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ASSESSMENT OF SOME BOTANICALS ON THE LIFE-TABLE PARAMETERS OF OKRA MOTH, *EARIAS VITTELLA* (FABR.) (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT: The okra moth *Earias vittella* is one of the dangerous pests attacking okra in India. The present study was conducted aiming at evaluation of effects of various botanicals, *viz.*, aqueous extract of garlic bulb (AEG), aqueous extract of neem leaves (AEN) and NeemGold (NG) on the life-table parameters of this insect. Different concentrations of each botanical had been applied on the host plant, *Abelmoschus esculentus*. The current investigation recorded significant reduction of the age-specific survivorship, reproductive and net fecundity rates; intrinsic rate of natural increase and doubling time of the population of the pest while generation time remains unaffected. Also, longevity of the adult females was remarkably shortened. The strongest shortening action was determined by NG, followed by AEG and AEN, respectively. Total fecundity rate (R_t) was reduced to 102.17 (AEG), 68.00 (AEN), 54.67 (NG), 235.67 progeny/female (Control), respectively and net reproductive rate (R_o) were 52.00 (AEG), 33.83 (AEN), 26.50 (NG) and control was 119.67daughter/female. Likewise, values of the intrinsic rate (r_m) were 0.1689 (AEG), 0.1524 (AEN), 0.1440 (NG), 0.2035 (control), respectively. The generation time (GT) insignificantly varied between 22.79 to23.51 days. Reproductive periods and post-reproductive periods were significantly affected (decreased) by the tested botanicals. The present data may be informative for an IPM programme of *E. vittella.*

KEYWORDS: Adult, development, emergence, fecundity, larva, longevity, mortality, population, reproduction, survivorship.

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1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench), also known as ladies' fingers, is a flowering plant in the family Malvaceae. It is cultivated in tropical, subtropical and warm temperate regions as vegetable crop for its edible green seed pods. Although, *A. esculentus* is a perennial herb, is cultivated as an annual crop in temperate climates. It is rich in dietary fiber, vitamin C, E and K, along with moderate amount of thiamin, folate and calcium, iron, magnesium, phosphorus, potassium and zinc [1]. The okra is mainly cultivated in West Bengal (14%) followed by Bihar (12%), Gujarat (12%), Andhra Pradesh (10%), Odisha (9%), Jharkhand (7%), Chhattisgarh (7%), Telangana (6%), Madhya Pradesh (5%), Maharashtra (4%), Haryana (3%), Assam (3%), Uttar Pradesh (2%), and others (6%) [2]. In India, okra is cultivated in an area of 524.00 mha with an annual production of 6203.00 MT with productivity rate 11.90 MT/ha in 2013-14 [2]. It is infested by several insect pests of which the shoot and fruit borer, *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) is a major pest [3]. In India it is distributed almost in all states [4]. The larvae of okra moth feed on fruit internally making exit hole which is a sign of infestation. It also feeds on growing point internally as borer along with the inflorescence, leaves and stems. *E. vittella* was reported to cause upto 57% fruit infestation [5] and 54.04 % net yield loss in this plant [6]. To deal with these sucking pest threat, a number of chemical insecticides have been freely sprayed on this crop, which led to several ecological problems like toxic residues [7], elimination of natural enemies [8], environmental disharmony and development of resistance among insect pests [9]. The present paper deals with the effect of plant derived biopesticides on the life-table parameters of *E. vittella* as these tend to be less toxic, quickly biodegradable and more targeted to the specific pest [10]. Life table offers an important means to understand the population variation of the insect pest throughout its life cycle. It is a supportive approach in entomology, where developmental stages are discrete and death rates may vary extensively from one life stage to another. Life table is an important analytical measure in the ecological studies, since it presents detailed information of population dynamics to create simple but more helpful statistics. It also provides a complete account of the survivorship, development and expectation of life [11-12]. In the area of population dynamics of insects, usefulness of life table is becoming more recognized with the recent emphasis. A life table is a tabular device which describes every particular age of interval. In addition, life table studies provide an opportunity to assess and evaluate the impact of specific mortality factors acting on insect population [13-15]. Also, life tables can make quantitatively and qualitatively evaluation of various host plants [16]. The value of the life table in the study of natural population was identifies [17] and called it as "life equation" [13]. As for example, first detailed example of a life table for natural population of spruce budworm was presented by [18]. The life tables provide a way to tabulate birth and death rate of insects. With the help of life tables, we can calculate the life expectancy of insects and can be used for their control. On this basis, we can practice a plan for the managing of insect

