



Feasibility of Timing Insecticide Applications based on Pheromone Trap Catches of Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) in Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/ajaar/2025/v25i1575>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/129101>

Original Research Article

Received: 27/10/2024

Accepted: 30/12/2024

Published: 03/01/2025

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ABSTRACT

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith), an invasive pest has recently spread to all over India and several other countries. For management of this pest, it is important to monitor moth activity by using pheromone traps. In the present study pheromone traps (Polythene sleeve type) baited with 'GAIAGEN Lures' (rubber septa) were installed @ 12 traps/ha in the experimental fields. The adult male moths caught during an observational week were counted. Per cent plant infestation was recorded at every seven days interval. The results have revealed that there was a gap of several weeks between peak field infestation and peak moth catch/trap, it indicates that field infestation was high even though moth trap catch was low and there is a negative association between the trap catches and per cent plant infestation. The relationship between field infestation (No. of larvae/plant and % plant infestation) and trap catches were negatively correlated for all the five weeks i.e., n^{th} , $(n-1)^{\text{th}}$, $(n-2)^{\text{th}}$, $(n-3)^{\text{th}}$, $(n-4)^{\text{th}}$ in both 2022-23 and 2023-24 years. There was no concrete evidence of field infestation taking place after adult trap catches. Therefore, it can be concluded that only pheromone trap catch data cannot be taken into consideration for timing insecticide application. Field scouting could be better option for monitoring fall armyworm in maize.

Keywords: Fall armyworm; maize; monitoring; pheromone traps; field infestation.

1. INTRODUCTION

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) was originally known to be endemic to the Western Hemisphere but now it is present in major maize (*Zea mays* L.; Poaceae) growing regions of Africa, Asia (He et al. 2021). The rapid incursion of this pest into various countries has now become a global concern (Tepa-Yotto et al. 2022). The first report of FAW in Asia was confirmed in Karnataka, India in 2018 (Sharanabasappa et al. 2018), which was followed by its discovery from other states of the country and several Asian countries, including Bangladesh, China, Sri Lanka, Thailand and Vietnam. More recently, FAW was reported in Australia, the Canary Islands and New Caledonia (Keni et al. 2022).

Generally, invasive alien species cause a significant threat to agricultural crops. They are always been foresee to increase with a changing climate and increased international trade (Pratt et al. 2017). Research have shown that invasive alien species can also take the place of native organisms, negatively impact biodiversity, and make alternations to ecosystems causing huge economic losses (Pratt et al. 2017, Rai & Singh 2020). Nevertheless, developing countries are particularly at risk to IAS impacts because the greater part of people living in these countries own land of 2 ha or sometimes less (Wiggins et al. 2010). For developing productive management strategies of FAW in given locality, information on motoring data is required (Rahmathulla et al. 2015). The quick spread of *S.*

frugiperda on maize (*Zea mays* L.; Poaceae) fields made it important to assess various integrated pest management strategies to control this pest. However, effective monitoring and surveillance efforts are necessary for these initiatives to succeed (Meagher et al. 2019). Pheromone trapping, which involves luring adult males into a collection trap by using sex pheromones, is an effective way to find fall armyworms population in a particular area and can significantly ease pest monitoring (Mitchell et al. 1985). Pheromone based monitoring demonstrated a consistent reduction in adult moth populations (Rajashekhar et al. 2024). Integration of sustainable management approaches consisting of pheromone traps at a rate of 4 per acre reduces the application of chemical insecticides and enhances the population of natural enemies which would be beneficial to maize farmers (Anilkumar et al. 2024). This pest shows fluctuations in its natural environment. The information on monitoring of FAW is inadequate under Pundibari location situated in the terai agroclimatic zone of West Bengal, India. So, this study was conducted to monitor the male moth activity with the objective to assess the relationship between adult trap catches and larval infestation in this location to time the insecticide application for future infestation of FAW.

2. MATERIALS AND METHODS

The field experiments were conducted in rabi seasons of 2022–23 and 2023–24 at the Instructional Farms, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West

Bengal, India on maize. The crop variety used for the experiment was Samriddhi (HMH 789). The number of observational plots were 3, each with a plot size of 10 m × 10 m and a buffer zone of 1m was maintained between the plots. Row to row spacing of 60cm and plant to plant spacing of 30cm was maintained. The crop was raised following all the recommended agronomical practices. Pheromone trap (Polythene sleeve type) baited with 'GAIAGEN Lures' (rubber septa) was installed at 1 metre height from the ground level on the day of sowing. The traps were installed at the rate of 12 traps/ha in the experimental fields. Height of the pheromone trap was increased with the crop growth. The rubber septum containing the lure was changed for every 15 days. The adult male moths trapped were collected daily and the total number of moths caught during an observational week were counted. Per cent plant infestation was recorded at every seven days interval by counting number of infested plants and total number of plants from each plot and it was calculated by using the formula:

$$\text{Per cent infestation} = \frac{\text{No of infested Plants}}{\text{No. of total plants}} \times 100$$

