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Research Article

LIFE HISTORY STATISTICS AND COMPARATIVE MORPHOMETRIC ASSESSMENT OF RICE GRASSHOPPER, *OXYA JAPONICA* (ORTHOPTERA: ACRIDIDAE)

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ABSTRACT

The present study describes the stadial time and comparative morphometric variations of each post embryonic developmental stage of rice grasshopper, *Oxya japonica*. Measurements of body parts including total body length, antennal length, pronotum length, pronotum width, head length, prothoracic leg, mesothoracic leg, metathoracic leg, abdominal length, abdominal width and hind femur length of instar stages and adult male and female hoppers were made. Statistical analysis of the measurements revealed a progressive increase and significant differences in the morphology of various instars and adults. The study on the growth and development revealed that *O. japonica* is a highly fertile species and its fecundity is affected by various abiotic factors. The number of instars recorded in the present study was five. The stadial time of lower instars (first to third) was much lower than those of the higher instars (fourth and fifth) and adults owing to the rapid development of early instars. A strong relationship between the stages and the stadial time was observed in correlation analysis. The average pre-oviposition period, average oviposition period and average post-oviposition period was recorded to be 6.2±0.50, 18.14±0.07 and 4.98±0.31 days, respectively. The average longevity of male and female was 36.4±0.52 and 38.84±0.15 days, respectively. The information is pivotal for the understanding of *O. japonica* behaviour and for devising various control strategies against it.

Keywords: Fecundity, Longevity, Oviposition, *Oxya japonica*.

INTRODUCTION

The rice grasshopper, *Oxya japonica*, an oligophagous insect pest, is widely distributed throughout Asia, Africa, Northern Africa, and Algeria. As the name suggest, rice grasshopper usually feeds on a few graminaceous species including rice, the main staple food for most people of the Asian countries as it is an important source of carbohydrates and is considered as one of the most important agricultural pests causing reduced crop yield (Hollis, 1971). Notably, the rice grasshopper can also be found infesting different grasses in the natural wetlands. Due to the great damage caused by *Oxya japonica* to rice fields, different kinds of pesticides are being used for its control in many areas.

Life history of different species of Orthoptera was studied in the laboratory as well as field conditions by various workers (Roffey, 1979; Sharma & Gupta, 1996), however, information on the biology of *Oxya japonica* (Thunberg) commonly found in the grass and paddy fields of Kashmir region and elsewhere are only briefly reported in the literature. As reported by Dempster (1963) various grasshopper species compete with humans for different plant resources all over the world and often cause extensive damage to crops invading cropping areas in swarms of millions of individuals leaving behind devasted fields and plantations. For their aggressiveness, gregariousness and swarm forming behavior the grasshoppers are generally termed as 'locusts'. Destruction of rice by grasshoppers is a major factor responsible for low level of agricultural output in many tropical countries. For managing such pests, information on biology is essential and the stadial time of each instar stage should be known which is not available in literature. Also, without a comprehensive knowledge of the biology of the insect, which morphometrics are part of; the control strategies would be ineffective. However, in order to do this effectively, the stadial time of each instar stage should be known which is not available in literature.

The geometric morphometrics technique is regarded as an effective tool for analyzing external morphology related phenotypic variations among organisms (Roth and Mercer, 2000). Effect of various host plants on morphometry and

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fecundity of *Z. variegates* was studied by Chikwuma (2010). Cisneiros *et al*. (2012) described morphometric variations in the grasshopper, *Chromacris speciosa* from two localities in the state of Pernambuco, Brazil. Owing to the paucity of information on the biology and morphometrics of *Oxya japonica*, the present study is aimed to work out the life history and to access the nature and extent of morphometric variations in the post embryonic instar stages and the extent of sexual dimorphism in the adults. The study would be instrumental in understanding and devising population management strategies to avoid any possible future outbreak.

