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Morphometric differences of *Pachnoda interrupta* (Oliver) (Coleoptera: Scarabaeidae) in Gedarif and Khartoum States

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Abstract
This study was conducted in Gedarif and Khartoum States to detect whether the insect found in Khartoum is similar to that in Gedarif. Adults of *Pachnoda interrupta* were collected from infested plants and taken to the laboratory at the Faculty of Agriculture, University of Khartoum. Specimens of sorghum chafer which were collected from both study sites were subjected to morphometric microscopic examinations, collected data were analyzed. Correlation coefficient was calculated for measurements of different parts of insect body. Observations of collected beetles revealed that the adult is black with reddish-brown margins and number of spots and stripes of the same color. Beetles have lamellate antennae, black legs with 5 tarsal segments and 2 claws; the hindwings are black transparent. Specimens of beetles collected from both states are not different in terms of the measurement of body, head, antennae, thorax, hindwings, hind legs and abdomen. Length of forewings (11.9 mm), forelegs (9.4 mm) and mid legs (12.5 mm) of specimens collected from Khartoum State were significantly higher than the respective parts of specimens collected from Gedarif State (9.2, 7.8, 9.9 mm, respectively). Correlation coefficient between different pair-wise parts of the insect body collected from the two sites of the study revealed that, the percent of the difference was 87.5%. This indicates that the specimens of the sorghum chafer which were collected from Gedarif State seem to be different from those which were collected from Khartoum State. The results recommend further studies, especially at the DNA level to confirm these findings.

Keywords: *Pachnoda interrupta*, microscopic, specimens, morphometric, Gedarif State, Khartoum State, insect body, Sudan

Introduction
The beetle *Pachnoda interrupta* (Coleoptera: Scarabaeidae: Cetoniinae) is one of the major insect pests with great notoriety for attacking the crop (FAO, 1972) [5]. It was first reported attacking sunflower on the African subcontinent in Ethiopia in 1992 (Ethiopian Humanitarian update, 2000). *P. interrupta* is a polyphagous pest distributed particularly in Africa (Grunshaw, 1992) [7]. In Ethiopia, surveys conducted about 20 years ago revealed the presence of nine species of *Pachnoda* (Clark and Crowe, 1978) [3]. The adult of *P. interrupta* feeds on the flowers and grains during the milky stage of sunflower and serious damage has been reported to occur when 2-3 beetles present/plant (Abdou *et al*., 2011) [1]. During the early 1990s, the sorghum chafer emerged as a key pest on sorghum in Ethiopia (Hiwot, 2000) [8]. *P. interrupta* is present in semi-arid parts of Africa which are subject to strong seasonal variations in rainfall and temperature, mainly in the Sahel and Sudan Ecoregions (Schmutterer, 1969; Grunshaw, 1992; Jago, 1995; Sastawa and Lale, 2000) [12, 7, 9, 11]. In Sudan it is uncommon but widespread in some parts of the central rain lands, for instance in the Nuba Mountains and in Gedarif area. The beetle feeds towards the end of the rainy season on the milky–ripe grains of sorghum, and millet heads, but flowers of sunflower, henna, cucumber, roses and capsules of okra are also attacked (Schmutterer, 1969) [12].
During autumn of 2011 an outbreak of *Pachnoda interrupta* occurred for the first time in Sudan on four genotypes of sorghum (*Sorghum bicolor*), four of pearl millet (*Pennisetum glaucum*) and eight of sunflower (*Helianthus annuus*) in the Gezira Research Station farm (Tag Elsir *et al*., 2013) [13].
Due to the importance of sunflower and sorghum as commercial and food crops and the high damage caused by sorghum chafer on these crops this study aims to answer the question:
* Are there any morphological differences between specimens of sorghum chafer collected from Gedarif and Khartoum States (Faculty of Agriculture, University of Khartoum)?

Materials and Methods
Specimens Collected from the Faculty of Agriculture, University of Khartoum
Specimens of *P. interrupta* were hand-collected from plots of sunflower grown at the Faculty of Agriculture, University of Khartoum. The collected specimens were preserved in chloroform until used for examination. Specimens collected from Gedarif State and the Faculty of Agriculture, University of Khartoum were subjected to microscopic examination and measurement. These examination and measurements were carried out at the laboratory of the Department of Crop Protection, Faculty of Agriculture, University of Khartoum.