Correlation studies of pheromone trap catches with field infestation: The relationship between the moth activity and the actual field infestation were assessed through correlation studies. To do so, per cent infestation recorded in the n^{th} week was correlated with the number of male moth trapped in the n^{th} week, the previous week i.e. the $(n-1)^{\text{th}}$ week, two weeks back i.e. $(n-2)^{\text{th}}$ week, three weeks back i.e. $(n-3)^{\text{th}}$ week and four weeks back i.e. $(n-4)^{\text{th}}$ week.

3. RESULTS AND DISCUSSION

3.1 Population dynamics of *Spodoptera frugiperda* (J.E. Smith) on Rabi season Maize

3.1.1 Pheromone trap monitoring:

Seasonal fluctuation in the population of adult male moth of *S. frugiperda* were monitored with the help of pheromone traps during two consecutive rabi seasons of 2022-23 and 2023-24 (Tables 1 and 2). During first year, the pheromone trap catch data reveals the commencement of first catch of adult moth in maize by 3rd week of December (17.12.22 to

23.12.22). The moth catches in trap remained low till 3rd week of February (18.02.23 to 24.02.23). Then the trap catches started increasing and peak trap catches were attained during the 2nd week of March (11.03.23 to 17.03.23). Thereafter, the moth catches started decreasing but did not vanish completely though the crop was approaching maturity stage.

During the second year i.e., rabi 2023-24, the pheromone trap catch data reveals the commencement of first catch of adult moth in maize by 4th week of December (27.12.23 to 02.01.24). The moth catches in traps remained low till 4th week of February (21.02.24 to 27.02.24) with 2 moths/trap. Number of moths/trap started increasing from 4th week of February (28.02.24 to 05.03.24), since then the trap catch count was almost uniform with the highest number recorded in last week of March (20.03.24 to 26.03.24) with 15 moths/trap.

3.1.2 Field infestation

The maximum field infestation per cent of 6.51 and 6.09% was recorded on 21.01.2023 and 31.01.2024 respectively, when there was no moth catch in the trap. Field infestation was decreased to 4.13 and 3.80% on 18.03.2023 and 27.03.2024, respectively during two rabi seasons when the moth catch/trap was at peak level with 21 moths/trap and 15 moths/trap in these weeks, respectively. There was a gap of several weeks between peak field infestation and peak moth catch/trap during both the years, which indicates that field infestation was high even though moth trap catch was low and there is a negative association between the trap catches and per cent plant infestation (Tables 1 & 2). These findings are in agreement with Londhe et al. (2024) who found a negative correlation between captured males of fall armyworm and infestation of maize crops, their results showed that the percentage of fall armyworm infestation in maize crops dropped as pheromone trap densities increased. Kumar et al. (2009) and Shivakumara (2001), worked on different lepidopterous pests including *Helicoverpa armigera* where the findings of their field trials, with pheromone traps indicated a negative correlation between pheromone trap catches and field damage, in case of tomato fruit borer moth, *H. armigera*, okra shoot and fruit borer moth, *Earias insulana* and brinjal shoot and fruit borer moth *Leucinodes orbonalis*.

Table 1. Population of *S. frugiperda* in relation to weather parameters during Rabi 2022-23

Date of observation	No. of moths/ trap	No. of larva/pl.	Per cent Plant infestation	Temp °C		R.H. (%)		R.F. (mm)
				Max.	Min.	Max.	Min.	
10.12.22	0	0.020	2.84	29.30	8.74	73.57	46.00	0.00
17.12.22	0	0.026	3.73	27.13	9.04	85.71	51.71	0.00
24.12.22	1	0.031	4.47	26.82	8.84	83.57	54.57	0.00
31.12.22	0	0.035	5.08	24.05	7.41	94.85	54.28	0.00
07.01.23	0	0.040	5.69	22.94	6.63	95.43	57.14	0.00
14.01.23	0	0.041	5.90	25.06	7.29	95.71	49.86	0.00
21.01.23	0	0.045	6.51	20.84	8.17	93.86	65.00	0.00
28.01.23	0	0.045	6.37	25.83	9.24	81.29	46.00	0.00
04.02.23	0	0.044	6.23	25.90	12.71	95.29	61.00	0.00
11.02.23	2	0.043	6.11	24.10	12.47	87.29	60.43	0.00
18.02.23	4	0.042	5.96	24.10	12.47	87.29	60.43	0.00
25.02.23	4	0.038	5.43	28.41	15.91	84.00	57.00	0.00
04.03.23	13	0.037	5.29	29.87	16.16	70.29	47.29	0.00
11.03.23	19	0.032	4.54	31.46	16.20	68.86	41.71	0.00
18.03.23	21	0.029	4.13	30.99	16.73	68.14	44.57	20.20
25.03.23	18	0.026	3.72	25.83	16.53	84.43	67.86	83.80
01.04.23	9	0.024	3.46	30.16	18.50	79.29	55.00	0.00