MATERIAL AND METHODS

Stock culture

Mature adult grasshoppers and various immature nymphal stages of *O. japonica* were mostly collected from cultivated rice fields and other surrounding vegetation of grasses from different climatic zones of Kashmir province, during months of May-September in the year 2013-14. The insects were caught with insect sweep net and were mass reared in cages measuring 112×82×82 cm, which served as the stock culture. Green leaves of *Andropogon sp.* were clipped and placed into 50 ml conical flask filled with water. The front side of the cage was made of glass while the opposite side was made of wire mesh, to provide the necessary photoperiod and aeration to hoppers, respectively. The other two opposite sides were made of wood, fitted with windows for cleaning the floor, transferring the insects and clearing the grasses. The floor of the cage was made of wire mesh provided with six metallic tubes, measuring 11cm in length and 3 cm in diameter, filled with moist sterilized sand which provided pseudo earth for oviposition. The cages were thermostatically control by the temperature apparatus. Each cage was provided with a number of plant twigs for perching, moulting and for basking. The humidity of the cage was maintained by placing petridish containing moist cotton in the cage.

Studies on life history

Eggs taken from the stock culture were kept on the moist cotton bed in petridish for observing the incubation period. Immediately after emergence, each nymph was transferred to fresh tender shoot of *Andropogon sp.* kept in glass jars measuring 15×5 cm individually and fed twice per day at a temperature of 30°C with 65±5 % RH. Total nymphal durations were recorded for each instar based on moulting and mortality. The adults were identified as male and female by examining their abdomen as the abdomen of female was slightly larger than that of the male. A pair of adults was released in each glass jar covered with muslin cloth and secured with rubber band. The jars were maintained at 30°C and 65% relative humidity. Adult longevity, pre-oviposition, oviposition period, pre-mating and mating period was recorded for each pair. All observations were replicated ten times up to successive three generations. The collected data were used to compute per cent adult survival, adult emergence, fecundity and fertility.

Morphometric studies

For the comparative morphometric studies, as each developmental stage emerged, 10 insects each of all the nymphal stages (first to fifth instar) and adult male and female insects were immobilized with desiccators containing chloroform, and the measurements of various body parts were taken with the help of Vernier's digital caliper. Measurements on following body parts were taken: Total body length, Antennal length, Head length, Pronotum length, Pronotum width, Abdominal length, Abdominal width, Prothoracic leg, Mesothoracic leg, Metathoracic leg and Hind femur length.

Statistical analysis

The statistics parameters i.e. mean and standard deviation were obtained using MS Excel software 2007. A comparison of mean of all the data was done using one-way analysis of variance (ANOVA) (Primer software) with repeated measures and significant means determined by Fischer's test (F) using Tukey's Multiple Comparison Test (TMCT). The accepted level of significance in all cases was $p<0.05$. Correlation and regression analysis were also employed to determine the relationship between measured parts.

RESULTS

Life history

The mean pre-oviposition period of *O. japonica* varied from 6.8±0.65days in first generation to 5.9±0.02 days in second generation to 5.91±1.01 days in third generation. Mean oviposition period was 17.3±0.36, 19.5±0.35 and 17.64±0.23 days respectively, for the three successive generations. Eggs were laid in egg pods, which were barrel in shape with yellowish-brown colour. Egg pods are curved, about 10-12 mm in length and about 5mm in breadth. Mean number of eggs per pod was recorded to be 24.21±0.50. Mean post-oviposition period varied from 5.2±0.01 days in first generation, 4.15±0.03 days in second generation to 5.6±0.56 days in third generation.

There were five nymphal instars in the entire life cycle and the total nymphal period was 59.9±1.12 days, 61.3±1.04 days and 64.7±0.54 days for the three successive generations (Figure 1). The mean head capsule width was found to be 1.18±0.36, 1.90±0.28, 3.37±0.56, 3.42±0.54 and 4.22±0.45 mm for I, II, III, IV and V instar, respectively (Figure 2). Nymphs were green in colour and active. The mean (for three generations) total body length (mm) of different nymphal instars has been recorded to as 6.5±0.93, 7.62±0.07, 13.66±0.18, 21.11±0.53 and 27.07±0.07 mm for the five instar stages (Table 1). On an average the total development period from egg to adult emergence ranged from 75.11±0.95 in first generation, 77.11±1.18 in second generation to 74.56±1.03 in third generation. The female fecundity for the three years was recorded to be 3.17±0.07, 5.62±0.12 and 4.1±0.94 egg pods per female for the three generations, respectively.

