ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2017; 3(11): 437-441
www.allresearchjournal.com
Received: 04-09-2017
Accepted: 05-10-2017

Gabeyehu Feleke
Insect Physiology and Dry land Ecology, Department of Biology, CNS Wolaita Sodo University, Ethiopia

Correspondence
Gabeyehu Feleke
Insect Physiology and Dry land Ecology, Department of Biology, CNS Wolaita Sodo University, Ethiopia

Developmental ecology of sorghum chafer (*P. interrupta* Oliver, Coleoptera: Scarabaeidae) amid diverse physical and biological factors

Gabeyehu Feleke

Abstract
Ethiopia is primarily an agrarian based economy with rich fertile lands with ancient type of agricultural farming systems. Among various agricultural products Sorghum [*Sorghum bicolor* (L) Moench] is an extremely important staple food in Ethiopia. The sorghum production however, is threatened by a wide range of both pre and post-harvest pests of which the sorghum chafer, *Pachnoda interrupta* (Oliver) (Coleoptera: Scarabaeidae) cause much damage due to lack of successful control methods.
Present work is the laboratory study report supported with field observations made to understand the life cycle and development of *Pachnoda interrupta* (Oliver), along with its interaction on impact of physical factors and soil types on its development. Soil samples collected from Afar, Tikur-Inchini and sandy soil from Guder River near Ambo were used separately and mixed with different proportion of cow-dung. Eight types of food substances were tested for their effect as bait in the infested area. In the life cycle study (at 25 ˚C & Moisture 17%) the average oviposition rate was found to be 0.58 eggs/ day/ female. Whitish soft shelled eggs were laid separately in soil varying (strata) from 3-18 cm. in depth. The mean number of days for egg hatching was 9.63±1.4 ranging between 8 and 13. Larval development took an average of 59.09± 1.94 days ranging between 42-73. Body length was constantly increasing up to around 52 days where it reached 30.2 mm and was shrinking to its last days and measured 28mm at about the 70th days. Larval head capsule width however showed discontinuous but constant increase and at an average 3.14±0.01mm was measured in final days (62-70). Papal development ranged from 18-30 days with an average of 24.47 ±3.5 days. When soil moisture is less the larvae went down deep in to the soil to pupate and when it is high, they remained in the upper layers. Soil temperature however did not show significant effect on pupation depth. The adults required an average of 93.79± 1.8 days, ranging from 68-116 to emerge.
The laboratory study and the field observation confirmed that *P. interrupta* are univoltine insects having two phases in their life cycle (emerging seasons). The presence of cow-dung in the soil was found necessary for the completion of life cycle in *P. interrupta*.

Keywords: Bait, food choice, larval stages, life cycle, pests, physical factors, soil types, sorghum

Introduction
Sorghum, *sorghum bicolor* (L) Moench is among the major cereal crops grown for food in Ethiopia. Sorghum comparatively, has a tremendous genetic diversity in Ethiopia, which thrived under wider ranges of environments than any other crops in the country. The significant feature of Ethiopian sorghum is that it is the dominant crop in lowlands where drought and poor harvest are common occurrences (Abraham Negasi and Abraham Tadesse, 1985) [3], occupies 16-20% of the total cereals; covering more than 1.5 million hectares of land out of the 9 million hectares covered by all cereal crops and an estimated annual production of over 16 million quintals (CSA 2000) [5]. Sorghum is highest yielding crop in the eastern sub-region of Amhara due to its unique adaptability to the arid climate and soils.
The production of sorghum is threatened by a wide range of both pre and post-harvest pests. These include insect pests (stack borers, armyworm, sorghum shoot fly and sorghum chafer), birds (Quelea quelea, chestnut weaver, Village weaver, staling, doves and pigeons), weeds (Striga *spp*.) and storage pests (Weevils, Angoumois grain moths), (Hiwot Lemma, 2000) [8]. Sorghum chafer plays important role and represents a critical constraint to increased sorghum production because of the level of damage it inflicts due to lack of successful control methods.

According to the report of (CSA, 2000) [5] the annual loss could range from 45-80% on sorghum and about 20% on maize.

