J. of Bio. Res & Biotech. 1, (2), 11-20 (July/December, 2003)

Effect of Sex, Age, Starvation and Feeding, Isolation and Crowding and Oviposition on Longevity of *Zonocerus Variegatus* (Orthoptera: Pyrgomorphidae)

W.A. Muse
Department of Zoology,
Obafemi Awolowo University,
Ile-Ife, Nigeria

ABSTRACT
The effects of starvation, feeding, sex and oviposition on the longevity of adult Zonocerus variegatus L. in isolation or in groups was investigated in the laboratory. Females lived significantly longer than males either in isolation or in groups during feeding and to some extent in starvation. Females in groups with a male-biased sex ratio lived significantly longer than females in groups with a female – biased sex ratio. Oviposition significantly reduced longevity of mated females. Decrease in weight during starvation was gradual and similar in the two sexes.

Key Words: Longevity, *Zonocerus* feeding, starvation.

INTRODUCTION

A pyrgomorphid grasshopper, *Zonocerus variegatus* (Linnaeus) is polyphagous (Modder, 1984) and frequently causes damage to the cassava plant, *Manihot esculenta* Cranz, in the form of defoliation and debarking in West and Central Africa (Page, 1978; Toye, 1982). *Z. variegatus* feeds constantly on *Manihot* leaves especially during the adult stage, and this has been reported to enhance their survival (Bernays *et al.*, 1975). King and Hopkins (1963) and Hooker *et al.* (1987) reported that adult longevity of pteromalid, *Nasonia vitripennis* (Walker) and eulophid parasite *Pediobius foveolatus* (Crawfard) were affected by body size, sex, crowding and isolation. Male and female *Z. variegatus* live for up to 15 weeks in the laboratory (pers. Obs.) which gives the spaces ample time for egg maturation, oviposition and remating. The length of life could however be reduced by male: male: male: female interactions and oviposition. Mating triggers ovarian development in several species of insects owning to transfer of sperm and/or secretions of the male reproductive system (Davey, 1985). Sex isolation also reduces risk of predation and expenditure of energy and time by males while securing mate. (Kuba and Ito, 1993). The objective of this study was to determine the possible relationships of adult longevity with such independent variables as sex, age, starvation, isolation, crowding, feeding, oviposition and mating in *Z. variegatus* and to answer the following specific questions. Is the longevity of young males and females exposed to starvation in isolation or in group, the same as old males and females similarly exposed? Do females at every age live longer than males when both sexes are similarly exposed to starvation? Does isolation enable them survive better during starvation than those maintained in groups? Is the act of oviposition deleterious to the females? To my knowledge, this is the first preliminary study that investigate isolation and crowding, starvation and feeding on the longevity of *Z. variegatus*.

MATERIALS AND METHODS

Various nymphal stages of *Z. variegatus* were collected with a sweep net at different location on Obafemi Awolowo University Campus, Ile-Ife, Nigeria between March and April, 1995. They were maintained in a cage (24 x 35 x 42 cm) at 28 $\pm$ 2^{0}C and 70 – 80% R.H. in one insectary. The insects were provided with siam weed, *Chromolaena odorata* (Linn.) King and *Manihot esculenta* shoot as food and moulting sites. Newly emerged adult males and females were removed from the cages, marked variously on the pronotum with an indelible marker and put in different cages (35 x 35 x 80 cm) according to sex.

Effect of starvation, isolation, crowding and sex on longevity: Males and females at age 0 (newly emerged adult), 7, 14, 21, 28, 35, 42, 49, 56, 63 or 70 days were kept without food in isolation in small cages (12 x 12 x 12 cm). Another groups of five males and five females each were kept in large cages (20 x 20 x 20 cm). They were checked daily at 0900 and 1700 hours for mortality. Assays where cannibalism were detected were discarded.

