LIFE CYCLE AND MORPHOMETRIC STUDIES OF VARIEGATED GRASSHOPPER, *ZONOCERUS VARIEGATUS* (LINNAEUS, 1758)

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ABSTRACT: Morphometric analysis of the external parts and the alimentary canal as well as the stadia time of each post embryonic developmental stage of variegated grasshopper, *Zonocerus variegatus* was carried out. Data collected included body weight, length of pronotum, prothoracic leg, mesothoracic leg, metathoracic leg, antenna, whole body and gut. The result of the study showed that the size of the measured parts and the body weight of the insects increased progressively during the post embryonic development. There was a strong positive relationship between the body length and body weight (0.858) on one hand and between the body weight and antenna length (0.952) on the other hand. The body weight and body length slope between 1st – 5th instar was less than the slope between the 6th instar and adult stage. There were six nymphal stages and adult stage for the insect. The number of days spent in lower instars was less than those spent in higher instars. The nymphal periods were 7.0, 7.6, 10.0, 19.1, 20.5 and 46.9 days respectively for 1st - 6th instars. The total days spent in adult stage ranged between 101.9-127.9 days. The relevance of this information in the understanding of *Z. variegatus* behavior and possible control was discussed.

KEY WORDS: *Zonocerus variegatus,* stadial time, morphometrics, pest control.

The variegated grasshopper *Z. variegatus* is a polyphagous pest found in the forest and Savanna zones of central and West Africa (Chiffaud & Nestre, 1990). The increasing impact of *Z. variegatus* as observed today in fields is a result of deforestation and increase in surface of herbaceous fallow. The damage caused by this pest is higher in fields adjacent to *Chromolaena odorata* and herbaceous fallow than in those adjacent to forest as shrubby fallows (Kekeunou et al., 2006).

There usually six nymphal stages (Youdeowei, 1974), but Jerath (1965) recorded as many as eight or nine nymphal stages. Chapman et al. (1977) however, recorded a total of five nympal stages. Nymphal development is completed in 3-4 month and reversal of the wings occur in the fifth instar. After the final moult, the newly emerged adult rests for 2-3 hours to permit the wing and cuticle to harder before it begins to feed. Adult begin to copulate when they are 2-3 weeks old and female begin to lay eggs when they have mated 2 or 3 times.

The life cycle of *Z. variegatus* occupies a full year with two populations: a dry season population (Nov.-March) and a wet-season population (April–October). The early instars of development of *Z. variegatus*, that is the 1st - 3rd instars have different characteristics from the other later instars, that is the 5th - 6th and the adult. While the 1st - 3rd instars are closely – packed (aggregation), the later instar are more dispersed (Modder, 1986). Similarly while 1st – 3rd instars survive on weeds as *C. odorata* and *Aspilia africana* (Toye, 1982), the later instars prefer *Manilot esculenta* (Chapman et al., 1986).

It is obvious from literature that it would be more convenient and economical to direct control operations to the usually conspicuous aggregated nymphs, 1st – 3rd instars. However in other to do this effectively, the stadial time of each instar stage should be known which is not available in the literature. Also, our control strategies will be handicapped without a comprehensive knowledge of the biology of the insect which morphometrics are part of. The aim of this work is to carry out morphometric analysis and determine stadial period of each instar stage of *Z. variegatus* body parts during post embryonic development of the insect.

MATERIALS AND METHODS

A known oviposition site for adult of *Z. variegatus* at uncultivated farm on Campus of University of Agriculture, Abeokuta (UNAAB) was marked and monitored until first instars nymphs were hatched. The insects were caught with insect sweep net and later transferred to the Insectaria in Department of Biological Sciences, UNAAB. The insect were reared in wire cages (30 x 30 x 45 cm) and fed daily fresh leaves of *Chrolaena odorata* and *Manilot esculenta*. Twenty first instar nymphs were collected from the stock of insects and were used for this experiment. Readings were taken on the developmental periods for every instar. After the emergence of the adult, one male and female were placed in another cage that has five 1.25 m plastic jar filled with soil to one-fifth of its capacity to serve as oviposition site. Five such pairs were set up and fed *ad libitum* with *M. esculenta*. They were maintained until they all died.

