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A Study on the Feeding and Growth Patterns of the Variegated Grasshopper *Zonocerus Variegatus* (L) in the Laboratory

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Abstract
The feeding and growth patterns of the variegated grasshopper, Zonocerus variegatus (L) were studied in the laboratory to ascertain the amount of food intake, food assimilated and faeces excreted by its nymph and adult stages on a mixed diet of Cassava (Manihot esculenta) and Siam weed (Chromolaena odorata) leaves. Also, the length and weight of the nymph and adult insects were determined separately while the behavioural patterns of food selection were observed. Although temperature and relative humidity affected the

activities of the insects, and were not regulated in the experimental room, these did not affect their feeding pattern and as such, could not be the main factors' affecting the insect's feeding and growth patterns. Results obtained from the analysis of data obtained showed that the nymphal stages of the grasshoppers consumed and utilized more feed for growth and development than their adult stages. Consequently, it could be inferred that the nymphal stages would constitute more serious pest problems on the vegetation they attack than the adults. Therefore, significant management of this pest can be achieved when control measures are aimed more at the nymphal stages than the adults.

Key Words: Zonocerus variegatus, feeding and growth patterns, mixed diet, nymphal and adult stages.

Introduction

The variegated grasshopper, *Zonocerus variegatus* (L) is a common grasshopper, which feeds on and defoliates a large number of crops Youdeowei (1974). In Nigeria, it is primarily associated with the forest regions but its distribution extends into the savannah where it is restricted to river habitats (Chapman *et al.,* 1986).

Z. variegatus though exhibiting preferences is polyphagous, feeding on a wide range of wild and cultivated plants. However, not all food plants eaten are adequate for its survival and development. For example, Cassava (*Manihot esculenta*) and Bitter leaf *Vernonia amygdalina* have been shown to support growth and development in *Z. variegatus* (McCaffery *et al.,* 1978., Page, 1978., Tamu, 1990). One the other hand, *Citrus spp* only supported growth while the Siam weed *Chromolaena odorata* is nutritionally inadequate although useful to them because of its secondary product (Pyrrolizidine alkaloids) which the insects sequester (Idowu, 1997).

Zonocerus variegatus not only feeds on a wide variety of plants but also appears to require a mixed diet for proper growth and development (Bernays, *et al* 1997). Thus, considerable movements between plants occur. In addition, other factors such as physical properties, nutrient quality, and water contents of plants, temperature, photoperiod, and the internal state of the grasshoppers may induce their foraging and feeding behaviours (Chapman, 1990; Lockwood *et al.*, 1996; Woods *et al.,* 1997).

This study was therefore carried out to observe the behaviour of *Zonocerus variegatus* during feeding, growth and the rate of utilization of a mixed diet

of Cassava (*Manihot esculenta*) and Siam weed (*Chromolaena odorata*) as food by their nymphal and adult instars.

Materials and Methods

Collection and Maintenance of the Insects

The early nymphal instars were collected from a crop farm inside the campus of Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. The collection was made daily between the early hours of 6 – 8am for a period of 1 month. Early instars occurred mainly on young growing *Chromolaena odorata* and *Manihot esculenta while* older ones were predominantly on older *C. odorata* plants.

The nymphs were carried in plastic cages to the laboratory where they were maintained in 5 fine wire-mesh cages (45cm x 30cm x 80cm) under natural photoperiods and room temperature and relative humidity of 29 ± 2^{0}C and (85 – 88%) respectively. Each cage contained 3 small plastic cups with moist sand at the base for oviposition by females. Each cage had 30 nymphs in them.

Experimental Procedure

A mixture of freshly cut twigs of *Chromolaena odorata* and *Manihot esculenta* were measured using an electronic weighing balance and recorded before placement into the rearing cages. This was done every 2 – 3 days. Before the insects were allowed to feed, their body length and weight measurements were taken. The placement of feed and recording of data for the insects where done independently. The leftover feed and faecal droppings were weighed and recorded in order to determine the amount of diet assimilated by the insects.

The behaviour of the insects in selecting their food was carefully noted and recorded. Temperature and relative humidity within the laboratory were equally recorded during the course of the experiment.

The observation on the feeding pattern and growth of the variegated grasshopper was carried out in the laboratory for a period of 3 months.

