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STUDIES OF LIFE TABLE ON FALL ARMYWORM (*SPODOPTERA FRUGIPERDA* J.E. SMITH)

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ABSTRACT

Studies on life table of *Spodoptera frugiperda* were carried out for two years (2019-20 and 2020-21) at Main Agricultural Research Station (MARS) and in Department of Agricultural Entomology, UAS, Dharwad. From the two years of studies, it was confirmed that the pest passed through five generations between June to February under field conditions. The third generation which began at the beginning of September was most destructive to the crops by the beginning of November month. However, in the field, overlapping generations have been observed. After February month, the pest was not traceable in the field until May, although the host crop was available. A very high negative correlation was observed among total life cycle and average temperature. However, the relative humidity was negatively correlated with total life cycle during both the years. Totally, 3 parasitoids have been recorded on *Spodoptera frugiperda* in the present investigation. In general, the major mortality influencing factors observed were larval cannibalism and the entomopathogenic fungus, *Metarhizium rileyi*. Among the parasitoids, *Campoletis chloridae* was the dominant species on larval stage. The other species included *Exorista xanthaspis* and *Cotesia ruficrus* on larva and none of the parasitoids were recorded on pupa. The fall armyworm completed five generations between June to February with overlapping generations under field conditions. The mortality rate was higher in the egg stage and larval mortality in LP-2 stage in both the years and the generation survivability declined rapidly from I generation to V generation. The key factors influencing the overall mortality (K) included cannibalism followed by *Metarhizium rileyi* and *Campoletis chloridae*.

Keywords: Infertility, unknown causes, *Campoletis chloride*, cannibalism

Introduction

Maize is originated in Mexico and Central America, later from centre of origin it spread to different parts of the world including America, Europe, Africa, and Asia. . It was introduced to India from Central America in the beginning of 17th century (Hossain *et al.,* 2016). In world, the countries with large maize growing area include Argentina, Brazil, China, Hungary, India, Indonesia, Italy, Mexico, Philippines, South Africa, Rumania, United States and Yugoslavia. The United States, China, Brazil and Mexico account for 70 per cent of global production.

Under present situation, the average yields of maize are lower in India due to variety of factors. Prominent abiotic factors such as irregular rainfall, moisture stress and market price fluctuation; among the biotic factors among which, the insect pests are considered as one of the most important constraints. As many as 141 insect pests cause varying degree of damage to maize crop right from sowing till harvest. Apart from these, the recent invasive pest, fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is of serious concern due to its notorious and polyphagous behaviour. It is a serious threat to agriculture and costs billions of dollars in terms of reduced production and productivity.

It can colonize over 80 different plant species of which corn is not an exception. It also attacks crops such as alfalfa, soybean, sorghum, cotton and other diverse pasture grasses (Virla and Murua, 2004). A total of 353 larval host plants for fall armyworm, *S. frugiperda* (J.E.Smith) have been recorded belonging to 76 plant families, predominantly from Poaceae (106), Asteraceae (31) and Fabaceae (31) (Ankush *et al.,* 2019). It can cause a yield loss in corn as much as 70 per cent of a whole production (Ayala *et al*., 2013). From Northern Karnataka however, the pest has been reported to cause infestation ranging from 6.00 to 100 per cent on maize during *kharif* season (Mallapur *et al.,* 2018a).

The nocturnal behaviour of the adult makes them active generally during the warm and humid evenings. Approximately, fecundity accounts to 1500- 2000 per female moth and each egg mass contain 150-200 eggs, laid by the female in two to four layers that are deep on the surface to the lower part of the leaf. The egg is dome shaped which measures 0.4 mm in diameter and 0.3 mm in height, pale yellow or creamy in colour at the time of oviposition which later changes into light brown before hatching (Prasanna *et al.,* 2018).

The freshly laid eggs are covered with a protective, felt-like layer of white scales (setae) from the female abdomen and this gives a mouldy appearance, but eggs laid by mature females are less or not covered and visible with naked eyes or through hand lens. Duration of the egg stage is only 2 to 3 days at 20-30°C temperature (Sharanabasappa *et al.,* 2018).

