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Effect of temperature on the reproductive ability of Fall Armyworm - *Spodoptera frugiperda* (J.E. Smith) under laboratory condition

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Abstract
Fall Armyworm is a sporadic pest with a diverse host range and also an economically crucial polyphagous insect which is native to tropical and sub-tropical region of America with national importance causing economic damage to many of the agricultural crops (Hardke *et al.*, 2015) [6]. It has high dispersal ability, wide host range, high fecundity, holometabolous and capable of producing an estimated 12 generations per year in tropical climates (Busato *et al.*, 2005) [4] that makes the Fall Armyworm a notorious pest and one of the most severe economic pests (Chormule *et. al.*, 2018). The purpose of this study is to examine the reproduction rate of *S. frugiperda* in laboratory over a different controlled temperature range of 18±2ºC, 22±2ºC, 26±2ºC, 30±2ºC, 32±2ºC. Further, to derive oviposition, longevity and fecundity table at different temperature range which will predict the exact temperature that stimulates the reproduction of *S. frugiperda*. The purpose of this study is to contribute the control strategy of Fall Armyworm as their quality of dependence on temperature for the reproduction under laboratory condition.

Keywords: Fall armyworm, reproductive ability, pre-oviposition, oviposition and post-oviposition, fecundity

1. Introduction
Maize (*Zea maize* L.) is one of the main and popular cereal crops due to its high value content as stable food as well as its high demand for animal feed and fuel and also for construction purpose. India is one of the top 10 maize producers in the world; it contributes around 2-3 percent of the total maize produced globally and is one of the top 5 maize exporters in the world contributing almost 14 percent of the total maize exported to different countries around the world. India ranks fourth in the world in maize production (27.23 MT) with 9.18 M ha. area and yield were 2965 kg $^{-ha}$ (Anonymous, 2019) [1]. Traditionally maize is grown in *Kharif*-monsoon season, which is accompanied by high temperature that is more than 35°c and rainfall. Total maize production was around 70 percent. *Rabi* is the second most important season that covers around 15 percent of total area of maize. The yield for maize crop varies by region to region depending on climatic conditions. However, with the development of new cultivars and appropriate production technology, winter cultivation of maize has emerged as a viable alternative mainly for fodder purpose. Fall Armyworm has a specific temperature range at which they will prefer to reproduce. Temperature is the most crucial abiotic factor which will influence the development and reproductive rate. The impact of temperature on the reproductive rate of insect can be determined by the duration of pre-oviposition, oviposition and post-oviposition, life span of egg viability and total fecundity per female (Kim & Lee 2003). Temperature below or above the optimum for a specific insect species can be used to predict the influence of climate change on the population growth of the insect. Temperature among the environmental factors is considered as the key driver of insect's reproductive ability. Therefore, it is very essential to study the pre-oviposition, oviposition, post-oviposition period and fecundity of Fall Armyworm at different constant temperature for understanding, the capabilities and the potentials of pests to deal with temperature changes can be sophistically analyzed with the help of temperature dependent study.

2. Materials and methods
2.1 Source of Culture of Fall Armyworm *S. frugiperda*
The culture of *S. frugiperda* larvae were collected from the maize fields around Pune and reared on maize plant under laboratory conditions for studying the reproduction ability of Fall Armyworm under different constant temperature. The equipment were compound microscope, BOD incubator, humidifier, various containers, oviposition cage, plastic container, petri plates, muslin cloths, cotton, vessels, tubes and food etc.

Used for raring of Fall Armyworm and the facilities were provided by All India Coordinated Research project Biological Control Laboratory, Agriculture Entomology Section, College of Agriculture Pune.

2.2 Mass rearing and maintenance of Fall Armyworm *S. frugiperda* culture in laboratory

2.2.1 Collection of Larva: Fall Armyworm larvae were collected from the maize plot of NARP Ganeshkhind Pune, Agronomy research farm of College of Agriculture. Pune where incidence have been noticed and which were brought in laboratory under ambient temperature.