Statistical Analysis

Descriptive statistics was used to calculate the mean and standard error values of the parameters while Pearson's correlation analysis was used to test the relationship between them.

Results

In this study, it was noted that when the grasshopper (both nymphs and adults) were about to select their food, they usually walked over the surface of the leaves. As they moved about, they tapped the tip of their labial palps on the surface of the leaves. By doing so, they would probably be able to perceive the desirable qualities of the food before commencing to feed on it. Further observations showed that they usually took small bites of the freshly supplied leaves prior to commencement of actual feeding. It was also observed that *Z. variegatus* started active feeding early in the morning between 6 – 8am.

Although the temperature and relative humidity in the experimental room were recorded, they were not regulated. Both factors however, did not vary significantly and therefore did not appear to affect the general trend of the feeding and growth of *Z. variegatus*.

The summary of the data obtained for both nymph and adults of *Zonocerus variegatus* are illustrated in Tables 1, 2 and 3 respectively. The correlation coefficients of these parameters were shown in Tables 4 and 5. From both tables 1 and 2, it could be noted that a total of 150 first instar nymphs were initially caged, but after 2 months of observation, 52 had already died, while 98 already metamorphosed into adults. None were still juveniles.

The bivariate correlation procedure using Pearson's correlation coefficient revealed that at the nymphal stages of the insects, the mean length and body weight were significantly and positively correlated ($r = 0.942$; $P < 0.01$) [Table 4]. The mean body weight was however, significantly and negatively correlated with the weight of feed consumed (-0.956; $P < 0.01$), weight of faeces (-0.946; $P < 0.01$), and the weight of faeces per insect (-0.874; $P < 0.01$). Similarly, the mean body weight was significantly and negatively correlated with the weights of feed consumed (-0.932; $P < 0.01$), weight of faeces (-0.932; $P < 0.01$), and the weight of faeces per insect (-0.844; $P < 0.01$). The weight of feed consumed daily was significantly and positively correlated with the weight of faeces (0.971; $P < 0.01$). Also, the weight of feed consumed per insect was significantly and positively correlated with the weight of feed assimilated per insect (0.993; $P < 0.01$) [Table 4].

For the adult stages, the mean length was significantly and positively correlated with the mean body weight (0.967; $P < 0.01$), the weight of feed consumed (0.951; $P < 0.01$) and the weight of faeces (0.953; $P < 0.01$). The mean body weight was also significantly and positively correlated with the

weight of feed consumed (0.929; $P < 0.01$) and the weight of faeces (0.936; $P < 0.01$). Similarly, the weight of feed consumed per insect and the weight of feed assimilated per insect were significantly and positively correlated (0.998; $P < 0.01$) (Table 5)

Discussion

As observed in this study, *Z. variegatus* at both the nymphal and adult stages usually walked over the leaf surface on which they were to feed. As they sensed the food, they tapped its surface with the tip of their labial palps and took little taste bites of the freshly supplied leaves before full commencement of feeding. This observation agrees with similar reports by Bernays *et al* (1975) and Yang and Joern (1994). Also, the observation that *Z. variegatus* started active feeding early in the morning between 6 – 8 am was in agreement the findings of Modder (1984) which suggested that confined nymphs of the insects started active feeding in the morning at a temperature of 17^0C and extremely massive feeding later in the day at a temperature of 34^0C.

The results obtained from the correlation analysis indicated that at the nymphal stages in *Z. variegatus*, the mean body weight significantly increased as its body length increased. This should be expected in normal growth and development. At the same time, as the body weight/ body/body length increased with time, the amount of feed consumed together with the quantity of feed assimilated would drop (Table 4).

Similarly, as mean body length and weight were significantly and negatively correlated with the amount of feed consumed, it therefore suggests that small and more juvenile grasshoppers of this species would consume more foliage. This however, does not agree with the findings of Ortego *et al.,* (1996) which suggested that the older and later instars of grasshoppers would cause more defoliation to the crop vegetation on which they feed. Although Toye (1974) and Barnays *et al* (1975) reported that later instars of *Z. variegatus* were responsible for defoliation of Cassava alone, the result obtained in this study could be due to the mixed diet given to the insects (Bernays, *et al* 1997).

