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Life table parameters of cotton mealy bug *Phenacoccus solenopsis* (Tinsley) on okra

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Abstract
Phenacoccus solenopsis life table experiments on the okra (*Abelmoschus esculentus* L.) host plant were conducted in the laboratory. The overall life cycle was completed in 53 days during the late summer (*Kharif*) season, according to the findings. On the 6th day, the highest mortality (d x) was seen, while the highest life expectancy (ex) was observed on the 25th day. The II instar had the highest death rate (19.50%), followed by the I instar (16.50 %). The intrinsic rate of increase was 0.188 (female/female/day), and the net reproductive rate was 183.76 (females/female/generation). The mean generation time was 29.47 days. The oviposition period was 23 days long. On the 4th day of crucial age, the highest natality (53.5 eggs/ female) was reported, while the lowest fecundity (5) was recorded on the 1st and 16th days. The study found that the sequential arrangement of all key life table parameters led to the conclusion that *Phenacoccus solenopsis* potential fecundity 405.5 eggs/female/generation and doubling time (3.68 days) with mean survival time 40.35 days were indicative of serious proportions, and thus may have a negative impact on okra production in India.

Keywords: *Phenacoccus solenopsis*, Okra, life table, natality, mortality, fecundity

Introduction

As a member of the Malvaceae family, okra (*Abelmoschus esculentus* L.) is also known as lady's finger in several parts of the world where it is cultivated. Other common names for okra include bhindi, okura, quimgombo, bamia, gombo, and lai long ma [15]. Okra is thought to have come from close to Ethiopia, where Egyptians commonly planted it in the 12th century. From there, it spread to the rest of the Middle East and North Africa [21,31]. Okra is a popular garden crop as well as a farm crop that is grown annually, primarily in tropical and subtropical regions of the world. It is a widely grown food crop that is renowned across the world for being delicious. Cotton, okra, tomato, brinjal, sesame, sunflower, and china rose are among the horticultural and field crops that have suffered severe economic loss [9,26,32]. The pest's potential to cause substantial harm, combined with its adaptation to a wide host range and habitat, poses a serious threat to agricultural crop cultivation in the future. This basic bioecology information is thus required to deal with the problem and to take preventative measures and prompt pest management.

Phenacoccus solenopsis Tinsley (Pseudococcidae: Homoptera) is a very polyphagous pest that has been found to infest 149 plant species, including crops, weeds, vegetables, ornamentals, and medicinal plants [1]. According to the research, *Phenacoccus solenopsis* had spread throughout India (South > Centre > North) [8]. *Phenacoccus solenopsis* was first reported on *Hibiscus rosa-sinensis* in Nigeria[3]. A life table is a useful tool for determining an organism's survival and mortality parameters in natural conditions [24,13] which can help researchers better understand the dynamics of an insect population while also revealing the best time to manage it [13, 29]. The intrinsic rate of increase is the most appropriate biological metric for determining the compatibility of various host plants and determining the amount of plant resistance to insect herbivores [30]. The life table is a unified and comprehensive account that contains information on development timeframes, growth stage survival rates, and population fecundity and life expectancy [14, 10, 11, 23, 33].

Result

A study of the age-specific life table of *Phenacoccus solenopsis* indicated that the generation took a maximum of 53 days to complete. On the 6th day, the highest mortality (d x) of 6.5 was observed, followed by 4.5 on the 46th day. Life expectancy (ex) was highest on the 25th day and lowest on the 52nd day (Fig.3). The mortality trend did not match the age-specific mortality trend. The second instar had the highest mortality rate (23.35 %), followed by the first instar (16.50 %), and the pre-adult or pupal stage had the lowest mortality rate (10.43 %) (Figure II). The highest survival percent (10.16) was found in the pre-pupal stage of the third instar, while the lowest (0.766) was found at the second instar stage. The mortality survival ratio for *Phenacoccus solenopsis* was initially (0.198) in the I instar, then increased to 0.305 at the second instar, which was the highest of all the stages, before decreasing to 0.113 and 0.117 at the III instar or pre-pupal stage and pre-adult or pupal stage, respectively. The indispensable mortality results followed a pattern similar to the mortality survival ratio. From the 22.5th day, the oviposition period lasted 23 days. On the fourth day of crucial age, the greatest natality (53.5 eggs/ female) was recorded. Egg laying was dramatically reduced after the sixth day. The maximum egg laying rate was more than 80% over the first few days. The first and sixteenth days had the lowest fecundity (5) (Figure. 4). The net reproduction rate was found to be 183.76, with the intrinsic rate of increase and mean generation time values of 0.188 and 29.4 respectively (Table. 1). In age-specific fecundity table mean survival time was 40.35 days with standard deviation 1.68 (Table. 2) Survival distribution function of age-specific and age-specific fecundity table were plotted with the Kaplan-Meier plot as shown in (Figure 1) and (Figure 2) respectively.