2.2.2 Rearing on Laboratory: Fall Armyworm were raised for one generation to enable the field stock to acclimatize to laboratory condition. The larvae were reared on fresh maize leaves in a separate plastic jars of (10x12 cm) and provided with sufficient food and space. The jar was covered tightly with clean white muslin cloth by rubber band for preventing the larval escaping but with proper supply of oxygen. Everyday fresh and tender leaves were collected from the field at morning and evening hours. Maize leaves were washed in sterilized water before feeding. Fresh leaves were given to the larvae daily two times (i.e. morning and evening) until pupation. Larval plastic jars were cleaned every day for two times. Larva were transferred from one jar to another with the help of camel brush by dipping into the water. Sanitary conditions were maintained nicely by cleaning the partially eaten leaves, dried leaves and larval excreta to avoid the bacterial and fungal contamination in the plastic jar. The pupae were transferred into another petri plate and adults emerged from that pupa were collected daily. The pair of adults were releases in wooden cage of 30x30cm for mating. The male and female adults were determined by observing the shape, pattern and color of wings. Female moth's wing span was larger than male and there was a pronounced white blotch near the tip of the fore wings were present in the male moth while marking on female were more brownish. Potted maize plant along with young leaves were placed inside the oviposition cage for the egg laying purpose. A swab of cotton dipped in 5 percent honey solution was kept inside the cage as food for adult and the cotton changed daily for escaping from ants. Female moth started laying eggs on underside of the maize leaves and these eggs were counted as F1 generation and used for further studies.

2.3 Experimental details- The experiment was carried out at 65 ± 10% relative humidity and a 14:10 h (L: D) in BOD incubator.

Treatment Details

Treatment No.	Temperature
T_1	18±2°C
T_2	22±2°C
T_3	26±2°C
T_4	30±2°C
T_5	32±2°C

2.3.1 Formulation of fecundity rate of Fall Armyworm *S. frugiperda* in different constant temperature under laboratory condition

Individual male and female that emerged during the same 24 hours will be paired in 5 pairs. The pairs will be transferred to a plastic oviposition chamber under the same 5 different temperatures in BOD incubator and calculate the pre oviposition, oviposition, post oviposition and average fecundity of the adult.

2.3.2 Fecundity of fall armyworm at constant temperature

Five pair of male and female moth were taken for calculating the fecundity rate of each female. Single pair of adults were released in a single oviposition cage. At each constant range of temperature five pairs of male and female moth were kept to observe and number of eggs laid by a single female was counted.

2.3.3 Pre- oviposition, oviposition and post- oviposition and longevity of fall armyworm at constant temperature

For determining the Pre oviposition, oviposition and Post oviposition period of the adult 5 adult pair that kept separately in the mating chamber at each constant temperature and completion days were counted. The period between emergence of adult female and commencing egg laying was recorded as the pre- oviposition period. The period between commencing egg laying and ceasing of egg laying by individual female was recorded as oviposition period. The period between ceasing of egg laying to death of the female adult was noted as post oviposition period. Longevity of male and female moths were calculated separately from the data on emergence to the death of the adults. 5 pairs of male and female which were kept in mating cages at different temperature and provided with 5 percent of honey solution are used for studying the adult longevity.

3. Result and Discussion

3.1 Effect of temperature on pre-oviposition, oviposition and post-oviposition period of Fall Armyworm *S. frugiperda* at different constant temperature under laboratory condition

The male and female adults of Fall Armyworm *S. frugiperda* kept in mating chamber at five different constant temperature i.e.18 ±2^{0}C, 22±2^{0}C, 26±2^{0}C, 30±2^{0}C and 32±2^{0}C and recorded pre-oviposition, oviposition, post-oviposition period, male and female longevity are presented in table 3.1.

3.1.1 at 18±2 ºC

At 18±2ºC temperature, the female moth of Fall Armyworm required 4.31 ± 0.39 days for completing the pre oviposition period, 7.06 ± 0.07 days for oviposition period and 1.08 ± 0.08 days for post oviposition period.

