Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith, 1797) may not be a Major Threat on Maize in South India: A Revelation Through its Life Table Studies

Begum Bennihalli RIYANA¹ Aralimarad PRABHURAJ” Pramod KATTI²
Shivanand G. HANCHINAL³ Yatagal Sharanappa AMARESH⁴

¹Department of Agricultural Entomology, College of Agriculture, UAS, Raichur-584104, Karnataka, INDIA
²Nodal officer-ICAR, UAS, Raichur, Karnataka, INDIA
³AICRP on cotton, Main Agricultural Research Station, UAS, Raichur, Karnataka, INDIA
⁴Department of Plant Pathology, College of Agriculture, UAS, Raichur, Karnataka, INDIA

E-mails: ¹riyanabegum08@gmail.com, ²prabhusha2014@gmail.com, ³pkatti2007@gmail.com, ⁴shanchinal@gmail.com, ⁴ysama2008@rediffmail.com

ORCID IDs: ¹0009-0003-2248-6259, ²0000-0001-7703-4266, ³0000-0001-7171-5706, ⁴0000-0002-6162-6133, ⁴0009-0008-0007-7071

”Corresponding authors

ABSTRACT

Life table of *Spodoptera frugiperda* (J. E. Smith) on maize was studied in the laboratory set at 27 ± 1 °C to identify the key natural mortality factors. The net reproductive rate \( (R_0) \) was 389.88 females with a mean generation time \( (T) \) of 31.45 days. The intrinsic rate of increase \( (r_m) \) and daily finite rate of natural increase \( (\lambda) \) were 0.18 and 1.20 females/female/day, respectively, with weekly multiplication rate \( (\lambda) \) of 3.58. The present study elucidates this pest as high-risk species capable of causing considerable economic loss to maize in coming years. However, the life table studies of field population recorded 18 mortality factors. The highest ‘K’ value (mortality rate) was observed in egg stage with maximum mortality (59.70%) followed by the late larval stages (25.23%). Generation survival was as low as 0.2577 with survivorship curve of type III typical to any invertebrate population which will have higher mortality in early developmental period and relatively lower mortality in surviving population. The higher egg and larval mortality is attributed to native egg and larval parasitoids belonging to Hymenoptera and Diptera. Thus, it can be predicted that, in coming days, this pest can be managed effectively by conservation and exploitation of its natural enemies population along with other control methods.

Keywords: Fall armyworm, Invasive pest, mortality factors, natural enemies, life table.


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INTRODUCTION

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae), a crop pest native to tropical and subtropical regions of the America, was reported for the first time from South India during 2018 on maize (Sharanabasappa et al, 2018). The pest was believed to be migrated from African continent where it was first noticed in late 2016 covering 44 African nations (Goergen & Tarmo, 2016; Nagoshi et al, 2019; Rwomushana et al, 2018). After its invasion to India, reports of its occurrence in several parts of South India started appearing profusely (EPPO, 2018; Shylesha et al, 2018; Sharanabasappa et al, 2018). Simultaneously, its presence was also reported from other states viz., Andhra Pradesh (Venkateswarlu & Muralikrishna, 2018), Tamil Nadu (Srikanth et al, 2018), Chhattisgarh (Deole & Paul, 2018), Maharashtra (Chormule et al, 2019), Gujarat (Sisodiya et al, 2018), Odisha (Kerketta, Verma, Ayam, & Yadav, 2020) and West Bengal (Dhar et al, 2019).

