Life tables of cashew stem and root borers, *Plocaederus ferrugineus* and *Polcaederus obesus* (Coleoptera: Cerambycidae)

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Abstract

Cashew stem and root borers, *Plocaederus ferrugineus* L. and *Plocaederus obesus* Gahan are major pests of cashew (*Anacardium occidentale*). Life tables of these pests were constructed by rearing them on cashew bark under laboratory conditions. The population parameters such as, fecundity (ΣF_x), net reproductive rate (R_o), cohort generation time (T_c), innate capacity to increase (r_c), finite rate of population growth (λ) and doubling time (DT) were estimated. The larval stage in *P. ferrugineus* and egg stage in *P. obesus* were higher in contributing to the stable age distribution (C_x) of these pest species. The R_o for *P. ferrugineus* and *P. obesus* was 29.00 and 25.96, respectively. The finite rate of population growth (λ) was more than 1.0 for both the species, which indicated an increasing population. The doubling time for *P. ferrugineus* and *P. obesus* was 60.18 days and 70.21 days, respectively. The analysis of age-specific life table indicated that egg and early larval stages at 1 to 45 days of age showed high age-specific mortality (q_x) and the later larval stages, aged 90 to 120 days showed high mean expectancy of life (e_x). The population survival curves for both the species were comparable, with a sharp decline in the survival rate for early stages, indicating these were the most vulnerable stages.

Keywords: Cashew, stem and root borers, life tables, *Plocaederus ferrugineus*, *Plocaederus obesus*

Introduction

Among the several insect pests infesting cashew, stem and root borer (CSRB) of cashew and tea mosquito bug (TMB) are considered as major pests, while, leaf and blossom webbers, apple and nut borers, shoot tip caterpillar, leaf and inflorescence thrips, leaf beetles *etc*., are considered as pests of regional importance. The major CSRB species, *P. ferrugineus* and *P. obesus*, (Coleoptera: Cerambycidae) constitute a main impediment in sustaining the optimum tree population in cashew. Among the CSRB species, *P. ferrugineus* has been reported from India (Ayyar, 1942) and other cashew growing countries like China (Liu Kangde *et al.,* 1998), Cambodia (Krishnamurthy, 2007), Nigeria (Asogwa *et al.,* 2009a) and Vietnam (Renkang Peng *et al.,* 2011) while, *P. obesus* was reported from India (Pillai *et al.,* 1976).

The adult *P. ferrugineus* beetles are chestnut red coloured with body length ranging 35 - 45 mm while adult *P. obesus* are straw coloured with a body length ranging 40 - 45 mm. The adult beetles feed on plant sap, oviposit in fissures of the bark at collar region and also on exposed roots of host trees. The larvae feed on the bark tissues of main stem, primary branches and primary roots of cashew trees, thereby hindering the flow of plant sap leading to premature canopy yellowing, leaf fall and drying of the twigs followed by gradual death of infested trees (Ayyanna and Ramadevi, 1986). These are internal feeders and their initial symptoms of damage are generally inconspicuous, preventing timely detection of the

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pest by the cashew farmers, hence CSRB are hidden killers. In certain trees, the tap root or stout lateral roots below soil may be extremely damaged and the tree may look healthy during rainy months, but may die suddenly without showing any external symptoms prior to leaf yellowing.

The biology of *P. ferrugineus* has been reported by earlier workers (Mariamma, 1991). Raviprasad and Bhat (2000; 2007) standardized the rearing technique for the field collected stages, egg collection and laboratory rearing technique for *Plocaederus* species. CSRBs are reported to complete its life cycle on three host plants namely, cashew, drumstick (*Moringa oleifera*) and silk cotton (*Ceiba pentandra*) (Mohapatra and Jena, 2007). Senguttuvan and Mahadevan (1997) had studied the population fluctuation of *P. ferrugineus*. Asogwa *et al.* (2009b) reported the host plant range and morphometrics of *P. ferrugineus*. Age estimation technique for the field collected CSRB larvae by measuring the prothoracic shield (PTS) width was standardized Raviprasad and Bhat (2010). The duration and the morphometrics of biological stages of *P. ferrugineus* and *P. obesus* were recorded by Vasanthi and Raviprasad (2013).