Weight changes of starving males and females. In order to determine the changes in weight during starvation, males and females each at 0 (newly emerged adult), 7, 14, 21, 28, 35, 42, 49, 56, 63, or 70 days were kept without access to food in separate cages (20 x 20 x 20 cm) according to sex. They were put in a specimen bottle each (25ml capacity) and weighed on a Mettler balance every 24 hours until they died.

Longevity of males and females kept separately in group and maintained on *Manihot* shoot. Fourteen-day-old males and unmated females (10 each) were separately kept with *Manihot* shoot in cages (20 x 20 x 20). Ten mated females of the same age were maintained in another cage as control. They were examined daily for mortality.

Effect of oviposition on longevity. Five pairs of males and females were held with *Manihot* shoot in a cage (20 x 20 x 20 cm). Three cups (180 ml capacity) filled with moderately moist sand were put in the cage as oviposition sites. Five pairs of males and females were similarly kept without sand cups as controls. The cages were checked daily for mortality and oviposition.

Effect of sex ratio on longevity. Five 21-day-old females were kept in a cage (20 x 20 x 20 cm) with a male of the same age. Five males and one female were similarly kept together. They were maintained on *Manihot* shoot and checked daily for mortality. This experiments were repeated three times.

The data obtained were analyzed using the Kruskal-Wallis test, the Mann-Whitney U test, the student t-test, ANOVA, and Tukey multiple comparisons.

RESULTS AND DISCUSSION

Effect of starvation, isolation, crowding and sex on longevity:

Longevity was minimum for starved day 0 (newly emerged) insects (range, 4 – 6 d) except for females in group which survived for 10.6 ± 1.32 (range, 6 – 14 d) (Table 1). This is expected since bulk of food consumed by the last nymphal instar would have been used for the formation of adult structures resulting in poor responses of newly ecdysed adults to starvation. Longevity of males kept in isolation were less than those of females similarly kept, but the differences between the two sexes in isolation were not significant, except for adults transferred at days 14, 35 or 70 (U-test, $p < 0.05$). Similarly, males kept in groups survived less than females similarly kept, but the difference in longevity was significant only for those starved at days 0, 14, or 56 (U-test $p < 0.05$). Generally, females exposed to starvation lived longer than males, whether in isolation or in group. Studies with females cockroaches showed that they have the ability to withstand starvation longer than males (Barcay and Bennett, 1991). Males are generally more active than females and therefore sequester energy reserves more than the females, making food deprivation more disadvantageous to males than to the females. There was no significant difference in the longevity of males kept in isolation and those kept in groups. This was similarly observed for females, although a significant difference was observed for those at age 0 (newly emerged) 56, and 70 day-old (U-test, $p < 0.05$). Interaction among males and females separately kept in group did not affect longevity at starvation. Longevity of males and females at 7, 14, 21, 28 and 35 d were not different from those at ages 42, 49, 56, 63 and 70 d either in isolation or in group. This suggests that food consumption and therefore energy reserves and activity are same in young and old adults. The effects of starvation and rearing density on longevity in males and females throughout the experimental period were compared using an analysis of variance test (ANOVA). The age of transfer to starving condition affected longevity significantly for males in isolation ($F = 5.06$, df = 10, 44, $p < 0.05$), females in isolation ($F = 3.76$, df = 10, 44, $p < 0.05$) males in group ($F = 3.77$, df = 10, 44, $p < 0.05$) and females in group ($F = 3.24$, df = 10, 44, $p < 0.05$). Table 2 showed that individuals, probably due to their physiology, react differently to starving condition at every age and also independent of isolation or crowding conditions.

Table 1: Comparison of longevity (mean ± S.E.) under starvation between males and females kept in isolation and in group.