Materials and Methods

Sampling plan and techniques

The investigations were undertaken with some modifications over Harcourt (1961). Four stages *viz*., egg, larval period-1 (included I, II and III instars), larval period-2 (included IV, V and VI instars) and pupa were chosen for sampling of *S. frugiperda*. The larval stage was conveniently divided into LP-1 and LP-2 as the first three larval instars of the insect can be easily distinguished from the later ones based on the size. The observations were made on the number of generations per year along with their approximate period of occurrence. Durations of pre-oviposition, egg, larval and pupal stages were recorded and the total life cycle for each generation was determined and correlated with the weather parameters. Simultaneously, the field incidence for each insect stage was recorded on 20 plants at a stretch at 5 spots in the field. For pupal stage, in addition to sampling the whole plants, the soil area surrounding the base of the plants was also searched. The egg counts were recorded at the time of sampling for egg stage or examined for the different stages of the pest.

Preparation of Life-tables

In the present study of life-tables, the column headings used earlier by Morris and Miller, (1954) was adapted, as detailed below.

1 × = stage or age interval at which the sample is taken; egg, larva and pupa.
2 lx = the number surviving at the beginning of the stage stated in the × -column.
3 dx = the number dying within the age interval stated in the × -column.
4 d × F = the mortality factors responsible for dx.
5 100qx = Percentage mortality (dx as percentage of 1x).
6 Sx = Survival rate within the stage mentioned in the x-column.

Criteria for filling the column in Life-table

The criteria used by Harcourt, (1963) for filling the data in the life-table for each age interval was used with slight modifications. The columns were filled by collecting and rearing known number of each stage from recording the actual counts in the field.

Recording dx values for each stage

While recording the number in each stage *viz*., egg, larval period in 1 and 2, pupa, these stages were collected and reared up to adult stage. Eggs were transferred along with the leaf bit attached to it on a fresh maize leaf kept in a petri cage, the number of unfertile eggs were recorded. Larval stage -1 and 2 were reared in the insect rearing cages while pupae were kept in small insect rearing cage. The number parasitised were recorded by counting the number of solitary parasitoids emerging from them or by examining the larvae or pupal cases from which parasitoids emerged. All the stages were reared up to adult stage, since most of the parasitoids that parasitise the early instars of larvae emerge in late larval or pupal stage. The dx values in the egg, larval periods 1 and 2, and pupa were based on rearing 100, 50, 20 and 10 numbers, respectively. When these numbers could not be obtained, the number was made up as per the requirement.

Results and Discussion

To study the life tables of *Spodoptera frugiperda* on maize

Generations and life cycles of *Spodoptera frugiperda*

The studies made on the population dynamics of the fall armyworm under field conditions revealed that the pest completed five generations per year, the first generation commenced from the month of July and the last generation terminated by the end of February. The period occupied by each generation, the probable dates of peak-egg laying, hatching, pupation and moth emergence, along with the duration of each stage have been furnished in the Table 1 and 2.

The first generation commenced from 14th July during 2019-20 and completed over a month period. After a gap of 3 days, the II generation started. The third generation began at the beginning of October. The fourth and fifth generations commenced from 13th November and 11th January, respectively under field conditions and the pest was not traceable by the end of February. Similarly, during the second year of study (2020-21), the pest started appearing in the field by 16th June. The subsequent generations commenced from 26th July, 02nd September, 16th October and 6th December.

The pre-oviposition period was 3 days for the first two generations, while it extended to 4 days in other generations in both the years. During 2019-20, the egg period occupied three days for the first three generations while, it was four days for last two generations. Whereas,

the egg period occupied three days for first three generations, four days for third, fourth and fifth generations during second year. The larval duration was minimum (24 days both in 2019-20 and 2020-2021) during the first generation and it prolonged gradually from generation to generation to reach 41 days at the end. Similarly, the pupal period ranged from 9 days in first generation to 11 days at the last generation.

The pest took 36, 37, 39, 56 and 44 days to complete its life cycle in I, II, III, IV and V generation, respectively during 2019-20. In the second year, the period of life cycle was 36, 36, 40, 46 and 58 days, respectively.

Interpretation on life-table data

The life tables have been prepared for five generations of *Spodoptera frugiperda* each during 2019-20 and 2020-21 and depicted in table 7 and 8. Among various factors causing pest mortality, huge contribution was due the cannibalism followed by the fungal entomopathogen, *Metarhizium rileyi* and the larval parasitoid, *Campoletis chloridae* in different generations during both the years.

Cannibalism

The mortality rate of larvae due to cannibalism was higher in larval period-2 (LP-2) as compared to larval period-1 (LP-1). The larval mortality due to cannibalism ranged from 39.66 to 58.00 and 52.80 to 60.40 per cent during 2019-20 and 2020-21, respectively in larval period-1. In case of larval period-2 (LP-2), the cannibalism among the later instars of FAW resulted in the larval mortality to the extent of 48.15 to 85.19 and 31.80 to 67.70 per cent, respectively during 2019-20 to 2020-21.