3.1.2 at 22±2 ºC

The female moth of Fall Armyworm completed pre oviposition period within 3.03 ± 0.04 days and oviposition period in 6.05 ± 0.07 days at 22 ±2ºC. Whereas 2.03 ± 0.04 days period required for post oviposition.

3.1.3 at 26±2 ºC

The data revealed that the female adult of Fall Armyworm required 2.66 ± 0.46 days for completing the pre-oviposition period at 26±2 ºC. In case of oviposition period, 5.02 ± 0.04 days were required. Whereas it took 1.83 ± 0.38 days period for post-oviposition.

3.1.4 at 30±2 ºC

The data presented in table no 3.1 clearly indicated that the Fall Armyworm female required 2.05 ± 0.07, 4.05 ± 0.07 1.05 ± 0.07 days period for completion of pre-oviposition, oviposition and post-oviposition respectively at 30±2ºC temperature under laboratory conditions.

3.1.5 at 32±2 ºC

The female adult of Fall Armyworm completed its pre-oviposition period in 4.03 ± 0.04 at 32±2 ºC while 3.06 ± 0.07 days and 1.02 ± 0.04 days were required in case of oviposition and post-oviposition.

3.2 Longevity of male and female adults of fall armyworm

3.2.1 at 18±2 ºC

The data presented in table no 3.1 revealed that the adult female Fall Armyworm survived up to 12.46 ± 0.35 days with the range of 12.24 to 13.08 days and adult male survived up to 11.28 ± 0.45 days with the range of 11.00 to 12.08 days at 18±2 ºC temperature.

3.2.6.2 at 22±2 ºC

Fall Armyworm adult female completed its life span in 11.11 ± 0.04 days with the range of 11.08 to 11.16 days at 22±2 ºC. Whereas adult male completed in 9.73 ± 0.52 days with the range of 9.16 to 10.16 days.

3.2.6.3 at 26±2 ºC

The longevity of adult female of Fall Armyworm completed in 9.51 ± 0.45 days with the range of 9.16 to 10 days while in case of adult male in 8.91 ± 0.8 days with the range of 8.16 to 10.08 days.

3.2.6.4 at 30±2 ºC

The data presented revealed that the adult female of Fall Armyworm completed its longevity in 7.14 ± 0.07 days with the range of 7.08 to 7.24 days whereas the adult male completed in 7.05 ± 0.07 days with the range of 7.00 to 7.16 days at 30±2 ºC.

3.2.6.5 at 32±2 ºC

The Fall Armyworm adult female completed its longevity in 8.13 ± 0.07 days with the range of 8.08 to 8.24 days at 32±2 ºC and adult male fall armyworm completed in 7.46 ± 0.53 days with the range of 7.00 to 8.08 days.

3.3 Fecundity of fall armyworm *S. frugiperda* at constant temperature under laboratory condition

The five pairs of Fall Armyworm *S. frugiperda* fed with 5 per cent aqueous honey solution in separate chamber and temperature. The fecundity recorded for five females of Fall Armyworm at each constant temperature in laboratory and presented in table 3.2. The eggs laid by the female was in the range from 582 to 612 with an average of 597 ± 11.34 eggs at 18±2ºC temperature. At 22 ±2ºC temperature, 592 to 740 eggs laid with an average of 666.8 ± 26.88 per female. Fall Armyworm female laid 460 ± 3.58 average eggs with range from 456 to 466 at 26±2ºC while it was in the range of 344 to 368 and 280 to 292 with an average of 355.2 ± 9.26 and 285 ± 4.47 at 30±2ºC and 32±2ºC, respectively. Highest fecundity of Fall Armyworm (666.8 ± 26.88 eggs) recorded at 22±2 ºC which was followed by 602.2 ± 11.34 eggs at 18±2ºC and minimum number of eggs i.e. 285 ± 4.47 eggs laid by the female at 32±2 ºC.

