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Effects of some Food Plants on the Growth, Development and Fecundity of *Zonocerus variegatus* (L)

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ABSTRACT

The performance of the variegated grasshopper, *Zonocerus variegatus* (L) fed on different food plants namely: cassava (*Manihot esculenta*), pawpaw (*Carica papaya*) and acalypha (*Acalypha wilkesiana*) and mixtures of these plants (mixed diets) from 5th nymphal instar to adult were investigated. Survivorship and longevity of nymphs and the reproductive performance of adult *Zonocerus* was greater and better for insect fed on cassava and mixed diets, as compared to those fed only on *Acalypha* and pawpaw. Adults emerged between the 5th- 16th week in cages containing 5th instars fed on cassava and mixed diets, and between 7-23 weeks for those fed on acalypha and pawpaw. There were significant differences in the measurements of the body parameters of insects fed on the four different food plants (ANOVA $P \geq 0.05$). Ranking was Cassava>Mixture>pawpaw>Acalypha. Sex had no significant effect on the measurement of body parameters irrespective of the food plants (ANOVA $P \geq 0.05$). Feeding assay showed that cassava was the most preferred and most consumed food plant. This had a corresponding effect on the weight gained by the insects. The results of the proximate analysis showed significant differences in the dry matter, crude protein and fat content of *Z. variegatus* fed on the different food plants (ANOVA $P \geq 0.05$). A positive correlation existed between the body weight and protein and fat content of *Z. variegatus* fed on the different food plants ($R=0.99$).

INTRODUCTION

The variegated grasshopper, *Zonocerus variegatus* (L) (Orthoptera: Pyrgomorphidae) is widespread in Western and Central Africa. It is primarily associated with the forest regions, but extends into the savanna, where it is restricted to riverine habitats (Chapman *et al.*, 1986). Its polyphagous habits and typical group behaviour contribute to its status as a pest (Chapman *et al.*, 1986). *Z. variegatus* is a polyphagous

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insect and its food plants include a wide range of wild and uncultivated plants (Modder, 1986). Nevertheless it exhibits preferences. However, not all the food plants eaten by *Z. variegatus* are adequate for survival and development (Bernays *et al.*, 1975 and Tamu 1990). For example cassava, *Manihot esculcuta* (Gantz) (Bernays *et al.*, 1975; McCaffery *et al.*, 1978; Tamu, 1990) and *Vernonia amygdalina* (Shreb) (Tamu, 1990) have been shown to support growth and development of *Z. variegatus*. On the other hand, *Citrus spp* only support growth while *Chromolaena odorata* and *Aspilia africana* (L) do not support growth of insects (Bernays *et al.*, 1975, McCaffery *et al.*, 1978). *Z. variegatus* thrives very well on *C. odorata* from the 1st to the 4th nymphal instar. The early instars do not eat cassava in the field, although they may roost on it (Bernays *et al.*, 1975); it is the later instars that are responsible for damage. Bernays *et al.* (1975) also found that insects reared on cut leaves of cassava in the laboratory fed readily on the cut leaves, development was more rapid and the resultant insects were heavier than on other food plants.

The purpose of these studies was to determine the impact of the different food plants associated with the population of *Z. variegatus* in the University of Agriculture, Abeokuta on its growth, development and fecundity as well as its proximate analysis.

MATERIALS AND METHODS**Collection and Maintenance of Insects:**

Populations of *Z. variegatus* resident in grounds of University of Agriculture, Abeokuta were studied for 3 years. Oviposition sites were marked in the previous seasons and the population was monitored from hatching until moulting to 5th nymphal instar. Newly moulted 5th nymphal instars of *Zonocerus* were collected and maintained in wire mesh cages (47×30×30cm) in the laboratory under ambient temperature (29±2°C) and relative humidity (79-85%) conditions. Four cages each containing 150 5th instar nymphs, were fed different diets of standard food plants, namely cassava (*Manihot esculcuta*), pawpaw (*Carica papaya*) and *Acalypha* (*Acalypha wilkesiana*) and mixed diet (a mixture of pawpaw, cassava and *Acalypha*) respectively. Insects were starved for 24 hours before being fed. The growth and development of nymphs were monitored until fledging. Upon fledging, adult insects from different cages were marked with indelible ink for easy identification in accordance with the experimental designs described below. Mated females were separated into oviposition cages with the different tags bearing the name of the respective food plants. The number of eggs laid per individual female were counted and recorded.