In the morphometrics studies, as each developmental stage emerged, 30 insects each of all the nymphal stages (1^{st} – 6^{th} instars) and male adults (female insects were excluded from this study because of variations in their structures in the 6^{th} and adult stages of development due to reproduction processes) were immobilized in a dessicator containing chloroform soaked cotton wool. Measurements on the following parts were taken under a dissecting microscope: Pronotum, Mesothoracic leg, Prothoracic leg, metathoracic leg, antennae, whole body length and gut length. The body weight was taken by a sensitive weighing balance (Mettler-PM11-K). For the measurement of the gut the insects were dissected as described by Youdeowei (1974) and the whole gut was removed carefully with the aid of forceps.

A comparison of mean of all the data was subjected to ANOVA and Duncan multiple range as illustrated by steel and Torries (1990) Regression analysis was also used to determine the relationships between the measured part.

RESULTS

The measurements of the body parts examined are shown in Table 1 below. There was a progressive increase in the sizes of the pronotum, prothoracic leg, mesothoracic leg and metathoracic leg.Regression analysis showed a strong positive relationship between the body weight and the length of the antenna (0.952) as well as between the body weight and the whole body length (0.858). There was a significant difference ($P<0.05$) in the sizes of the antennae, body length, prothoracic legs, mesothoracic legs, and metathoracic legs during post embryonic development. Similarly, the size of the gut was steadily increasing from the 1^{st} instar to the adult.

The body weight and body length showed a two phase relationship (Figure 1), the slope of 1^{st} – 5^{th} instar was less than those of later instar 6^{th} and adult.

Examination of the instars showed that there were six instar stages and adult stage. Figure 2 shows in percentage the stadial time of each nymphal stage during the life cycle. Statistical analysis showed that there was a significant difference in the developmental periods (stadial time) across the post embryonic development.

It can also be seen from figure 2 that relatively fewer days were spent on lower instar stages than the higher instars. Furthermore, correlation analysis revealed a strong positive relationship between the stages of development and stadial time (0.6015).

The total number of days spent for nymphal development was 111.1 ± 0.02 while the total days on adult stage for male and female were 101.2 ± 0.32 and 127.9 ± 0.22 respectively, hence the total life cycle of *Z. variegatus* was between 210.8 and 237.5 days (Table 2). The breakdown of days spent by the adult stage showed that after emergence, 68.9 days were spent before copulation began and mating duration was for 10.9 days. 16.8 days were used for oviposition and the insect further lived 31.3 days before death (Table 2).

DISCUSSION

There was a progressive increase in the size of all the parts measured as the insect ages during the post embryonic development. A similar finding was recorded by Chapman et al. (1977) that the sizes of appendages of *Z. variegatus* (L.) increased during development. Clarke & Richards (1976) likewise reported that the growth in locust is rapid and as the insect undergoes molting, there is an increase in body parts. The positive strong relationship between body weight and body length and between body weight and antenna length means that one is a good indication of the other. Idowu (1995) likewise found that a good/strong relationship existed between the body size and the size of the repellent gland.

The slope of body weight and body size from 1^{st} – 5^{th} instars was less than that from 6^{th} to adult. This is not unexpected as the adult stage is the main stage where sexual maturity is reached and this involves development of additional structures and for these to be accommodated, there must be a commensurate increase in the size of the adult stage. Anya (1973) opined that in variegated grasshopper there is much more pronounced development of reproductive structures in adults than other instars. Chapman (1980) established that in the development of hemimetabolus insects, the degree of change from last instar to adult varies considerably and may be marked.

The gradual increase in the gut length corroborates Ademolu & Idowu (2011) observation that there was increase in the microbial load of *Z. variegatus* gut as it molts from 1^{st} instar to the adult stage. The increase in the length is necessary probably in order to accommodate the increase in food consumption during the post embryonic development.