pest at particular time. Key factor analysis has proven to be a valuable aid in identifying the environmental factors most closely related to intergenerational population trend [19]. In the present investigation effect of foliar application of aqueous extract of neem leaf and garlic bulb, and NeemGold [Azadiractin A 0.03% (300 ppm), Neem oil 90.57%, Hydroxy EL 5.00%, Epichorohydrin 0.50% and Aromex 3.90% manufactured by Foliage Crop Solution Private Limited # 5, iii Floor Sun Plaza, 19, G.N, Chetty Road, Chennai 600006] was observed on the life table of *E. vittella.* Following life table parameters of *E. vittella* were calculated: survival curve/age specific survival rate, age-specific net fecundity rate, estimation of net and total fecundity rate, estimation of intrinsic rate of increase (r_m), estimation of other life table parameters such as generation time (GT), doubling time (DT), weekly multiplication rate (r_w) etc. and the variations in all statistics were discussed.

2. MATERIALS AND METHODS

2.1. Rearing of the test insect

The *E. vittella* were reared in the laboratory adopting the standard methods [16, 20]. The stock of *E. vittella* was maintained by procuring infested okra (*Abelmoschus esculentus*) fruits from the local fields. As per requirement, different lots of such infested okra fruits were kept in rectangular insectaries (15x15x15 cm) made of card board, the top and four sides were fitted with soft fine mesh plastic net for ventilation. Inside the infested fruits, the larvae steadily grew till pupation by consuming the developing seeds. The full grown larva (approx. 2.0 cm in size) after completing development inside the okra fruit makes its exit and selects a suitable spot viz., the wall of the insectary, or even the outer surface of the fruit itself to pupate in a tough silken cocoon. Under optimal conditions, the pupal period lasts for 5 to 9 days at the end of which new generation of adult moths emerges after sunset.

2.2. Preparation of biopesticides

2.2.1. Aqueous extract of garlic bulbs (AEG)

Aqueous extract of garlic bulb was prepared by grinding 1 kg of garlic bulbs with 1 liter of distilled water. The extract was squeezed through fine meshed rayon cloth and finally filtered through Whatman filter paper. The filtrate (w/v) was used for foliar application as test biopesticide on experimental plant.

2.2.2. Aqueous extract of neem leaves (AEN)

Leaves of neem (*Azadirachta indica*) were locally collected. Its aqueous extract was prepared by grinding 1 kg of fresh leaves with 1 liter of distilled water. The extract was squeezed through fine meshed rayon cloth and finally filtered through Whatman filter paper. The filtrate (w/v) was used as test biopesticide for foliar application on experimental plant.

2.2.3. Neem Gold preparation (NG)

NeemGold was purchased from local market. It contains Azadiractin A 0.03%, Neem oil 90.57%, Hydroxy EL 5.00%, Epichorohydrin 0.50% and Aromex 3.90%, and is manufactured by Foliage Crop Solution Private Limited, Chennai, 600006, India. For preparation of its test solution, 1 ml of NeemGold was dissolved in 100 ml of distilled water.