Being a polyphagous pest, it is known to feed on more than 80 crop species (Goergen et al, 2016). However, maize is most preferred host and its infestation in Africa, India and Indonesia ranged from 6-100 per cent (Mallapur, Naik, Hagari, Prabhu, & Patil, 2018; Sari, Suliansyah, Nelly, & Hamid, 2021). It was estimated that, in the absence of suitable management practices, the FAW can cause yield losses in maize to the range of 8.3 to 20.6 Million tonnes per annum in African continent (Day et al, 2017). After its incursion to India, the total production of maize was reduced from 28,753 MT (2017-18) to 27,720 MT (2018-19) (Anonymous, 2019). In India, the pesticide expenditure to produce 100 kg of maize grains has increased from US$ 0.124 in 2017 to US$ 1.39 in 2020 due to the invasion of fall armyworm (Deshmukh et al, 2021).

The severity of FAW in terms of causing considerable yield losses in economically important agricultural crops was attributed to its wide host range, high dispersal ability, high fecundity rate and the absence of diapause (Knipling, 1980). The pest can migrate over 500 km before oviposition (Prasanna & Peschke, 2018).

For the successful establishment of an invasive pest, favourable environmental conditions akin to the place of its origin, high reproductive capacity and growth rate, stable resource availability and minimum/no biotic stress in the form of natural enemy are essential (Sallam, 2013).

In many cases, it has been observed that, many pests that are notorious in the regions of their origin failed to establish in invaded areas (Huber et al, 2002). At the same time, some of the insignificant or average pests in the areas of origin became highly pestiferous in the migrated regions (Kfir, 1997; Sallam, 2013). Fall armyworm has been successfully established in the invaded areas including India causing huge economic losses (Anonymous, 2019). However, whether the same trend continues in a longer run is the matter of concern and research. The biotic potential (the innate ability of survival and reproduction) and the environmental resistance (especially biotic resistance in the form of natural enemies and competition with other closely related species for food and space) are the key factors to decide the fitness of an organism in a long run (Choudhury, Rizvi, & Satpule, 2012).
The life table is one of the important analytical tools in pest management as it reveals the most opportune periods, vulnerable stages of the insect species, thus providing detailed information on population dynamics to generate more informative statistics. Further, it also gives a comprehensive description of life history parameters, survivorship, expectation of life, key mortality factors and development of predictive model which can be tested against the natural population fluctuations (Harcourt, 1969; Bellows & Elkinton, 1992; Kakde & Tayade, 2014). Life table studies of S. frugiperda have been initiated in India since its invasion and highlighted the biotic potential of the pest (Ashok et al, 2020). Therefore, the present study aimed to assess the biotic potential and the environmental resistance exerted by natural enemies on FAW through life table studies. The study also helps in assessing the performance of FAW as a serious pest in the coming years which helps in developing better management strategies.

MATERIALS AND METHODS

The investigations on life table study of FAW on maize were carried out during 2019-2020 at the Department of Agricultural Entomology, UAS, Raichur, India (16.2036° N latitude and 77.3300° E longitude).

Life table studies under laboratory conditions from laboratory reared population

Insect culture

The FAW culture was maintained in the laboratory on maize leaves and grains at 27 ± 1 °C with 75 ± 05% r.h. throughout the study period. Larvae were reared individually in glass vials (10 ml capacity) plugged with cotton wad. After completion of larval period, pre-pupal stage was allowed for pupation in the moist sand (10%). Emerging male and female moths were released into the insect cages (30 x 30 x 30 cm) and provided with potted maize seedlings (20-25 days old) for egg laying. In each cage, five pairs of adults were maintained. Cotton roll dipped in 10% honey solution was provided in the cage for adult feeding. Life table studies were initiated from 1-d-old batches of eggs laid by adult female during oviposition period.