Treatment of individuals	Age*	Sex	Longevity* (days) x ± (S.E)	Mann-Whitney U-test U-values	Mann-Whitney U-test P
a) Isolated	0 (newly emerged)	M	5.3 ± 0.49		
		F	6.2 ± 0.49	9.5	0.5300
	7	M	8.4 ± 0.51		
		F	11.6 ± 1.96	5.0	0.1172
	14	M	7.6 ± 2.20		
		F	17.6 ± 2.58	2.0	0.0283
	21	M	18.8 ± 2.45		
		F	21.6 ± 3.13	10.0	0.6015
	28	M	9.8 ± 1.11		
		F	21.6 ± 3.26	4.5	0.0947
	35	M	9.8 ± 1.82		
		F	20.8 ± 2.43	2.0	0.0283
	42	M	12.0 ± 1.45		
		F	13.0 ± 1.84	9.0	0.4547
	49	M	11.2 ± 2.21		
		F	14.2 ± 2.70	10.0	0.6015
	56	M	16.0 ± 1.80		
		F	16.2 ± 1.41	11.0	0.754
	63	M	11.2 ± 2.22		
		F	18.2 ± 2.72	4.5	0.0947
	70	M	15.4 ± 0.81		
		F	19.0 ± 1.15	1.5	0.0216
b) In group	0 (newly emerged)	M	4.0 ± 1.22		
		F	10.6 ± 1.32	2.0	0.0283
	7	M	8.0 ± 0.83		
		F	11.8 ± 1.24	3.5	0.0601
	14	M	11.2 ± 0.97		
		F	16.4 ± 1.56	2.0	0.0283
	21	M	13.4 ± 1.62		
		F	17.8 ± 1.59	6.5	0.2101
	28	M	11.4 ± 0.97		
		F	15.2 ± 2.72	6.5	0.2101

35	M	12.6 ± 2.72		
	F	18.4 ± 3.30	7.5	0.2963
42	M	11.6 ± 1.83		
	F	13.2 ± 1.88	11.5	0.8345
49	M	14.8 ± 1.62		
	F	17.8 ± 2.25	5.0	0.1172
56	M	14.4 ± 1.08		
	F	22.6 ± 0.60	0	0.009
63	M	13.8 ± 2.43		
	F	17.6 ± 1.03	6.0	0.1745
70	M	11.2 ± 1.93		
	F	12.0 ± 2.02	10.5	0.6761

- means are based samples of five individuals
- Age at transfer to starving conditions.

P < 0.05

Table 2: Longevity (mean ± S.E.) under starving conditions in males and females <u>Z. variegatus</u> kept separately in isolation or in group.

* Age of transfer to starving conditions	Longevity* (mean ± S.E.) days			
	Isolation		Group	
	Male	Female	Male	Female
0 (newly emerged)	5.3 ± 0.49b	6.2 ± 0.49b	4.0 ± 1.22b	10.6 ± 1.32b
7	8.4 ± 0.51c	11.6 ± 1.96a	8.0 ± 0.83a	11.8 ± 1.24a
14	7.6 ± 2.28d	17.6 ± 2.58a	11.2 ± 0.97a	16.4 ± 1.56a
21	18.8 ± 2.45e	21.6 ± 3.13c	13.4 ± 1.62b	17.8 ± 1.59a
28	9.8 ± 1.11a	15.2 ± 3.26a	11.4 ± 0.97a	15.2 ± 2.72a
35	9.8 ± 1.82a	20.8 ± 2.43d	12.6 ± 2.72a	18.4 ± 3.30a
42	12.0 ± 1.65a	13.0 ± 1.84a	11.6 ± 1.83a	13.2 ± 1.88a
49	11.2 ± 2.21a	14.2 ± 2.70a	14.0 ± 1.62c	17.8 ± 2.55a
56	16.0 ± 1.81f	16.2 ± 1.41a	14.4 ± 1.08d	22.6 ± 0.60c
63	11.2 ± 2.22a	18.2 ± 2.72a	13.8 ± 2.43e	17.6 ± 1.08a
70	15.4 ± 0.81g	19.0 ± 1.15e	11.2 ± 1.93a	12.0 ± 2.02a

Different letters (a, b, c, d, e, f and g) in the columns indicate a significant difference in the mean longevity of males and females at 5% (TUKEY multiple comparisons).
* Insects were maintained on <u>Manihot</u> shoot before transfer.

Changes in weight of starving males and females.