Table 2. Population of *S. frugiperda* in relation to weather parameters during Rabi 2023-24

Date of observation	No. of moths/ trap	No. of larva/pl.	Per cent Plant infestation	Temp °C		R.H. (%)		R.F. (mm)
				Max.	Min.	Max.	Min.	
20.12.23	0	0.014	1.98	26.76	11.23	85.43	58.86	0.00
27.12.23	0	0.018	2.58	28.39	10.86	73.57	45.43	0.00
03.01.24	1	0.021	2.92	26.69	12.26	89.43	53.57	0.00
10.01.24	0	0.024	3.45	24.59	10.39	87.86	56.14	0.00
17.01.24	0	0.035	5.02	18.44	11.56	96.86	82.14	0.00
24.01.24	0	0.037	5.22	20.47	8.94	93.29	65.57	0.00
31.01.24	0	0.043	6.09	23.50	8.03	92.71	51.57	0.00
07.02.24	0	0.042	5.96	23.97	10.93	81.14	55.86	0.00
14.02.24	2	0.041	5.89	25.01	8.33	86.43	45.86	0.00
21.02.24	3	0.041	5.76	26.99	12.21	87.29	47.71	0.00
28.02.24	2	0.040	5.69	25.74	14.26	77.57	50.14	0.40
06.03.24	8	0.041	5.69	28.56	13.73	79.57	41.29	0.00
13.03.24	14	0.033	4.75	29.93	12.63	68.57	34.71	0.00
20.03.24	13	0.031	4.34	32.67	15.21	69.43	34.14	0.00
27.03.24	15	0.027	3.80	25.40	17.84	85.86	71.86	51.80
03.04.24	12	0.023	3.32	30.90	20.27	76.86	55.43	2.20
10.04.24	11	0.023	3.25	32.77	20.33	72.00	54.00	0.00

3.2 Relationship between Pheromone Trap Catches and Corresponding Field Population

The correlation was done between male moth trap catch with both number of larva/plant and per cent plant infestation for five weeks i.e., with n^{th} , $(n-1)^{\text{th}}$, $(n-2)^{\text{th}}$, $(n-3)^{\text{th}}$ and $(n-4)^{\text{th}}$ weeks for both 2022-23 and 2023-24 rabi seasons (Tables 3 & 4). Results of the first-year correlation data have shown that there was no significant correlation between number of larva/plant and per cent plant infestation with male moth trap catch data for the n^{th} week. However, there was significant negative correlation between number of larva/plant and per cent plant infestation with male moth trap catch data for $(n-1)^{\text{th}}$, $(n-2)^{\text{th}}$, $(n-3)^{\text{th}}$ and $(n-4)^{\text{th}}$ weeks at 1% level of significance. The relationship between field infestation (No. of larvae/plant and % pl. infestation) and trap catches were negatively correlated for all the five weeks i.e., n^{th} ($r = -0.396$ and $r = -0.398$), $(n-1)^{\text{th}}$ ($r = -0.713$ and $r = -0.713$), $(n-2)^{\text{th}}$ ($r = -0.839$ and $r = -0.836$), $(n-3)^{\text{th}}$ ($r = -0.844$ and $r = -0.843$), $(n-4)^{\text{th}}$ ($r = -0.796$ and $r = -0.789$) for the year 2022-23. The values were non-significant and negatively correlated for the n^{th} week and significant and negatively correlated for $(n-1)^{\text{th}}$, $(n-2)^{\text{th}}$, $(n-3)^{\text{th}}$, $(n-4)^{\text{th}}$ weeks during the year 2022-23.

During the year 2023-24, correlation data have shown that there was no significant correlation between number of larva/plant and per cent plant infestation with male moth trap catch data for n^{th} and $(n-1)^{\text{th}}$ weeks. However, there was significant negative correlation between number of larva/plant and per cent plant infestation with male moth trap catch data for, $(n-2)^{\text{th}}$ week at 5% level of significance and at 1% level of significance for $(n-3)^{\text{th}}$ and $(n-4)^{\text{th}}$ weeks. The relationship between field infestation (No. of larvae/plant and % pl. infestation) and trap catches were negatively correlated for all the five weeks i.e., n^{th} ($r = -0.125$ and $r = -0.130$), $(n-1)^{\text{th}}$ ($r = -0.392$ and $r = -0.394$), $(n-2)^{\text{th}}$ ($r = -0.577$ and $r =$

0.581), $(n-3)^{\text{th}}$ ($r = -0.748$ and $r = -0.753$), $(n-4)^{\text{th}}$ ($r = -0.812$ and $r = -0.813$), n^{th} and $(n-1)^{\text{th}}$ weeks were non-significant and negatively correlated, $(n-2)^{\text{th}}$, $(n-3)^{\text{th}}$, $(n-4)^{\text{th}}$ weeks were significant and negatively correlated for the year 2023-24.