Parameters to be tested
Measurements of different parts of the insect body (head, antennae, thorax, forewings, hindwings, forelegs, mid legs,

hind legs and abdomen) were taken. The measurements were carried out in ten adult insects randomly selected from the samples that were collected from each study site (Faculty of Agriculture, University of Khartoum and Gedarif State). Glass slides were prepared from antennae and legs of insects to facilitate measurement under the microscope.

The mean length of the different parts of the insect body were compared between the insect samples collected from Gedarif State and the Faculty of Agriculture, University of Khartoum, to detect the variability between species collected from the two study sites.

Statistical Analysis

The collected data from Gedarif State and the Faculty of Agriculture, University of Khartoum were subjected to T-Student Test described by Gomez and Gomez (1984) [6]. In addition, the correlation coefficient was calculated for the different pair-wise parts of the body for specimens collected from each study site.

Results

The Morphology of *Pachnoda interrupta* Adult

1. Morphology of *Pachnoda interrupta* Adult collected from the Faculty of Agriculture, University of Khartoum

The adult is black in color with reddish-brown margins and a number of spots and stripes of the same color. The body is 17.9 mm long, the head 3mm long, antennae lamellate 2 mm long, the thorax is 7 mm long, the legs are black in color and had 5 tarsal segments and 2 claws, the forelegs, mid legs and hind legs are 9.4 mm, 12.5 mm and 13.1mm long, respectively. The forewings are black with reddish- brown spots and stripes, 11.9 mm long; the hind wings are black transparent, 17.5 mm long. The abdomen is 7.9 mm long.

2. Morphology of *Pachnoda interrupta* Adult Collected from Gedarif State

The adult is black in color with reddish-brown margins and a number of spots and stripes of the same color. The body is flat when viewed from above and is 17.7 mm long, the head is 3mm long, antennae lamellate 2mm long, the thorax is 6.6mm long. The legs are black in color with 5 tarsal segments and 2 claws, the forelegs are8.7mm long; the mid legs and hind legs are 9.9mm and 12.1 mm long, respectively. The forewings are black with reddish-brown spots and stripes, 9.2 mm long, the hind wings are transparent black in color, 17.9 mm long and the abdomen is 8.1mm long.

Assessment of the Variability between *Pachnoda* Specimens Collected from the Faculty of Agriculture, University of Khartoum and Specimens Collected from Gedarif State

Statistical analysis showed no significant difference in the length of body, head, antenna, thorax, hind wing, hind legs and abdomen between insects collected from Gedarif and those collected from the Faculty of Agriculture, University of Khartoum, (Table 1 and Figures 1-3). The overall mean of body length

Body length (BDL) was 17.8 mm; 3 mm head length (HDL), 2 mm antennal length (ANL), 6.8 mm thorax length (THL), 17.7 mm hind wings length (HWL), 12.6 hind legs length (HLL) and 8mm abdomen length (ABL).

Highly significant difference (p<0.01) was detected in the mean length of forewings of insects collected from the Faculty of Agriculture University of Khartoum, (11.9 mm) and that of insects collected from Gedarif State
(9.2 mm) (Table 1).

The mean length of forelegs of insects collected from the Faculty of Agriculture, University of Khartoum, (9.4 mm) is significantly higher (p<0.05) than that of insects collected from Gedarif State (8.7 mm) (Table 1)

The T-Test indicated highly significant difference (p<0.01) in the mean length of midlegs of insects collected from the Faculty of Agriculture, University of Khartoum, (12.5 mm) and that of insects collected from Gedarif State (9.9 mm) (Table 1).

Table 1: Correlation of different parts of the insect body of adult collected from Faculty of Agriculture University of Khartoum

KHASP	BDL	HL	ANL	THL	FWL	HWL	FLL	MLL	HLL	ABDL
BDL	-	-	-	-	-0.04	-0.38	-0.3	0.51	0.79	1
HL	-	-	-	-	-	-	-	-	-	-
ANL	-	-	-	-	-	-	-	-	-	-
THL	-	-	-	-	-	-	-	-	-	-
FWL	-0.04	-	-	-	-	-0.04	-0.29	0.11	0.19	-0.04
HWL	-0.38	-	-	-	-0.04	-	-0.11	-0.54	-0.14	-0.38
FLL	-0.3	-	-	-	-0.29	-0.11	-	0.46	-0.16	-0.03
MLL	0.51	-	-	-	0.11	-0.54	0.46	-	0.63	0.51
HLL	0.79	-	-	-	0.19	-0.14	-0.16	0.63	-	0.79
ABDL	1	-	-	-	-0.04	-0.38	-0.3	0.51	0.79	-