Males and females progressively decreased in weight with increase in duration of food deprivation (Figs. 1 & 2). An estimate of the slope of the percent change in weight of starving females and males approximate 2.9% and 3.3% loss in weight per day respectively during exposure, showing that loss in weight of females and males are positively correlated ($r = 0.94$, $p < 0.0001$). The pattern of decrease was similar for males and females. It seems that energy was similarly depleted in males and females *Z. variegatus* during starvation indicating that weight loss in males and females was independent of age and sex in the insects.

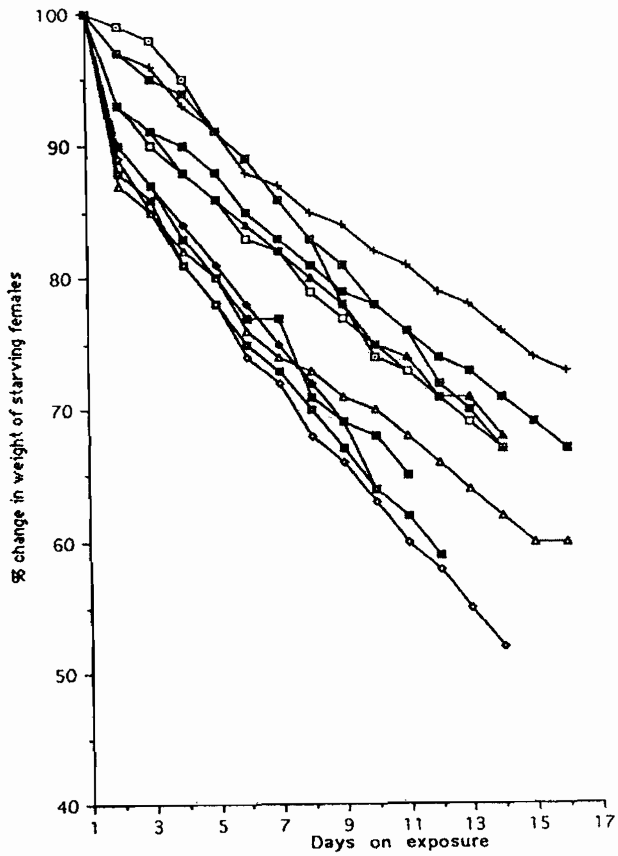

Fig. 1 Daily changes in weight of starving females of Zonocerus at different ages (days). ( ) 0; ( ) 7; ( ) 14; ( ) 21; ( ) 28; ( ) 35; ( ) 42; ( ) 49; ( ) 56; ( ) 63; ( ) 70.

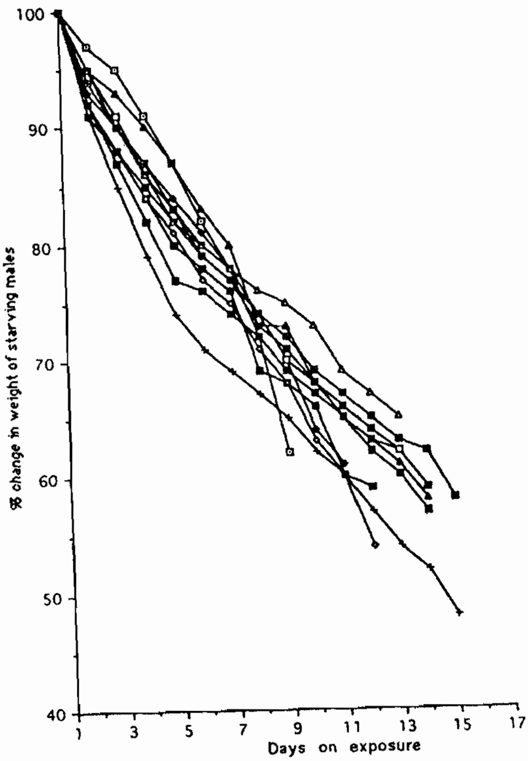

Fig. 2 Daily changes in weight of starving males of Zonocerus at different ages (days). (□-□) 0; (◆-◆) 7; (■-■) 14; (◇-◇) 21; (■-■) 28; (□-□) 35; (▲-▲) 42; (△-△) 49; (■-■) 56; (+-+) 63; (▣-▣) 70.