The adult beetle is the damaging stage. It feeds on the flowers and sucks all the contents of the sorghum, maize and wheat grains at milk stage. Schmutterer (1969) stated that *P. interrupta* feeds towards the end of the rainy season, in late September on milk stage grains of sorghum and pennisetum millet heads. Such insect pests attacking panicles of sorghum are especially damaging as they affect crop development at late stage and have direct harmful quantitative and qualitative effects on grain yields that maximizes economic losses and there is little scope for crop to compensate for damage done so close to harvest. In the present work an attempt was made to survey relevant information on the life cycle of *P. interrupta* in the laboratory with respect to the effect of soil type, response to physical factors such as temperature and moisture along with depth of pupation site under different temperatures, preferable baits and related factors contributing for their success to overcome tough situations for a long period.

Materials and Methods

A series of field observations were made in areas regularly infested by sorghum chafer in the Afar and Amhara regions. The first survey was made around Shewa-Robit covering localities which border the Afar Regional State and all the way from Showa-Robit to Knombolcha, at a time in which damaging new generations of the pest emerge and attack crops. Observations were made on different host plants, plant parts attacked, and time of the day preferred for heavy attack. Large number of newly emerged insects were collected and transported in rearing jars with removable lids to Ambo Plant Protection Research Centre (APPRC).

Soil surveys were made for two main purposes, for search of different developmental stages and overwintering adults. Both larvae and adults were dug out to an average depth of 70cm deep, with about 80 cm width and to a length of 1m, carefully searching for eggs, larvae and pupae in the soil in late June. The larvae from early laid eggs completed their development to adults in days approximately eight weeks, pupae encased in their protective pupation cells.

Consecutive soil sample surveys were made in November in Afar region around Melka-Worer and Awash National Park and in ANRS in March covering places around Shewa Robit up around Kombolcha with main aim of looking for overwintering sites. In both cases the diapausing adults obtained were transported with the soil they were found in using rearing jars to APPRC for further study and laboratory analysis. The first group was provided with small amount of water after 40 days to avoid desiccation and analysis on them was made after they were kept 119 days in the laboratory without being provided with food. All laboratory-based experiments were conducted at Ambo Plant Protection Research Centre (APPRC) Entomology Laboratory along with utilizing their facilities.

Sources of insects

Sexually matured first phase beetles were obtained, segregated and equal numbers of mating pairs were put in rearing jars supplied with ripe banana as food and allowed to lay eggs. Rearing jars were constructed from circular plastic containers (19.5-cm height, 7.87-cm radius and a volume of 3.8 liters) with a removable lid. A circular opening (10-cm diameter) has been cut in the lid and covered with a synthetic fine mesh to inlet air and light. Each plastic jar was filled with 2.5-kg.of soil sun-dried; steam sterilized (at 121 ^{0}C for 15 minutes) and was moistened with distilled water to the required soil moisture.

Life cycle studies

2.5 kg of soil enriched with cow dung, sun dried, steam sterilized, moistened by 500ml of water to obtain 17% of water to soil. Eight pairs of sexually matured beetles were placed in the rearing jar placed at 25 ^{0}C (determined by preliminary observation), fed with banana allowed to lay eggs that multiplied thrice. Newly laid eggs were collected every two days, as beetles disturbed daily for egg collection often ceased laying and transferred to petridishes (120 mm. diameter) containing Whatman no1. Filter paper placed on water agar medium. The water agar medium enables to maintain the moisture inside the petridishes necessary for embryonic development.

Eggs

Eggs were incubated in respective temperature similar to that of the parent beetle and were checked daily for eclosion. Duration (days) required for eclosion was checked and percentage of eclosion was also calculated. Length, width and volume of ten newly laid eggs and ten others that were nearly approaching to eclosion were measured. Donaldson's (1985) [6] method described below was used to measure the volume of eggs.

$V=L-D.\pi. (D/2)^2 +4\pi/3(D/2)^3$

Where: V= volume,

L = longer measurement and

D= diameter or shorter measurement

Larval stages

Larvae were placed in Petri dishes (120 mm diameter) filled with soil as mentioned before and incubated at 25 ^{0}C. Similar soil was replaced every other two days. In order to establish the duration of each larval instar, the body length and diameter of the head capsule width were measured every other two days. Pupae were left in petridishes and in soil of similar type to that of the larvae and their duration until pupation was recorded.