Table 2: Correlation of different parts of the insect body of adult collected from Gedarif State

GEDSP	BDL	HL	ANL	THL	FWL	HWL	FLL	MLL	HLL	ABDL
BDW	-	-	-	0.97	0.18	0.27	0.01	0.29	0.32	0.3
HL	-	-	-	-	-	-	-	-	-	-
ANL	-	-	-	-	-	-	-	-	-	-
THL	0.97	-	-	-	0.21	0.16	-0.03	0.29	0.28	0.09
FWL	0.18	-	-	0.21	-	0.46	0.35	0.91	0.13	-0.06
HWL	0.27	-	-	0.16	0.46	-	0.21	0.61	-0.09	0.52
FLL	0.01	-	-	-0.03	0.35	0.21	-	0.13	0.04	0.21
MLL	0.29	-	-	0.29	0.91	0.61	0.13	-	-0.5	0.02
HLL	0.32	-	-	0.28	0.13	-0.09	0.04	-0.5	-	0.21
ABDL	0.3	-	-	0.09	-0.06	0.52	0.21	0.02	0.21	-

Table 1: Measurements of body parts (means) of specimens of *Pachnoda interrupta* collected from the Faculty of Agriculture, University of Khartoum and Gedarif State

Measurement of Body part	Specimens collected from		T-value
	Fac. of Agric. (Univ. of Khartoum)	Gedarif State	
Body length	17.7±0.31 a	17.9±1.49 a	0.41
Head length	3.0±0.0 a	3.0±0.0 a	0.0
Antennal length	2.0±0.0 a	2.0±0.0 a	0.0
Thorax length	7.0±0.0 a	6.6±1.42 a	0.88
Forewings length	11.9±0.87 a	9.2±1.03 b	6.31
Hind wings length	17.5±1.35 a	17.9±0.73 a	-0.82
Forelegs length	9.4±0.69 a	8.7±0.48 b	2.60
Mid legs length	12.5±1.71 a	9.9±1.19 b	3.92
Hind legs length	13.1±1.37 a	12.1±1.44 a	1.58
Abdomen	7.9±0.32 a	8.1±0.32 a	-1.41

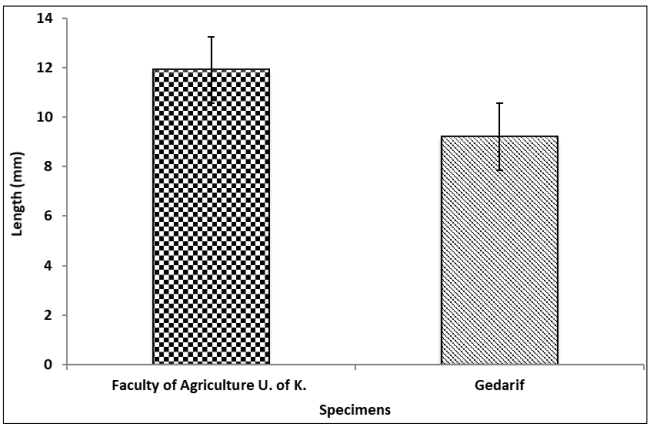


Fig 1: Mean length (mm) of forewings of specimens collected from the Faculty of Agriculture, University of Khartoum and Gedarif State

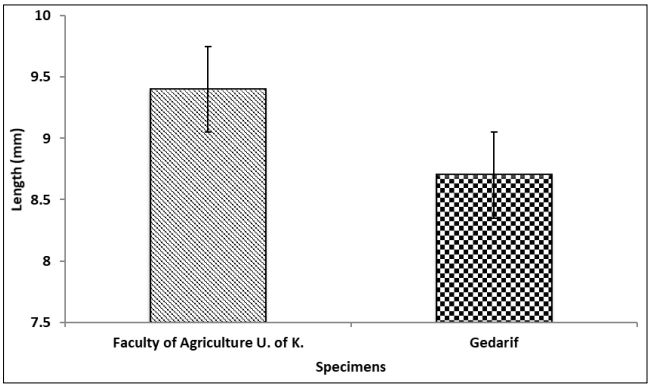


Fig 2: Mean length (mm) of forelegs of specimens collected from the Faculty of Agriculture, University of Khartoum and Gedarif State