Life table studies

A batch containing 100 one-d--old eggs was placed in a plastic vial (5.0 x 4.0 cm) with the help of camel hair brush. Immediately after hatching, larvae were individualized in a plastic vial (5.0 x 4.0 cm) and fed with bits of tender maize leaves for first three instars and with fresh corn seeds thereafter at 24 h interval till the completion of the larval period. A sub batch of 10 individuals was made for recording life table parameters. Once larval period was completed, pre-pupa was transferred to a vial containing sterilized moist (10%) sand to facilitate pupation. Throughout the developmental period from egg till the death of an adult moth, various observations such as survivability of each individual, duration of each stage, pre-ovipositional, ovipositional, post-ovipositional durations and fecundity of female moth was recorded daily.
Age-specific distribution life table

Age-specific distribution life table was constructed by partitioning its life cycle into distinct developmental stages viz., egg, larva, pupa and adult and evaluated the developmental time and survival or mortality for each of the developmental stages. The number of eggs hatched was counted immediately after hatching. Dead and malformed stages were recorded and removed as they occurred. The stable age distribution table was constructed as suggested by (Andrewartha & Birch, 1954; Atwal & Bains, 1974): \( x = \) pivotal age in days, \( L_x = \) stable age distribution \( (l_x + (l_x + 1)/2) \) where \( l_x = \) survival of individuals at different age interval, \( r_m = \) intrinsic rate of increase in number by solving equation \( \log_e R_0/T \) (Where \( e = 2.71828 \) and \( T = \) Mean generation time). Per cent distribution of each age group \( (x) \) was calculated by multiplying the \( L_x \) with \( e^{-r_m(x+1)} \). By combining, the percentage under each stage viz., egg, larva, pupa and adult, the expected per cent distribution was worked out.

Observation for above characters were recorded for two generations and used for constructing life table.

Age-specific fecundity life table

The total number of adults emerged on the same day were paired and each pair was placed in insect oviposition cage (30 x 30 x 30 cm) having 1 mm metal mesh on four sides separately with 10 per cent honey solution as food. Maize leaves were used as substratum for oviposition and were introduced daily in the cages. Observations on fecundity were recorded and continued up to the death of all female moths. As the sex ratio of majority of insects including noctuid moths is 1:1, the number of eggs obtained per female was divided by two to get the number of born females \( (m_x) \).

The following parameters of fecundity life table are worked out as proposed by Howe (1953): \( l_x = \) survival of female at age ‘\( x \)’, \( m_x = \) age schedule for female births at age ‘\( x \)’, \( R_0 = \) Net reproductive rate \( (\sum x.l_x.m_x) \), \( P_f = \) Potential fecundity \( (\sum m_x) \), \( l_x.m_x = \) Reproductive expectation, \( T = \) Mean length of generation \( (\sum x.l_x.m_x/R_0) \), \( \lambda = \) Finite rate of increase in number \( (\text{antilog } e^{r_m}) \), \( \lambda^7 = \) Weekly multiplication of population, \( DT = \) Doubling time \( (\log_e 2/r_m) \), \( (R_0)^2 = \) Hypothetical \( F_2 \) female.

Life expectancy

Life expectancy of \( S. \) frugiperda was worked out by using columns \( x, \) \( l_x, \) \( d_x, \) \( 100q_x, \) \( L_x, \) \( T_x \) and \( e_x \). Where, \( l_x = \) Number of survival at the beginning of the interval out of 100, \( dx = \) Number dying during ‘\( x \)’, 100q_x = mortality rate per hundred alive at the beginning of the age interval \( (d_x.100/l_x) \), \( L_x = l_x+(l_x+1)/2 \) is alive between \( x \) and \( x+1 \), \( T_x = \) Number of individual’s life days beyond ‘\( x \)’, \( e_x = \) expectation of further life \( (T_x/l_x x 2) \).