Table 3.1: Effect of temperature on pre-oviposition, oviposition and post-oviposition period of Fall Armyworm *S. frugiperda* at different constant temperature under laboratory condition

Temperature (^{0}C)	Period	Pre-oviposition period (Days)	Oviposition period (Days)	Post-oviposition period (Days)	Female Longevity (Days)	Male Longevity (Days)
18 ±2^{0}C	Min.	4.08	7.00	1.00	12.24	11.00
	Max.	5. 00	7.16	1.16	13.08	12.08
	Average ± SD	4.31 ± 0.39	7.06 ± 0.07	1.08 ± 0.08	12.46 ± 0.35	11.28 ± 0.45
22±2^{0}C	Min.	3.00	6.00	2.00	11.08	9.16
	Max.	3.08	6.16	2.08	11.16	10.16
	Average ± SD	3.03 ± 0.04	6.05 ± 0.07	2.03 ± 0.04	11.11 ± 0.04	9.73 ± 0.52
26±2^{0}C	Min.	2.16	5.00	1.16	9.16	8.16
	Max.	3.00	5.08	2.00	10.00	10.08
	Average ± SD	2.66 ± 0.46	5.02 ± 0.04	1.83 ± 0.38	9.51 ± 0.45	8.91 ± 0.80
30±2^{0}C	Min.	2.00	4.00	1.00	7.08	7.00
	Max.	2.16	4.16	1.16	7.24	7.16
	Average ± SD	2.05 ± 0.07	4.05 ± 0.07	1.05 ± 0.07	7.14 ± 0.07	7.05 ± 0.07
32±2^{0}C	Min.	4.00	3.00	1.00	8.08	7.00
	Max.	4.08	3.16	1.08	8.24	8.08
	Average ± SD	4.03 ± 0.04	3.06 ± 0.07	1.02 ± 0.04	8.13 ± 0.07	7.46 0.53

The review of reports on egg laying capacity of Fall Armyworm at 27 ± 1 ºC was 427.3 ± 12.47 of Ashok *et al.*, (2020) which is inconformity with the present result. However, Plessis *et al.*, (2020) [7] and Schlemmer *et al.*, (2020) showed some variation in the egg laying capacity at constant temperature. This might be due to the effect of different host plants on which the larvae were fed or food given to the adults in laboratory.

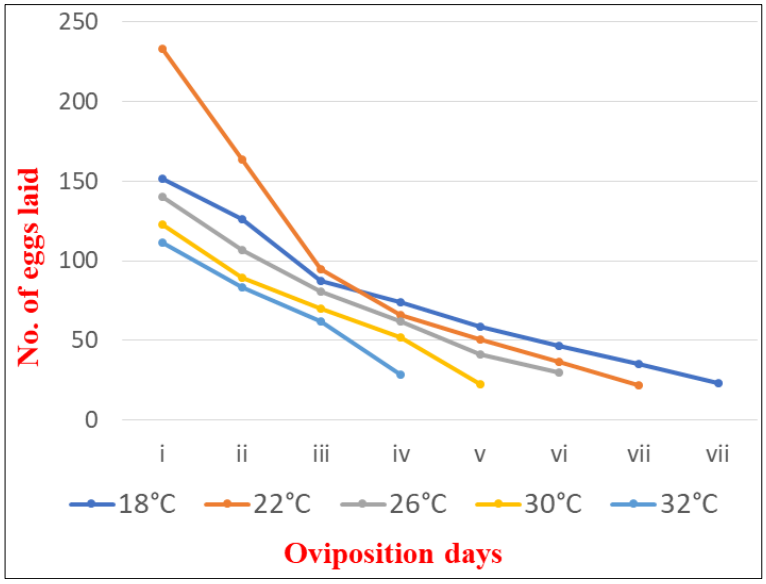

Fig 3.1: Eggs laid by Fall Armyworm *S. frugiperda* during oviposition period at different constant temperature under laboratory conditions

Table 3.2: Fecundity of Fall Armyworm *S. frugiperda* at different constant temperature under laboratory conditions