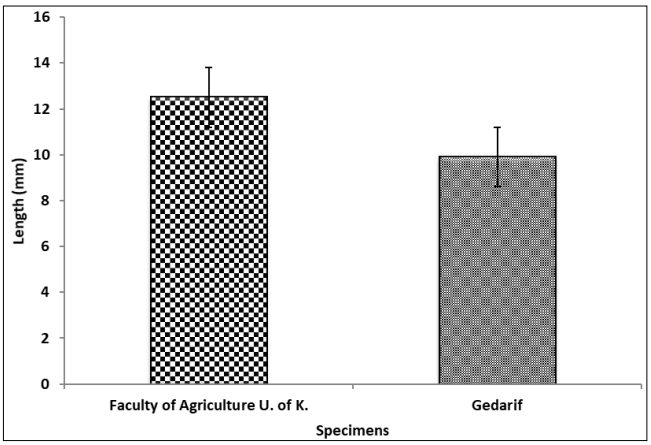


Fig 3: Mean length (mm) of mid legs of specimens collected from the Faculty of Agriculture, University of Khartoum and Gedarif State

Correlation between the Different Parts of the Insect Body

Correlation between the Different Body Parts of Insects Collected from the Faculty of Agriculture, University of Khartoum

A high positive correlation (r=0.79) was detected between the body length (BDL) and the hind leg length (HLL) on one hand, and between the body length and the abdomen length (ABL) (r=1.0) on the other hand. Furthermore, the body length exhibited positively moderate correlation (r=0.51) with the mid legs length (MLL), and negatively weak correlation with the length of forewing (FWL) (r=-0.04), and with the length of hind wing (HWL) (r=-0.38), and with the length of forelegs (FLL) (r=-0.3).

Head length (HL), antennal length (ANL) and thorax length (THL) were not correlated with other different parts of the body.

The forewing length (FWL) showed negatively weak correlation with the length of hind wing (HWL) (r=-0.04), and with the length of forelegs (FLL) (r=-0.29), and with the length of the abdomen (ABL) (r=-0.04).

A weak correlation was detected between the forewing length and the mid legs length (MLL) (r=0.11) on one hand, and the length of the hind legs length (HLL) (r=0.19), on the other hand. The forewings length was not correlated with head length (HL), antennal length (ANL) and thorax length (THL).

Hind wing length (HWL) exhibited negatively moderate correlation (r=-0.54) with mid legs length (MLL). A negatively weak correlation (r=-0.11) was detected between the length of the hind wing (HWL) and the length of the foreleg, (FLL), and the length of the hind legs (HLL) (r=-0.14), and the length of the abdomen (ABD) (-0.38).

Correlation between the Different Body Parts of Insects Collected from Gedarif State

The body length (BDL) of beetles collected from Gedarif State revealed positively high correlation (r=0.97) with the thorax length (THL) on one hand. A weak correlation, on the other hand, was detected between the body length and the other body parts.

Thorax length (THL) was negatively weakly correlated (r=-0.03) with the forelegs length (FLL) but weakly correlated with the other body parts. Hind wings length (HWL) showed positively moderate correlation with the forewings length (FWL) (r= 0.46) and with the mid legs length (MLL) (r=0.61) and with the abdomen length (ABL) (r=0.52).

The mid legs length (MLL) showed positively high correlation (r=0.91) with the forewings length (FWL), and positively moderate correlation (r=0.61) with the hind wings length (HWL). On the other hand, they revealed negatively weak correlation (r=-0.50) with the hind legs length (HLL) and a weak correlation with the other body parts.

The hind legs length (HLL) has negatively weak correlation (r=-0.09) with, the hind wings length (HWL). On the other hand, the hind legs length was weakly correlated with the other body parts.

The abdomen length (ABL) showed a positively moderate correlation (r=0.52) with the hind wings length (HWL). However, it has weak correlation with the other body parts. No correlation was detected between the head length (HL) and antennal length (ANL), each with the other body parts.

Correlation between *Pachnoda* Specimens Collected from the Faculty of Agriculture, University of Khartoum and Specimens Collected from Gedarif State

The percent of the difference in correlation between the different parts of the insect body collected from the two study sites was 87.5%. This indicates that the two specimens seem to be different from each other.

Feeding Behavior of *Pachnoda interrupta*

In sunflower the beetles appeared in the field at the flowering stage. The feeding started from the periphery of the disc toward the center. In sorghum, however, the feeding

appeared as consumption of partial or the whole endosperm of the grain. The feeding started from the top towards the bottom of the spike/panicle; the consumed part turned chafed.

