

Life table and population dynamics of a major pest, *Leptocorisa acuta* (Thunb.) (Hemiptera: Alydidae), on rice and non-rice system

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ABSTRACT

The life table study of the rice bug, *Leptocorisa acuta* (Thunb.) on rice (R) and non-rice (NR) system were conducted in the laboratory condition. The average individual fecundity was recorded 100.999 and 59.019 eggs on R and NR system, respectively. The nymphs were observed to pass through six instars with in the duration of 24 and 22 days respectively on R and NR host. The accumulated survival of adult was 20 ± 0.58 and $12.22 \pm 0.33\%$ respectively on R and NR system. The demographic parameters of *L. acuta* on R was significantly differed ($F=10.931$, $P < 0.005$) from the NR system with higher intrinsic (r_m) and finite (λ) rate of increase (0.020 and 1.020, respectively) through shorter doubling time (DT) of 34.449 days. The total generation mortality (K) of *L. acuta* was minimum on R system (2.7721) and maximum on NR system (3.1496), whereas the overall generation survival (GS) was in reverse order of K values (0.2 and 0.122, respectively). These differences in the demographic parameters are due to better nutritional quality in R system relative to NR system. Thus, by knowing such variations and most vulnerable stages from life table, one can make time based application of appropriate control measures against the pest population.

Key words: *Leptocorisa acuta*, demographic parameters, nutritional quality, vulnerable stages.

INTRODUCTION

Life table study is a central theme in ecological research to understand the temporal and spatial patterns in population dynamics^{8, 44}. It is used to calculate the vital statistics on pest population dynamics and also give a comprehensive description of the survivorship, development, age or stage-specific fecundity, mortality rates, basic reproductive rates and life expectancy^{7,45,46,14,23}. A life table developed based on field data may be used to estimate fitness of a population but unfortunately, it is often difficult to construct because tracing of population survival and reproduction in the open field under variable environmental conditions. To overcome these constrictions a standard cohort life table can easily be constructed in the laboratory conditions. Rizvi *et al.*³² were conducted both, age-specific (horizontal) and stage-specific (vertical) life-table of cabbage butterfly, *Pieris brassicae* on various crops. But, in our current study, we have used only the stage-specific life table approach similar with the previous study of Roy^{35,36} as it is with lower biasness and more useful in the field condition.

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There are several reports on the life table study of different pest species like, *Spilosoma obliqua* on sunflower⁵², *Plutella xylostella* on cauliflower¹⁶, *Spodoptera litura* on cotton¹³, *Podontia quatuordecimpunctata* on hog-plum³⁵, *Diacrisia casignetum* Kollar on jute³⁶ for their management.

Rice (*Oryza sativa* L.) is the most economically important food crop in many developing countries⁵⁰. But, insect pests are among the most important biological constraints limiting rice yield potential and reflect large scale reduction both in quality and quantity^{4,5}. The rice crops of Asia are dominated by the rice bugs belong to the genus *Leptocorisa* including *L. acuta*, *L. oratorius*, *L. varicornis*, *L. chinensis*, etc.^{1,10,11,18,20,24,26,49,54}. Among them, *L. acuta* (Thunb.) (Hemiptera: Alydidae) has been reported earlier in many tropical countries including India^{27-30,38}. They aggregate on non-rice weeds (*Echinocola* spp. *Paniculum* spp. *Cyperus* spp. etc.) grown in and around paddy fields before rice flowers^{29,38,49}. The losses due to this bug may range from 10 – 20% to total crop failure depending on the degree of infestation⁵. Both their nymphs and adults feed on the milky juice of the developing rice grains which discolours the panicles and reduces yield^{4,18}. The adult bugs emit a pungent smell when disturbed. Growing rice bug nymphs are more active feeders than adults, but adults cause more damage because they feed for a longer period on milk stage which causes reduce grain quality and yield loss^{4,49}. Control strategies in current use against the pest are largely based on chemical insecticides but intensive use creates an ecological imbalance through destruction of non-target beneficial insects, and accumulation of toxic residues in the environment. Also the resistant rice varieties and the use of natural enemies like predators and parasites in the management of rice bug population have not been promising²⁶. Today, the population dynamics along with limiting factors of this pest are very essential for timely adoption of different management practices. Though, few studies have been made in the past to correlate the incidence of rice bug with meteorological factors but all relations were site specific with some extent spatial and temporal variations^{12,41,42}. So, there is a need to develop a standard cohort life tables on both R and NR system to understand their population dynamics for safer and ecologically sustainable management of the pest.