In ecological study, the construction of life tables is an important tool for understanding the population dynamics of an insect. Age-specific fertility life tables serve as a framework for organizing data on mortality and natality. It generates simple summary statistics including life expectancy and natality rate. Analysis of life tables is the most suitable method to evaluate natality and reproduction of a population (Southwood, 1978). Deevey (1947) reported that a life table is a concise summary statement for every interval of age, the number of deaths (d_x), the number of survivors at the beginning of the age class x (l_x), the rate of mortality (q_x), and the expectation of life remaining for individuals of age x (e_x). The table also includes numbers living between the ages x and x+1, which is the age structure (L_x). In such studies, developmental times and survival rates of each stage, longevity of adults, and daily fecundity of females are recorded for every individual (Chi, 1988). The aim of this study was to construct life tables of CSRB on cashew bark, estimate the finite rate of increase of the two major CSRB species, to determine the survival proportion at different stage and to identify the most vulnerable stage of the pest species.

Materials and methods

The life table of *P. ferrugineus* and *P. obesus* were constructed, at the Kemminje campus of the Directorate of Cashew Research, Puttur (12º45’ N latitude, 75º40’ E longitude; 90 m above MSL), from Dakshina Kannada, India, under ambient conditions of 23 - 31 °C, with 60 - 86 per cent relative humidity. The protocol involved collection of immature stages of pest species from field infested cashew trees, rearing them in the laboratory on cashew bark and maintenance of adults. These adults, eggs and various developmental stages were utilized for the construction of fertility and age specific mortality life tables.

Rearing of CSRB

The adults of *P. ferrugineus* and *P. obesus* were obtained by rearing the larvae collected from the infested cashew trees, on cashew bark under laboratory conditions. The larvae were weighed and the pro-thoracic shield (PTS) width was measured to estimate the age (Raviprasad and Bhat, 2010) and later transferred to individual glass rearing bottles (12 cm height x 6 cm width; 500 ml capacity). Fresh cashew bark collected from already infested cashew trees was cut into small pieces (5 x 5 x 3 cm size) and the larvae were supplied with three to four such bark pieces as feed. The bark pieces were replaced regularly once in 10 days to sustain the growth of the larvae. The initiation of pupal chamber construction was identified by the smearing of white calcareous material, on the inner wall, usually at the bottom of the rearing bottles. These bottles were labeled as pupa and date of pupation was recorded. Observations were made once in two days on the emergence of adult beetles and the date of emergence was recorded. The adult beetles were transferred to acrylic rearing cages (30 x 30 x 30 cm) with 20 per cent honey as adult feed and allowed for mating. A cashew twig (30 cm long, 3 cm diameter) was wound with a 1 cm wide cotton tape, spirally, around it and was provided in the rearing cage as oviposition niche.

Fertility life table

The adults emerged from the above culture of both the species of *Plocaederus* were utilized to develop fertility life table and to elucidate the age-specific mortality, sex ratio and longevity of the species. The age-specific fecundity and the finite rate of increase were estimated by the eggs obtained in the life time of single female. (10 individuals, each for *P. ferrugineus* and *P. obesus* were used). Data analysis was carried out following the 'single sex method' in which only female eggs were considered for age-specific fecundity (Southwood, 1978) using MS Excel tool for calculations.

Following parameters were estimated:

Total number of eggs laid by a female (eggs female^{-1}generation^{-1}), life time fecundity = ΣF_x.

Mean daily fecundity *i.e.*, eggs female^{-1}day^{-1} $(F_x) = \Sigma F_x$ per number of days.

Age-specific fertility, which indicated the female eggs female^{-1}day^{-1} $(m_x) = F_x/2$ in case of *P. ferrugineus* as the sex ratio was 1: 1 and $F_x/2.2$ in case of *P. obesus* as sex ratio was 1:1.2.

$$\text{Proportion surviving at a specific age } (l_x) = \frac{\text{Number surviving at pivotal age } (N_x)}{\text{Original number of females } (N_o=10)}$$

Later, the total female births per female in each age interval $(l_x m_x)$ was calculated. The net reproductive rate (R_o), *i.e.*, the number of female births per generation or the number of times population increased was obtained; $R_o = \Sigma\, l_x m_x$. Since only females were considered for the analysis, R_o was depicted as females per female generation.