Discussion

The beetles collected from Gedarif and the Faculty of Agriculture, University of Khartoum were found black in color with reddish-brown margins and a number of spots and stripes of the same color. This coloration is the same as that described by Schmutterer (1969) [12]. On the average, the body length of adult beetles collected from Gedarif and the Faculty of Agriculture, University of Khartoum, was found 17.8 mm. This finding agrees with that stated by Schmutterer (1969) [12] who reported that the adult beetle is 13-17 mm long and that the beetle has blackish ground color with reddish–brown margins and a number of spots and stripes of the same color.

The forewings of our specimens were black with reddish-brown spots and stripes; this observation agreed with those of Grunshaw (1992) [7] and Matthews and Jago (1993) [9] who reported that the elytra and pronotum have yellow–brown or red–brown spots and stripes.

The antennae of the beetles collected from Gedarif and the Faculty of Agriculture, University of Khartoum are of the lamellate type; this finding agrees with that reported by Borror *et al.* (1976); they are 2 mm long.

The measurements of specimens collected from Gedarif State and the Faculty of Agriculture, University of Khartoum revealed some degree of variability. Morphometrically, the forewings of the beetles collected from the Faculty of Agriculture were significantly longer (11.9 mm) than those of the beetles collected from Gedarif State (9.2mm). Furthermore, the forelegs of those beetles collected from the Faculty of Agriculture were significantly longer (9.4 mm) than those of Gedarif State (8.7 mm). The mid legs of beetles collected from the Faculty of Agriculture were significantly longer (12.5 mm) than those of beetles collected from Gedarif State (9.9 mm). These differences may be related to the difference of environmental or genetically factors. Concerning the feeding behavior of the sorghum chafer on sunflower, the beetle started feeding from the periphery of the disc toward the center. In this manner the beetle follows the development of the seeds in the disc; those at the periphery develop earlier compared to those at the center of the disc. On sorghum heads, the beetles partially or completely consume the grain endosperm. At the level of spike/panicle, the beetles feed from the top and proceed downward. The infested part of either crop turned chafed; this observation is in line with that of Tag Elsir *et al.* (2013) [13].

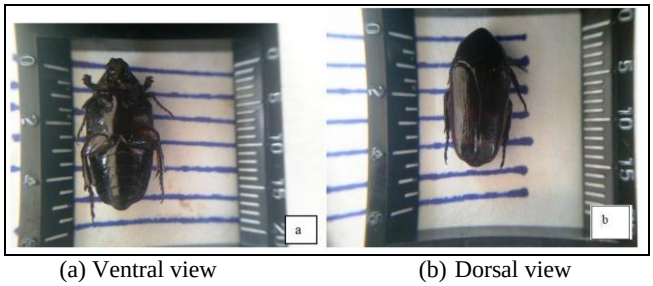
Conclusion

Morphologically, specimens of *P. interrupta* collected from the Faculty of Agriculture, University of Khartoum are significantly different from those collected from Gedarif State in some aspects, *viz* length of forewings, forelegs and mid legs.

The specimens of sorghum chafer which were collected from Gadarif State and those which were collected from Khartoum State seem to be different from each other.

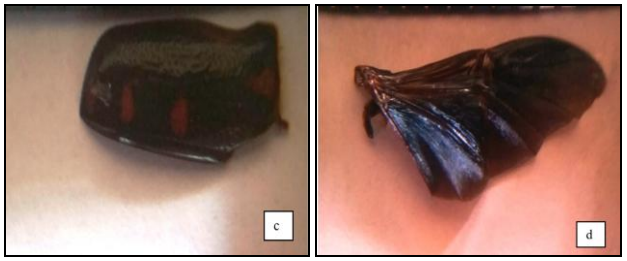
Support materials

1. Plate 1: Body parts of *Pachnoda interrupta* adult collected from the Faculty of Agriculture, University of Khartoum, Shambat
2. Plate 2: The body parts of *Pachnoda interrupta* adult collected from Gedarif State
3. Plate 3: Adult of *Pachnoda interrupta* feeding on sorghum head (a) and sunflower disc (b)



(a) Ventral view (b) Dorsal view

Plate 1: Body parts of *Pachnoda interrupta* adult collected from the Faculty of Agriculture, University of Khartoum, Shambat