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Measurement of Body Parameters:

The length of the body, elytron, antennae, femur and the length of the entire leg as well as the body weight of adult *Z. variegatus*, 18 days after emerging as adults (n=50) were recorded using a Vernier caliper and electric balance (Mettler-Toledo A.G. Model number A.E.240).

Dissection of Insects:

Adult 18 days old *Z. variegatus* of (n=10) from the different cages were dissected for the reproductive structures. The measurements of the right and left rows of ovarioles and testicular follicles of individual insects were counted under a dissecting microscope. The lengths of ovarioles and testicular follicles, including the median ligaments, terminal-filament, and vagina were measured.

Haemocytetes Estimation:

Thin smears were made from the haemolymph of both sexes by cutting the antennae. These were air dried and treated with Leishman's stain. Identification of the cells was made as described by Chapman (1982).

Proximate Analysis:

Proximate analysis for crude protein, fat, moisture and carbohydrate content of the adult

Z. variegatus fed on different food plants was determined by standard methods of AOAC (1980). The moisture content of food plants was also determined.

Insect Feeding Assays:

Five adult instars (8-12 days old) from the different cages, were removed, starved for 24hrs, weighed and placed in small cages with 20g excised leaves of each of the food plants described above. The insects were observed for 3hrs between 10am-1pm, which coincided with the peak feeding period of *Z. variegatus* (Idowu & Akinsete, 2000). Insects and plants were then re-weighed and the difference between the initial and final weight of the insects and plants was recorded as weight gained and food consumed by the insects.

RESULTS

Developmental Period

The duration of nymphal development of *Z. variegatus* fed on the different food plants from 5th instars to adult ranged between 5-23 weeks. Insects fed on pawpaw and *Antypha* required significantly longer period to develop and to moult to adults than

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insects fed on cassava and mixed diets. Observation showed that during the period of developing from 5th to 6th and finally to adult, mortality value of 10%, 12%, 46% and 50% were recorded in cages containing cassava, mixed diet, pawpaw and acalypha, respectively. Eclosion into adult was first observed in the 5th week in cages containing insects fed on cassava and mixed diets. By the 7th week of feeding, 57% & 33% of 5th instars fed on cassava and mixed diets, respectively had moulted to adult whereas moulting was 7% and 1% for insects fed on pawpaw and *Acalypha* respectively. Moulting was completed by the 16th week for insect fed on cassava and the mixed diet while that of pawpaw and *Acalypha* was by 23rd week. Percentage mortality of emerged adults just before copulation was 2.2, 9.3, 24.1 and 45.7 for insects fed on cassava, mixed diets, pawpaw and acalypha respectively. Overall mortality of grasshopper fed on pawpaw and *Acalypha* was very high compared to those fed on cassava and mixed diets. Insects fed on excised cassava leaves had the highest percentage food consumption (14.8%) with highest weight gained (8.1%) while insects fed on pawpaw had the least (0.4% and 1.5% for food consumption and weight gained respectively). Mixed diets had 7.8% for food consumption and 7.9% for weight gained while *Acalypha* had 5.8% and 3.5% for food consumption and weight gained, respectively. Observation also showed that cassava leaves were most preferred even among the mixture of food plants.

Morphology

Measurement of the body parameters (body length, wing length, antennae, femur and entire leg length as well as the body weight) of adult male and female *Z. variegatus* fed on the different food plants are presented in Tables 1 & 2, respectively. The average body length, wing length, femur and legs including the body weight of adult insects followed the trend: cassava > mixture > pawpaw > *Acalypha*. No significant differences were recorded in the body length, wing length, femur and entire leg measurements of adult insects except for those fed on *Acalypha*, which had significant low measurement (ANOVA $P \geq 0.05$). Also, there was no significant difference in the measurements recorded for the various body parameters of the female and male adult *Z. variegatus* irrespective of the food plant ($P \geq 0.05$).