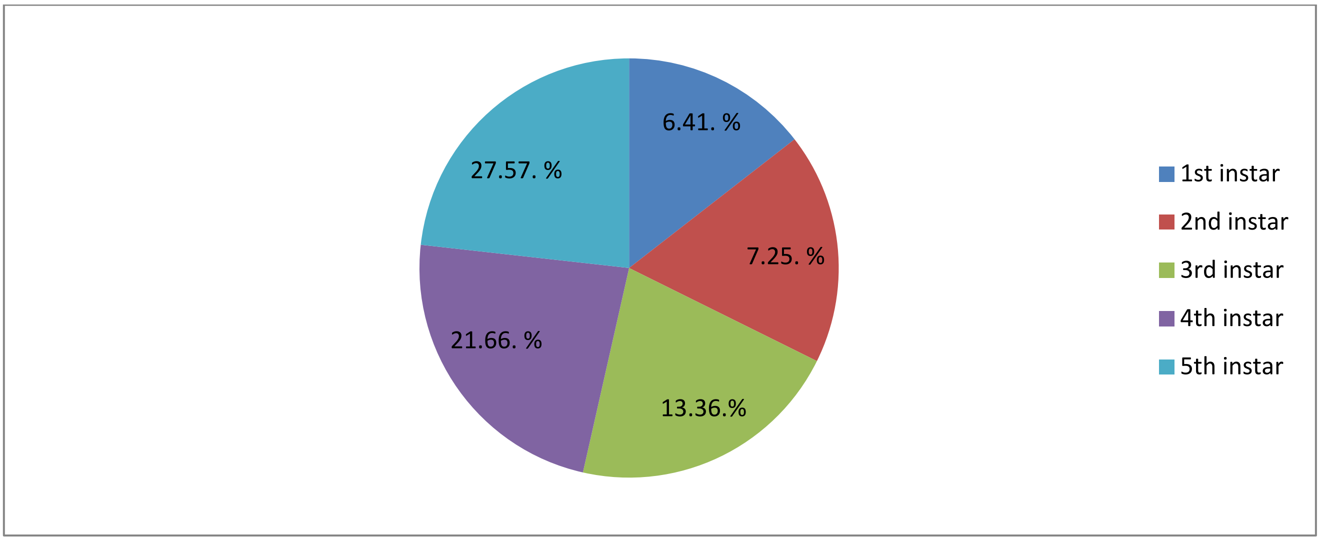

Figure 1. Stadial time for the nymphal stages of *Oxya japonica*.