The length of antenna was progressively increasing from 1^{st} instar to adult stage. This observation may likely explain the gregarious behaviour of the lower instars (1^{st} – 3^{rd}) and the dispersing character of the 5^{th} instar to adult as reported by Toye (1982). The difference between prothoracic leg and mesothroacic leg means was not statistically different ($P>0.05$), however, there was a significant difference between mesothoracic and metathoracic legs. This might likely be explained in terms of their functions. While prothoracic leg and mesothoracic leg are both sets of walking legs, metathoracic legs are for hopping in prygomorphs (Chapman, 1980).

It can be observed from this study that body parts and gut length of *Z. variegatus* was increasing as the insect advanced in age, which became more pronounced in 6^{th} to adult stage, thus increasing in complexity. Interestingly, the concentration of tissue metabolites increased as the insect moult from the first instar to the adult stage of development (Ademolu et al., 2007). It is thus advisable to launch control attacks on the early instars that are physiologically less complicated.

The number of instars recorded for *Z. variegatus* in this study was six and this is in agreement with the findings of Chapman et al. (1986) and Toye (1981). The stadial time of lower instars (1st -3rd) was much lower than those of the higher instars (4th-6th) and adults. The time required for the development of structures especially in the adult stage might necessitate the longer stadial time. During the development of lower instars, the only changes involved are increases in the body length and weight (Borror et al., 1989). However, the stage between 6th and adult stage is for preparation for reproduction activities which are the major concern of the adult stage.

Correlation analysis revealed a strong relationship between the stages and the stadial time. Oke (2004) recorded similar observation for *Neochetina eichhorcae*, that is, as the ages of the insect increases, the stadial time also increases. After the emergence of the adult, sixty-eight days lapsed before mating activity started. This is likely due to the non-maturation and non readiness of the reproductive organs and structures. Richards & Davies (1984) reported that after emergence, the adult hemimetabolus insect spent some days before reproductive activities commence during which the gonads and accessory organs attain their full size and become functional.

Female adult *Z. variegatus* lived for another 31.3 days after the oviposition exercise, while the male spent 32.3 after mating. This observation is in deference or contrary to what happen in *Cerasus auratus* where the female is known to eat the male after mating and female also passes away after oviposition process. Post mating time or life is used by the males to assist the females in finding and selecting the oviposition site for the laying of the eggs for the next generation (Chapman, 1980).

The total stadium for the adult male and female were 101.2 and 127.9 days respectively. This agrees with Muse (2004) observation that laboratory reared adult *Z. variegatus* spent 3-4 months. The total life cycle of the insect covered 210.8-237.5 days and this is not contrary to observation of Toye (1981) and Messi (2006). This relative long life span compared to other insects afford the *Z. variegatus* to have two have two populations in a year. The adult of one population will still be on the field when the first instar of the second population will emerge. This phenomenon makes the insect to be available on the field all the year round as reported by Youdeowei (1974) and Modder (1986).

This information will be of particular interest to crop protection agents and farmers. The knowledge of the stadial time of each developmental stage of *Z. variegatus* will help to determine the exact time to administer control strategies. It is noteworthy that the lower instars (1st – 3rd) that are easier to control because of their simplicity (Ademolu & Idowu, 2006) and gregarious habit (Toye, 1981) spend very few days on this stage.

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Table 1. Mean Length (±s.e) of nymphs and adults of *Zonocerus variegatus* during post embryonic development (cm) (n= 30).