The minimum time required for the birth of a female, *i.e.*, cohort generation time $Tc = \Sigma\, x\, l_x\, m_x / \Sigma\, l_x\, m_x$. where, x= Pivotal age of a female

From these values, innate capacity for increase $r_c = \ln R_o / T_c$ was calculated**.**

In order to understand and predict the buildup of pest population, the finite rate of increase (λ) was calculated by using the formula, $\lambda = e^{rc}$ Further**,** the number of days required by a population to double, was calculated as $DT = \ln 2/r_c$.

Fertility curves were obtained by plotting l_x, the proportion surviving against m_x, the female eggs. The fecundity, net reproductive rate and cohort generation time for both the species of *Plocaederus* were estimated and were statistically analyzed by one tailed T test.

Age-specific mortality life table

The immature stages of development obtained from the above adults were used for calculation of age-specific mortality for the construction of the age specific life table of both *P. ferrugineus* and *P. obesus.* The calculations were done using MS Excel software as per the formulae mentioned by Southwood (1978) and Siswanto *et al.* (2008)

x = pivotal age of the pest,

N_o = Original number of stage (Eggs).

n_x = number surviving at the beginning of age class x.

Number dying during the age interval x;

$d_x = n_x - n_{x+1}$

Proportion surviving at the beginning of age x $(l_x) = n_x / n_o$; where n_o = original number of eggs (881 in case of *P. ferrugenius* and 921 in case of *P. obesus*).

$100\, q_x = (d_x / n_x) \times 100$ *i.e.* per cent individuals entering a stage and gives information on the per cent dying at a particular stage.

Where, q_x (age-specific mortality)

Survival fraction, $S_x = (n_x - d_x)/n_x$

e_x = expectation of life remaining for individuals of age x.

In order to obtain e_x, two other parameters, namely, L_x and T_x were computed as follows.

Number of individuals alive between age x and x+1; $(L_x) = (n_x + n_{x+1})/2$.

Total number of individual x age units beyond the age x; calculated by cumulatively adding,

L_x values from bottom to top. $T_x = L_x + (L_{x+1}) + (L_{x+2})$ - - L_w where L_x = the last age interval. L_w= first age interval.

$e_x = T_x / n_x$ or the expectation of life remaining for individuals of age x days where n_x is the number surviving at the beginning of age class x (Southwood 1978).

Contribution to the stable age distribution (SAD) which is an indication of the proportionate abundance of the x^{th} age class in the year 't' was calculated (Derived from Euler equation).

$$Cx = \frac{B^{-rx}\, lx\, mx}{\sum_{x=0} B^{-rx}\, lx\, mx}$$

Survivorship curves

The proportion of individuals surviving, l_x at a pivotal age of both the species of pest were obtained from the age specific mortality table and were represented in the form of 'Survivorship curves' to identify the most vulnerable stage in the life cycle of these pest species.

Results and discussion

The mortality of the early larval stage was high (63.57% and 57.7% respectively in *P. obesus* and *P. ferrugineus*). The survival fraction (S_x) of later larval instars (>90 days) was high (0.97 and 0.98 respectively in *P. obesus* and *P. ferrugineus*) in both the species.

Fertility life table of *P. ferrugineus*

The observations on the population parameters of *P. ferrugineus,* indicated that sex ratio (F:M) was 1:1 and females oviposited from the second or third day after emergence until 17 to 45 days. The mean fecundity (ΣF_x) was 58.6 (eggs female^{-1} generation^{-1}), the female eggs day^{-1} female^{-1} (m_x) was 0.64, the total number of female births per generation of a female (R_o) was 29.00; the generation time was (T_c) was 292.5 days under laboratory conditions, when not confronted by the natural enemy or the abiotic factors. It was observed that the innate capacity for increase (r_c) was 0.012 females/female^{-1}day^{-1}and finite rate of increase (λ) was 1.012 indicating an increasing population and doubling time (DT) was 60.21 days (Table1). The age-specific survival (l_x) of adults was high in early stages of life cycle and the age specific fertility (m_x) curve showed a steady peak in early life with fluctuations throughout the life span (Fig.1). Percentage contribution by pre-reproductive stages for stable age distribution of the pest species was 95.18 per cent, and it was only 4.82 per cent by adults in case of *P. ferrugineus* (Table 4).