Temp (^{0}C)	Period (Days)	No. of eggs deposited on day								Fecundity (No.)
		First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eight	
18 ±2^{0}C	Min.	147	116	78	67	49	37	25	19	583
	Max.	159	133	98	81	64	52	47	29	612
	Av. ± SD	151.2 ± 5.02	126.4 ± 6.66	87.6 ± 7.3	74 ± 6.32	58.6 ± 5.94	46.2 ± 6.22	35.2 ± 8.26	23 ± 3.81	602.2 ± 11.34
22±2^{0}C	Min.	201	150	86	58	44	27	13	-	645
	Max.	259	177	102	79	63	46	29	-	708
	Av. ± SD	233.2 ± 23.58	163.8 ± 11.43	94.8 ± 7.66	65.8 ± 8.23	50.8 ± 7.19	36.8 ± 6.87	21.6 ± 6.77	-	666.8 ± 26.88
26±2^{0}C	Min.	136	100	76	58	39	27	-	-	456
	Max.	143	111	85	66	44	32	-	-	466
	Av. ± SD	139.8 ± 2.59	107 ± 4.36	80.4 ± 3.65	62.2 ± 3.56	41.4 ± 2.07	29.8 ± 1.92	-	-	460.6 ± 3.58
30±2^{0}C	Min.	118	83	62	49	19	-	-	-	344
	Max.	126	93	76	55	25	-	-	-	368
	Av. ± SD	122.6 ± 3.58	89 ± 3.94	69.6 ± 5.94	51.8 ± 2.59	22.2 ± 2.17	-	-	-	355.2 ± 9.26
32±2^{0}C	Min.	107	80	59	26	-	-	-	-	280
	Max.	116	88	65	31	-	-	-	-	292
	Av. ± SD	111.2 ± 3.27	83.4 ± 3.44	61.6 ± 2.79	28.8 ± 1.92	-	-	-	-	285 ± 4.47

Plate 1: Life stage of Fall Armyworm reared under laboratory condition

Plate 2: Rearing of Fall Armyworm in BOD Incubator at controlled atmosphere for reproduction ability studies

Plate 3: Pupa and adult of Fall Armyworm developed at constant temperature

6. Conclusions

Regarding the pre-oviposition, oviposition and post oviposition period at 18 ±2ºC was 4.31 ± 0.39,7.06 ± 0.07 and 1.08 ± 0.08 days respectively, at 22 ±2 ºC, 3.03 ± 0.04, 6.05 ± 0.07, 2.03 ± 0.04 days, at 26 ±2ºC, 2.66 ± 0.46, 5.04 ± 0.04, 1.83 ± 0.38 days, at 30 ±2ºC, 3.05 ± 0.07, 4.05 ± 0.07, 1.05 ± 0.07 days and at 32 ±2ºC, 3.66 ± 0.46, 3.08 ± 0.00, 1.02 ± 0.04 days. However, the highest pre oviposition period was recorded at 4.31 ± 0.39 at 18 ºC, highest oviposition period at 7.06 ± 0.07 at 18 ±2ºC and highest post oviposition period 2.03 ± 0.04 at 22 ± 2ºC whereas the lowest pre oviposition was 3.05 ± 0.07 at 30 ºC, lowest oviposition 3.08 ± 0.00 at 32 ±2 ºC and lowest post oviposition period 1.02 ± 0.04 at 32 ±2 ºC.

The longevity of Fall Armyworm observed at 18 ±2, 22 ±2, 26±2, 30±2, 32 ±2ºC was 12.46 ± 0.35, 11.11 ± 0.04, 9.56 ± 0.45, 8.14 ± 0.12, 7.94 ± 0.29 days respectively, while that of male ranges 11.28 ± 0.45, 9.73 ± 0.52, 8.91 ± 0.8, 7.05 ± 0.07, 7.58 ± 0.53 days at the same ranges of temperature respectively. Therefore, the highest female longevity observed 12.46 ± 0.35 at 18 ºC and lowest 7.94 ± 0.29 at 32 ±2ºC whereas the highest male longevity observed 11.28 ± 0.45 at 18 ±2ºC and lowest 7.05 ± 0.07 at 30 ±2ºC.