Table 1: Life table indices of *Phenacoccus solenopsis*

Host	Pf	R0	R_m	Λ	Tc	ɾ	DT	∑*IxMx.x*
Average	404.5	183.76	0.188	1.206834	29.47584	27.73208	3.686953	5416.48

Table 2: Mean survival time of age specific fecundity table

Mean survival time	Standard deviation	lower bound (95%)	Upper bound (95%)
40.3564	1.6895	37.0451	43.6677

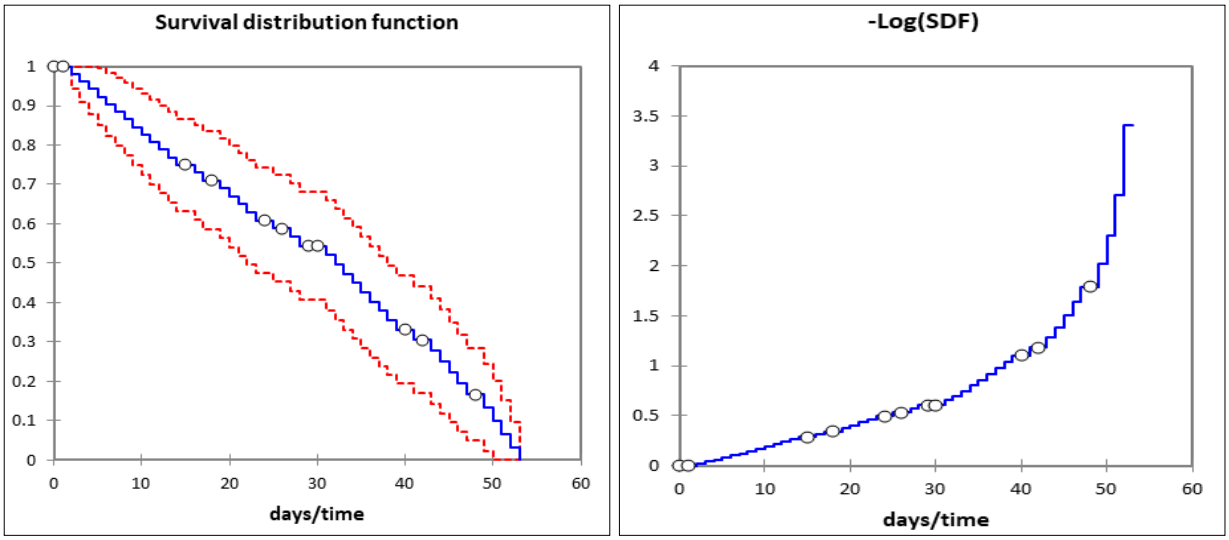

Fig 1: Age specific survival distribution function of *Phenacoccus solenopsis*

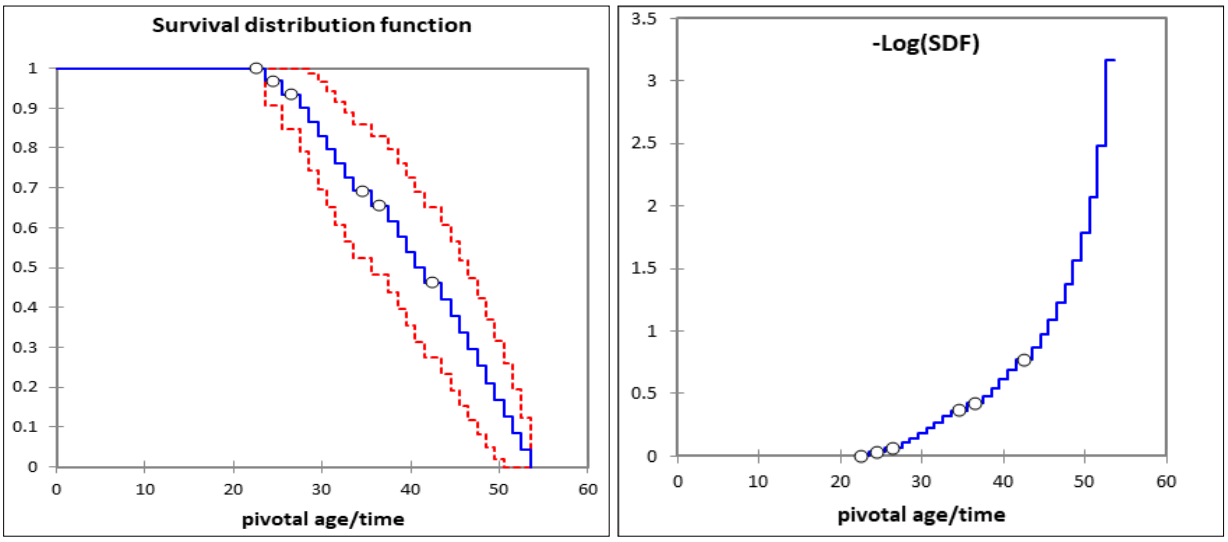

Fig 2: Age specific fecundity survival distribution function of *Phenacoccus Solenopsis*