The positive and direct relationship between feed consumption and assimilation at the nymphal stages shows that with increasing amount of foliage consumed, the hoppers would assimilate and utilize more feed for growth and development even though a substantial amount is passed out as faeces. Nevertheless, by the time the nymphs have moulted into the adult stage, they have increased tremendously in length and now weigh heavier. At

this stage, with increased body weight, they consumed fewer amounts of feed and producing fewer faeces, thus appearing to retain less food. This would mean that the adult *Z. variegatus* required less amount of food and therefore consumed less. This finding agrees with Amorim and Adis (1994) report. The reason could be that the adults only utilized the little amount consumed for normal maintenance and not for growth and developments as nymphs.

The implication of these findings is that the young and juvenile stages of *Zonocerus variegatus* would constitute very serious defoliators on a mixed diet of Cassava (*Manihot esculenta*) and Siam weed (*Chromolaena odorata*) than their older counterparts. At the same time, the adult grasshoppers are not likely to cause any significant amount of defoliation compared to their nymphs. Thus, any attempt at controlling this import crop defoliator must be aimed more at the nymphs especially their earlier instars.

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Table 1: Measurements of the parameters used in the study of the feeding and growth patterns for the nymphal stages of *Zonocerus variegatus*

Number of days	Number of insects (N)	Number of Moulted Insects	Number of dead Insects	Mean length of insects, $l=L_t/N$ (cm)	Mean weight of insects, $w = W_t/N$ (g)	Weight of feed consumed daily, F_t (g)	Weight of faeces, E_t (g)	Mean weight of feed consumed, $f = F_t/N$ (g)	Mean weight of faeces, $e = E_t/N$ (g)	Weight of feed assimilated, $A = f - e$ (g)	Temp (^{0}C)	Relative Humidity (%)
1	150	0	0	3.20	6.40	228.68	16.78	1.52	0.11	1.41	27	86
3	150	0	0	3.20	6.60	236.19	12.80	1.57	0.09	1.49	26	86
5	145	0	5	3.25	6.50	222.50	14.50	1.53	0.10	1.43	28	87
8	142	0	3	3.31	6.80	220.85	12.78	1.56	0.09	1.47	30	87
10	142	0	0	3.35	7.20	225.20	12.38	1.59	0.09	1.50	30	86
12	130	0	12	3.38	7.50	211.40	12.66	1.63	0.10	1.53	32	86
15	130	0	0	3.38	6.70	210.88	11.00	1.62	0.08	1.54	28	87
17	116	10	4	3.40	7.90	189.45	11.10	1.63	0.10	1.54	28	87
19	108	6	2	3.41	7.20	176.30	10.38	1.63	0.10	1.54	28	89
22	98	10	0	3.43	8.40	165.82	10.66	1.69	0.11	1.58	28	89
24	93	5	0	3.44	8.00	158.55	10.19	1.70	0.11	1.60	27	87
26	79	12	2	3.47	8.70	138.00	9.43	1.75	0.12	1.63	27	87
29	57	18	4	3.51	9.50	102.53	8.98	1.80	0.16	1.64	28	86
31	51	5	1	3.53	9.90	94.85	8.55	1.86	0.17	1.69	29	88
33	45	0	6	3.56	10.20	84.80	8.25	1.88	0.18	1.70	29	87

36	30	11	4	3.59	10.80	56.41	6.44	1.88	0.21	1.67	31	87
38	26	0	4	3.63	11.40	48.96	5.17	1.88	0.20	1.68	31	89
40	26	0	0	3.63	11.90	50.54	5.49	1.94	0.21	1.73	28	89
43	10	15	1	3.72	10.70	20.11	2.40	2.01	0.24	1.77	28	87
45	5	2	3	3.75	11.60	11.44	1.25	2.29	0.25	2.04	29	87
47	0	4	1	0	0	2.50	0.10	0	0	0	28	89
Mean and Standard error		4.67 ± 1.26	2.48 ± 0.63	3.46 ± 0.04	8.70 ± 0.42	136.00 ± 17.72	9.10 ± 0.95	1.75 ± 0.04	0.14 ± 0.01	1.61 ± 0.03		

Table 2: Measurements of the parameters used in the study of the feeding and growth patterns for the adult stage of *Zonocerus variegatus*