Bait (food choice) test

Attraction response was examined in a free choice chamber using the techniques of Yadau and Tanwar (1985). The bottom wooden plate (2 cm thick) was provided with a square central hole of 1.2 cm deep and an area of 36^2 cm. Eight additional circular wholes (1.5 cm) in diameter, equidistant (15 cm) from the center of the central hole and between them- selves were made around the bottom plate. The olfactory chamber was covered with transparent lid. The height from the bottom plate to glass cover was 6.5cm. In each of the eight holes, 8 different types of food (bait) substances were placed at a time as per the information obtained from farmers in the outbreak areas. Fifty active, (25 male and 25 female) hungered adult beetles were released from the central hole and the chamber was closed immediately. After about half an hour of flying and/ or walking within the chamber, most of the beetles were found settled in one or the other food substance. The number and sexe of insects in each hole was counted and removed. After washing and sun drying of the plates same food types were

placed in the holes such a way that every food substance was placed in every hole. The test was repeated 6 times for each hole so that 6x8 = 48 tests were conducted.

Statistical Analysis

Analysis was made using SPSS 18.0 for windows computer software (SPSS Inc). One way and two-way analysis of variance were performed and Duncan's Multiple Range Test (DMRT) at 5% level of significance, separated means. Chi squire test (χ^2) analysis was also used to check whether there is a significance variation between females and males that were collected from field and also selected a particular type of food at 5% level of significance by Watt (1997).

Discussion

An oviposition rate of 0.58 eggs/female/day was obtained from laboratory reared beetles. This is less when compared to that reported by Seneshaw Aysheshim and Mulugeta Negeri, 2000) [12] as being 1.8 eggs/female/day. The reason for these differences could be accounted to the source of the insects and in the methodologies used for egg collection. The source of insects used in the present study was laboratory reared and was not exposed to natural environment to collect nutrients, which could have enriched their ovary mainly with amino acids. Many workers who dealt with different insects in this regard suggest that the rate of egg production is higher when insects feed on a diet that contains protein. In bees similarly as the proportion of pollen in their diet increased their longevity was also positively correlated. Improved ovary development and egg lying in the queen, were also recorded which is probably due to the fact that pollen contains all the essential amino acids (Stanley and Linskens, 1974). The fact that the reproductively matured adults, that emerge during towards the end of June to the beginning of July mainly depend as food on *Acacia Spp*. and other yellow flowers. It was also noted that constant disturbance of egg laying adults for egg collection affected egg lying. The size of eggs laid in the present study ranged from 1.0-1.4mm in width to a length of 1.3-1.6 mm with an average of 1.33±0.034 in newly laid eggs and 1.5-1.9mm in width and 1.9-2.4mm in length averaging 2.14±0.07 in eggs at eclosion approaching to hatch.

Table 1: Duration of the immature stages of laboratory reared *P. interrupta*

stages	Days until change		Numbers observed	percentage of survival
	Range	mean±SE		
Eggs	8-13	9.63±0.14	48	86
Larvae	42-73	59.69±1.64	28	58.33
Pupae	18-30	24.47±0.80	19	67.86
Days of adult emergence	68-116	93.79±1.76	19	100

It was also observed that the egg eclosion period, (9.63 days) and percentage of survival (86) was less than that of Seneshaw Aysheshim and Mulugesta Negeri's (2000) [12] which according to their reports were 11.3 days and > 95% respectively. The percentage survival of larvae was also less (Table 1) compared to previous studies due to variations in egg collection methodologies. In present study the average larval duration was 59.69±1.64 days and the total time to complete the life cycle were 93.79±1.76 day.