Disease (*Metarhizium rileyi*)

The incidence of fungal pathogen, *Metarhizium rileyi* on FAW was more predominant in larval period-2 (LP-2) than larval period-1 (LP-1). The death of larvae due to its infection ranged from 2.90 to 7.14 and 4.20 to 8.80 per cent in larval period-1 during 2019-20 to 2020-21, respectively. While, the mortality of FAW larvae caused by the fungus in larval period-2 (LP-2) varied from 0.00 to 11.10 and 12.0 to 22.60 per cent, respectively during 2019-20 to 2020-21.

Larval parasitoid, *Campoletis chloridae*

Parasitisation by this species resulted in larval death ranging from 0.00 to 2.86 in larval period-1 only during during 2019-20. However, in larval period-2, the larval mortality due to this parasitoid ranged from 0.00 to 12.50 and 0.00 to 11.10 per cent, respectively during 2019-20 to 2020-21.

Larval parasitoid, *Exorista xanthaspis*

Compared to *C.chloridae*, this species was found in low number only in larval period-2 (LP-2) only. The parasitoid made its appearance from third generation onwards with 0.00 to 7.40 and 0.00 to 13.60 per cent mortality, respectively during 2019-20 and 2020-21.

Larval parasitoid, *Cotesia ruficrus*

The death of larva occurred by this parasitoid only in larval period-2 (LP-2) during both the years. The larval mortality ranged from 0.00 to 11.10 and 0.00 to 13.60 per cent during 2019-20 to 2020-21, respectively.

Infertility

This was a major mortality factor in the egg stage in all the generations of the pest during both the years of study. No parasitoid could be recorded on the egg stage. The sterility of eggs increased considerably from I generation to V generation. The per cent sterility varied from 3.0 to 22.0 and 4.0 - 8.0 per cent during 2019-20 to 2020-21, respectively.

Unknown causes

The pest mortality which could not be included under any of the above mentioned heads (*i.e.* the cause being not known) was considered under unknown causes. During 2019-20, the mortality due to this factor ranged from 8.0 to 30.0, 0.00 to 3.86, 0.00 to 6.67 and 0.00 to 50.00 per cent in egg, larval period-1, larval period-2 and pupal stage, respectively. The corresponding values for the second year were 24.00 to 44.00, 0.00-1.80, 0.00-0.00 and 0.00- 0.00 per cent in different generations.

Generations and life cycle of the pest

From the two years of studies, it was confirmed that the first generation of the fall armyworm, *Spodoptera frugiperda* commenced from July, passed through five generations and the pest activity was terminated by February under field conditions in Dharwad. The third generation which began at the beginning of September was most destructive to the crops. However, in the field, overlapping generations have been observed. After February month, the pest was not traceable in the field although the host crop was available until March. The pre-oviposition period was 3-4 days for different generations and egg period lasted for 3-4 days in the present investigation which is in line with the findings of Paul and Deole (2020) who concluded that the incubation period of the eggs under laboratory conditions ranged between 2 to 4 days with an average of 2.9 days.

The larval duration which was 24 days in the first generation increased gradually and peaked to 41days during the last generation. The larval period tends to be about 14 - 30 days as reported by Pitre and Hogg (1983). According to Tiwari and Deole (2021) the total larval period of FAW varied from 16 to 18 days with an average of 16.65 ± 0.16 days, when the insects were reared in sweet corn. Ashok *et al.* (2020) reported the total larval period at 14.48 days (I instar- 2.55 days, II instar- 2.12 days, III instar-2.08 days, IV instar- 2.00 days, V instar-2.04 days, VI instar- 3.69 days). All these findings are in support of the present results.

Table 1 : Life Tables for five generations of *Spodoptera frugiperda* during 2019-2020 (I, II, III, IV and V generations)