The perusal of the results on the association of trap catches of adult moths with field infestation revealed that mostly significant negative correlations were found between these parameters. This might be due to the fact that when the adult moth population started increasing in the field, the maize crop was approaching tasselling stage by that time. In the field fall armyworm infestation was mostly found during the vegetative stage of the crop. After tassel formation till maturity no new infestation could be observed in the field. So, despite high number of adult moths trapped during that period, it could not translate to corresponding high infestation in the field. This trend of results is supported by Niassy et al. (2021), who found a sharper decrease in larval counts (scouting), as compared with adult catches (trap count), when the crop approached maturity. Prasad and Jayakrishna (2013) in their three-year experiment on *Spodoptera litura* and *H. armigera*, noted that there was a lag of two weeks between peak of moths in traps and highest incidence of *S. litura* in tobacco nurseries. Throughout the three years of the study, there was no consistent trend in the peak moth catch. For all crops studied, *H. armigera* incidence was low in two of the three crop seasons, and there was no clear correlation between field incidence and pheromone trap catch during these years. But the above results are in contrast to Pal et al. (2014) who found that larval count of *H. armigera* in the n^{th} week had significant positive association with the moth catch data of the preceding week i.e. $(n-1)^{\text{th}}$ week. Muthukrishnan et al. (2022) also found significantly positive correlation between larval counts and pheromone trap catches for *S. frugiperda* in maize.

Table 3. Correlation coefficient (r) between male moth trap catches and field infestation during 2022-23

Male moth trap catches	Field infestation	
	No. of larva/pl.	Per cent pl. infestation
Current week (n)	-0.396	-0.398
One week back (n-1)	-0.713**	-0.713**
Two weeks back (n-2)	-0.839**	-0.836**
Three weeks back (n-3)	-0.844**	-0.843**
Four weeks back (n-4)	-0.796**	-0.789**

**Significant at 1% level

Table 4. Correlation coefficient (r) between male moth trap catches and field infestation during 2023-24

Male moth trap catches	Field infestation	
	No. of larva/pl.	Per cent pl. infestation
Current week (n)	-0.125	-0.130
One week back (n-1)	-0.392	-0.394
Two weeks back (n-2)	-0.577*	-0.581*
Three weeks back (n-3)	-0.748**	-0.753**
Four weeks back (n-4)	-0.812**	-0.813**

*Significant at 5% level

**Significant at 1% level

The funnel width, height of the funnel and funnel diameter and lure components of the company influenced the trap catches (Prasannakumar et al. 2009). More fall armyworm moths were caught by traps positioned at 1.5 and 2 meters above the ground than by traps at the other placement heights. The lure-trap combination's interaction effects revealed notable variations in fall armyworm catch among the three sites. In terms of catching non-target insects at the three sites, there were also notable variations in the designs of the lures and traps. The number of FAW moths captured per day varied with the type of pheromone lure used. It was also revealed that there was a direct correlation between the number of FAW male moth captures and trap placement height. Traps placed at 1.5 m and 2 m above ground level captured a greater number of male moths than traps at lower placement heights. Interestingly, no statistically significant difference was detected on the numbers of male moths captured at these two placement heights, i.e., 1.5 and 2 m and showed decrease in fall armyworm trap catches with increasing maize maturity. This suggests that for effective management of the fall armyworm, pheromone-baited traps should be set up during the early maize growth stage, as previously found (Sisay et al. 2024). The number of *S. litura* males trapped by pheromones cannot always reflect the population correctly (Akira et al. 2020). It may be important to count the number of female moths. Therefore, pheromone traps, food traps, meteorological data and manual observations of the crop fields should be used in conjunction to establish a more reliable pest monitoring and prevention system (Rao et al. 2015).

4. CONCLUSION

It can be concluded that field infestation cannot always be estimated by using only pheromone trap catch data. It depends on some other factors

also like wind speed, type of pheromone trap used, type of lure used and height at which pheromone trap is positioned which could affect the pheromone trap catch. So, the control measures against the fall armyworm in maize cannot be initiated based on only the trap catch number of adult moths and it is not feasible to time insecticide application on the basis of pheromone trap catch data. Rather, field scouting for larval infestation at periodic level would be more reliable approach to estimate an increasing larval infestation in the field to decide on initiation of pesticide application.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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