MATERIALS AND METHODS

Insect mass culture and development: The study on population dynamics and life table parameters of gundhi bug, *Leptocorisa acuta*, was carried out in the laboratory condition ($27\pm 1^{\circ}\text{C}$, $65\pm 5\%$ RH and a photoperiodism of 12:12 [L:D]). The initial population of this notorious insect pest was collected from the field near Chinsurah Rice Research Center ($22^{\circ}53'$ N, $88^{\circ}23'$ E), Hooghly, West Bengal, India and was taken to the laboratory. Developmental time and survivability of *L. acuta*, was determined on rice (R) and non-rice weeds (NR) under the same laboratory condition. The bugs were placed for copulation followed by oviposition in glass jar (4l) covered with nylon net. Fresh rice panicles in the milk stage and non-rice weeds were added to the conical flasks as food for the bugs. The laid eggs were removed and placed in new glass jars after counting for their emergence. The newly emerged nymphs were observed daily throughout their developmental stages up to adult. Duration and survival for each molt were recorded in the laboratory condition of three generations for construction of their stage-specific life table.

Life table parameters: The construction of *L. acuta* life table includes several parameters which were calculated with the formulae of Carey⁷, Krebs²¹ and Price²⁵. These parameters include probability of survival from birth to age x (l_x), proportion dying each age (dx), mortality (qx), survival rate (sx) per day per age class from egg to adult stages. Using these parameters, the following statistics like, average population alive in each stage (L_x), life expectancy (ex), exponential mortality or killing power (kx), total generation mortality (K), generation survival (GS), individual fecundity (F_x), gross reproductive rate (GRR), net reproductive rate (R_0), mean generation time (T_c), doubling time (DT), intrinsic rate of population increase (r_m) and finite rate of population increase (λ) were also computed, using Carey's formulae^{7,8}.

Statistical Analysis: Effect of the R and NR system on development and survival of *L. acuta* were analyzed using one-way ANOVA⁵⁵. All the statistical analysis was performed using the statistical program SPSS v. 13.0⁴⁷.

RESULTS

The biology of *L. acuta* was carried out in the laboratory on R and NR system and each stage was photographed in order to present a pictorial demonstration of the different life stages (Figure 1). The three cohorts containing 30 eggs in each were reared separately on R and NR system, respectively to construct the life table of this notorious pest, *L. acuta*. The developmental duration and accumulated survival for each stage on R and NR system, from egg to six nymphal instars followed by adult is presented in figure 2 and 3, respectively. It was observed that the average incubation period from the time of egg laying to hatching lasted for 4 ± 0.58 and 4.66 ± 0.33 days on R and NR, respectively. The period for each molt was recorded on the basis of exo-skeleton of the surviving nymphs present in each culture. The average shortest period was observed for the 2nd instar (2.66 ± 0.33 and 2.33 ± 0.33 days), while the average longest period was recorded for the 6th instar (7.33 ± 0.33 and 6.33 ± 0.33 days) on R and NR system, respectively (Figure 2). The accumulated survival of adult was 20 ± 0.58 and $12.22 \pm 0.33\%$ respectively on R and NR system (Figure 3).