Age specific mortality life table for *P. ferrugineus*

Observations on the age-specific mortality life table of *P. ferrugineus* revealed that, the total pre-reproductive mortality was 80.93 per cent and only 19.06 per cent of the eggs reached the adult stage. Mortality was maximum (100 qx = 57.7%) during the 45 days larval stage and it decreased in the subsequently stages. Conversely, the survival fraction (S_x) was maximum (0.98) in 90 to 120 days larva and was the least (0.42) in larvae aged less than 45 days. The expectation of life remaining (e_x) was high in the larval stages *viz*., 45 to 90 days (3.46) and 90 to 120 days (3.31) (Table 2).

Fertility life table for *P. obesus.*

In case of *P. obesus,* the sex ratio (F: M) was 1:1.2 and females oviposited on the second day after

Table 1. Fertility life table details of *P. ferrugineus* and *P. obesus*

Fertility parameters	*P. ferrugineus*	*P. obesus*
Total fecundity (SF_x)	58.6 ± 14.19 *	66.86 ± 7.42 *
Mean daily fecundity (F_x)	1.3 ± 0.69 *	1.6 ± 0.48 *
Female eggs/female^{-1}day^{-1} (m_x)	0.64 ± 0.49 *	0.72 ± 0.57 *
Net reproductive rate (R_o)	29.00 ± 0.70 *	25.96 ± 0.51 *
Cohort generation time (T_c) days	292.5 ± 6.61 *	334.42 ± 6.34 *
Innate capacity for increase (r_c)	0.012	0.009
Finite rate of increase was ('λ')	1.012	1.009
Doubling time (DT) days	60.21	70.18
Sex ratio	1:1.02	1:1.20

*= Mean ± SD , Statistically NS; T-Test; degree of freedom = 46

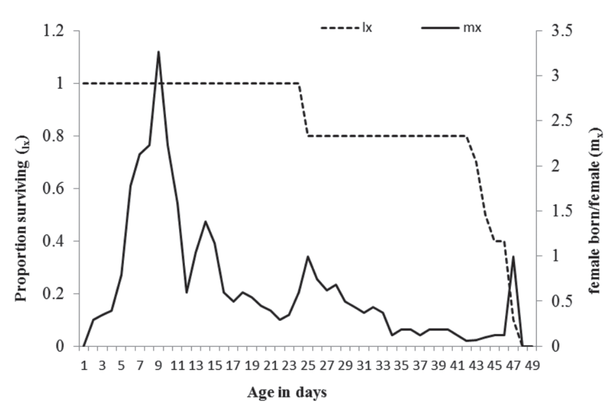

Fig. 1. Age specific survival (l_x) and fertility (m_x) for *P. ferrugineus*

Table 2. Age-specific life table for *P. ferrugineus*

Pivotal age (x)	n_x	d_x	l_x	100 q_x	S_x	L_x	T_x	e_x
Eggs (0-6days)	881	316	1.00	35.87	0.64	723.00	1952.59	2.22
Larva (6-45 days)	565	326	0.64	57.70	0.42	402.00	1229.59	2.18
Larva (45-90 days)	239	53	0.27	22.18	0.77	212.50	827.59	3.46
Larva (90-120 days)	186	3	0.21	1.61	0.98	184.50	615.09	3.31
Larva (120-210 days)	183	19	0.20	10.38	0.89	182.50	430.59	2.35
Pupa (<270 days)	182	23	0.20	12.64	0.92	169.50	248.09	1.36
Adult	168	168	0.18	100.00	1.00	78.59	78.59	0.50