Table 2: Mean duration of immature stages and adult emergence at different temperatures

Temp (^{0}C)	Larvae Mean ±SE	Pupae Mean ±SE	Adults Mean ±SE
20	73.0±3.52c	19.63± 2.89c	_
25	72.0± 4.3bc	22.0± 1.26ab	86.75± 2.84c
30	52.0± 4.27a	26.08 ±1.58b	73.86 ±2.96b
35	50.0 ±4.18a	15.0± 0.00a	62.0± 1.73a

In Grunshaw's (1992) [7], work mean larvae duration was 43.3 falling in the range of 39-50 days. These differences most probably have been, caused because of the differences in temperature regimes used. In the present study 25 ^{0}C was used, while the above mentioned works were performed at 28±2 ^{0}C and 30 ^{0}C, respectively. Ambient temperature is known to be the most important factor governing insect development time. The change on development rate was linear in the middle temperature range, fastest at the optimal temperature and then decreased beyond the optimum coincided with that of Grunshaw. As the temperature increased from 25, 30 to 35 ^{0}C day of larval duration also changed to the next stage and went down from 72.0±4.3 to 52.2 ± 4.27 and 50.0 ± 4.18 consequently (Table 2).

Table 3: Mean body length and head capsule width of larvae in different moisture and temp regimes.

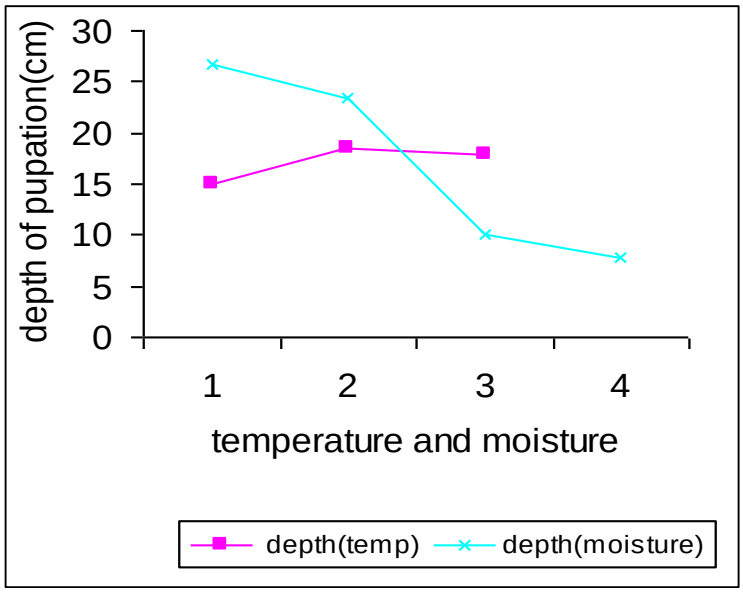
Temperature (^{0}C)	Larval body length Mean±SE	Larval head width Mean±SE
20	7.3 ±0.3b	0.79 ±0.03b
25	7.21± 0.35b	0.77±0.03b
30	7.12± 0.47b	0.74± 0.05b
35	9.6± 0.52a	1.05± 0.06a
Moisture (%)		
9	4.8± 0.28c	0.56± 0.03c
17	10.06 ±0.45a	1.04± 0.05a
23	9.14± 0.49a	0.98± 0.05a
29	7.22± 0.43b	0.76± 0.04b

The temperature around 30 ^{0}C seemed to be optimal for *P. interrupta.* The shortest larval time at 35 ^{0}C does however not on its own confirm that temperature was the most detrimental, because only few of the experimental insects were able to complete total life cycle. The early immature stages were particularly affected by high temperature. The effect of lower temperature on pupae was also observed as it led to delayed adult emergence where it increased from 62.0±1.73, 73.86± 2.96 and 86.75± 2.84 as the temperature decreased from 35, 30 to 25 ^{0}C and agreed with previous work by Ramesh and Azam, (1988) [11]. Another reason for difference in larval duration could be from the frequency of larval measurement days. The larval period varied enormously from 73 to 377 days due to disturbance of larvae to determine instar periods. In the present work, observation ceased counting 14 males and 11 female adult beetles, 4 months and 10 days after they had begun laying eggs. The instar number and period of determination based on head capsule width in the present study showed certain agreement with that of Seneshaw and Mulugeta (2002) [13].

Table 4: Mean duration of immature stages and adult emergence reared in laboratory at different ranges of soil moisture.