Fig. 1: Schematic representation of the life cycle of *L. acuta*

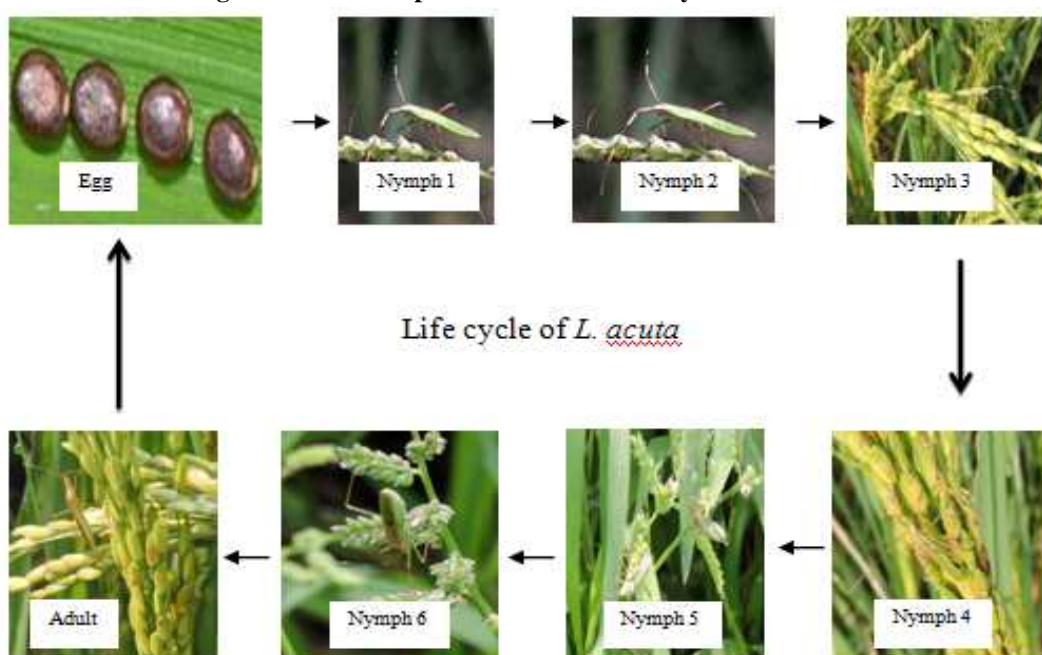


Fig. 2: Stage-specific developmental duration of *L. acuta* on rice (R) and non-rice (NR) systems

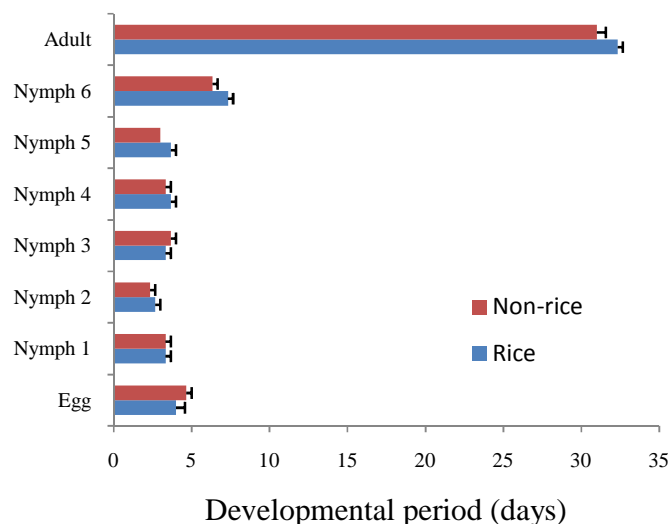
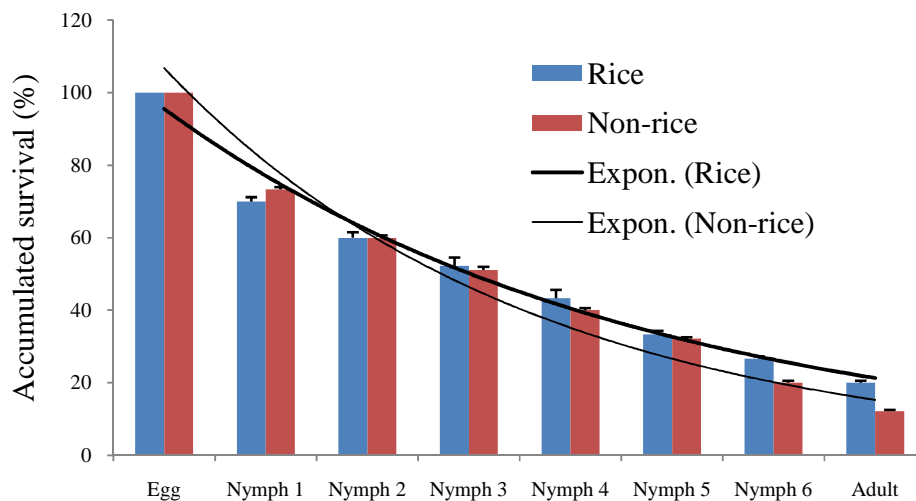


Fig. 3: Stage-specific accumulated survival (with exponential trend line) of *L. acuta* on rice (R) and non-rice (NR) systems