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Table 1: Measurement of the body parameters of adult male *Z. variegatus* fed on different plants

Plants	Mean Wt. (g) ± S.E	Mean Length (cm) ± S. E				
		Body	Leg	Femur	Wing	Antennae
Cassava	1.01±0.03	3.8± 0.03	4.1± 0.03	1.8±0.02	2.6±0.06	1.7±0.03
Mixture	0.65±0.04	3.7±0.03	4.0±0.04	1.8±0.05	2.6±0.05	1.5±0.05
Pawpaw	0.92±0.04	3.7±0.04	4.0±0.03	1.8±0.03	2.5±0.09	1.6±0.03
Acalypha	0.54±0.05	2.9±0.08	3.5±0.11	1.6±0.04	1.8±0.04	1.6±0.04

Table 2: Measurement of the body parameters of adult Female *Z. variegatus* fed on different plants

Plants	Mean Wt. (g) ± S.E	Mean Length (cm) ± S. E				
		Body	Leg	Femur	Wing	Antennae
Cassava	1.05±0.06	3.9±0.04	4.1±0.02	1.8±0.03	2.5±0.08	1.6±0.02
Mixture	0.76±0.05	3.7±0.05	3.9±0.05	1.7±0.04	2.5±0.10	1.5±0.03
Pawpaw	0.99±0.04	3.8±0.04	4.1±0.03	1.7±0.04	2.4±0.10	1.5±0.03
Acalypha	0.59±0.03	3.2±0.10	3.6±0.06	1.6±0.03	1.8±0.04	1.5±0.04

Haemocyte Types:

The frequency and occurrence of blood cell types (haemocytes) in both sexes of adult *Z. variegatus* fed on four different food plants is given in Table 3. Only 6 types were recognised, namely: Prohaemocytes (PRS), Plasmohaemocytes (PLS), Granulocytes (GRS), Spherulocytes (SPS), Adipohaemocytes (ADS) and Oenocytes (OES) (Chapman, 1982). There was a significant decrease in the number of haemocytes as the adult age increased except for adipohaemocytes that increased with the age of the grasshopper (Table 3). The number of haemocytes found in the insects fed on cassava was significantly higher than those found in other food plants.

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Table 3: Average frequency of haemocyte, types in male and female adult *Z variegatus* (L) fed on different food plant (Cassava, Pawpaw and Acalypha)

		PRS						PLS						GRS					
Plants	Sex	NM	8	18	PRE	C	PC	NM	8	18	PRE	C	PC	NM	8	18	PRE	C	PC
Cassava	M	24	07	09	06	06	03	43	17	19	17	15	10	30	25	26	19	21	13
	F	10	11	10	11	09	09	47	37	29	17	19	15	24	33	30	28	27	20
Pawpaw	M	18	04	04	03	03	*	50	11	10	08	06	*	42	20	19	13	11	*
	F	22	09	08	05	06	*	51	16	12	07	11	*	43	22	20	17	15	*
Mixed diet	M	11	22	16	16	11	03	30	41	29	26	20	10	30	31	28	28	26	13
	F	11	30	15	13	10	09	39	49	41	38	27	15	41	42	37	39	30	20
Acalypha	M	13	02	04	02	*	*	30	07	10	07	*	*	37	11	11	11	*	*
	F	21	06	05	04	*	*	24	13	10	09	*	*	24	18	15	12	*	*

		SPS						ABS						OES					
Plants	Sex	NM	8	18	PRE	C	PC	NM	8	18	PRE	C	PC	NM	8	18	PRE	C	PC
Cassava	M	31	35	28	16	22	16	111	19	18	14	11	10	0	07	07	10	05	04
	F	23	47	38	35	26	17	09	27	27	18	21	15	0	13	10	12	09	05
Pawpaw	M	35	11	19	13	11	*	06	06	06	06	06	*	0	06	06	05	03	*
	F	42	13	20	17	15	*	16	13	11	09	09	*	0	08	06	05	05	*
Mixed diet	M	15	34	32	28	17	16	12	25	27	23	16	10	0	20	14	13	11	04
	F	20	56	43	36	25	17	13	37	32	28	23	15	0	24	20	15	09	05
Acalypha	M	28	21	17	12	*	*	06	17	15	11	*	*	0	02	03	03	*	*
	F	16	29	18	13	*	*	10	14	10	09	*	*	0	06	07	06	*	*