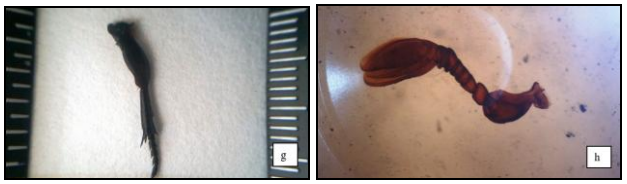


(c) Forewing (d) Hind wing

Plate 1: (Continued)

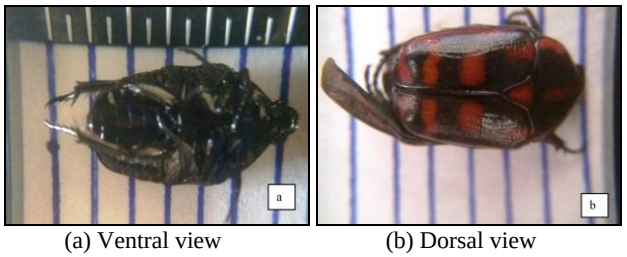
(e) Foreleg (f) Mid leg

Plate 1: (Continued)



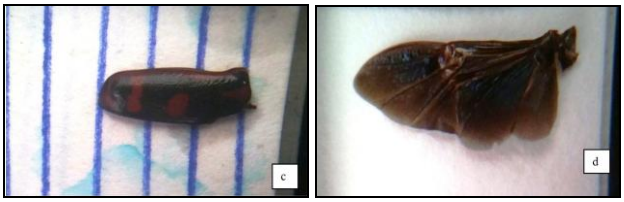
(g) Hind leg (h) Antenna

Plate 1: (Continued)



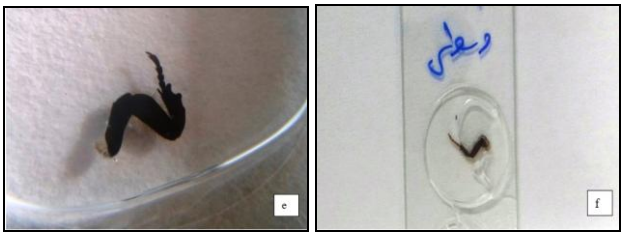
(a) Ventral view (b) Dorsal view

Plate 2: The body parts of *Pachnoda interrupta* adult collected from Gedarif State



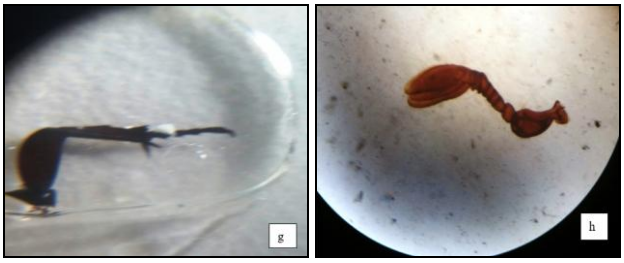
(c) Forewing (d) Hind wing

Plate 2: (Continued)



(e) Foreleg (f) Mid leg

Plate 2: (Continued)



(g) Hind leg (h) Antenna

Plate 2: (Continued)

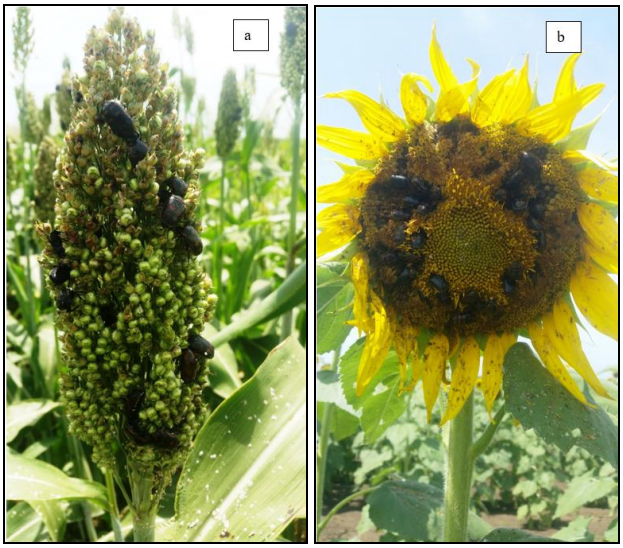


Plate 3: Adult of *Pachnoda interrupta* feeding on sorghum head (a) and sunflower disc (b)

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