Life Table: The stage-specific life table of *L. acuta* was constructed on R and NR system separately and showed three distinct stages with six nymphal stages (Table 1 and 2). The demographic data of *L. acuta* reared on the two system represent similar pattern of development with significant variations ($P < 0.005$) (Table 1 and 2). The proportion of surviving (l_x) and average population alive in each stage (L_x) of *L. acuta* on each host system were gradually decreased throughout the developmental stages (Table 1 and 2). Whereas, proportion of dying (d_x) and mortality (q_x) were increased particularly in the early stages and subsequently decreased with variations in advance stages on both host system (Table 1 and 2). Life expectancy (e_x) also followed the same pattern of l_x and L_x for each kind of host system (Table 1 and 2). The killing power (k_x) was gradually increased with developmental advancement in reverse of e_x and L_x on both kind of host systems (Table 1 and 2). All the population parameters (l_x , d_x , q_x , s_x , L_x and e_x) of *L. acuta* were significantly higher ($F_{1, 7} = 223.24, 31.04, 7.04, 7.04, 178.16$ and 141.07 , respectively, $P < 0.005$) on R system relative to NR system except K_x ($F_{1, 7} = 1.07, P = 0.45$). Ultimately, the total generation mortality (K) of *L. acuta* was minimum on R system (2.7721) and maximum on NR system (3.1496), whereas the overall generation survival (GS) was in reverse order of K values (0.2 and 0.122, respectively).

The survival of *L. acuta* indicated a gradual increased rate of mortality during initial developmental stages and then it relatively decreased in the advanced stages up to adulthood which may reflect a type-III survivorship curve (Table 1 and 2). The observed accumulated survival data of *L. acuta* on R and NR system indicated that the immature in early stages are more susceptible to NR system than R system may be due to their poor nutritional quality (Figure 3). The proportion of male to female was 0.80 and 0.57 for R and NR system, respectively. The average life span from egg to the death of adults was 60.33 and 57.66 days for the three cohorts reared on R and NR system, respectively.

The average individual fecundity (F_x), gross reproductive rate (GRR), net reproductive rate (R_0), intrinsic rate of natural increase (r_m) and the daily finite rate of increase (λ) always significantly higher ($P < 0.005$) on R system (100.998, 20.199, 3.366, 0.020 and 1.020, respectively) than NR system (59.019, 11.803, 1.967, 0.012 and 1.011, respectively). The generation time (T_c) was also significantly higher on R system (60.33 days) relative to the NR system (57.33 days) due to higher developmental duration (Table 3). Whereas, the doubling time (DT) was significantly lower on R system (34.45 days) relative to the NR system (58.73 days) due to higher L_x , F_x and lower K_x (Table 1, 2 and 3). Thus, the population growth parameters of *L. acuta* were significantly affected by the different host system due to variation in their nutritional constituents.

Table 1. Stage-specific pooled life table of *L. acuta* on rice (R) system

Developmental stages on rice	lx	dx	qx	sx	Lx	Tx	ex	kx
Egg-0	1.000	0.300	0.300	0.700	0.850	3.656	3.656	0.000
Nymph 1	0.700	0.100	0.143	0.857	0.650	2.806	4.008	0.155
Nymph 2	0.600	0.078	0.130	0.870	0.561	2.156	3.593	0.222
Nymph 3	0.522	0.089	0.170	0.830	0.478	1.594	3.053	0.282
Nymph 4	0.433	0.100	0.231	0.769	0.383	1.117	2.577	0.363
Nymph 5	0.333	0.067	0.200	0.800	0.300	0.733	2.200	0.477
Nymph 6	0.267	0.067	0.250	0.750	0.233	0.433	1.625	0.574
Adult-7	0.200	0.000	0.000	1.000	0.200	0.200	1.000	0.699

Table 2. Stage-specific pooled life table of *L. acuta* on non-rice (NR) system

Developmental stages on non-rice	lx	dx	qx	sx	Lx	Tx	ex	kx
Egg-0	1.000	0.267	0.267	0.733	0.867	3.450	3.450	0.000
Nymph 1	0.733	0.133	0.182	0.818	0.667	2.583	3.523	0.135
Nymph 2	0.600	0.089	0.148	0.852	0.556	1.917	3.194	0.222
Nymph 3	0.511	0.111	0.217	0.783	0.456	1.361	2.663	0.291
Nymph 4	0.400	0.078	0.194	0.806	0.361	0.906	2.264	0.398
Nymph 5	0.322	0.122	0.379	0.621	0.261	0.544	1.690	0.492
Nymph 6	0.200	0.078	0.389	0.611	0.161	0.283	1.417	0.699
Adult-7	0.122	0.000	0.000	1.000	0.122	0.122	1.000	0.913

Table 3. Population and reproductive life table of *L. acuta* on rice (R) and non-rice (NR) systems

