ecology. Clark & Crowe (1977) have described few aspects of the life cycle of *P. interrupta* based on field observations in north Ethiopia. Grunshaw (1992) has also briefly described some aspects of the life history and feeding habits of *P. interrupta* and estimated the yield loss using caged experiments in pearl millet fields of Mali.

This study was conducted to elucidate development durations of immature, adult emergence and flight period of *P. interrupta* in northeastern Ethiopia based on laboratory studies and field observation.

Materials and Methods

Sexually matured *P. interrupta* were collected from Sefi Beret (09° 5474^N, 040° 0309^E) area in mid June 1999 and transported using plastic cages covered with wire mesh that allows the inlet of air. In the laboratory, the males and females were segregated and 30 mating pairs were transferred into each of the 14 large glass jars (11 liters) that were half filled (14 cm depth) with steam pasteurized moist (~18 %) soil rich in compost. The soil was kept damp by adding water and replaced with fresh steam pasteurized soil weekly. The adults were provided banana and freshly cut *Acacia* flowers, replacing daily. The laboratory was maintained at a controlled temperature of 28 $\pm$ 2°C and a day light period of 12 hours.

Each of the jars was covered with glass-cover that allows the inlet of air. The soil was turned out and eggs collected at different time (6, 10, 6 and 2 days) intervals, as beetles disturbed daily for egg collection often ceased laying (Donaldson & Giliomee 1992). In this study, all eggs collected in 24 days (5 to 24 July 1999) were used to determine the oviposition rate. Newly laid eggs, which are white in appearance, were placed on damp Whatman No. 1 filter paper in Petri dishes (diameter 90 mm), and kept in the dark. To maintain the moisture, the filter paper was moistened daily. Follow up of the eggs was made daily until eclosion and the calculation of the incubation period was only approximate, as the eggs were not collected daily.

When the eggs hatch, to prevent overcrowding, we reduced the number of larvae to ten per Petri dish. Every five days, fresh pasteurized soil mixed with compost was replaced. In order to establish the duration of each larval instar, the body length and width of the head capsule were measured every five days interval, and the biometric discrimination was done as described by Ben-Yakir et al. 1996. Analysis of variance (ANOVA) was performed to separate means of width of head capsule and body length measurements for each instar (SPSS 1994). Pupae were placed in damp soil until the beetles emerged and their duration recorded. The newly emerged adults were then transferred into big glass jars and conical flasks covered with glasses that inlets air. The beetles were fed fresh banana and supplied with drinking water using wet cotton placed inside the jars.

Results

Oviposition

Field collected sexually matured *P. interrupta* were brought to the laboratory and the oviposition rate studied from 5 to 29 July 1999. Although we began follow up since mid-June, large number of eggs were not laid until the first week of July. During the experimental period, some of the eggs hatched into larvae. Therefore, oviposition rate was calculated by dividing the total number of eggs and larvae found in each cage with the number of female beetles per number of days. A total of 14,893 eggs and 590 larvae (3.81% of all eggs laid) obtained from about 400 female beetles were considered to determine the oviposition rate (Table 1).

Data from 14 cages, each containing 30 mating couples, showed that on the average a single female laid 1.75 eggs per day (Table 1), which is equivalent to 52.5 eggs per month. Eggs were laid singly stratified throughout the soil at depths varying from 1cm below the surface to the bottom (14 cm) of the jars. Although we found eggs at the bottom (14 cm) of the jars, it may not indicate the maximum depth of oviposition. Grunshaw (1992) has recorded that eggs could be laid at depths of 20 cm. We were not, however, able to show if eggs are laid during the day or night.

Table 1. Summary of oviposition rate of *Pachnoda interrupta* in damp soil under laboratory condition (28 ± 2°C).

Experiment dates	Ovipositi on period (days)	No. of beetles alive at the end of the test period	Total no. of eggs laid	No. of newly hatched larvae found during the test period (% hatched)	No. of eggs/♀/day
5 - 11 July	6	384♀ & 384♂	4130	113 (2.66%)	1.84
11- 21 July	10	403♀ & 403♂	5087	100 (1.93%)	1.29
21- 27 July	6	402♀ & 402♂	4065	377 (8.49%)	1.84
27 - 29 July	2	399♀ & 401♂	1611	-	2.02
Total	24 days		14,893	590	Mean = 1.75 eggs/♀/day

Estimated rate of oviposition = 12.2 eggs/♀/week

Newly laid eggs are white and ovoid-spherical in shape about 1.2 mm wide. The mean number of days required for egg hatching was 11.3 (n = 1181, range 6-16) (Table 2). Almost 95 % of the eggs hatched and no diapausing eggs were observed. As a result of fungal infection, however, few eggs (<5%) failed to hatch.