Various population indices were included and computed in this study from the fecundity table as suggested (Howe, 1953; Birch, 1948).
Life table studies of field population under laboratory conditions

**Egg sampling:** The investigation was carried out to identify the key natural mortality factors of *S. frugiperda* in maize ecosystems of Raichur and Koppal district during 2019. These two districts grow maize as sole crop for two seasons (monsoon and post monsoon season) in a year. Since many farmers of these regions have small to marginal land holdings, they often do not take up any control measures. Samples were drawn from the field populations throughout the cropping season. Egg masses (containing 300-400 eggs) present on different plant parts were collected carefully, placed inside the polythene bags and brought to the laboratory. Each batch was transferred to a rearing container (ventilation size, 4mm) and incubated separately at 27 ± 1 °C to observe the egg mortality due to parasitization, infertility, desiccation or unknown reasons. Totally, 10 such batches were maintained for observation. In each batch, egg parasitoids if any emerged, were collected and preserved in 70 per cent ethanol for identification. The preserved egg parasitoids were sent for identification to National Bureau of Agricultural Insects Resources (NBAIR), Bengaluru based on morphological characteristics. The desiccated and other non-viable eggs due to unknown causes were discarded after recording their number and only hatched larvae were reared up to adult emergence.

**Larval sampling:** Larvae of *S. frugiperda* were collected at monthly interval from the same fields where eggs were collected. The identity of the pest was established on the basis of typical feeding injury on leaf whorls and on the presence of fresh excrements (Sharanabasappa et al, 2019). Larval samples were grouped into three categories viz., early stage (1st and 2nd), mid stage (3rd and 4th) and late stage larvae (5th and 6th). Accordingly, the collected larvae were placed in a separate bread box (30 x 15 x 10 cm) containing bits of maize leaves (early stage larvae) and pieces of tender cobs (mid and late stage larvae). Later, larvae were placed individually in plastic vials along with food and maintained at 27 ± 1 °C to observe the mortality in each stage to record key natural mortality factors such as parasitization, diseases or unknown reasons. The parasitoids emerged from different growth stages (larval, prepupal and pupal) were collected and preserved in 70 per cent ethanol. Late instar larvae were placed in plastic vials containing sterilized wet sand to facilitate pupation. The observations were made daily basis on the number of malformed, diseased, mechanically damaged and incompletely developed larvae, prepupa, pupa and adult.

**Construction of field life table**

The different larval stages of *S. frugiperda* collected was referred as egg (N1) while constructing field life table as suggested by Morris and Miller (1954). After the construction of life table, the survivorship curves, mortality factors (K- factors) and relationship between mortality of *S. frugiperda* and K-values were worked out.

In the present study, the life table was constructed according to the method described by Morris and Miller (1954); x = Age or stage interval at which the sample was taken (egg, larva, pupa or adult), lx = The number surviving at the beginning of the stage noted in the ‘x’ column, dx = The number dying within the age interval...
stated in the ‘x’ column. The mortality factors responsible for dx, 100qx = Mortality rate during stage ‘x’ (dx as percentage of lx), Sx = Survival rate within the stage mentioned in the x column. K = Age specific key mortality. Key factor which is primarily responsible for increase or decrease in number from one generation to another was calculated. However, the total generation mortality was calculated by adding ‘K’ values of different life stages.

Age-specific survivorship and mortality

The survivorship curve was drawn by plotting the number of survivors in a given age (lx) against the age interval (x). The shape of the curve describes the distribution of mortality factors in relation to age (Slobodkin, 1980). Different mortality factors were identified and corresponding K- values were assigned for each of the mortality factors at different developmental stages and the relationship S. frugiperda mortality and K- values was calculated.

RESULTS

Life table studies under laboratory conditions from laboratory reared population

Survival of different developmental stages

The mean duration of different life stages viz., egg, larva and pupa of S. frugiperda was 3, 13 and 10 days, respectively. Out of 100 eggs observed, 92 eggs hatched into larvae of which 82 successfully completed their development, whereas, 72.5 succeeded to enter into pupal stage and same number of adults emerged. The cumulative mortality in egg, larval and pupal stages was 8, 18 and 27.5%, respectively (Table 1).

Table 1. Survival (%) of different developmental stages of S. frugiperda on maize.