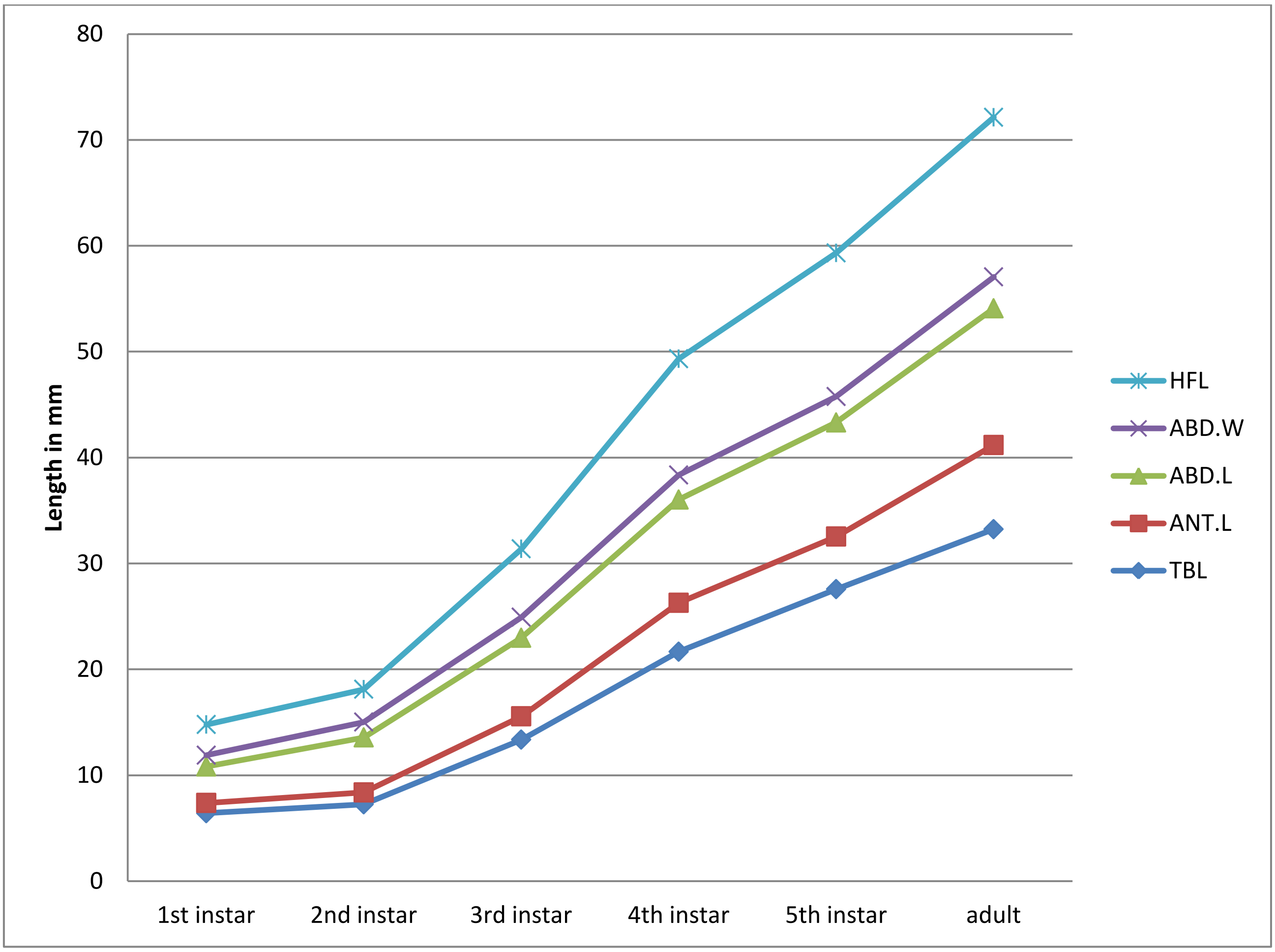

Figure 2. Variation in morphometric parameters of *Oxya japonica*.

Table 1. Life history, growth and development of *O. japonica* on *Andropogon sp.*

Parameters	Generation				
	I	II	III	Range	Mean ± SD
Nymphal period (days)	59.9±1.12	61.3±1.04	64.7±0.54	58-65	61.96±0.31
Head capsule width (mm ± SD)					
I instar	1.36±0.01	1.14±0.01	1.04±0.65	1-1.5	1.18±0.36
II instar	1.85±0.15	1.96±0.05	1.91±0.58	1.5-2.1	1.90±0.28
III instar	3.51±0.01	3.65±0.01	2.96±0.98	2.5-3.5	3.37±0.56
IV instar	3.74±0.05	3.12±0.10	3.42±1.02	3-3.9	3.42±0.54
V instar	3.96±0.91	4.52±0.01	4.2±0.42	3.5-4.2	4.22±0.45
Total body length (mm ± SD)					
I instar	6.23±0.02	6.95±0.04	6.32±1.65	6.2-7.0	6.5±0.93
II instar	7.04±0.25	7.92±0.36	7.9±0.21	7-8.5	7.62±0.07
III instar	13.95±0.36	13.16±0.36	13.87±0.68	13.1-14.3	13.66±0.18
IV instar	21.96±1.06	20.12±1.03	21.25±0.92	19.8-22.1	21.11±0.53
V instar	26.47±1.21	27.12±1.07	27.62±1.08	25.3-27.8	27.07±0.07
Adult emergence (%)	71.75±1.15	74.61±1.25	71.12±0.06	67-78	72.49±0.66
Total development period (days)	75.11±0.95	77.11±1.18	74.56±1.03	66-82	75.59±0.11
Adult longevity-female (days)	37.90±0.85	40.52±0.96	38.12±0.65	36-44	38.84±0.15
Adult longevity-male (days)	36.12±1.65	38.56±0.65	34.52±0.85	34-42	36.4±0.52
Pre-oviposition period (days)	6.8±0.65	5.9±0.02	5.91±1.01	5.5-8	6.2±0.50
Ovipositional period (days)	17.3±0.36	19.5±0.35	17.64±0.23	15-20	18.14±0.07
Post-oviposition period (days)	5.2±0.01	4.15±0.03	5.6±0.56	3-8	4.98±0.31
Fecundity (eggs pods /female)	3.17±0.07	5.62±0.12	4.1±0.94	3-9	4.29±0.48
Eggs per pod	25.54±0.21	24.8±1.21	22.3±0.56	23-28	24.21±0.50