PRS	-	PROHAEMOCYTE	NM	-	NEWLY MOULTED ADULT
PLS	-	PLASMATOCYTE	PRE	-	PRE-COPULATING ADULT
GRS	-	GRANULOCYTE	C	-	COPULATING ADULT
SPSs	-	SPHRULOCYTE	PC	-	POST-COPULATING ADULT
ADS	-	ADIPOHAEMOCYTE	8 & 18	-	8 TH & 18 TH DAY AFTER MOULTED TO ADULT
OES	-	OENOCYTE	*	-	NOT DETERMINED

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Reproductive Structures and Fecundity

The mean count and length of the reproductive structures of adult *Z. variegatus* fed on four different food plants are presented on Tables 4 and 5. Insects fed on cassava and mixed diets had a significantly higher measurement (ANOVA $P \geq 0.05$). Observation showed that ovarioles on the right ovary and right testicular follicles were more in number than those on the left row irrespective of the food plants. However, there was no significant difference in the male and female reproductive measurement of adult grasshopper fed on these food plants (T-test $P > 0.05$) (Tables 4 and 5). The average number of eggs laid by the adult insects fed on cassava and mixture were 59.8 ± 1.53 and 55.4 ± 1.94 respectively. No copulation was observed among adults *Zonocerus* fed on pawpaw and *Acalypha*. Those that copulated in cages containing pawpaw did not lay egg and when some of these insects were dissected, there were no developing follicles.

Table 4: Male reproductive structures of Adult *Z. variegatus* fed on different food plants.

Plants	No of test. Follicles \pm S. E		Length of Test. Follicles (cm) \pm S. E		Length of vas. Deff. (cm)	Test. + Med. Lig. \pm S. E (cm).
	Right	Left	Right	Left		
Cassava	45 \pm 0.87	43 \pm 1.09	0.18 \pm 0.01	0.16 \pm 0.01	1.07 \pm 0.01	2.22 \pm 0.01
Mixture	44 \pm 0.37	42 \pm 0.58	0.18 \pm 0.003	0.17 \pm 0.003	1.06 \pm 0.01	2.23 \pm 0.01
Pawpaw	43 \pm 1.08	41 \pm 1.14	0.13 \pm 0.01	0.11 \pm 0.01	1.03 \pm 0.01	2.11 \pm 0.11
Acalypha	39 \pm 0.50	37 \pm 0.00	0.12 \pm 0.00	0.10 \pm 0.01	1.02 \pm 0.01	2.08 \pm 0.03

Table 5: Female reproductive structures of Adult *Z. variegatus* fed on different food plants.

Plants	No of ovarioles \pm S.E		Ovarioles Length (cm) \pm S. E		Vaginal Length \pm S. E	Ovi. + Calyx length \pm S.E	Length of Term. Fil. (cm) \pm S.E
	Right	Left	Right	Left			
Cassava	45 \pm 0.37	43 \pm 0.66	0.20 \pm 0.01	0.19 \pm 0.01	0.27 \pm 0.01	1.85 \pm 0.02	1.73 \pm 0.07
Mixture	41 \pm 0.55	39 \pm 0.51	0.16 \pm 0.003	0.14 \pm 0.003	0.23 \pm 0.01	1.59 \pm 0.01	1.39 \pm 0.31
Pawpaw	44 \pm 0.90	42 \pm 1.03	0.18 \pm 0.01	0.16 \pm 0.01	0.24 \pm 0.01	1.86 \pm 0.00	1.55 \pm 0.11
Acalypha	39 \pm 0.58	37 \pm 0.33	0.14 \pm 0.003	0.12 \pm 0.03	0.21 \pm 0.01	1.57 \pm 0.01	1.38 \pm 0.07

Proximate Analysis:

Proximate analysis performed on adult *Z. variegatus* fed on four different food plants is given in Table 6. Insects fed on cassava and mixture had a significantly higher dry matter (37.2% and 35.7% respectively) than insects fed on pawpaw and *Acalypha*,

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which had 30.0% & 26.5% respectively. The crude protein and fat contents (27.1% & 8.7% respectively) obtained for the insects fed on cassava food plant was significantly higher than those obtained for other food plants. However, crude protein content of grasshoppers fed on pawpaw and mixture were not significantly different ($P \geq 0.05$). The carbohydrate content of the insects fed on mixture was found to be highest (4.8%) while cassava had the least carbohydrate content (0.8%) (Table 6). Result of the moisture content of the different food plants showed no significant difference (Table 6).