<table>
<thead>
<tr>
<th>Replication</th>
<th>No. of eggs</th>
<th>Egg stage (0 to 3 days)</th>
<th>Larval stage (4 to 16 days)</th>
<th>Pre pupa and Pupal stage (17 to 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>8.5</td>
<td>6.5</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>8.5</td>
<td>8</td>
<td>6.5</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>10</td>
<td>7.5</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>9.5</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>8.5</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7.5</td>
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<tr>
<td>7</td>
<td>10</td>
<td>8.5</td>
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<td>7.5</td>
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<td>8</td>
<td>10</td>
<td>10</td>
<td>8.5</td>
<td>7.5</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>8.5</td>
<td>7.5</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Cumulative survivability (%)</td>
<td>92</td>
<td>82</td>
<td>72.5</td>
<td></td>
</tr>
<tr>
<td>Cumulative mortality (%)</td>
<td>8</td>
<td>18</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>Duration of growth stages in days</td>
<td>3</td>
<td>13</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

The mortality rate did not change significantly among the egg, larva and pupal stages of S. frugiperda, although numerically it was highest at larval (10%) followed by the pupa (9.5%) and egg (8%) Stage.
Fall Armyworm, Spodoptera frugiperda may not be a Major Threat on Maize

Age-specific distribution

Towards stable age distribution, eggs contributed to the tune of 56.91% followed by larvae (39.80%) and pupae (2.88%). The lowest contribution (0.39%) was made by adult stage.(Fig. 1).

![Age-specific distribution](image)

**Figure 1.** Contribution of different life stages of *S. frugiperda* to the stable age distribution.

Age-specific fecundity

The pre-oviposition period of *S. frugiperda* ranged from 26\textsuperscript{th} to 28\textsuperscript{th} day of pivotal age. Females started laying eggs on 29\textsuperscript{th} day (mx = 145.73) and continued up to 37\textsuperscript{th} day (mx = 7.47), with lx values of 0.315 and 0.195, respectively. The maximum number of offspring per female per day (mx = 307.73) was achieved in 31\textsuperscript{st} day, whereas, the lowest number of progenies per female per day (mx = 7.47) was recorded on 37\textsuperscript{th} day. The net reproductive rate (Ro) was 389.88 numbers. The mortality of first female within the cohort occurred on the 7\textsuperscript{th} day after its emergence \textit{i.e.}, on the 32\textsuperscript{nd} day (lx = 0.31) and increased thereafter (R\textsuperscript{2} = 0.41), indicating steady decrease in survival rate (lx) (Fig. 2).

![Age-specific fecundity](image)

**Figure 2.** Age-specific fecundity of *S. frugiperda* on maize.

Population growth parameters

Mean generation time (T) of *S. frugiperda* was 31.45 days. The intrinsic rate of increase (rm) and finite rate of natural increase (λ) were 0.18 and 0.20 females/female/day, respectively. Under a given set of conditions, FAW population doubled
in 3.67 days with multiplication rate of 3.58 times per week. The hypothetical female population in F$_2$ generation was 152006.414 with a potential fecundity (Pf) of 1272.41 eggs per female (Table 2).

Table 2. Population growth parameters of *S. frugiperda* on maize.

<table>
<thead>
<tr>
<th>Population growth parameters</th>
<th>Calculated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net reproductive rate (Ro)</td>
<td>389.88 numbers</td>
</tr>
<tr>
<td>Mean length of generation (Tc)</td>
<td>31.45 days</td>
</tr>
<tr>
<td>Innate capacity for increase in number (rm)</td>
<td>0.1895 females/female/day</td>
</tr>
<tr>
<td>Finite rate of increase in number (λ)</td>
<td>1.20 females/female/day</td>
</tr>
<tr>
<td>Arbitrary ‘rm’ (rc)</td>
<td>0.19</td>
</tr>
<tr>
<td>Weekly multiplication of population(λ)</td>
<td>7.58 days</td>
</tr>
<tr>
<td>Doubling time (DT)</td>
<td>3.67 days</td>
</tr>
<tr>
<td>Potential fecundity (Pf)</td>
<td>1272.41</td>
</tr>
<tr>
<td>Hypothetical F2 female (Ro)2</td>
<td>152006.414 number</td>
</tr>
</tbody>
</table>