Age Interval	**Number alive at beginning of x**		**Factors responsible for**	**Numbers dying during x**		**Dx as percentage**	**Survival rate**
x	**lx**		**d x f**	**dx**		**100 qx**	**Sx**
	Lab	**Field**		**Lab**	**Field**		
14-07-2019 to 18-08-2019 , 21-08-2019 to 27-09-2019, 01-10-2019 to 09-11-2019, 13-11-2019 to 07-01-2020 and 11-01-2020 to 23-02-2020							
Eggs	100.00	639.00, 1130.00, 812.00, 884.00, 353.00	Sterility/ mortality	5.00, 3.00, 22.00, 22.00, 18.00	32.00, 34.00, 178.00, 194.00, 63.00	5.00, 3.00, 22.00, 22.00, 18.00	
			Telenomus spp	-	-	-	
			Unknown Causes	26.00, 23.00, 8.00, 30.00, 24.00	166.00, 260.00, 65.00, 265.00, 85.00	26.00, 23.00, 8.00, 30.00, 24.00	0.00, 0.74, 0.70, 0.52, 0.58
			Total	31.00, 26.00, 30.00, 52.00, 42.00	198.00, 294.00, 243.00, 459.00, 148.00	31.00, 26.00, 30.00, 52.00, 42.00	
LP_1	69.00, 74.00, 70.00, 52.00, 58.00	440.00, 836.00, 568.00, 460.00, 205.00	Cannibalism	40.00, 42.00, 31.00, 20.00, 23.00	255.00, 474.00, 251.00, 177.00, 81.00	58.00, 56.75, 44.29, 38.46, 39.66	
		(275.00, 351.00, 223.00, 204.00, 72.00)	*Campoletis chlorideae*	0.00, 2.00, 2.00, 0.00, 0.00	0.00, 23.00, 16.00, 0.00, 0.00	0.00, 2.70, 2.86, 0.00, 0.00	
			Exorista xanthaspis	-	-	-	0.39, 0.00, 0.46, 0.00, 0.00
			Cotesia ruficrus	-	-	-	0.00, 0.34, 0.00, 0.52
			Diseases (Fungal)	2.00, 5.00, 5.00, 3.00, 3.00,	13.00, 56.00, 41.00, 27.00, 11.00	2.90, 6.76, 7.14, 5.77, 5.17	
			Unknown Causes	0.00, 0.00, 0.00, 0.00, 2.00	0.00, 0.00, 0.00, 0.00, 7.00	0.00, 0.00, 0.00, 0.00, 3.45	
			Total	42.00, 49.00, 38.00, 25.00, 28.00	268.00, 553.00, 308.00, 221.00, 99.00	60.90, 66.22, 54.29, 48.07, 48.28	
LP_2	27.00, 25.00, 32.00, 27.00, 30.00	172.00, 282.00, 260.00, 239.00, 166.00	Cannibalism	23.00, 19.00, 18.00, 13.00, 20.00	146.00, 214.00, 146.00, 115.00, 71.00	85.19, 76.00, 56.25, 48.15, 66.67	
		(62.00, 72.00, 49.00, 36.00, 15.00)	*Campoletis chlorideae*	0.00, 2.00, 4.00, 2.00, 0.00	0.00, 23.00, 33.00, 18.00, 0.00	0.00, 8.00, 12.50, 7.40, 0.00	
			Exorista xanthaspis	0.00, 0.00, 0.00, 2.00, 1.00	0.00, 0.00, 0.00, 18.00, 3.00	0.00, 0.00, 0.00, 7.40, 3.33	0.00, 0.00, 0.00, 0.15, 0.07
			Cotesia ruficrus	0.00, 0.00, 3.00, 3.00, 3.00	0.00, 0.00, 24.00, 26.00, 11.00	0.00, 0.00, 9.38, 11.10, 10.00	0.11, 0.08, 0.09, 0.10, 0.09
			Diseases (Fungal)	0.00, 2.00, 2.00, 3.00,	0.00, 23.00, 16.00, 26.00,	0.00, 8.00, 6.25, 11.10,	
			Unknown Causes	0.00, 0.00, 0.00, 0.00, 2.00	0.00, 0.00, 0.00, 0.00, 7.00	0.00, 0.00, 0.00, 0.00, 6.67	
			Total	0.00, 23.00, 29.00, 23.00, 28.00	146.00, 260.00, 235.00, 203.00, 99.00	85.19, 92.00, 90.62, 85.19, 48.28	
Pupa	4.00, 2.00, 3.00, 4.00, 2.00	26.00, 23.00, 24.00, 35.00, 7.00	Abnormal	2.00, 1.00, 2.00, 2.00, 1.00	13.00, 13.00, 16.00, 18.00, 4.00	50.00, 50.00, 66.67, 50.00, 50.00	0.50, 0.50, 0.50, 0.50, 0.00
		(2.00, 2.00, 2.00, 2.00, 1.00)	Unknown Causes	0.00, 0.00, 0.00, 0.00, 1.00	0.00, 0.00, 0.00, 0.00, 4.00	0.00, 0.00, 0.00, 0.00, 50.00	0.00, 0.00, 0.00, 0.00, 0.00
			Total	2.00, 1.00, 2.00, 2.00, 2.00	13.00, 13.00, 16.00, 18.00, 7.00	50.00, 50.00, 66.67, 50.00, 100.00	
Moth	2.00, 1.00, 1.00, 2.00, 0.00	13.00, 10.00, 8.00, 17.00, 0.00	-	-	-	-	-
		(-)	-	-	-	-	-