2.3. Experimental setup

LC_{50} for each treatment of biopesticides was calculated [21] and 20% and 60% of 24h, 48h, 72h and 96 h of LC_{50} of given biopesticides were applied on fresh leaves of okra plant and dried under the fan and in case of control, leaves were dipped in distilled water and dried accordingly. The females were allowed to deposit their eggs on these leaves. Treated leaves kept in the beakers having moist filter paper at their bottoms at alternate day. The numbers of eggs laid were counted within 3-4 days of egg laying to observe total fecundity. These eggs were kept under observation until hatching. After hatching, the neonate larvae were transferred gently on bisected fresh pods with the help of camel brush treated and dried under fan with biopesticides as mentioned earlier until pupation and pods were changed an alternate days. The investigation on life tables of *E. vittella* was carried out at a constant temperature of $26\pm1^{o}C$ in laboratory on okra. To construct the life table, 10 pairs of adults were kept for egg laying in 45 x 45 x 60 cm wooden cages and were fed on a small sponge piece soaked in 20% honey solution. The sides of the cage were covered with muslin cloth. Tender leaves of okra were inserted in a conical flash (4 inch diameter) containing fresh water to keep them fresh and turgid, were placed into the cage for resting and oviposition of the adult moths. Eggs laid on white muslin cloth or on leaves were used for this study. In order to construct the life tables, 100 eggs were collected carefully with the help of wet camel hair brush and placed in ten plastic containers (8 cm x 4.5 cm) in batches of 10 each. The eggs were glued on black card paper in one row to facilitate observations on hatching. Immediately after hatching, larvae were transferred individually on okra plant. Fresh food was provided daily at morning. Data of larval development, pupation, adult emergence and fecundity were recorded daily. Age-specific mortality in different developmental stages was also recorded. With a view to determine the age-specific fecundity, total number of adults emerged on the same day were caged for oviposition. Number of eggs laid on subsequent days on okra and muslin cloth was recorded. Fecundity had been considered until female death. As the sex ratio was almost 1:1, the number of eggs obtained per female was divided by two to get the number of female birth (m_x).

2.4. Age-specific life-table statistics

Age-specific life-table statistics were calculated by Lotka-Euler model [22]. The death and survival rates during each day were recorded for the ovipositing adult females. The proportion of surviving females from birth to age X (l_x) was calculated. The intrinsic rate of natural increase (r_m) was estimated by iterating Lotka-Euler equation: $\sum l_x m_x \exp(-r_m X) = 1$, where m_x = the mean number of

daughtersper female of age X (pivotal age: developmental time + age at oviposition). The net productivity rate (R_o) defined as the mean number of daughters produced by one female during its mean life-span, was calculated by the equation: $R_o = \sum l_x m_x$. Similarly, total fecundity rate (R_t) defined as the mean number of progeny yielded by one female during its mean life-span was calculated as $R_t = \sum l_x t_x$, where t_x is the mean number of progeny per female of age X. The generation time (GT) which was equivalent to the mean period elapsed between the birth of parents and the birth of the progeny was calculated as: $GT = \ln R_o / r_m$. The doubling time (DT), defined as the time required to double the population size were calculated as : $DT = \ln 2 / r_m$. The finite rate of increase λ_m was calculated as $\lambda_m = \exp(r_m)$. $(\lambda_m)^7$ gives the factor of the population by which the population increase per week, i.e., r_w (weekly multiplication rate).

3. RESULTS AND DISCUSSION

3.1. Age-specific survivorship rate and longevity

Life expectancy of insects can be calculated by predicting natural things in particular instar within which the maximum mortality of the pests is obtained and plan for managing pests in time [23]. Life table for *E. vittella* was constructed when reared on okra fruits, seeds and epicarp [24]. The pattern of female survival [l_x] was diagrammed in Figure 1.
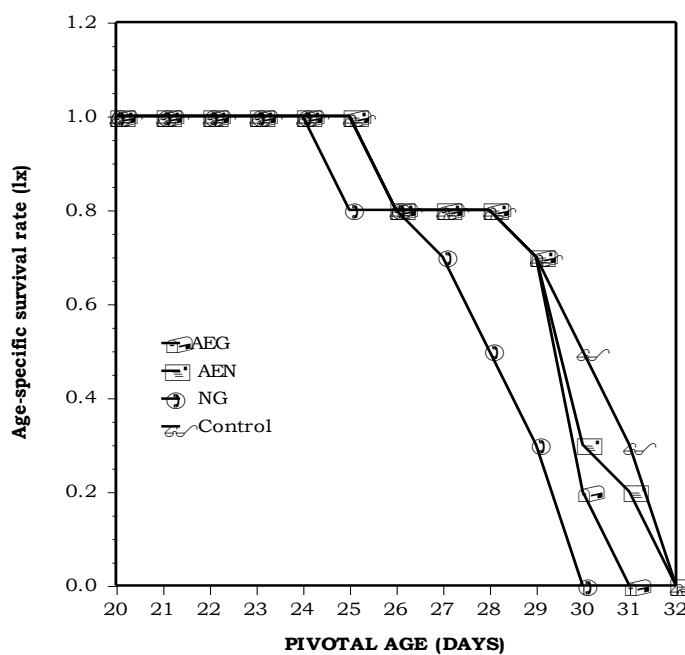