**Life expectancy**

The life expectancy (ex) of *S. frugiperda* declined gradually as the age advances. The life expectancy of newly deposited eggs was 19.61 days. However, the mortality rate (dx) was comparatively high on 33$^{rd}$ to 36$^{th}$ day of pivotal age when the expected further life was reduced from 19.61 days in the beginning to 0.5 day ($R^2 = 0.87$) (Fig. 3).

![Figure 3. Life expectancy (Ex) of *S. frugiperda* on maize](image)

**Life table studies of field population under laboratory conditions**

**Life table studies:** Among the 1785 eggs observed throughout their development period, the highest mortality was recorded in the egg stage (59.70%), followed by the late larval stage (25.23%), the pupal stage (10.96%), the mid larval stage (10.63%), the early larval stage (5.44%) and the adult stage (3.77%).

The egg parasitoids such as *Trichogramma* and *Telenomus* genera accounted to the tune of 9.8 and 30.43 per cent mortality, respectively. The factor of desiccation was of 19.46 per cent. During the early stage larval development, 5.33 per cent population died due to unknown reason, while hymenopteran parasitoids represented only 0.11 per cent. The mortality factors in the middle larval stage were mainly due to unknown reason (6.25%), hymenopteran parasitoid (3.05%), entomopathogenic fungi (1.21%) and dipteran parasitoid (0.12%). However, in the late stage larval development, the mortality rate
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increased considerably due to contribution of unknown factor (11.71%), entomopathogenic fungi (5.93%), hymenopteran parasitoids (4.58%) and dipteran parasitoids (3.01%). Among the various key mortality factors in larval stage, the unknown factor contributed to the highest percentage of mortality (23.29%) followed by hymenopteran parasitoids (7.74%), entomopathogenic fungi (7.14%) and dipteran parasitoids (3.13%).

Total mortality in the pre pupal stage was 9.04% of which 5.61% was due to dipteran parasitoids, followed by unknown factor (3.42%). In pupal stage, the total mortality recorded was 10.96% in which death due to unknown factor contributed 9.47% followed by dipteran parasitoids (1.49%). In the adult stage, a mortality rate of 3.77% was recorded due to the malformation.

The generation survival (SG) of *S. frugiperda* was 0.2577, indicating that only 25.77% of the population was able to survive and successfully complete the generation. The mortality of eggs due to egg parasitoids contributed high ‘K’ value of 0.4659. For larval stages, unknown factor contributed to high ‘K’ value (0.2437) followed by hymenopteran parasitoids, entomopathogenic fungi and dipteran parasitoids with ‘K’ values of 0.0788, 0.0732 and 0.0317, respectively (Table 3).

**Survivorship curve**

In the present investigation, the survivorship curve obtained fits to type III curve, which indicates the lowest age specific survival rate in the early stage of life and a high probability of survival for those passing through this bottleneck (Fig. 4). The highest rate of mortality was observed in the egg stage (59.70%) and thereafter it stabilizes in early and mid larval stages. However, the survival rate dips further from late stage larva to prepupal stage (25.23%) and again stabilizes.

![Type III survivorship curve of *S. frugiperda* on maize.](image)

**Mortality factors (K- factors)**

A total of 18 mortality factors (K1 to K18) were identified. Some of the major identified mortality factors were hymenopteran egg (K1 and K2) and larval parasitoids (K4, K6 and K10), dipteran parasitoids (K7, K11, K14 and K16), entomopathogenic fungi (K8 and K12) and desiccation (K3). Other factors included adult malformation (K18) and death due to unknown reasons (K5, K9, K13, K15 and K17) (table 3). The relationship between mortality factors of *S. frugiperda* and K-value indicated that as
the percentage mortality increases, K-values also increases (Fig. 5). Generally, K-values depict only the extent of mortality but not the nature of association.