STAGES	ANT	PNT	PTL	MSL	MTH	GTH
1ST	0.19±0.12^{c}	0.10±0.01^{c}	0.36±0.02^{b}	0.46±0.01^{c}	1.13±0.01^{c}	0.86±0.01^{b}
2ND	0.27±0.01^{c}	0.11±0.01^{c}	0.50±0.01^{b}	0.54±0.01^{c}	1.16±0.01^{c}	0.89±0.02^{b}
3RD	0.29±0.01^{c}	0.17±0.01^{c}	0.58±0.02^{b}	0.64±0.01^{c}	1.54±0..01^{c}	0.90±0.01^{b}
4TH	0.45±0.01^{c}	0.26±0.01^{b}	0.75±0.01^{b}	0.78±0.01^{b}	1.70±0.03^{c}	0.98±0.03^{b}
5TH	0.54±0.01^{c}	0.34±0.01^{b}	0.80±0.02^{a}	0.88±0.01^{b}	2.28±0.02^{b}	1.05±0.01^{b}
6TH	0.85±0.03^{b}	0.44±0.04^{b}	1.04±0.04^{a}	1.12±0.03^{b}	2.78±0.06^{b}	1.95±0.04^{a}
ADULT	1.73±0.06^{a}	0.95±0.04^{a}	1.88±0.04^{a}	1.93±0.03^{a}	4.37±0.09^{a}	2.64±0.02^{a}

Mean values in same column having different superscript are significantly different ($p<0.05$)
ANT-ANTENNA, PNT-PRONOTUM, PTL-PROTHORACIC LEG, MSL-MESOTHORACIC LEG, MTH- METATHORACIC LEG., GTH-WHOLE GUT LENGTH.

Table 2. Breakdown of days spent on adult stage.

PRE MATING DAYS	MATING DAYS	OVIPOSITION DAYS	LONGEVITY	TOTAL
68.9±0.01	10.9±0.14	16.8±0.07	31.3±0.51 (32.3±0.02)	127.9±0.02 (101.2±0.32)

Values in ( ) are for male adult

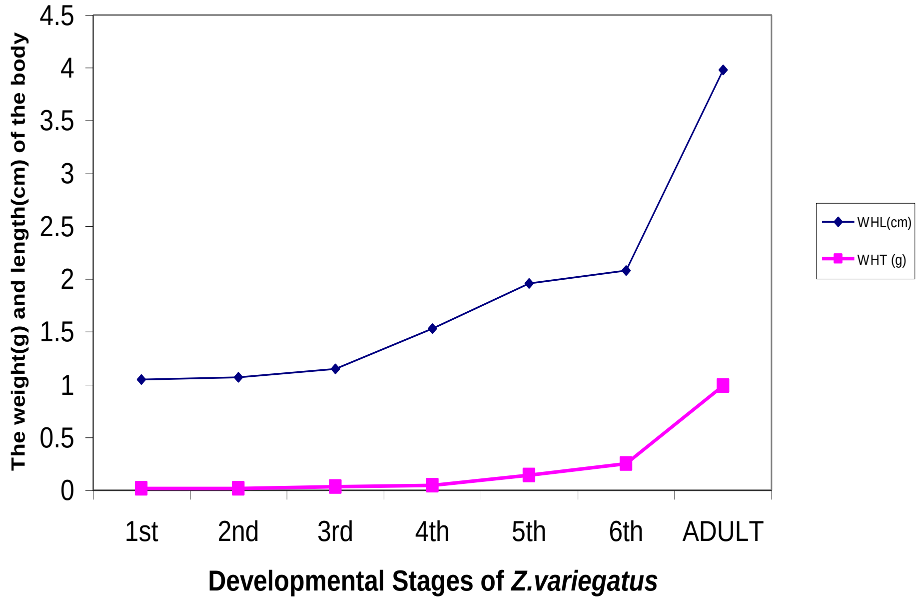

Figure 1. Growth relationship of *Z. variegatus* as indicated by body length and weight.

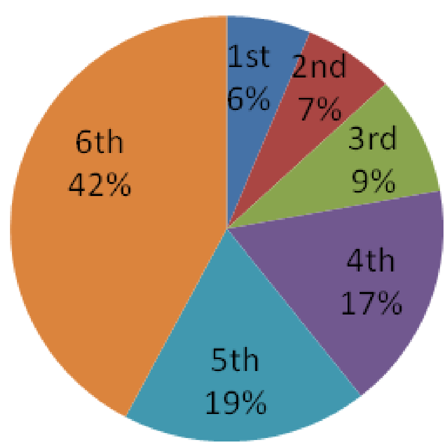

Figure 2. Stadial time for nymphal developmental stages of *Z. variegates*.