Table 2 : Life Tables for five generations of *Spodoptera frugiperda* during 2020-2021 (I, II, III, IV and V generations)

Age Interval	**Number alive at beginning of x**		**Factors responsible for**	**Numbers dying during x**		**Dx as percentage**	**Survival rate**
x	**lx**		**d x f**	**dx**		**100 qx**	**Sx**
	Lab	**Field**		**Lab**	**Field**		
16-06-2020 to 23-07-2020, 26-07-2020 to 30-08-2020, 02-09-2020 to 12-10-2020, 16-10-2020 to 02-12-2020 and 06-12-2020 to 04-02-2021							
Eggs	100.00	214.00, 783.00, 1210.00, 796.00, 272.00	Sterility/ mortality	4.00, 5.00, 4.00, 6.00, 8.00	9.00, 39.00, 48.00, 48.00, 22.00	4.00, 5.00, 4.00, 6.00, 8.00	
			Telenomus spp	-	-	-	
			Unknown Causes	24.00, 25.00, 25.00, 37.00, 44.00	51.00, 196.00, 303.00, 295.00, 120.00	24.00, 25.00, 25.00, 37.00, 44.00	0.72, 0.61, 0.71, 0.57, 0.48
			Total	28.00, 30.00, 29.00, 43.00,	60.00, 235.00, 351.00, 343.00,	28.00, 30.00, 29.00, 43.00,	
LP_1	72.00, 70.00, 71.00, 57.00, 48.00	154.00, 548.00, 859.00, 454.00, 131.00	Cannibalism	38.00, 39.00, 38.00, 29.00, 29.00	81.00, 305.00, 460.00, 231.00, 79.00	52.80, 55.70, 53.50, 50.90, 60.40	
		(94.00, 295.00, 367.00, 203.00, 64.00)	*Campoletis chlorideae*	-	-	-	
			Exorista xanthaspis	-	-	-	
			Cotesia ruficrus	-	-	-	0.43, 0.36, 0.38, 0.39, 0.33
			Diseases (Fungal)	3.00, 6.00, 6.00, 5.00, 3.00	6.00, 47.00, 73.00, 40.00, 8.00	4.20, 8.60, 8.50, 8.80, 6.30	
			Unknown Causes	0.00, 0.00, 0.00, 1.00, 0.00	0.00, 0.00, 0.00, 8.00, 0.00	0.00, 0.00, 0.00, 1.80, 0.00	
			Total	41.00, 45.00, 44.00, 1.00, 32.00	87.00, 352.00, 533.00, 8.00, 87.00	57.00, 64.30, 62.00, 1.80, 66.70	
LP_2	31.00, 25.00, 27.00, 22.00, 16.00	66.00, 196.00, 327.00, 175.00, 44.00	Cannibalism	21.00, 16.00, 12.00, 7.00, 9.00	45.00, 125.00, 145.00, 56.00, 25.00	67.70, 64.00, 44.40, 31.80, 56.30	
		(31.00, 73.00, 75.00, 42.00, 10.00)	*Campoletis chlorideae*	0.00, 2.00, 3.00, 2.00, 1.00	0.00, 16.00, 36.00, 16.00, 3.00	0.00, 8.00, 11.10, 9.10, 6.30	
			Exorista xanthaspis	0.00, 0.00, 1.00, 3.00, 0.00	0.00, 0.00, 12.00, 24.00, 0.00	0.00, 0.00, 3.70, 13.60, 0.00	0.09, 0.12, 0.11, 0.14, 0.13
			Cotesia ruficrus	0.00, 1.00, 3.00, 3.00, 2.00	0.00, 8.00, 36.00, 24.00, 5.00	0.00, 4.00, 11.10, 13.60, 12.50	
			Diseases (Fungal)	7.00, 3.00, 5.00, 4.00, 2.00	15.00, 24.00, 61.00, 32.00, 5.00	22.60, 12.00, 18.50, 13.60, 12.50	
			Unknown Causes	-	-	-	
			Total	28.60, 25.00, 24.0019.00, 14.00	60.00, 173.00, 286.00, 152.00, 38.00	90.30, 88.00, 88.80, 86.30, 87.60	
Pupa	3.00, 3.00, 3.00, 3.00, 2.00	6.00, 24.00, 36.0024.00, 6.00	Abnormal	2.00, 2.00, 2.00, 2.00, 2.00	4.00, 16.00, 24.00, 16.00, 6.00	66.70, 66.70, 66.70, 66.70, 100.00	0.33, 0.33, 0.33, 0.33, 0.00
		(1.00, 2.00, 3.00, 2.00, 1.00)	Unknown Causes	-	-	-	
			Total	2.00, 2.00, 2.00, 2.00, 2.00	4.00, 16.00, 24.00, 16.00, 6.00	66.70, 66.70, 66.70, 66.70, 1000.00	
Moth	1.00, 1.00, 1.00, 1.00,	2.00, 8.00, 12.00, 24.00,	-	-	-	-	-
		(-)	-	-	-	-	-