Longevity of fed males and females in groups

There was no significant difference in longevity among males, unmated and mated females (Kruskal Wallis test, $p > 0.05$) (Table 3). Unmated female *Z. variegatus* lived significantly longer than males ($t = 2.97$, $df = 9$, $p < 0.05$) and there was a significant difference in longevity between mated and unmated females ($t = 6.102$, $df = 9$, $p < 0.05$) Landa (1960) cited by Leopold (1976) observed that resorbed spermatophores were responsible for better physiological condition, including provision of food and increased fat body in mated versus virgin female *Melolontha melolontha* (L.). Boggs and Gilbert (1979) suggested that male material may contribute to female somatic maintenance with a possible effect on longevity of *Danaus plexippus* (L.), *Heliconius hecale* (L.) and *H. erato*. Spermatophore has not been reported in this species of grasshopper but the spermatozoa transferred to female contain larger quantity of nutrients (Gwynne, 1984; Sakaluk, 1985) and was probably responsible for increase in longevity of mated females.

Table 3: Longevity of fed males and females in groups

Rearing condition	N	Longevity (x ± S.E.) days	Range, Days
Males only	10	139.5 ± 6.48	105 – 172
Females only	10	142.7 ± 6.71	95 – 174
Mated female	10	150.1 ± 10.95	95 – 188

Table 4: Relationship between sex ratio and longevity of male and female

Sex ratio	Longevity (x ± S.E.) days	Range, days
5 males + 1 female	Male: 86.2 ± 4.88	48 102
	Female: 123.0 ± 20.08	119 – 126
1 male + 5 females	Male: 94.0 ± 2.66	89 – 98
	Female: 107.0 ± 2.55	90 - 115

Oviposition and Longevity

Females maintained with males but without access to oviposition substrate [166.0 ± 5.97 (S.E.), range, 150 – 185 d)] lived longer than females maintained with males and provided with oviposition substrate [(133.80 ± 4.30 (S.E.), range, 122 – 140 d)] (U-test, $p < 0.01$). Chapman *et al.* (1979) reported that relatively few *Z. variegatus* survived to lay a second egg pod in the field. Mortality was very high after the first oviposition owing to stress of oviposition activity involving the stretching of abdominal segments (Chapman and Page, 1979). Legaspi *et al.* (1987) also reported ovipositor pumping behaviour, and elongation and contraction of abdomen during oviposition in *Goniozus triangulifer* (Kieffer). These processes accompanying oviposition, including digging in *Z. variegatus* may contribute to decrease in the life span of properly ovipositing female *Z. variegatus*. The absence of oviposition substrate, however did not prevent gravid females from laying eggs on the sides and floors of the cage.

Sex ratio and Longevity

A significant difference was observed in longevity between sexes in either of the sex ratio groups (Kruskal Wallis test, $p < 0.0003$ (Table 4). Females of the "five males: 1 female" ratio lived significantly longer than females of the "1 male: 5 females" ratio (U-test, $p < 0.05$). The single female group was frequently mated than the five females group which was probably responsible for difference in their longevity as suggested by Boggs and Gilbert (1979). Mclain *et al* (1990) reported that longevity was significantly correlated with the number of copulations in *Nezara viridula* (L.).

Male from the "1 male: 5 females" ratio (n = 3:15) lived significantly longer than males of the "5 males: 1 female" ratio (n = 15:3) (U-test, $p < 0.05$). Interaction among males in the male-biased sex ratio seems to have significant effect since males have to compete for the female, resulting in dissipation of energy as a result of fighting which therefore resulted in decrease longevity compared to the male in isolation with females. Longevity of females was significantly longer than males in the 1 male: 5 females ratio and in the 5 males: 1 female ratio (U-test, $p < 0.05$). Generally, females live longer than males. However, more experiments are needed to confirm these generalizations and suggestions on sex ratio, longevity and effects of other factors for more understanding of the biology of *Z. variegatus*.