Figure 1. Age-specific survival rate (l_x) of the *E. vittella* on host plant treated with botanicals
Depending on the plotted curve, all adult female moths survived 3-11 days after treatment with different botanicals. The l_x decreased gradually. Thereafter, mortality of adult females commenced so that all females died on day 11. The mean survival periods (longevity) was significantly influenced (F =11.64, P < 0.01) by botanicals at 26°C which were 9.33±1.75, 9.50±2.17, 6.33±0.55, 11.67±1.37days in AEG, AEN, NG treated leaves and untreated leaves, respectively. It implied that the life-span of the adult females had been shortened (46%, 19%, 20% after treatment with NG,

AEN and AEG, respectively compared to untreated congeners. No significant effects of the tested botanicals had been observed on pre-reproductive period (F = 1.67, insignificant) whereas these botanicals significantly influenced the reproductive (F =6.18, P < 0.01) and post-reproductive periods (F =3.81, P < 0.05) of the pest insect (F< 0.05) of botanical was observed. The post-reproductive period was maximum 2.67 days in case of control and minimum 0.50 days in case of NG treated leaves. Life table of the corn earworm *Helicoverpa armigera* was constructed on different food plants [25]. The results showed that cotton and soybean had higher viability at the stages of growth, higher rate of survival of adult females in the reproductive period than the other host crops, and similar values for insects reared on an artificial diet, revealing that cotton and soybean can be appropriate for rearing *H. armigera* on a natural diet [25].

3.2. Age-specific net fecundity rate (m_x) and net fecundity rate (R_0)

The age specific net fecundity rates (m_x) were diagrammatically presented in Figure 2. The average value of daily net fecundity rate (m_x) reached the maximum of 9.01 daughters/female/day in control setup on first day while it was half of control setup, 4.89 female/day after treatment with AEG. After treatment with AEN and NG, it drastically decreased to 2.87 and 3.01 female/day, respectively.
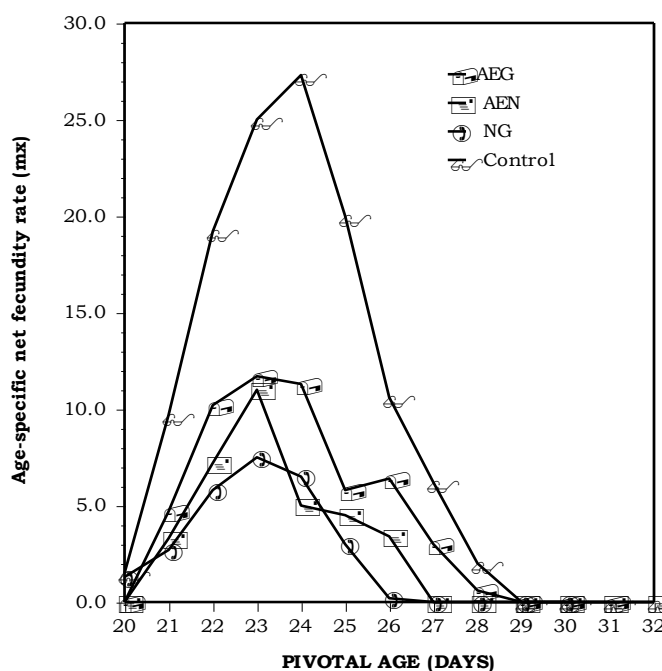

Figure 2. Age specific net fecundity rate (m_x) of *E. vittella*.

The m_x was highly influenced by the tested botanicals. The estimate of net fecundity (R_0) of *E. vittella* was 119.67 daughters/female in control setup which decreased nearly half 52.00 daughters/female on AEG, whereas on AEN and NG, 33.83 and 26.50 daughters/female were observed, respectively. It showed significant effect (F= 80.11, P < 0.01) of the tested botanicals. The highest net reproductive rate (R_0) of that pest was recorded in 185.27 and the intrinsic rate of natural increase in number (r_m) ranged from 0.16 to 0.17 females per female per day on okra fruits [26].