Fecundity at 18 ±2ºC was in the range from 582 to 612 eggs per female with an average of 597 ± 11.34 eggs, as well as at 22 ±2ºC, 592 to 740 eggs with an average of 666.8 ± 26.88 eggs, at 26 ±2ºC, 456 to 466 with an average of 460 ± 3.58 eggs, at 30 ±2 ºC, 344 to 368 with an average of 355.2 ± 9.26 and at 32±2 ºC, 280 to 292 eggs with an average of 285 ± 4.47 eggs. The highest fecundity (666.8 ± 26.88) noticed at 22 ±2ºC and lowest fecundity (285 ± 4.47) was at 32 ±2ºC.

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6. References

1. Anonymous. Agricultural Statistics at a glance 2019, Ministry of Agriculture and Farmers Welfare, Department of Agriculture Cooperation and Farmers Welfare, Directorate of Economics and Statistics 2019, 58-59.
2. Barfield CS, Mitchell ER, Poe SL. A temperature-dependent model for Fall Armyworm development. Ann. Entomol. Soc. Am 1978;71:70-74.
3. Bhavani B, Chandra Sekhar V, Kishore Varma P, Bharatha Lakshmi M, Jamuna P, Swapna B. Morphological and molecular identification of an invasive insect pest, fall army worm, *Spodoptera frugiperda* occurring on sugarcane in Andhra Pradesh, India. J of Entomol and Zoo. Studies 2019;7(4):12-18.
4. Busato GR, Grutzmacher AD, Garcia MS, Giolo FP, Zotti MJ, Bandeira JM. Thermal requirements and estimation of the number of generations of biotypes 'corn' and 'rice' of *Spodoptera frrugiperda*. Pesqui Agropec Bras 2005;40:329-335.
5. Chormule A, Shejawal N, Sharanabasappa Kalleshwaraswamy CM, Asokan R, Mahadeva Swamy HM. First report of Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on sugarcane and other crops from Maharashtra, India. J of Entomol. and Zoo. Studies 2019;7(1):114-117.
6. Hardke JT, Lorenz III GM, Leonard BR. Fall Armyworm – *Spodoptera frugiperda* (Lepidoptera: Noctuidae) ecology in Southeastern Cotton. J of IPM 2015;6:10.
7. Plessis H, Marie-Louise S, Van den Berg J. The effect of temperature on the development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae), Journal-Insects 2020;11:228: Doi: 10.3390/Insects11040228.
8. Sharanabasappa, Kalleshwaraswamy CM, Muruthi MS, Pavithra HB. Biology of inavasive Fall Armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) on maize. Indian J of Entomol 2018;80(3):540-543.
9. Simmons AM. Effects of constant and fluctuating temperature and humudities on the survival of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) pupae Fla. Entomol 1993;76:333-340.
10. Tendeng E, Labou B, Diatte M, Djiba S, Diarra K. The Fall Armyworm *Sprodoptera frugiperda* (J E Smith), a new pest of maize in Africa: biology and first native natural enemies detected. Int. J Biol. Chem. Sci 2019;13(2):1011-1026.
11. Vilarinho EC, Fernandes OA, Hunt TE, Caixeta DF. Movement of *Spodoptera frugiperda* adults (Lepidoptera: Noctuidae) in Maize in Brazil. Fla Entomol 2011;94:480-488.
12. Westbrook JK, Nagoshi RN, Meagher RL, Fleischer SJ, Jairam S. Modeling seasonal migration of Fall Armyworm moths. Int. J Biometeorol 2016;60:255-267.
13. Zhihui LU, Shuqi HE, Naisheng YAN, Wenjie ZHAO, Wanfu CHEN, Yaping TONG *et al*. Effects of temperature on the development and reproduction of Fall Armyworm (*Spodoptera frugiperda* Smith). J of Plant Protectn 2013. Doi: 10.16688/j.zwbh. 2019390-en.