x = developmental stage; n_x = number of entering stage; l_x= proportion surviving at that stage; L_x = number alive between age x and x+1d_x = number dying in stage x100; q_x = percentage specific mortality; S_x = survival rate within stage; T_x= Total number of age x units beyond the age x; e_x = life expectancy

emergence until 25 to 45 days. The mean fecundity (ΣF_x) was 66.86; the mean female eggs day^{-1} female^{-1} (m_x) was 0.72. The total number of female births per generation of a female (R_o) was 25.96; the generation time was 334.42 days under laboratory conditions, when not confronted by the natural enemy or the abiotic factors. The innate capacity for increase (r_c) was 0.009 females female^{-1} day^{-1} and finite rate of increase (λ) was 1.009 indicating an increasing population and doubling time (DT) was 70.21 days.

The beetles showed different levels of fertility throughout their life span. Fecundity was more (ΣF_x= 66.86) than *P. ferrugineus* (ΣF_x= 58.6) but not statistically significantly different (Table 1). The age-specific fertility curve showed fluctuation in oviposition throughout life span in *P. obesus* (Fig. 2). The total percentage contribution of pre reproductive stage was higher (98.66%) to the stable age distribution whereas; the adults contributed

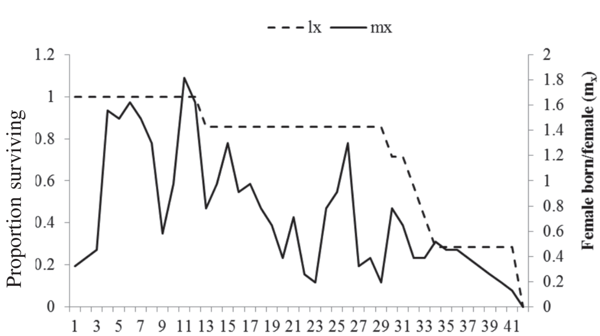

Fig. 2. Age specific survival (l_x) and fertility (m_x) for *P. obesus*

only 1.34 per cent, which was much lesser than that of *P. ferrugineus* (4.82%) (Table 4).

In the present study it was noticed that, the fertility parameters *of P. ferrugineus* and *P. obesus* were not significantly different.

Age specific mortality life table for *P. obesus*

Observations on the age-specific life table *P. obesus* revealed that, the total pre-reproductive age-specific mortality was 95.6 per cent and only 4.34 per cent of the eggs reached adult stage. The survival fraction (S_x) was maximum (0.98) for 120-180 day old larva and age-specific mortality (100 q_x) was maximum in the early larva stage (64%) and subsequently decreased in the later stages. The mean expectation of life (e_x) was high (2.61) in 45-90 day larva and 90-120 day larva (2.82) (Table 3).

Survivorship curves

The proportion surviving (l_x) in pivotal age 'x' of both *P. ferrugineus* and *P. obesus* revealed high mortality during egg and the early instar stages, which gradually decreased during further instars and other life stages of development. This trend of survivorship was considered as "type IV survivorship curve" as per the classification of Slobodkin (1962). The survivorship curves for both *P. ferrugineus* and *P. obesus* displayed similar trend, with a decline in the survival rate of early developmental stages, indicating them to be the most vulnerable (Fig. 3).

The results obtained in the present study differed from the earlier reports on the biology of *Plocaederus* species by different workers. Mariamma (1991) reported a total fecundity of

Table 3. Age-specific life table for *P. obesus*

Pivotal age (x)	n_x	d_x	l_x	$100q_x$	S_x	L_x	T_x	e_x
Eggs (0-6 days)	921	490	1.0	53.20	0.47	676	1380.50	1.50
Larva (6-45 days)	431	274	0.47	63.57	0.36	294	704.50	1.63
Larva (45-90 days)	157	57	0.17	36.31	0.64	128.5	410.50	2.61
Larva (90-120 days)	100	3	0.11	3.00	0.97	98.5	282.00	2.82
Larva (120-210 days)	97	2	0.11	2.07	0.98	96.0	183.50	1.89
Pupa (<270 days)	95	55	0.1	57.89	0.42	67.5	87.50	0.92
Adult	40	40	0.04	100	1.00	20.0	40.02	0.5

x = developmental stage; n_x = number of entering stage; l_x= proportion surviving at that stage; L_x = number alive between age x and x+1; d_x = number dying in stage x100; q_x = per cent apparent mortality; S_x = survival rate within stage; T_x = Total number of age x units beyond the age x; e_x = life expectancy