3.3. Fecundity rates (t_x) and net fecundity rate (R_t)

Like m_x, the value of average daily t_x (Figure 3) reached the maximum (18.18 progeny/female/day) at control setup, which decreased approximately half on AEG treatment (9.58 progeny/female/day) and decreased to 6.29 progeny/female/day on AEN treatment and 8.00 progeny/female/day on NG treatment. Thus, AEG, AEN and NG significantly affected the value of t_x. The total fecundity rate (R_t) of *E. vittella* was 235.67 progeny/female in control setup, whereas it minimized more than half 102.17 progeny/female after treatment of AEG. The number of progeny had been reduced to 68.00 progeny/female by the treatment of AEN. Data revealed that it was highly affected by NG, which minimized it to 54.67 progeny/female. It also showed the significant effect of the tested botanicals (F= 87.39, P < 0.01). Depending on results on the latter authors, the net reproductive rate of *E. vittella* on okra fruits, seeds and epicarp were 114.50, 140.23 and 112.71 female progeny per female per generation, respectively. Also, the innate capacity for increase in (r_m) was 0.1569 on okra seed, 0.1384 on okra epicarp and 0.1569 on okra fruits [16] which were comparable to results obtained in the present study.
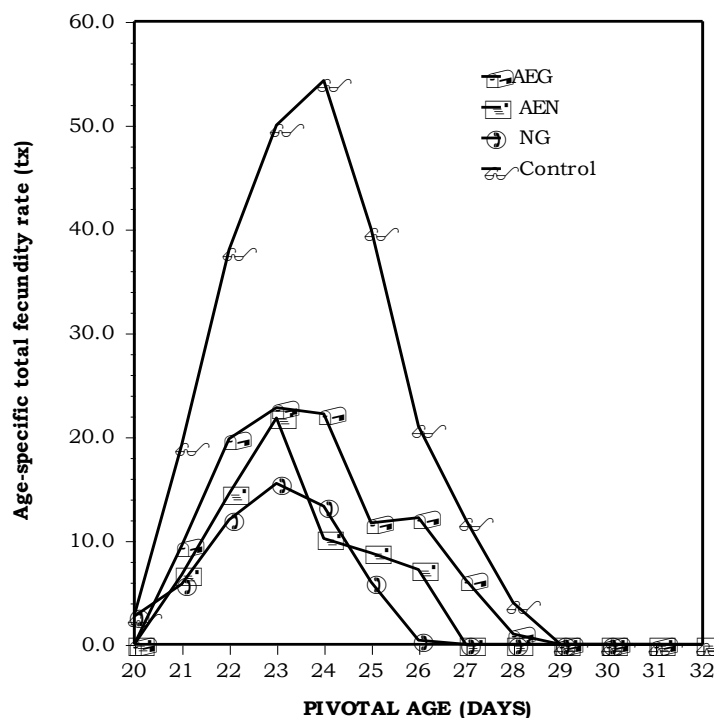

Figure 3. Age specific total fecundity rate (t_x) of *E. vittella*.

3.4. Intrinsic rate of natural increase and other life-table parameters

The value of intrinsic rate of natural increase (r_m) of *E. vittella* was estimated as 0.2035 in control set which was 21.9, 33.9 and 41.7% higher when the larvae were exposed to AEG, AEN and NG, respectively (Table 1, Figure 4). Nanthagopal and Uthamasamy (1989) studied the life-table of *Earias vitella* on four *Gossypium* spp. viz. *G. barbadense* (Suvin), *G. hirsutum* (MCU 9), *G. herbaceum* (TKHe 44) and *G. arboreum* (K 8) and reported its maximum survival from egg to adult on MCU 9, compared to other varieties. Net reproductive rate (R_o) was also maximum on MCU 9

and minimum on K 8. The intrinsic rate of increase (r_m), finite rate of increase (λ_m) and weekly multiplication (r_w) were maximum on Suvin and minimum on K8 [27].