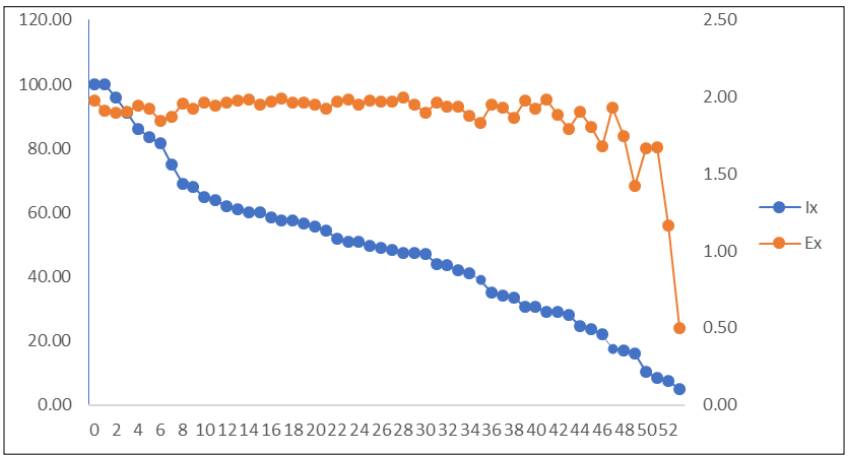

Fig 3: Age specific life expectancy of *Phenacoccus solenopsis*

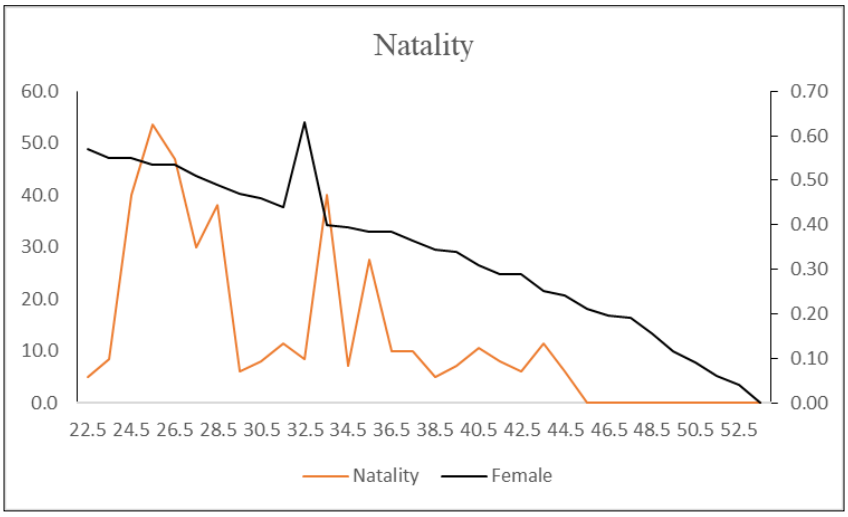

Fig 4: Age specific fecundity of female of *Phenacoccus Solenopsis*

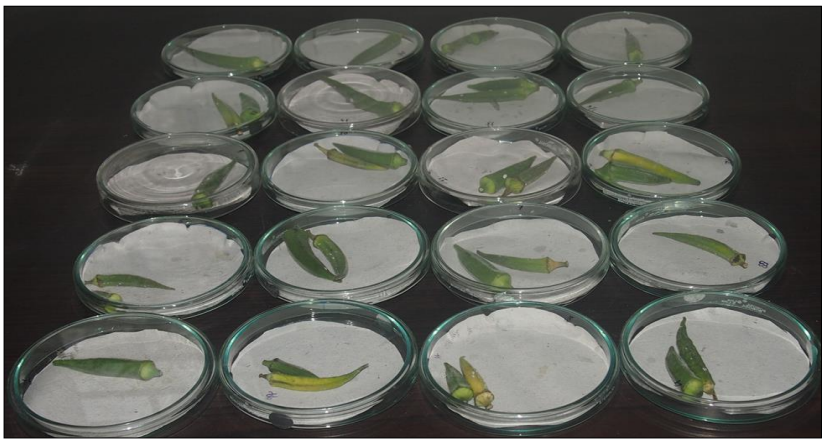

Fig 5: *In-vitro* study of life table parameters of *Phenacoccus solenopsis* on Okra

Fig 6: Microscopic view of male and female of *Phenacoccus solenopsis*

Discussion

The finite rate of increase(λ) time was (1.20) on okra and the net reproduction rate was found to be 183.76, with intrinsic rate of increase and mean generation values of 0.188 and 29.4 respectively, relatively similar results were obtained by [19] they found that the net reproductive rate of *Phenacoccus solenopsis* was 65.29 and 278.46 at vegetative stage of cotton during 2008 and 2009 respectively and same trend was observed in finite rate of increase (λ) with corresponding values 1.184 and 1.274, 1.114 and 1.123, 1.156 and 0.154 at vegetative, flowering and maturation stage during both seasons, respectively, with the precise (r^m) value 0.188 found similar to 0.183 during 2008. While the study conducted by [22] on age specific life tables of *Phenococcus parvus* on seven plant species revealed that the net reproductive rate 183.76 was low in *Phenacoccus solenopsis* as compare to the maximum on lantana (263) followed by tomato (249) and eggplant (231), whereas it

was least in *Clerodendron*. A sequential arrangement of all key life table parameters leads to a conclusion that potential fecundity 404.5 eggs/female/generation and doubling time (3.68) days relatively similar results were obtained by the[6]. They reported that the doubling time was lowest at 30℃ (3.94 days) and higher at 20℃ and 25℃ (7.98 and 4.23 days, respectively). indicative