36.47 (eggs female^{-1}generation^{-1}), adult longevity 43.63days with sex ratio, 1:0.7 (F:M) for *P. ferrugineus* while, Raviprasad and Bhat (2000) reported for *P. obesus* fecundity was 49.0 (eggs female^{-1}generation^{-1}) and sex ratio, 1:1.2 (F:M) when reared on cashew bark under laboratory conditions. In the present study, sex ratio was male biased for both the species of *Plocaederus*; however fecundity was higher than the earlier reports.

The reports on the biological parameters and life table parameters of *Plocaederus* spp. are scanty, however; results obtained in the present study revealed that, both the species of *Plocaederus* exhibited deviation in population growth parameters in comparison to some of the cerambycid pests reported by earlier workers.

The net reproductive rate (R_o) revealed the rate of multiplication in a generation (Lotka, 1945). Reproductive capacity *Anoplophora glabripennis*, on three host tree species under laboratory conditions was reported to be 61.2, 22.2 and 14.6 and the annual intrinsic rate of increase on different species of hosts ranged from 2.7 to 4.1 (Smith *et al.,* 2002). In the current study, the net reproductive rate for *P. ferrugineus and P. obesus* on cashew under laboratory conditions was 29.00 and 25.96 respectively, which was much lower than that of *A. glabripennis*. The innate capacity to increase for *P. ferrugineus* and *P. obesus* showed that the population displayed a steady growth (λ>1).

Mazaheri *et al*., (2007) reported that Sarta long horned beetle, *Aeolesthes sarta* (Coleoptera: Cerambycidae) had lower intrinsic rate of increase (r_c) 0.0067 ± 0.24 females female^{-1} day^{-1} due to the low reproductive period (22 days) in comparison to the long lifecycle of females (mean 602 days). The intrinsic rate of increase is a function of innate capacity to increase which, increase in case of both the species of *Plocaederus* was found to be higher (0.012 and 0.009 respectively for *P. ferrugineus* and *P. obesus*) than the above reported findings, which indicated that, the population growth of *Plocaederus* species was superior on cashew in comparison to the growth of population of *A. sarta*.

The lifetime mean fecundity *of A. glabripennis* was reported to be 35 eggs female^{-1} (30-80 eggs) on

Table 4. Percentage contribution of various stages to the stable age-distribution in *Plocaederus* spp.

Plocaederus sp.	Contribution of various stages to SAD			
	Egg	Larva	Pupa	Adult
P. ferrugineus	41.61	48.08	5.48	4.82
P. obesus	54.34	40.84	3.4	1.34