On an average the adult emergence ranged from 71.75±1.15 percent in first generation, 74.61±1.25 percent in second generation to 71.12±0.06 percent in third generation. Adult longevity of male was 36.12±1.65, 38.56±0.65 and 34.52±0.85 days for the three generations, respectively, while it ranged for female from 37.90±0.85, 38.12±0.65 and 40.52±0.96 days. Adult longevity was more in female than the male. The adult females appeared larger in size than females, with the robust abdomen.

Morphometric analysis

The measurements of various morphometric parameters examined are depicted in the table 2 and 3. A significant difference ($P < 0.05$) was observed between various parameters of different instar stages and adults. Overall, one way ANOVA revealed the following results: (i) for total body length ($F = 817.63$; $df = 5/54$;$p < 0.05$), (ii) for antennal length ($F = 203.07$; $df = 5/54$;$p < 0.05$) (iii) for pronotum length ($F = 48.94$; $df = 5/54$;$p < 0.05$) (iv) for pronotum width ($F = 43.72$; $df = 5/54$;$p < 0.05$) (v) for head length ($F = 63.11$; $df = 5/54$;$p < 0.05$) (vi) for prothoracic leg length ($F = 199.5$; $df = 5/54$;$p < 0.05$) (vii) for mesothoracic leg length ($F = 370.36$; $df = 5/54$;$p < 0.05$) (viii) for metathoracic leg length($F = 666.53$; $df = 5/54$;$p < 0.05$) (ix) for abdominal length ($F = 110.16$; $df = 5/54$;$p < 0.05$) (x) for abdominal width ($F = 6.95$; $df = 5/54$;$p < 0.05$) (xi) for hind femur length ($F = 216.39$; $df = 5/54$;$p < 0.05$). Regression analysis revealed a strong positive relationship between the total body length and the femur length as well as between the total body length and the length of antenna.

A significant different between the length of various body parameters help in the rough identification of various instar stages. As revealed in table III, total body length of above 30mm, abdominal length of more than 12mm and hind femur length of more than 13mm can be taken as the representative of the adult stage. Even though no significant difference could be seen in the first and second instar stage, the antennal length of less than 2mm with metathoracic leg length of less than 10mm can be taken as an indicator of first or second instar. Likewise, third instar stage could be identified on the basis of total body length of

10-18mm with metathoracic leg length of 10-20mm. For fourth instar, total body length 18-24mm and hind femur length of 8-10mm can be taken into consideration while in case of fifth instar total body length ranges between 24-30mm with hind femur length of 11-14mm.

Sexual dimorphism

Variation in various body parameters of both sexes revealed evident sexual dimorphism. As depicted in Table 4, one way ANOVA revealed significant difference ($P < 0.05$) between various parameters of different adult male and female. (i) for total body length ($F = 196.7$; $p < 0.05$) (ii) for antennal length ($F = 49.89$; $p < 0.05$) (iii) for pronotum length ($F = 33.19$; $p < 0.05$) (iv) for pronotum width ($F = 94.36$; $p < 0.05$) (v) for head length ($F = 135.92$; $p < 0.05$) (vi) for prothoracic leg length ($F = 67.09$; $p < 0.05$) (vii) for mesothoracic leg length ($F = 35.93$; $p < 0.05$) (viii) for metathoracic leg length($F = 35.86$; $p < 0.05$) (ix) for abdominal length ($F = 15.39$; $p < 0.05$) (x) for abdominal width ($F = 30.24$; $p < 0.05$) (xi) for hind femur length ($F = 29.09$; $p < 0.05$).