Parameter	Rice system	Non-rice system	Average	Variance
Individual fecundity (Fx)	100.999	59.019	80.009	881.160
Gross reproductive rate (GRR)	20.200	11.804	16.002	35.246
Net reproductive rate (R_0)	3.367	1.967	2.667	0.979
Mean generation time (T_c)	60.330	57.330	58.830	4.500
Doubling time (DT)	34.449	58.727	46.588	294.717
Intrinsic rate of increase (r_m)	0.020	0.012	0.016	0.000
Finite rate of increase (λ)	1.020	1.012	1.016	0.000

DISCUSSIONS

In this modern era with increasing human population there is a need to increase rice production per unit of land through economically and environmentally sustainable strategies. In fact, insects are a major constraint in the production of rice throughout the world including tropical and subtropical Asia. As rice is the staple food of most Asians, there is a need to control or manage populations of this pest¹⁸. Adult females oviposit in single or double rows from the booting stage to the milky stage of rice development similar with *L. oratorius*⁴. The egg incubation period and developmental duration of different stages of *L. acuta* are nearly similar with *L. oratorius* except 6th nymphal stage found only in *L. acuta*^{17,27}. They also can grow on a number of wild grasses like *L. oratorius*, although as food plants wild grasses were inferior to rice. In our study it is also found that R system can support the better development of *L. acuta* relative to the NR system which may be due to nutritional quality of the respective host plants. The nymphs had green body with outstanding long black legs and mimic ants in form and behavior. There were six nymphal stages with a total nymphal development period of about 22-24 days. Well developed wings appeared after the final molt from the 6th instar nymph into adults. The life table data along with all the stages of *L. acuta* development will make easy to identify this notorious pest for effective management in

the field to reduce qualitative and quantitative losses on the yield of rice. The study can describe duration and survival at each life stage which allow prediction of the population size and age structure of a pest insect at any time^{35,36}. It is very helpful to determine the different mortality stage as well as pattern of population growth on both R and NR system.

There is a range of innet capacity for individual of a population but the variation in available food quality^{22,51,53} along with environmental factors (geographic source, RH, temperature, rainfall etc.)^{2,40} always influence the growth, reproduction, longevity and survival of those populations^{35,36}. Even, the host plant quality traits are the key determinants of the fecundity of herbivorous insects affecting insect reproductive strategies such as: egg size and quality, allocation of resources to eggs, the choice of oviposition sites, and egg or embryo resorption³⁹. The effect of different food sources on population parameters were also observed in *P. xylostella*¹⁶, *P. quatuordecimpunctata*³⁵ and *D. casignetum*³⁶ on different host plants. The host plant quality during larval growth and development is a key determinant of both fecundity and fertility of adults^{3,33,34,37}. Shorter developmental time along with greater total reproduction of insects on a host indicate greater suitability of a host plant^{3,33,34,37}. In this study, the overall generation survival (GS) of *L. acuta* on R was significantly higher than NR system whereas total generation mortality (K) was in the reverse order. This difference was probably a result of different food sources taken up by the nymph and adult during their developmental growth similarly in other cases^{33,34,37,48}. This difference could be due to the presence of nutritional and anti-nutritional factors that directly affect the pest development and fecundity^{3,33,34,37,48}.

The overall accumulated survival rate suggest that the survival curve of *L. acuta* is of type III, with high mortality during the immature stages, according to the classification of Pearl⁴⁰ as found in most insect species^{25,35-37}. The r_m is a fundamental ecological parameter to predict the pest population growth under a given condition³¹. It would be a most appropriate index to evaluate the performance of an insect on different host plants as well as the host plant's resistance⁴³. It represents the rate of potential increase of a population under optimal environmental conditions when fecundity and survival are maximal and adequately summarizes the physiological qualities of an animal in relation to its capacity to increase⁶. The high value of R_0 on rice is a reflection of high r_m . Thus high r_m value on R system indicates that *L. acuta* has a greater reproductive potential and more preference on it relative to the NR system. The doubling time (DT) of *L. acuta* was significantly shorter on R than the NR system. Thus, the F_x , R_0 , r_m and DT are useful indices of population growth under a given set of conditions^{9,35,36,53}. This knowledge is very important when studying insect pest population dynamics for developing efficient pest management tactics^{9,19,35,36}. The low number of eggs laid on a plant could have been affected by larval feeding on nutritionally poor plants^{33,35-37,48}. Thus, R system had the lowest antibiosis resistance against *L. acuta* and was the most favorable one relative to the NR system due to high survival of immature stages as reflected in a higher value of r_m . With this understanding, the population dynamics of *L. acuta* is highly supported by R system due to high nutritional quality relative to the NR system. But it is also predicted that, NR system is an alternative source of their population growth in absence of R system. So the removal of NR system is of course a way to control the pest in field condition. Lastly, this study also informs the vulnerable stage of the pest that may help the farmers to control them with proper measures in the field condition.