of gaining serious proportions and hence may have an adverse impact on okra production in India.The term "generation time" refers to the period of time needed for a population to grow by a rate that is equal to its net reproductive rate [10]. When calculating the Generation Mean Length (Tc), a value of (29.47) days was calculated and similar results were obtained by the [6]. The second instar had the highest mortality rate (23.35 %), followed by the first instar (16.50 %), whereas according to the initial increased mortality seen at all temperatures could be explained by first-stage organisms overcoming their greatest mortality hazards [5]. The intrinsic rate of increase (rm) was 0.188 in this finding, which also summarized the physiological qualities of an insect relation to capacity to increase [7]. Net reproductive rate was 183.76 which would be affected, depending on the host and the environmental condition as the Longevity, reproductive rate, growth rate and Food supplies (host plants or host preys) and environmental factors like temperature may have an impact on population fluctuations[12]. *Phenacoccus solenopsis'* lifespan, generation time, and doubling time generally decreased with temperature and were comparable to those of Aphis gossypii Glover on cucurbits [4]. Our findings, which are presented here, clearly demonstrated how Okra affected *Phenacoccus solenopsis* lifespan, fertility, and rate of nymphal mortality. However, because insects are never exposed to constant temperatures in their natural habitat, it is difficult to predict how well parameters estimated under laboratory conditions at constant temperatures could function in the field. However, it produces straightforward summary statistics like life expectancy and reproduction rate on okra.