Table 2. Table reflecting comparative morphometric parameters (in mm) of *Oxya japonica* (n=10).

Stages	TBL	ANT.L	PL	PW	HL	PTL	MSL	MTL	ABD.L	ABD.W	HFL
1st	6.91± 0.12^a	0.95± 0.01^a	1.16± 0.21^a	0.91± 0.03^a	1.16± 0.02^a	2.1± 0.31^a	2.52± 0.01^a	7.12± 0.35^a	3.72± 0.66^a	1.02± 1.01^a	2.8± 0.6^a
2nd	8.65± 0.84^a	1.42± 0.57^a	2.52± 0.85^b	1.52± 0.54^a	1.91± 0.15^b	5.72± 0.89^b	5.97± 0.36^b	8.25± 0.85^a	5.41± 0.74^b	1.36± 0.23^a	3.12± 0.71^a
3rd	14.36± 1.01^b	2.29± 0.21^b	3.67± 1.02^c	2.72± 0.42^b	3.18± 0.42^c	7.56± 0.71^c	6.95± 0.97^c	14.94± 1.05^b	7.38± 0.62^c	1.98± 1.48^b	6.85± 0.79^b
4th	22.66± 2.21^c	4.52± 0.32^c	4.01± 0.84^c	3.65± 0.64^c	3.45± 0.36^c	9.12± 1.03^c	9.19± 0.88^d	23.13± 1.42^c	9.95± 1.21^d	2.41± 0.39^c	10.42± 1.05^c
5th	27.97± 1.04^d	5.01± 0.95^c	5.36± 1.02^d	4.13± 1.2^d	3.99± 0.41^d	13.41± 1.57^d	15.24± 1.32^e	29.44± 1.29^d	10.47± 1.02^d	2.51± 0.84^c	13.72± 1.39^d
Adult	33.63± 0.92^e	8.05± 0.87^d	6.81± 1.17^e	4.92± 0.99^e	4.09± 0.91^e	15.12± 1.46^e	17.13± 1.25^e	31.21± 2.06^d	12.74± 1.54^e	2.97± 0.77^d	15.81± 1.92^e
F	817.63*	203.07*	48.94*	43.72*	63.11*	199.5*	370.36*	666.53*	110.16*	6.95*	216.39*

Mean in the same column having different superscript(s), are not significantly different from each other at 5% level of probability (TMCT), * -significant; ns-not significant ($P < 0.05$).

TBL-Total Body Length, ANT.L- Antennal Length, PL- Pronotum Length, PW- Pronotum width, HL- Head Length, PTL-Prothoracic Leg, MSL- Mesothoracic Leg, MTL- Metathoracic leg, ABD.L- Abdominal Length, ABD.W- Abdominal Width, HFL-Hind Femur Length.

Table 3. Comparative morphometric analysis (in mm) for the stage identification of rice Grasshopper, *Oxya japonica*.

STAGES	TBL	ANT.L	ABD.L	MTL	HFL	HL
1-2	…….	Upto 2	Upto 4	<10	>4	Upto 2
3	Upto 18	…….	…….	Upto 20	…….	…….
4	Upto 24	…….	…….	Upto 25	8-10	…….
5	Upto 30	…….	…….	…….	Upto 14	…….
Adult	>30	…….	>11	…….	>14	>4

TBL-Total Body Length, ANT.L-Antenna Length, ABD.L-Abdominal Length, MTL-Metathoracic Leg, HFL- Hind Femur Length, HL- Head Length.