CONCLUSIONS

The life table study of *L. acuta* on R and NR system showed three distinct stages with six nymphs and represent similar pattern of development with significant variations ($P < 0.005$). The gross reproductive rate (GRR) and net reproductive rate (R_0) on R (20.120 and 3.367, respectively) was significantly higher than NR system which ultimately influence the fecundity. The r_m of *L. acuta* on R system was 0.020 per female per day and the λ was 1.020 female offspring per female per day with a mean generation time (T_c) of 60.330 days and the doubling time (DT) of 34.449 days. The generation survival (GS) of *L. acuta* on R (0.200) was significantly higher than NR (0.122) system, whereas total generation mortality (K) are in the reverse order. These differences in the demographic parameters are due to the variation in their nutritional quality of respective kind of host plants. So for first step management of the notorious insect pest, *L.*

acuta, is very essential to weed the R and NR areas which ultimately would reduce the population size of the paddy bug in the field condition. Their further management strategies may include different ecofriendly control measures following their population parameters.

Conflict of Interests: The authors declare that there is no conflict of interests regarding the publication of this paper.

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REFERENCES

1. Akbar S. S., The morphology and life history of *Leptocorisa varicornis* Fabr. A pest of paddy crop in India. *Publ. Aligarh. Univ. (Zool. Ser.) Ind. Ins. Typ.* **5**: 1-50 (1958).
2. Ali, A. and Rizvi, P. Q., Age and stage specific life table of *Coocinella septemounctata* (Coleoptera: Coccinellidae) at varying temperature, *World J. Agric. Sci.*, **6(3)**: 268-273 (2010).
3. Awmack, C. S. and Leather, S. R., Host plant quality and fecundity in herbivorous insects, *Annual Rev. Entomol.*, **47**: 817-844, (2002).
4. Baharally, V. and Simon, S., Biological studies on gundhi bug, *Leptocorisa oratorius* (Fabricius) (Hemiptera: Alydidae) under allahabad, uttar pradesh (up), india. *Int. J. Agri. Sci. Res. (IJASR)*, **4(3)**: 57-62 (2014).
5. Bhadauria, N. S. and Singh, P., Assessment of losses in paddy caused by *Leptocorisa varicornis*. *Ann. Pl. Protec. Sci.* **17(1)**: 231(2009).
6. Birch, L. C., The intrinsic rate of natural increase of an insect population, *J. Animal Ecol.*, **17**: 15-26 (1948).
7. Carey, J. R., *Applied demography for biologists with special emphasis on insects*, Oxford University Press, New York, NY, USA, pp.211 (1993).
8. Carey, J. R., *Insect biodemography*, *Annual Rev. Entomol.*, **46**: 79-110 (2001).
9. Chakrabarty, S. and Mondal, P., Age specific and female fecundity life table of *Calosobruchus chinensis* Linn. on green gram. *Int. J. Pure App. Biosci.*, **3(4)**: 284-291, (2015).
10. Cobblah, M. A. and Denhollander, J., Specific differences in immature stages, oviposition sites and hatching patterns in two rice pests, *Leptocorisa oratorius* (Fabricius) and *L.acuta* (Thunberg) (Heteroptera: Alydidae). *Insect Sci. Appl.*, **13**: 1-6 (1992).
11. Dale, D., *Insect pests of the rice plant, their biology and ecology*. E. A. Heinrichs Biology and management of rice insects, Wiley Eastern Limited, New Delhi, India, pp.363-486, (1994).
12. Estay, S. A., Lima, M. and Labra, F. A., Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modeling. *J. Appl. Entomol.*, **133(7)**: 491-499 (2009).
13. Gedia, M. V., Vyas, H. J., Acharya, M. F. and Patel, P. V., Life table, rate of increase and stable age distribution of *Spodoptera litura* (Fabricius) on cotton, *Annals Plant Protect. Sci.*, **16(1)**: 62-65 (2008).
14. Harari, R. Ben-Yakir, D. Chen, M. and Rosen, D., Life- and fertility-tables of *Maladera matrida* (Coleoptera: Scarabaeidae), *Env. Entomol.*, **27**: 45-48 (1997).
15. Harcourt, D. G., The development and use of life tables in the study of natural insect populations. *Ann. Rev. Entomol.*, **15**: 157-196 (1969).
16. Hemchandra, O. and Singh, T. K., Life table, rate of increase and stable-age distribution of *Plutella xylostella* (Linnaeus) on cauliflower. *Annals Plant Protect. Sci.*, **11(2)**: 269-273 (2003).
17. Hosamani, V., Pradeep, S., Sridhara, S. and Kalleshwaraswamy, C. M., Biological Studies on Paddy Earhead Bug, *Leptocorisa oratorius* Fabricius (Hemiptera:Alydidae). *Acad. J. Entomol.*, **2(2)**: 52-55(2009).
18. Jahn, G. C., Domingo, I., Liberty, M., Almazan, P. and Pacia, J., Effect of rice bug *Leptocorisa oratorius* (Hemiptera: Alydidae) on rice yield, grain quality, and seed viability. *J. Econ. Entomol.*, **97(6)**: 1923-1927 (2004).