Number of days	Number of insects (N)	Mean length of insects, l=L_t/N (cm)	Mean weight of insects, w = W_t/N (g)	Weight of feed consumed daily, F_t (g)	Weight of faeces, E_t (g)	Mean weight of feed consumed, f = F_t/N (g)	Mean weight of faeces, e = E_t/N (g)	Weight of feed assimilated, A = f - e (g)	Temp (^{0}C)	Relative Humidity (%)
17	10	3.47	8.88	20.44	3.50	2.04	0.35	1.69	28	87
19	16	3.56	9.09	28.86	5.64	1.80	0.35	1.45	28	89
22	26	3.62	10.00	45.21	6.16	1.74	0.24	1.50	28	89
24	31	3.73	11.98	56.80	6.72	1.83	0.22	1.62	27	87
26	43	3.88	13.00	74.32	6.72	1.73	0.16	1.57	27	87
29	61	4.00	14.06	104.68	9.10	1.72	0.15	1.57	28	86
31	66	4.35	14.68	113.67	8.76	1.72	0.13	1.59	29	88
33	66	4.42	13.54	115.31	11.70	1.75	0.18	1.57	29	87
36	77	4.39	14.70	128.63	8.90	1.67	0.12	1.55	31	87
38	77	4.46	14.90	130.08	9.45	1.69	0.12	1.57	31	89
40	77	4.49	15.25	131.32	11.48	1.71	0.15	1.56	28	89
43	92	4.51	15.69	154.86	11.52	1.68	0.13	1.56	28	87
45	94	4.54	16.35	155.68	12.22	1.66	0.13	1.53	29	87
47	98	4.58	16.96	160.22	12.87	1.63	0.13	1.50	28	89
Mean and Standard error		4.14 ± 0.11	13.50 ± 0.70	101.43 ± 12.79	8.91 ± 0.76	1.74 ± 0.03	0.18 ± 0.02	1.56 ± 0.02		

Table 3a: Correlation coefficient of the parameters used in the study of the feeding and growth patterns for the nymphal stages of *Zonocerus variegatus*

	No. Moulted	No. dead	Mean length/cm	Mean wt/g	Wt of feed consumed daily/g	Wt of faeces Et/g	Mean wt of feed consumed Ft/g	Mean wt of faeces Et/g	Wt assimilated
No. Moulted	1								
No. dead	-.062	1							
Mean length/cm	.097	.127	1						
Mean wt/g	.204	.124	.834**	1					
Wt of feed consumed daily/g	-.320	.025	.189	-.358	1				
Wt of faeces Et/g	-.270	.078	.295	-.216	.949**	1			
Mean wt of feed consumed Ft/g	.130	.113	.961**	.926**	-.052	.055	1		
Mean wt of faeces Et/g	.224	.092	.634**	.920**	-.598**	-.456*	.798**	1	
Wt assimilated	.109	.113	.979**	.891**	.041	.138	.995**	.733**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3b: Correlation coefficient of the parameters used in the study of the feeding and growth patterns for the adult stage of *Zonocerus variegatus*

	Mean length/cm	Mean wt/g	Wt of feed consumed daily/g	Wt of faeces Et/g	Mean wt of feed consumed Ft/g	Mean wt of faeces Et/g	Wt assimilated
Mean length/cm	1						
Mean wt/g	.946**	1					
Wt of feed consumed daily/g	.977**	.978**	1				
Wt of faeces Et/g g	.933**	.907**	.942**	1			
Mean wt of feed consumed Ft/g	-.766**	-.804**	-.807**	-.784**	1		
Mean wt of faeces Et/g	-.853**	-.922**	-.884**	-.772**	.834**	1	
Wt assimilated	-.177	-.149	-.207	-.324	.627*	.093	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: Correlation coefficient of the parameters used in the study of the feeding and growth patterns for the adult stages of *Zonocerus variegatus*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

	Mean length of insects	Mean body weight of insects	Weight of feed consumed	Weight of faeces	Weight of feed consumed per insect	Weight of faeces per insect	Weight of feed assimilated per insect
Mean length of insects	1						
Mean Body weight of insects	0.967**	1					
Weight of feed consumed	0.951**	0.929**	1				
Weight of faeces	0.953**	0.936**	0.881**	1			
Weight of feed consumed per insect	0.010	-0.061	0.149	-0.083	1		
Weight of faeces per insect	0.249	0.170	0.108	0.435*	0.190	1	
Weight of feed assimilated per insect	-0.005	-0.072	0.144	-0.110	0.998**	0.134	1