Table 4. Comparative morphometric analysis (in mm) reflecting sexual dimorphism in rice Grasshopper, *Oxya japonica.*

Sex	TBL	ANT.L	PL	PW	HL	PTL	MSL	MTL	ABD.L	ABD.W	HFL
♂	32.56± 0.12[a]	7.25± 0.35[a]	6.02± 0.65[a]	4.16± 0.36[a]	3.63± 0.12[a]	14.49± 0.21[a]	16.01± 0.34[a]	29.43± 0.03[a]	12.04± 1.01[a]	2.14± 0.68[a]	14.12± 0.89[a]
♀	35.1± 0.56[b]	8.65± 0.52[b]	7.42± 0.41[b]	5.58± 0.29[b]	4.89± 0.32[b]	17.01± 0.95[b]	18.03± 1.01[b]	31.23± 0.95[b]	13.76± 0.95[b]	3.80± 0.82[a]	16.02± 0.67[b]
F	196.7*	49.89*	33.19*	94.36*	135.92*	67.09*	35.93*	35.86*	15.39*	30.24*	29.09*

Mean in the same column having different superscript(s), are not significantly different from each other at 5% level of probability (TMCT), * -significant; ns-not significant ($P < 0.05$).

TBL-Total Body Length, ANT.L- Antennal Length, PL- Pronotum Length, PW- Pronotum width, HL- Head Length, PTL-Prothoracic Leg, MSL- Mesothoracic Leg, MTL- Metathoracic leg, ABD.L- Abdominal Length, ABD.W- Abdominal Width, HFL-Hind Femur Length**.**

DISCUSSION

A progressive increase in size of head capsule and body length was observed in the successive instar nymphs during post embryonic development. The results were in confirmation with those of Chapman *et al.* (1977) who found the similar results in *Z. variegates.* Growth was observed to be rapid during the instar stages, with the maximum percentage of time spend in fourth and fifth instar stage. The gradual increase in the abdominal length is in confirmation with the observations of Ademolu and Idowu (2011) who profounded that there is increase in the microbial load of *Z. variegates* gut as it moults from first instar to adult stage and it enables to accommodate the increase in food consumption during the post embryonic development.

The results suggest that *O. japonica* is a highly fertile species and fecundity is highly affected by various abiotic factors like food quality, temperature and humidity. The number of instars recorded in the present study was five. The stadial time of lower instars (first to third) was much lower than those of the higher instars (fourth and fifth) and adults, owing to the rapid development of early instars. A strong relationship between the stages and the stadial time was revealed in correlation analysis which is explained by the fact that adult stage being most complex might necessitate the longer stadial time. The total nymphal period was observed to be 61.96±0.31 days. It is noteworthy that the lower instars (first to third) are easier to control due to the simplicity in their structural organization and physiology.

As expected, the slopes of various body parameters viz. total body length, antennal length, abdominal length, abdominal width and hind femur length was maximum from fifth instar to adult, reason being that the adult stage is the main stage involving highest complexity in structure due to the development of additional stages, besides sexual maturity. Similar results were obtained by Chapman (1998) that there may be marked change in the development of hemimetabolus insects from last instar to adult stage. Anya (1973) likewise reported there is much more pronounced development of reproductive structures in adults of variegated grasshopper, *Zonocerus variegates* than other instars. There is rapid growth, moulting and increase in body parts in locusts. From all these observations it can be concluded that in case of *Oxya japonica* there exist a strong relationship between the growths of various body parameters and one can be taken as an indicator of other.

A significant difference in length between adult males and females was observed, with the female's abdomen being robust and rounded and male's abdomen being flatter. The occurrence of sexual dimorphism reflects the effect of sexual selection or ecological differences among sexes (Oliveira and Almada, 1995; Fairbairn *et al.* 2007). A significant difference between the means of mesothoracic and metathoracic legs ($P \leq 0.05$) explains their function as prothoracic and metathoracic legs are both set of walking legs and metathoracic legs are meant for hopping (Chapman, 1980). The length of antenna showed a progressive increase from first instar to adult stage which explains the gregarious behaviour of the lower instars (first to third) and the dispersing character of the fifth instar to adult as reported by Toye (1982). The present study has demonstrated that the analysis of various body parameters viz. total body length, head length, antennal length, abdominal length, metathoracic leg length and hind femur length can be used to separate various instar stages (Ademolu and Idowu, 2006).

CONCLUSION

This information might prove to be handy in the administration of various control strategies. Due to their simple physiology it is propounded that lower instars are easier to control than the later stages. It is advisable to launch control attacks on the lower instar stages that are physiologically less complicated.

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