Moisture (o/o).	Days required for the immature to change and for the adults to emerge		
	Larvae	Pupae	Adults
	Mean ± SE	Mean ± SE	Mean ± SE
9	72.5±8.61b	_	_
17	66.5±4.24a	23.92±1.68 a	80.8±4.3a
23	58.7±3.42a	22..5±2.52a	72.25±4.09a
29	59.7±5.12a	17.33±2.44a	65.0±0.00a

The present study as opposed to previous reports, however, confirms that cow dung (others need to be verified) was very essential for completion of the life cycle of *P. interrupta* in all soil classes (Table 5). Addition of a small proportion of cow dung to all these soils made the mixtures suitable for this beetle thereby improving and making, the sandy soil most preferred. The depth of pupation had no significant impact due to soil temperature. This could be explained in relation to the nature of a particular soil in terms of heat transfer since soil is poor conductor of heat. More over the temperature variation decreases with increasing depth thus providing more stable temperature. Moisture showed a significant negative correlation (P<0.05) with depth of pupation sites.



While the amount of moisture decreased depth of pupation increased and in higher moisture levels pupation was formed at relatively shallower depths the relation of pupation to soil moisture could be attributed to the importance of moisture (water) to construct the earthen cocoon. In general when the larva is ready to pupate, it forms an oval cocoon made from soils cemented with larval saliva. This supports, the result in the present study for the experimental beetles went deeper and deeper, to find the soil water when scarce in the upper soil surfaces.

The highly evolved system of dormancy for overwintering cyclic long-term life activities was referred here as "diapause" in contrast to quiescent used by Grunshaw (1992) [7]. It was also believed that unlike most other insects, diapause in *P. interrupta* was not initiated only by abiotic factors, but also mainly by biotic factors such as nutrition and availability of food. In the environment the beetles disappeared when the host was maturing or scarce not related to changes in physical conditions.

Table 5: Mean body length and head capsule width of *P. interrupta* larvae reared in different soil types

	Soil type	Mean body length ± SE	Mean head capsule width ±SE
1	Afar natural	4.68± 0.36e	0.59 ±0.04e
2	T. inchini natural	3.86±0.37e	0.48±0.04e
3	Sandy natural	0.99±0.15f	0.18±0.03f
4	Afar + 25% manure	8.87±0.56d	0.91±0.05d
5	T. inchini 25% manure	10.96±0.55ab	1.23±0.11a
6	Sandy + 25% manure	10.87±0.50ab	1.12±0.04ab
7	Afar+50% manure	9.52±0.54cd	1.04±0.05bcd
8	T. inchini 50% manure	10.25±0.64bc	1.09±0.06abc
9	Sandy + 50% manure	11.65±0.59a	1.22±0.06a
10	Afar- burned	0.83±0.13f	0.117±0.03f
11	T. inchini-burned	0.48±0.09f	0.12±0.02f
12	Sandy-burned	0.79±0.13f	0.16±0.03f
13	100%- Manure	8.43±0.61d	0.94±0.08cd

In the laboratory, all the experimental beetles died when denied food for 15 days and continued to survive for more than 3 months without diapausing when they were provided with food every day, at intervals of every 4 days or every week (Table 6). This agrees with that of Blossey and Hunt (1999) that newly emerged adults require a feeding period to accumulate fat reserves to overwinter successfully. The new generation, emerging directly from pupae, fed actively (so become worst pest), store sufficient amounts of nutrient and enters in to the soil for diapause In Ethiopia the natural environment for breeding as well as diapausing areas are very hot because of the latitude (around 9^0N) and low altitudes usually below 1800 msl. The diapausing season varies from mid-November to end of May known as dry season while February to May are especially seems very hot specially in the study area. Means within columns followed by the same letter are not significantly different from each other; P<0.05, DMRT. As far as vegetation is concerned, in the present work all the diapausing adults were found under plant shades. Before a successful overwintering, insects must prepare themselves for the potentially dangerous conditions that lie ahead. The death of all insects in the group which were not fed for 15 days in the present work (Table 6) agrees with statements mentioned above. At the same time the persistently increasing of lean dry weight, or size of the beetle and fat weight both in females and males obtained for pre–diapausing adults.