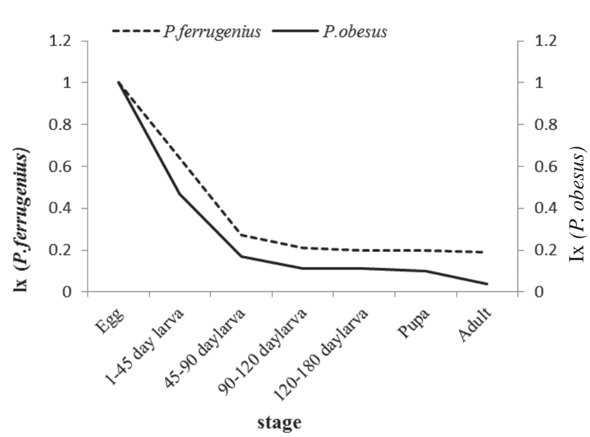

Fig. 3. Survivorship curve for *Plocaederus* species

Acer saccharum (Keena, 2000), which was much less than the fecundity of *Plocaederus* species revealed in the present study. The mean adult life span has been reported to be of 19 days and life time fecundity, 119 eggs per female for *Enaphalodes rufulus* (Cerambycidae) on red oak logs (Donley, 1978). In the present study, *Plocaederus* spp. had higher lifespan but lesser fecundity than the above species. Adult longevity was 47.3 days for *Acalolepta vastator* (Cerambycidae) on grapevine stem (Goodwin and Pettit, 1994). Akbulut and Linit (1999) reported that, adult longevity for *Monochamus carolinensis* (Cerambycidae) on pine logs was 38.3-61.4 days, which was comparable to *Plocaederus* species, however, fecundity (F_X) for *M. carolinensis* was reported to be 116.50 - 200 eggs per female and was more than the total fecundity of *Plocaederus* (F_X = 58.66 and 66.86 in *P. ferrugineus* and *P. obesus,* respectively) under laboratory conditions. The apple longicorn beetle, *Aeolesthes holosericea* had a total life span of approximately two years (25.16±1.83 months), single female laid 62.50±4.16 eggs and spent more than 17 months larval period including 4 to 5 months overwintering, to become pupa (Ruchie and Tara, 2013). In the current study, *P. ferrugenius* and *P. obesus* had comparatively lesser total life span duration of 313.53 days and 306.23 days, respectively.

The size of the future population at different stages was readily estimated based on the accumulated survival rates (l_x), sex ratio and average fecundity (F_x). The survival at different stage of these pest species varied and showed higher rates of survival at later stages of the pest which could point out the adult population in the next generation, which was indicative of the growth of the population. Age-specific survivorship (l_x) and fecundity (m_x) were not constant in ecological time, but fluctuated under variable environments in case of both the species of *Plocaederus*.

The current study revealed that, fertility was negatively correlated with age of the females in both the species of *Plocaederus*. The age specific mortality life tables of both the species of *Plocaederus* indicated that, the mortality in the pre-reproductive age was high and this maintained a natural check on the reproductive capacity of the species. The age-specific survival rate and age-specific fecundity are among the key population parameters influencing the intrinsic rate of increase (Birch, 1948). The mortality of the early larval stage was high and is a factor which curtailed the population growth. The survival fraction (S_x) of later larval instars (>90 days) was high (0.97 and 0.98, respectively in *P. obesus* and *P. ferrugineus*) in both the species that helped the population to maintain equilibrium. The percentage eggs reaching to adult stage were lesser in case of *P. obesus.*

Fritz (1979) reported that age specific birth and death rate played a chief role in attaining stable age distribution. The contribution of each stage of development of *Plocaederus* spp. revealed that, the adult stage of *P. ferrugineus* contributed higher than that of *P. obesus* adults to the stable age distribution. *P. ferrugenius* population had higher proportion of reproductive members. The lower sex ratio and lower contribution of adults to the stable age distribution in case of *P. obesus* would have resulted in the lesser value of finite rate of increase (λ).

Ruiliang Zhao (1993) constructed the life table for natural populations of *A. glabripennis* (Coleoptera: Cerambycidae) on *Populus pekinensis* and *P. dakuanensis*. Regular observations on the patterns and key influential factors for the population dynamics of *A. glabripennis* provided a scientific basis for population monitoring and integrated management of this pest. The results of present study also provide an insight on the population growth of these cashew pest species.

The investigation revealed that, the survivorship curves for both the species of *Plocaederus* to comprehend the most vulnerable stage of the pest and indicated similar patterns with high mortality occurring during egg stage and the early larval stage, which gradually decreased throughout further stages of development in both the species. This trend of mortality during early life stages and subsequently a gradual reduction as the population approached adulthood. This indicated that, the egg and early instar larval stages were the most vulnerable stages of the pest species.

Garcia-Ruiz (2012) recorded that the highest mortality of larvae of the grape pest, *Xylotrechus arvicola* (Coleoptera: Cerambycidae) occurred during the first few days of larval development. The laboratory-reared population exhibited a low intrinsic growth rate value (r_m= 0.01) as a result of its long duration for egg to adult development and its high larval mortality. The present investigation is in confirmation with the report. The early developmental stages (egg and early larval stages) of cashew stem and root borer were confirmed as the most vulnerable stage in the life cycle and hence these are the best stage for effectively implementing IPM strategies.

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