19. Kakde, A. M., Patel, K. G. and Tayade, S., Role of life table in insect pest management-a review. *IOSR J. Agric. Veterin. Sci.*, **7** (1): 40-43 (2014).
20. Kay, I. R., Brown, J. D. and Mayer, R. J., Insecticidal control of *Eysarcoris trimaculatus* (Distant) (Heteroptera: Pentatomidae) and *Leptocorisa acuta* (Thunberg) (Heteroptera: Alydidae) on rice in north Queensland, Australia. *Crop Protection*, **12**: 310-314 (1993).
21. Krebs, J., *Ecology: The Experimental Analysis of Distribution and Abundance*, 4th ed. Harper Collins College Publishers, New York, (1994).
22. Liu, Z., Li, D., Gong, P. and Wu, K., Life table studies of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), on different host plants. *Env. Entomol.*, **33**: 1570-1576 (2004).
23. Medeiros, R. S., Ramalho, F. S., Lemos, W. P. and Zanuncio, J. C., Age-dependent fecundity and life fertility tables for *Podisus nigrispinus* (Dallas) (Heteroptera: Pentatomidae). *J. Appl. Entomol.*, **124**: 319-324 (2000).
24. Misra, A. S., Bionomics of the rice gundhi bug, *Leptocorisa varicornis* Fabr. (Hemiptera, Heteroptera: Coreidae). *Allahabad Farming*, **42**: 75-77 (1968).
25. Price, P. W., *Insect Ecology*, Wiley, New York, (1998).
26. Rai, A. B., Singh, J., Rai, L., Natural enemies of rice gundhi bug *Leptocorisa varicornis* (Fabricius) in eastern part of Uttar Pradesh. *Science and Culture*, **54**: 241-242 (1988).
27. Rai, P. S., Life cycle of rice earhead bug, *Leptocorisa acuta* (Thunberg) (Coreidae: Hemiptera). *J. Maharashtra Agric. Univ.*, **6**: 252-253 (1981).
28. Reji, G. and Chander, S., A degree-day simulation model for the population dynamics of the rice bug, *Leptocorisa acuta* (Thunb.). *J. Appl. Entomol.*, **132**: 646–653 (2008).
29. Reji, G. and Chander, S., Thermal requirements for development of rice bug, *Leptocorisa acuta* (Thunb.) under variable temperature conditions. *J. Entomol. Res.*, **31**(3): 229-232 (2007).
30. Reji, G., Chander, S., Singh, V. S., and Satish, D. G., Determination of threshold of development and thermal constant of rice gundhi bug, *Leptocorisa acuta*. In: Proceedings of the national symposium on frontier areas of entomological research, Division of Entomology, IARI, New Delhi, pp.22-23, (2003).
31. Ricklefs, R. E. and Miller, G. L., *Ecology*, 4th ed. Freeman & Company, New York, (2000).
32. Rizvi, P. Q., Ali, A. and Khalid, S., Age and stage-specific life-table of cabbage butterfly, *Pieris brassicae* L. (Lepidoptera: Pieridae) on various cole crops. *J. Plant Protect. Res.*, **49**(2): 145-150 (2009).
33. Roy, N. and Barik, A., Influence of four host plants on feeding, growth and reproduction of *Diacrisia casignetum* (Lepidoptera: Arctiidae), *Entomol. Sci.*, **16**(1): 112-118 (2013).
34. Roy, N. and Barik, A., The impact of variation in foliar constituents of sunflower on development and reproduction of *Diacrisia casignetum* Kollar (Lepidoptera: Arctiidae),” *Psyche: J. Entoml.*, **2012**: 9 pages, Article ID 812091, (2012).
35. Roy, N., Host phytochemicals in regulation of nutritional ecology and population dynamics of *Podontia quatuordecimpunctata* L. (Coleoptera:Chrysomelidae). *Int. J. Hort.*, **5**(4): 1-11. (2015a)
36. Roy, N., Life table and population parameters of *Diacrisia casignetum* Kollar (Lepidoptera: Arctiidae) on jute, *Chorchorus capsularis* (cv. Sonali; JRC-321), leaves. *Int. J. Fauna Bio. Stud.*, **2**(3): 23-29. (2015b).
37. Roy, N., Role of *Chorchorus capsularis* phytochemicals on the feeding dynamics of *Diacrisia casignetum* Kollar (Lepidoptera: Arctiidae). *J. Entomol. Zoo. Stud.*, **2** (4): 227-236. (2014).
38. Sands, D. P. A., The biology and ecology of *Leptocorisa acuta* (Hemiptera: Alydidae) in Papua New Guinea. *Res. Bull. Dep. Prim. Ind. Papua, New Guinea*, **1**: 104 (1977).
39. Schoonhoven, M., Van Loon, J. J. A. and Dicke, M., *Insect-Plant Biology*, Oxford University Press, Oxford, (2005).
40. Schowalter, T. D., *Insect Ecology: An Ecosystem Approach*, 2nd edn. Academic Press, Tokyo, (2006).
41. Sen, A. C., Basic factors for forecasting epidemic outbreaks of rice bug, *Leptocorisa varicornis* Fabr. *Indian J. Entomol.*, **17**: 127-128 (1955).