Table 6: Proximate analysis of adult *Z. variegatus* fed on different food plants

Plants	% Moisture Content	% Dry Matter	% Ash Content	% Fat Content	% Crude Protein	% Crude Fibre	% Carbohydrate
Cassava	*81.23 62.82	37.18	0.49	8.67	27.05	0.19	0.78
Pawpaw	*81.09 70.02	29.98	0.58	5.99	21.96	0.23	1.22
Mixture	*79.00 64.28	35.72	0.60	8.61	21.29	0.47	4.75
Acalypha	*79.30 73.47	26.53	0.34	5.85	17.26	0.56	2.02

* Moisture content of the food plants.

DISCUSSION

The present study indicated a differential effect of different food plants on the growth, development and fecundity of *Z. variegatus*. This agrees with the findings of Bernays *et al.*, (1975) and McCaffery *et al.*, (1978) that *Z. variegatus* fed on cut cassava leaves compared to other plants are better, grow faster and resulting adults are heavier than on other food plants. The high mortality rate, prolonged developmental period, low relative food consumption, and low body weight of adult grasshoppers fed on *Acalypha* and pawpaw also agrees with the reports of Bernays *et al.*, (1975). The observed differences among the grasshopper could be linked to the efficiency of conversion of food materials to body substances as observed by McCaffery *et al.*, (1978). In a related study, Antonio and Silvia (1993) reported a high total mortality rate (56%), delayed nymphal development and poor reproductive performance in *Nezara viridula* (L) nymphs fed on immature fruits of radish. Most recently, Idowu and Idowu (2001)

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observed that food plants also had significant impact on the volume of secretion obtainable from the repellent gland of adult *Z. variegatus*.

In the present study, strong correlation ($R=0.99$) was observed between the body weight, fat content and crude protein content in the insects fed on cassava and mixed diet. Timmermann and Briegel (1996) also observed a significant positive correlation between body size, protein and fat content in the developmental stages of mosquito species fed on different diets. The result obtained from this study revealed a total of 6 haemocytetes in both male and female adult *Z. variegatus* fed on different food plant. The sudden appearance of adipohaemocytes (ADS) during the reproductive phase and its increment with the age of the insects could be in order to facilitate temporary storage and mobilization of fat as well as to supply energy for both sexes especially the male for reproductive behaviour (Gupta, 1985). The relative small proportion of oenocytes (OES) observed from this study correlate with the finding of Costin (1975), who also reported small proportion of OES in the haemolymph of *L. migratoria*.

The results of the study also agree with the reports of Zheng *et al* (1993) that food-supply was found to influence larval growth and development and adult fecundity of lacewing (*Chrysoperla carnea*). Adult female *Z. variegatus* fed on cassava and mixed diets produced an average of 59.8 and 55.4 eggs, respectively. These values are close to the values (55-60) recorded by Toye (1982). Iheagwam (1979) also recorded an average of 29.2-65.9 eggs for adult *Z. variegatus* fed on diets that included cut cassava. In West Africa, most of the loss inflicted by *Z. variegates* is to the crops of subsistence farmers especially cassava, which has almost become the number one staple food in the region (Toye, 1982). There is therefore the need to find a substitute food plant for the insect especially during the dry-season when cassava seems to be the only available food for the insect on the field. The only plant readily available and consumed by the insect in the field during the dry season period in Ibadan and Abeokuta where the first author has done substantial work on *Zonocerus* is *A. wilkesiana*.

In this study, Adult *Zonocerus* consumed Acalypha and gained weight. Report of past study showed that the plant supported the production of repellent secretion in adult *Zonocerus* fed solely on cassava from 1st to 6th instars (Idowu and Idowu 2001). On the other hand, the results of this study has shown that the plant along with pawpaw are not suitable for raising nymphal instars of *Zonocerus* as the adult that emerged are small and sterile. This has implication on the genetic make-up of emerging adult that needs to be investigated.

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