Figure 5. Relationship between mortality of *S. frugiperda* and K-value.

Table 3. Life table studies of field collected population of *S. frugiperda* under laboratory conditions.

<table>
<thead>
<tr>
<th>Age interval (x)</th>
<th>No. alive at the begging of x (lx)</th>
<th>Factors responsible for death (dx)</th>
<th>K’ s</th>
<th>No. of dying during x (dx)</th>
<th>Mortality per cent 100qx</th>
<th>Mortality d=dx/lx</th>
<th>Survival S=1-d</th>
<th>K’ value (-ln(s))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg (N1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1785</td>
<td>175</td>
<td>Trichogramma sp. K1</td>
<td>9.80</td>
<td>0.0980</td>
<td>0.9020</td>
<td>0.1031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1610</td>
<td>490</td>
<td>Telenomus sp. K2</td>
<td>30.43</td>
<td>0.3043</td>
<td>0.6957</td>
<td>0.3628</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1120</td>
<td>218</td>
<td>Desiccation K3</td>
<td>19.46</td>
<td>0.1946</td>
<td>0.8054</td>
<td>0.2164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub total</td>
<td>883</td>
<td></td>
<td>59.70</td>
<td></td>
<td></td>
<td></td>
<td>0.6823</td>
<td></td>
</tr>
<tr>
<td>Early stage larvae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>902</td>
<td>1</td>
<td>Hymenopteran parasitoids K4</td>
<td>1.11</td>
<td>0.0011</td>
<td>0.9989</td>
<td>0.0011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>901</td>
<td>48</td>
<td>Unknown reasons K5</td>
<td>5.33</td>
<td>0.0533</td>
<td>0.9467</td>
<td>0.0547</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub total</td>
<td>94</td>
<td></td>
<td>5.44</td>
<td></td>
<td></td>
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<td>3.77</td>
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<td>Reproducing females x 2</td>
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K-value = 1.3549
DISCUSSION

*Spodoptera frugiperda* exhibited greater survivability with minimum mortality from egg to adult stage when reared under a given set of congenial conditions. In the present life table study of laboratory reared populations, the immature stages are vulnerable compared to the adult stage, as a result eggs and larvae contribute most to the stability of age distribution of the population which was not only observed by other researchers on *S. frugiperda* (Ashok et al, 2020) but also on other phytophagous pests (Bilapate, Pawar, & Thombre, 1980; Acharya & Patel, 2007; Gedia & Patel, 2008; Patil & Jat, 2014; Patil & Shitap, 2015; Deb & Bharpoda, 2016; Basavaraj & Shadakshari, 2018; Sunil & Hanchinal, 2019). In the adult stage, the fecundity of female moth increased as age advances reached a peak and starts declining. In case of age-specific survival rate, the survivability of the adults decreased with age (Fig. 2). (Singh & Yadav, 2009; Patil et al, 2014; Patil et al, 2015; Deb & Bharpoda, 2016; Basavaraj et al, 2018).

The overall life table studies on laboratory reared FAW clearly indicated its ability for quick multiplication (3.58 per week) and doubling rate in minimum days (3.67 days) which is a common observation made so far in FAW on maize (Rosa, Trecha, Alves, Garcia, & Goncalves, 2012; Omoto et al, 2016; Ashok et al, 2020) as well as other noctuid pests viz., *Spodoptera litura* (F.) on groundnut (Sunil et al, 2019; Gedia et al, 2008) and tobacco (Patil et al, 2014; Patil et al, 2015) and *Helicoverpa armigera* (Hubner) on chickpea (Dhabi & Patel, 2007; Singh & Yadav, 2009) and tomato (Deb & Bharpoda, 2016).