42. Singh, M.P., and Chandra, S., Population dynamics of rice stink bug (*Leptocorisa varicornis* Fabr.) in relation to weather factors. *Indian J. Agric. Sci.*, **36**: 112-119 (1967).
43. Southwood, T. R. E. and Henderson, P. A., *Ecological Methods*, 3rd ed., Blackwell Science, Oxford, pp.575, (2000).
44. Southwood, T. R. E., *Ecological methods particular reference to study of insect population*, The English Language Book Society and Chapman and Hall, London, pp.524 (1978).
45. Southwood, T. R. E., *Ecological methods with particular reference to the study of insect populations*. Methuen London, pp391 (1966).
46. Southwood, T. R. E., *Ecological Methods*, 2nd ed., Chapman & Hall, London, United Kingdom, (1995).
47. SPSS, *SPSS Base 13.0 User's Guide*, SPSS Incorporation, Chicago, IL, (2004).
48. Syed, T. S. and Abro, G. H., Effect of brassica vegetable hosts on biology and life table parameters of *Plutella xylostella* under laboratory conditions, *Pakistan J. Bio. Sci.*, **22**: 1891-1896 (2003).
49. Torres, M. A. J., Lumansoc, J. and Demayo, C. G., Variability in head shapes in three populations of the Rice Bug *Leptocorisa oratorius* (Fabricius) (Hemiptera: Alydidae). *Egypt. Acad. J. biolog. Sci.*, **3(1)**: 173-184 (2010).
50. Tran, D. V., World rice production: main issues and technical possibilities In: Chataigner, J. (Ed.). *Cahiers Options Mediterraneennes*, **24 (2)**: 57-69 (1997).
51. Tsai, J. H. and Wang, J. J., Effects of host plants on biology and life table parameters of *Aphid spiraecola* (Homoptera: Aphididae), *Env. Entomol.*, **30**: 45-50 (2001).
52. Varatharajan, R., Singh, S. A., Keisa, T. J., Singh, O. D. and Selvasundaram, R., Life table of *Spilosoma obliqua* (Lepidoptera: Arctiidae) on sunflower, *Int. J. Trop. Insect Sci.*, **18**: 383-385 (1998).
53. Win, S. S., Muhamad, R., Ahmad, Z. A. and Adam, N. A., Life table and population parameters of *Nilaparvata lugens* Stal. (Homoptera: Delphacidae) on rice, *Tropical Life Sci. Res.*, **22(1)**: 25-35 (2011).
54. Yamashita, K., Sudo, K., Adachi, T. and Miura, K., Estimation of number of annual generations using effective heat unit of development for the rice bug, *Leptocorisa chinensis* (Dallas) (Hemiptera: Alydidae). *Appl. Entomol. Zool.*, **40**: 621-624 (2005).
55. Zar, H., *Biostatistical Analysis*, Prentice Hall, Upper Saddle River, NJ, (1999).