Table 2. Duration of the immature stages of laboratory reared *P. interrupta* at an ambient temperature of (28 ± 2°C).

Stage	Days until change		No. observed	Percentage survival
	Range	Mean ± SD		
Eggs	6-16	11.3 ± 3.1	1181	>95
Larvae	41-71	55.7 ± 6.2	72	>95
Pupae	11-26	18.9 ± 3.8	72	~65*
No. of days required for adult emergence	58-113	85.9 ± 9.3		

**some pupae died due to mite infestation.*

Larvae

The average time required to complete larval development was 55.7 days (n = 72, range 41-71) (Table 1). Width of head capsule and body length measurements of *P. interrupta* larvae showed that there was a progressive increment from day zero until 42 days, after which time, however, the head capsules width remained constant (3.0 mm) while the body length started to shrink indicating advancement to pupate. Based on head width and body length measurements, three larval instars were established. As can be seen in Fig. 1, three peaks were noted in the distribution of head width of laboratory-reared grubs. Means of head capsule width and body length varied significantly among larval instars (F 94.45; df 8, 63; $P < 0.01$), (F 202.46; df 8, 63; $P < 0.01$), respectively. Most of the grubs had body length measurements below 18 mm (48.4%) and above 23 mm (49%) (Fig.2.). Frequency distribution of the ratio between body length and head width doesn't seem to provide much help to discriminate the instars. Accordingly, the analysis revealed that the three instars could be defined as follows: first instars, head width below 1.43 mm; second instar, head width above 1.84 mm and body length below 24 mm; and third instar, head width above 2.84 mm.

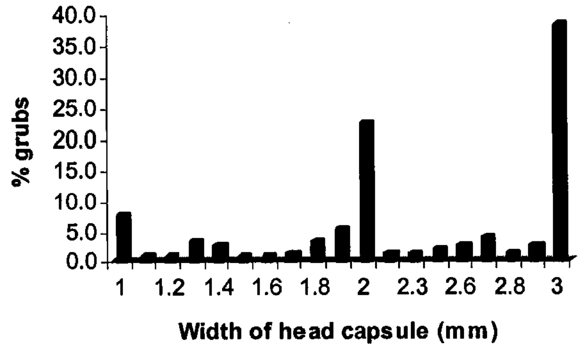

Fig.1. Frequency distribution of head width of *P. interrupta* larvae (n=158)

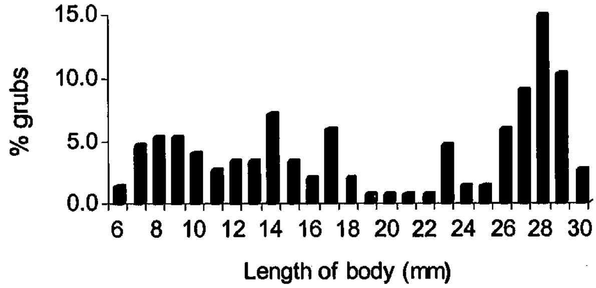

Fig.2. Frequency distribution of body length of P. interrupta larvae (n=157)

Pupae

When the larva was ready to pupate, it made an oval cocoon constructed from the soil cemented with larval saliva. Cocoons were usually found attached to the bottom of the container. The total length of pupal stage varied considerably and ranged from 11 to 26 days with a mean of 18.9 days though reared under identical conditions.

Adults

The adult beetle has a size of 12 to 16 mm long (apex of pronotum to apex of elytra) and the presence of shallow ventral groove distinguishes the male from the female, which has a convex abdomen (Grunshaw 1992). The duration of adult emergence under laboratory condition varied considerably and ranges from 58 to 113 days, the average being 85.9 days (Table 2). New adults leave the soil and make their way to find food.

Discussion

P. interrupta is a univoltine insect that multiplies only once in a year. Oviposition by caged beetles usually continues for two months (from end of June to August). Oviposition rate study under laboratory conditions showed that each female beetle oviposits on average 1.75 eggs in a day. This figure was not compared with the oviposition rate under field conditions. Studies by Donaldson (1985) on a related species, *P. sinuata*, showed that greater number of eggs are laid when there are only 10 to 12 females to a cage than when there are over 20 females and eggs are collected weekly. However, in contrary to the result of Grunshaw (1992), who reported 24, in our studies the maximum number of eggs laid by a single female in a day did not exceed 4.2. Diet of the beetle has been suggested to determine egg development. In our experiment, the beetles were exclusively fed banana and freshly cut *Acacia* flowers unlike Grunshaw who provided freshly cut flowering stems of *Combretum micranthum* as food for adults.