However, the life table studies of field populations of FAW gives a different picture in terms of population survival. A significant mortality was observed in all the developmental stages of FAW including adult stage. The major mortality factor was natural parasitisation by various hymenopteran and dipteran parasitoids followed by entomopathogens and unknown factor. Lepidopterans in general and noctuid pests in particular are attacked by innumerable hymenopteran parasitoids and *S. frugiperda* is no exception to that. Several species of hymenopteran/dipteran parasitoids and entomopathogens are known to attack egg, larval, and pupal stages of major noctuid pests such as *H. armigera* (Bisane, Khande, Bhamare, & Katole, 2009; Kaneria, Kabaria, Variya, & Bharadiya, 2018) and *S. litura* (Geetha & Jagadish, 2014; Kumar, Bharodia, & Acharya, 2015; Bhadane, Kumar, & Acharya, 2016) which are native to India.

In the present study, FAW was found to be vulnerable to different native hymenopteran and dipteran parasitoids at key developmental stages. The total parasitoid contribution to the mortality of FAW in the present study was accounted to the tune of 58.2% of which 40.23% was recorded in the egg stage alone. Several reports are also available in support of present study recording important egg parasitoids belonging to Trichogrammatidae and Platygastridae on FAW after its invasion in India (Shylesha et al, 2018; Dhar et al, 2019; Sharanabasappa et al, 2019; Gupta, 2019; Firake & Behere, 2020). Further, hymenopteran larval parasitoids belonging to Braconidae, Ichneumonidae, and Bethylidae were also found attacking FAW (Shylesha
et al, 2018; Sharanabasappa et al, 2019; Gupta, 2019; Firake & Behere, 2020; Sagar et al, 2022). The dipteran parasitoid of the family Tachinidae was reported on larval and larval-pupal stages of FAW (Sharanabasappa et al, 2019; Firake & Behere, 2020).

Further, in the present study, entomopathogens have contributed 7.14% mortality in the field population in support of similar such observations made in Indian FAW population (Shylesha et al, 2018; Mallapur et al, 2018a; Dhar et al, 2019; Sharanabasappa et al, 2019; Firake & Behere, 2020). In addition to biotic stress, other factors such as desiccation and unknown contributed 19.46 and 36.18%. This could be due to several factors of which prevailing environmental condition and the type of management practices that farmers’ follow plays an important role (Sari, Suliansyah, Nelly, & Hamid, 2021). The overall trend indicated that, the high mortalities observed in the egg and late larval stages have a greater contribution in the reduction of the S. frugiperda population on maize. Similar observation was also made by other scientists on FAW (Dhar et al, 2019), Spodoptera exigua (Hubner) (Farhani, Naseri, & Talebi, 2011) and S. litura (Geetha & Jagadish, 2014; Kumar et al, 2015; Bhadane et al, 2016).

Overall, it could be summarized that, S. frugiperda though has high biotic potential and quick multiplication rate, but suffer heavy mortality due to biotic stress in the form of parasitoids and entomopathogens. This is an encouraging since; the native natural enemies are extending their host range to the exotic species. With the present result it can be predicted that, in coming days, the populations of FAW can be managed effectively on maize by exploiting the native natural enemy population. In addition to this, insecticide management generally followed will further decrease the population. Thus, it can be anticipated that, its infestation on maize may not pose a serious threat to economical yield loss. However, care should be taken if S. frugiperda expands its host range.

CONCLUSION

Fall armyworm has made a big negative impact on the production of maize in India since its invasion. However, the present life table studies on field populations has revealed its vulnerability to many of the native natural enemies. The study has reported highest egg and larval mortality due to hymenopteran and dipteran parasitoids which is highly encouraging. Conservation of natural enemies with judicious use of insecticides would be a wise approach in containing this pest in India.

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REFERENCES


RIYANA, B.B., et al


Fall Armyworm, Spodoptera frugiperda may not be a Major Threat on Maize