REFERENCES

Barcay, S.J. and Bennett, G.W. (1991). Influence of starvation and lighting on the movement behaviour of German Cockroach (Blattodea; Blattelidae) *J. Econ. Ent*, 84; 1520 – 1524.

Bernays, E.A., Chapman, R.F., Cook., A.G. McVeigh, J. and Page, W.W. (1975). Food plants in the survival and development of *Zonocerus variegatus L. Acrida*, 4; 33 – 45.

Boggs, C.L. and Gilbert, L.E. (1979). Males contribution to egg production in butterflies: Evidence of transfer of nutrients at mating. *Science,. 206*; 83-84.

Chapman, R.F. and Page, W.W. (1979). Factors affecting the mortality of the grasshopper, *Zonocerus variegatus* in the Southern Nigeria. *J. Anim. Ecol., 48*; 271 – 288.

Chapman, R.F., Page, W.W. and Cook, A.G. (1979). A study of population changes in the grasshopper, *Zonocerus variegatus* is Southern Nigeria *J. Anim. Ecol., 48;* 247 –270.

Davey, K.G. (1985). The female reproductive tract. In: Comprehensive Insect Physiology, Biochemistry and Pharmacology (Edited by Kerkut G.A. and Gilbert (L.I.) pp 15 – 36. Pergamon Press Oxford.

Gwynne, D.T. (1984). Courtship feeding increases female reproductive success in bushcrickets. *Nature, 307*; 361 – 363.

Hooker, M.E., Barrows, E.M. and Ahmed, S.W. (1987). Adult longevity as affected by size, sex and maintenance in isolation or groups in the parasite, *Pediobius foveolatus* (Hymenoptera: Eulophidae). *Ann. Ent. Soc. Amer., 80;* 655 – 659.

King, P.E. and Hopkins, C.R. (1963). Length of life of the sexes in *Nasonia vitripennis* (Walker) (Hymenoptera: Pteromalidae) under condition of starvation. *J. expt. Biol., 40;* 751 – 761.

Kuba, H. and Ito, Y. (1993). Remating Inhibition in the melon fly, *Bactrocera cucurbitae* (Diptera: Tephritidae): copulation with sperm less males inhibit female remating. *J. Ethol. 11*; 23 – 28.

Legaspi, B.A.C., Shepard B.M. and Almazan L. P (1987). Oviposition behaviour and development of *Goniozus triangulifer* Kieffer (Hymenoptera: Bethylidae). *Environ. Entom., 16*; 1283 – 1286.

Leopold, R.A. (1976). The role of male accessory glands in insect reproduction. *Ann. Rev. Entomol., 21;* 199 –222.

Mclain, D.K., Lanier D.E. and N.B. Marsh (1990). Effects of females size, mate size and number of copulations on fecundity, fertility and longevity of *Nezara viridula* (Hemiptera: Pentatomidae). *Ann. Ent. Soc. Amer., 83*; 1130 – 1136.

Modder, W.W.D. (1984). The attraction of *Zonocerus variegatus* to weed *Chromolaena odorata* and associated feeding behaviour. *Bull. Ent. Res., 74*; 239 –247.

Page, W.W. (1978). The biology and control of the grasshopper *Zonocerus variegatus* L. *PANS, 24(3);* 270 – 277.

Sakaluk, S.K. (1985). Spermatophore size and its role in the reproductive behaviour of the cricket Gryllodes suplicans (Orthoptera: Gryllidae). *Can. J. Zool., 63*; 1652 – 1656.

Toye, S.A. (1982). Studies on the biology of the grasshopper pest, *Zonocerus variegatus* L. (Orthoptera: Pyrgomorphidae) in Nigeria. 1911 – 1981. Insect Sci. and *Appli.*, 3(1): 1-7.