Conclusion

From a pest management view, it is very useful, by knowing such vulnerable stages. We can make time-based application of insecticide after the prediction through the data of life table indices such as doubling time, net reproductive rate, cohort generation time etc for the management of insect pests, to avoid injudicious use of insecticide which leads to the conservation of natural parasites and predators at proper time and to reduce the environmental pollution. It would be the pioneer life table study of *Phenacoccus solenopsis* on okra after cotton, as *Phenacoccus solenopsis* is the serious sucking insect pest on cotton, but now it switches to food crop like okra. Therefore, this research could be used to develop the simulation model by incorporating artificial intelligence technology to formulate the best management tactic.

Materials and method

Plants

The experiment was conducted in experimental field at the Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh (U.P.), India, during in year 2017, where plants of okra (*Abelmoschus esculentus*), variety Prabhani Kranti was grown and no insecticides were used.

Group Insect rearing

Phenacoccus solenopsis stock culture was taken from the experimental field and cultured in a lab at 20 to 24°C and 60 to 70% relative humidity on fruits of the same variety of okra, Prabhani Kranti. In order to conduct a life table study, gravid females of *Phenacoccus solenopsis* were gathered and raised on the okra fruits separately for newly hatched nymphs in a laboratory. Nymphs were then released and placed onto okra fruit harvested from the experimental field (Figure 5 & 6).

Individual insect rearing.

For life table study, hatched crawlers(nymphs) were released on uninfested fresh okra variety (Prabhani Kranti) fruits with the help of fine hair brush and were kept in petri plates of 90 mm (two to three okra fruits were kept in each petri plate) under binocular microscope. Experiment with 100 crawlers (10 per petri plate) in two replications were conducted, and the average of the two replications was utilised to analyse the data. Fresh okra fruits were provided to the crawlers every three days, and the filter paper was changed daily to maintain hygienic conditions. Newly deposited crawler masses were inspected and counted using a binocular microscope, and daily mortality observations were recorded (Figure 5 & 6).

Life Table Analysis: Life tables were constructed using the following parameters in software, MS office Excel sheet:
X: The pivotal age for the age class in units of time (days).
lx: The number of surviving individuals at the beginning of age class x.
dx: The number dying during the age interval x
100qx: Percent apparent mortality100qx = [dx / lx] x 100 x = Age of the insect in days. lx = Number surviving at the beginning of each interval, out of 100dx = Number dying during the age interval, out of 100.
Tx: Total number of age x units beyond the age
Tx = lx + (lx + 1) + (lx + 2) ……+ lw.
ex: Life expectancy for individual of age xex = Tx / l xmx: Age specific fertility, the number of living females born per female in each interval
Ro: Net reproductive rate. This is equal to the sum of the lx.mx products, or Ro= ∑ lxmx.
T: Cohort generation time (in days), approximated by T = $\sum x\ l_x m_x / \sum l_x m_x$ (time between the birth of the parents to that of their progeny).

r_m **:** The intrinsic rate of natural increase, calculated by, r_m = ln (Ro)/T.
DT: Doubling time (in days), the number of days required by a population to double, calculated by, DT = ln (2)/r_m.
A: The finite capacity of increase, calculated by, λ =e^{r_m}.

Survival Analysis

The Kaplan-Meier method was used to estimate mean survival times of *Phenacoccus solenopsis* XLSTAT 2014.5.03 software, after changing the age specific life and age specific fecundity table in binary form for analysis of data at 5 percent significance level.

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Author contribution
Dr. Masarrat Haseeb edited, revised and improved English language. She also guided the experiment.

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