Table 6: Soil sources with specifications

Soil			Sand %	Silt %	Clay %	Class	Organic Carbon
No.	Source	Ph					
1	Afar	7.96	32	44	24	L	2.21
2	Tikur inchini	5.64	42	50	8	SIL	7.99
3	Sandy (Guder river)	7.55	96	2	2	S	0.15
4	Afar+25% Manure	7.63	48	35	18	L	4.34
5	Tikur nchini+25% Man.	5.89	47.5	43.5	9	L	8.67
6	Sandy+25% Manure	7.33	88	7.5	4.5	S	2.79
7	Afar+50% Manure	7.31	64	23	13	SL	6.47
8	T.inchini+50% Manure	6.15	53	37	10	SL	9.39
9	Sandy+50% Manure	7.1	80	13	7	LS	5.43
10	Afar-burned	6.38	36.58	40.5	18	L	1.16
11	T.inchini-burned	4.48	48	46	6	SL	7.81
12	Sandy-burned	6.04	97	1.5	1.5	S	0.14
13	100%Manure	6.65	64	24	12	SL	10.72

References

1. Abera Debelo, Ereneso D, Zenbaba GC. Ethiopian sorghum improvement Programme progress report. Addis Ababa -Ethiopia. 1996; 20:1-2.
2. Abera Debelo, Tadesse Mulata, Girma Tegene, Fasil Reda, Yeshi Chiche, Beyene Seboka *et al*. Sorghum Technology Transfer in Ethiopia: Achievements and limitations. In: sorghum and millet Research network in Eastern and central Africa. Kampala. Uganda, 1995, 131-151.
3. Abraham Negasi, Abraham Tadesse. A review of research on insect pests of maize and sorghum in Ethiopia. A review of crop protection research in Ethiopia (IAR), 1985.
4. Clark ROS, Crowe TJ. The genus Pachnoda in Ethiopia. Identification, pest status and control of the species. Institute of Agricultural Research Addis Ababa, 1977.
5. CSA (Central Statistics Authority of Ethiopia). Federal Democratic Republic of Ethiopia statistical Abstracts of Ethiopia, 2000.
6. Donaldson JMI. Biologies and rearing techniques for twenty-two species of Cetoniinae (Coleoptera: Scarabaeidae. Technical communication Department of Agricultural Development of Republic of South Africa. 1985-1992; 237:1-22.
7. Grunshaw JP. Field studies on the Biology and Economic importance of *Pachnoda interrupta* (Coleoptera: Scarabaeidae), Mali West Africa. Bulletin of Entomological Research. 1992; 82:19-27.
8. Hiwot Lemma. Historical background of the pest status and control of Sorghum chafer, *Pachnoda interrupta* (Olivier) (Coleoptera Scarabaeidae) in Ethiopia. In: proceedings of the work shop on development of monitoring and control strategy against Sorghum chafer, *P. interrupta* (Olivier) Coleoptera: Scarabaidae in Ethiopia, 2000, 9-15, Ethiopia.
9. Hiwot Lemma, Adane Kassa, Yeraswork Yilma, Legesse Zewde, Tsegaye Ejigu, Mohamed Seidet *et al*. The significance, Distribution and control of Sorghum chafer, *Pachnoda interrupta* (Olivier) (Coleoptera: Scarabaeidae) in Ambara and Afar Regions. MOA and EARO Addis Ababa, 1999.
10. Peters DC, Starks KJ. Pest management system for sorghum insects. In crop Research Centre. Handbook of pest management. CRC presses Boca Reton. Florida. 1979; III:549-562.
11. Ramesh T, Babu, Azam KM. Effect of low holding Temperature during pupal instar on adult emergence, pre oviposition and fecundity of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera). Insect science and its application. 1988; 9:175-177.
12. Seneshaw Aysheshim, Mulugeta Negeri. Study on biology of Sorghum chafer, *P. interrupta* (Coleoptera: Scarabaeidae). Proceedings of workshop on development of monitoring and control strategy against Sorghum chafer, *P. interrupta* (Olivier) in Ethiopia, 2000, 16-21.
13. Seneshaw Aysheshim, Mulugeta Negeri. Study on the biology of Sorghum chafer, *P. interrupta* (Coleoptera: Scarabaeidae) under laboratory condition. Pest Management Journal of Ethiopia. 2002; 6:31-36.