The temperature of the laboratory condition was adjusted to 28 ± 2°C to simulate the climatic situation of the infested areas. In 1999 the weather data of Melka Werer, one of the highly infested areas, showed that the daily average temperature was 28.14 °C (range: 24.3°C in December to 32.1°C in May). Thirty four years (1965-99) of climatic data of the same location showed that the daily average temperature was 27.15 °C (range 23.6 to 31.2°C). A temperature of 28 ± 2°C appeared to favor oviposition and development of immature, as shown by the high oviposition and survival rate of the eggs and the different stages.

Since the first week of August sexually matured beetles and eggs were often found under the shades of trees containing moist soils rich in organic mater, mainly of plant litters under field conditions. Preliminary laboratory studies also revealed that there was very little or no oviposition in dry soil. Although many species of Cetoniinae have been observed to breed in areas of compost or cattle dung heaps (Donaldson 1984), we didn't find one in dung heaps.

Eggs were laid singly stratified throughout the soil varying in depth from 1 cm to the bottom of the container (14 cm). Thus variation could also be high depending on the medium, soil type and moisture. For instance, Grunshaw (1992) reported that eggs of *P. interrupta* were found stratified throughout a depth of 4 - 20 cm (20 cm being the maximum depth of the container used to assess the depth).

There was a close similarity in the time of young beetle emergence between the laboratory and field conditions. In the laboratory, most of the June laid eggs completed their development and the new beetles emerged from the soil since the second week of September. Likewise in sorghum fields of North Shewa, Wello and Afar regions, newly emerged beetles were observed between 11 and 25 September both in 1999 and 2000, and often continued to feed on sorghum until mid-November or to some extent to the beginning of December, as shown in Bati-Fura, North Wello. Unlike the field condition, however, most laboratory-raised beetles became quiescent in early November for a reason that was not clear, and remained inactive until June.

The adult beetles that emerge during September and October are extremely numerous in number and often cause considerable damage to sorghum, maize and several other fruits and tree plants. They feed actively only during the day and spend most of the time on their food source above the ground. Studies carried out by Auerswald *et al* (1998) on a related genus *P. sinuata* showed that prior to take-off, the insect elevates its thoracic temperature either by basking in the sun or by warming endothermically to a narrow range around 34°C. A linear relationship has been found between wing beat frequency and thoracic temperature (i.e. when thoracic temperature declines, wing beat frequency also decreases in a linear manner). Hence the beetle's activity is limited to the warmer hours of the day. Consequently, control using hand picking is not easy when the temperature of the day is high.

Since the mouthparts of the insect are poorly developed, damages to the crops occur at the flowering and milky stages. In the end of November, as the grains became hard enough to be chewed by the beetle, the insect began to hide in the soil and remain as quiescent until it emerged again as a sexually matured adult beetle in the coming June. Preliminary field surveys showed that quiescent beetles could be found up to 50 cm depth favoring mainly moist fertile soil under the roots of some common shrubs and trees such as Acacia and Eucalyptus. During our laboratory studies, most of the quiescent beetles died for a reason that was not clear which significantly reduced the number of sexually matured adults that would emerge in June.

Under field conditions sexually matured beetles emerged starting from early June designating completion of quiescence, perhaps synchronized with the first rains, which soon mate and oviposit their eggs in moist soil. We now know that the adults require about ten months to attain sexual maturity under laboratory condition. Clarke & Crowe (1977) reported that once attained sexual maturity, mating is soon followed by egg laying and death. Our laboratory results, however, demonstrated that sexually matured adult beetles could live up to six months following egg laying. Based on the laboratory observation, the overall age of the adult beetle could reach up to 17 months.

The study overall enabled us to understand the duration of each of the life stages *of P. interrupta*. Based on this, it could be possible to figure out at which stage of the insect and time of the year should control be taken. Controlling the newly emerged beetles during September to October, which is already practiced by the farmers, is essential and encouraged. Moreover, sexually matured beetles that emerge in June should be given equal emphasis, as they are ancestors of the September beetles. In the long-term strategy, however, the larvae should also be considered as good targets for controlling adult beetles through application of insecticides on scattered sorghum and other crop plots alone doesn't provide long lasting control. Therefore, to achieve effective and sustainable control, the location of the major breeding and aestivation areas should be properly identified and control measures taken.

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