Interpretation on life-table data

A perusal of the life-tables constructed for both the years of study revealed that different mortality factors contributed towards the generation mortality of *S. frugiperda*. The different aspects of life-table study are discussed hereunder. The major contributing natural mortality factor of FAW during the study was found to be the cannibalism noticed in larval stage which ranged from 39 to 60 per cent in different instars, in general. Particularly at late larval stages, the extent of cannibalism was to the tune of 67 to 87 per cent. As per the reports of Beirne (1970), the fall armyworm larvae can also die by cannibalism, although cannibalistic behaviour is less frequent among early instars. High rates of cannibalism were observed in Brazil when FAW larvae were fed on corn leaves, in contrast with the significantly lower rates found on artificial diet (Nalim, 1991).

Bosa *et al*. (2004) reported the efficacy of *M. rileyi* isolates in Colombia, causing 73–100 per cent mortality in 2nd instar of *S. frugiperda*. Sharanabasappa *et al.* (2019) found the entomofungal pathogen, *Nomuraea rileyi* (Clavicipitaceae) associated commonly with fall armyworm and caused 10 to 15 per cent larval infection on *Spodoptera frugiperda* in maize during August. Jindal *et al.* (2021) reported that relative abundance of *Campoletis* sp. and *C. formosanus* parasitoids on *S. frugiperda* in maize ranged from 17.65- 82.35 per cent. The overall relative abundance for *Campoletis* sp. and *C. formosanus* was 59.86% and 40.14 per cent, respectively.

The other mortality factors included infertility in egg stage, meteorological factors and unknown causes in all the stages of *S. frugiperda.* The effect of meteorological factors on the population fluctuation has not been included in the life-table preparation since the present studies were conducted inside the laboratory. However, the difference between the expected population and actual counts in the field recorded in the life-tables indicated the extent of adverse effect of these parameters on the insect population. The findings of Murua *et al*. (2008) revealed that the mean percentage of egg unviability is flexible and may range from 10 to 68 per cent in natural FAW populations. A similar study performed by Busato *et al*. (2005) using lab-reared insects disclosed that 5 to 28 per cent of FAW eggs were found not viable.

Summary

From the two years of studies, it was confirmed that the pest passed through five generations between June to February under field conditions. The third generation which began at the beginning of September was most destructive to the crops by the beginning of November month. However, in the field, overlapping generations have been observed. After February month, the pest was not traceable in the field until May, although the host crop was available. A very high negative correlation was observed among total life cycle and average temperature. However, the relative humidity was negatively correlated with total life cycle during both the years. Totally, 3 parasitoids have been recorded on *Spodoptera frugiperda* in the present investigation. In general, the major mortality influencing factors observed were larval cannibalism and the entomopathogenic fungus, *Metarhizium rileyi*. Among the parasitoids, *Campoletis chloridae* was the dominant species on larval stage. The other species included *Exorista xanthaspis* and *Cotesia ruficrus* on larva and none of the parasitoids were recorded on pupa.

Conclusion

In Dharwad situation, the fall armyworm completed five generations between June to February with overlapping generations under field conditions. The mortality rate was higher in the egg stage and larval mortality in LP-2 stage in both the years and the generation survivability declined rapidly from I generation to V generation. The key factors influencing the overall mortality (K) included cannibalism followed by *Metarhizium rileyi* and *Campoletis chloridae*.

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Data availability statement

Data will be made available on request.

Author contribution statement

All authors contributed equally to the conception and design of the study. All authors read and approved the final manuscript.

Conflict of interest

No conflict of interest.

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