3.4.1. Intrinsic rate of total increase (r_t)

Similarly, the value of intrinsic rate of total increase (r_t) of *E. vittella* was estimated as 0.2330 for untreated larvae which was 17.6, 27.5 and 32.3% higher when the larvae were exposed to AEG, AEN and NG, respectively (Table 1, Fig. 4). These results demonstrated that the NG was more toxic for the population growth of the okra moth.

Table 1. Mean values of life-table parameters of *E. vittella* as affected by the tested botanicals

Particulars	AEG	AEN	NG	Control
Survival (in days)	9.33	9.50	6.33	11.67
Total fecundity rate, R_t (number of mummies yielded/female)	102.17	68.00	54.67	235.67
Net reproductive rate, R_o (number of daughters/female)	52.00	33.83	26.50	119.67
Intrinsic rate of natural increase (r_m)	0.1689	0.1524	0.1440	0.2035
Finite rate of increase (λ_m)	1.1840	1.1646	1.1549	1.2257
Intrinsic rate of total increase (r_t)	0.1982	0.1827	0.1761	0.2330
Mean length of generation time (GT, in days)	23.39	23.11	22.76	23.51
Weekly multiplication rate of population (r_w)	3.26	2.91	2.74	4.16
Doubling time of the population (DT, in days)	4.10	4.55	4.81	3.41
Pre-reproductive period (days)	1.00	1.00	0.67	0.67
Reproductive period (days)	6.67	5.83	5.17	2.67
Post- reproductive period (days)	1.67	2.67	0.50	2.67

3.4.2. Finite rate of increase (λ_m) and weekly multiplication rate (r_w)

The values of finite rate of increase (λ_m) calculated as $\lambda_m = \exp(r_m)$ is used to estimate the function by which the population increase in n days as λ_m^n. It is applied to know the weekly multiplication rate (r_w) as λ_m^7. In the present study, it is evident that the population of *E. vittella* increased 4.16 times when the larvae were untreated with biopesticides but this rate was found to decrease sharply when they were treated with biopesticides, more prominently with NG (only 2.74 times, i.e. decreased by 34.3%) (Table 1, Figure 4). The finite rate of increase in number was 3.23 females per female per day on okra fruits [26].
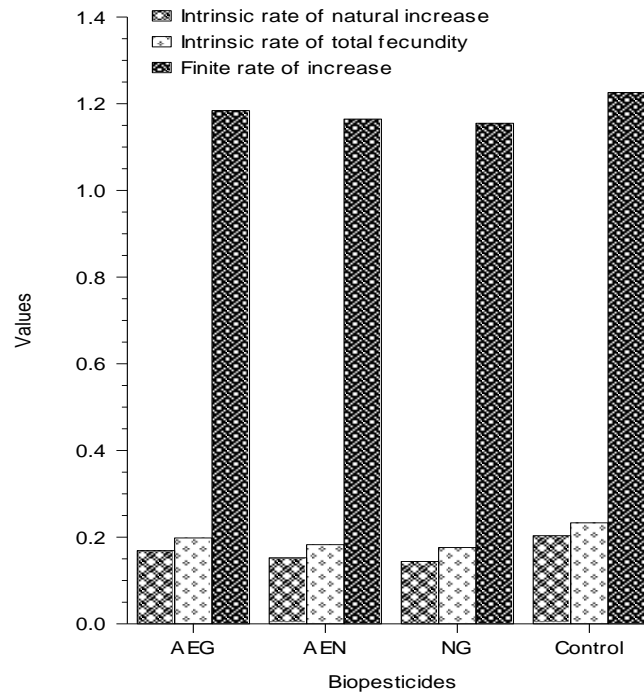
Figure 4. Effect of biopesticides on intrinsic rate of natural increase (r_m), intrinsic rate of total increase (r_t) and weekly multiplication rate of *E. vittella*.

3.4.3. Doubling time (DT)

The values of doubling time (DT) express the time taken to double the population. Table 1 and Figure 5 demonstrated that *Earias vittella* took 3.41 days to double the population while after treatment of LC_{50} of biopesticides, it took 4.10, 4.55 and 4.81 days for AEG, AEN and NG, respectively. The shorter generation time and higher intrinsic rate of population increase on okra seeds shortened the population doubling time of *E. vittella* to 5.67 days, while the doubling time was 6.64 or 9.00 days on cotton or *Abutilon indicum* seeds [28].

3.4.4. Generation time (GT)

The values of generation time (GT) of *E. vittella* was insignificantly affected by different botanicals. In case of untreated environment, the generation time of *E. vittella* was 23.51 days which differed very little when the larvae were exposed to different biopesticides Table 1 and Figure 5. Some difference in this study, in comparison with other reported studies [16, 29, 30] , might be due to some weather parameters. The highest net reproductive rate (R_o) of the present pest was recorded as 185.27 and the intrinsic rate of natural increase in number (r_m) ranged from 0.16 to 0.17 females per female per day on okra fruits. The survival (l_x) of immature stages of *E. vittella* on different host plants was 0.65 on okra, 0.56 on cotton, 0.54 on semi-synthetic diet and 0.51 on mesta [30].
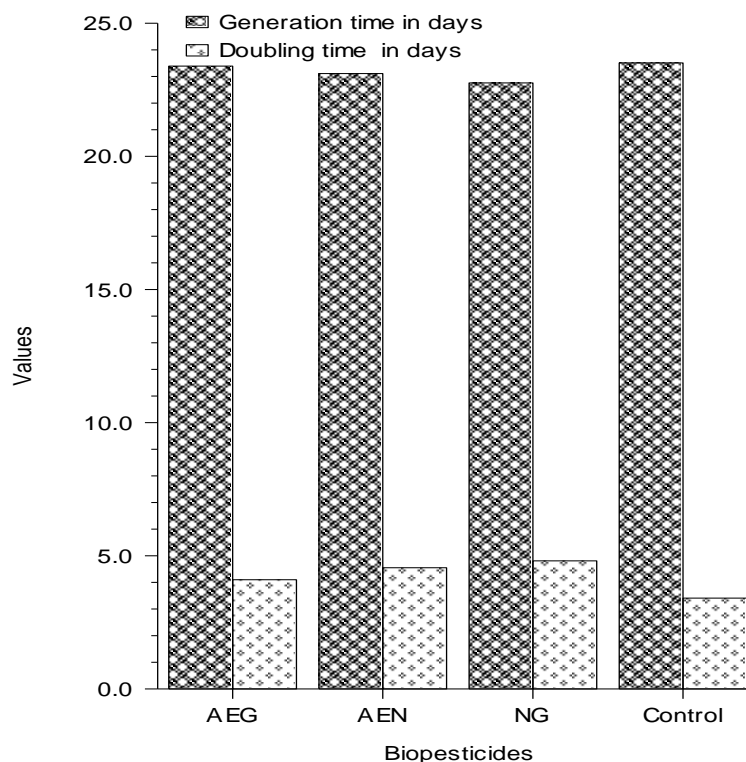
Figure 5. Effect of biopesticides on doubling time (DT) of the population and generation time (GT) of *E. vittella*.

The net reproductive rate (R_o), at the end of each generation, of *E. vittella* was 81.91 on okra, 56.70 on cotton, 53.02 on semi-synthetic diet and 36.63 on mesta (*Hibiscus cannabinus*). The net reproductive rate (R_o) followed the same order as the survival rate (l_x) on the different hosts. The innate capacity for increase in numbers (r_m) ranged between 0.0888 and 0.1334 females/female/day. In descending order, the r_m values on different hosts were okra (0.1334), cotton (0.1111), semi-synthetic diet (0.1029) and mesta (0.0888). We could not find reported results where life-table was constructed for any pest after exposure of pesticides/biopesticides. Therefore, the values obtained herein could not be compared. However, these parameters will be beneficial for programming the control program of *E. vittella* as it provides the expected age-distribution of the pest insects.

4. CONCLUSION

From the pest management standpoint, it is very useful to know when (and why) a pest population suffers high mortality. This is usually the time at which it is the most vulnerable. We can make time based application of insecticide for the management of insect pests by knowing such vulnerable stages from life table studies, to conserve the natural parasitoids and predators and to reduce the environmental pollution. The life table data obtained in the present study can provide an insight into the demographics of pest populations. Quantifying age-specific birth and death rates enables us to detect patterns and make predictions about the growth or decline of pest populations in the future.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of the present paper.

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