Feasibility of timing insecticide applications on the basis of pheromone trap catch number of Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on Maize

Abstract

Field experiments were conducted at the Instructional Farms, Uttar Banga Krishi Viswavidyalaya at Pundibari, Cooch Behar, West Bengal, Indiain rabi season of years 2022–23 and 2023–24 to monitor moth activity of fall armyworm, *Spodoptera frugiperda* by using pheromone traps.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 anobservational 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 % pl. infestation) and trap catches were negatively correlated for all the five weeks i.e., n^{th}, $(n-1)^{th}$, $(n-2)^{th}$, $(n-3)^{th}$, $(n-4)^{th}$ in both 2022-23 and 2023-24 years. Therefore, it can be concluded that only pheromone trap catch data cannot be taken into consideration for timing insecticide application.

Key words: 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 [1]. The rapid incursion of this pest into various countries has now become a global concern[2]. The first report of FAW in Asia was confirmed in Karnataka, India in 2018 [3],which was followed by its discovery from other states of the countryand several Asian countries, including Bangladesh, China, Sri Lanka, Thailand and Vietnam. More recently, FAW was reported in Australia, the Canary Islands and New Caledonia [4].

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 [5]. 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 [5] [6].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 [7].For developing productive management strategies of FAW in given locality, information on motoring data is required [8].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 [9].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 [10].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 trapswere 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 anobservational 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/plot recorded in the nth week was correlated with the number of male moth trapped in the nth week, the previous week i.e. the (n-1)th week, two weeks back i.e. (n-2)th week, three weeks back i.e. (n-3)th week and four weeks back i.e. (n-4)th week.

3.RESULTS AND DISCUSSION

Comment [AC1]: Should be in the same style as 'Introduction' and 'Materials and Methods'. Pls see the journal guidelines.

3.1. Population dynamics of *Spodopterafrugiperda* (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 (Table 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 4thweek 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 percent 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 seasonswhen the moth catch/trap was at peak level with 21moths/trap and 15moths/trap in these weeks, respectively. There was a gap of several weeks between peak field infestation and peak moth catch/trapduring both the years,which indicates that field infestation was high even though moth trap catch was lowand there is a negative association between the trap catches and per cent plant infestation (Table 1&2). These findings are in agreement with Londhe et al. (2024) [11] 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 etal. (2009) [12] and Shivakumara (2001) [13],worked on different lepidopterous pests including *Helicoverpaarmigera* 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, *~~Helicoverpa~~H.armigera*, okra shoot and fruit borer moth, *Erias insulana* and brinjal shoot and fruit borer moth *Leucinodesorbonalis.*

Table 1. Population of *~~Spodoptera~~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 *~~Spodoptera~~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 percent plant infestation for five weeks i.e., with n^{th}, $(n-1)^{th}$, $(n-2)^{th}$, $(n-3)^{th}$ and $(n-4)^{th}$ weeks for both 2022-23 and 2023-24 rabi seasons (Table 3 & 4). Results of the first-year correlation data have shown that there was no significant correlation between number of larva/plant and percent 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 percent plant infestation with male moth trap catch data for $(n-1)^{th}$, $(n-2)^{th}$, $(n-3)^{th}$ and $(n-4)^{th}$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), $(n-1)^{th}$(r =-0.713 and r =-0.713), $(n-2)^{th}$(r =-0.839 and r =-0.836), $(n-3)^{th}$(r =-0.844 and r =-0.843), $(n-4)^{th}$(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 $(n-1)^{th}$, $(n-2)^{th}$, $(n-3)^{th}$, $(n-4)^{th}$ 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 percent plant infestation with male moth trap catch data for n^{th} and $(n-1)^{th}$weeks. However, there was significant negative correlation between number of larva/plant and percent plant infestation with male moth trap catch data for, $(n-2)^{th}$ week at 5% level of significance and at 1% level of significance for $(n-3)^{th}$ and $(n-4)^{th}$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), $(n-1)^{th}$(r =-0.392 and r =-0.394), $(n-2)^{th}$(r =-0.577and r =-0.581), $(n-3)^{th}$(r =-0.748 and r =-0.753), $(n-4)^{th}$(r =-0.812 and r =-0.813),n^{th} and $(n-1)^{th}$ weeks were non-significant and negatively correlated, $(n-2)^{th}$, $(n-3)^{th}$, $(n-4)^{th}$ weeks weresignificant 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 etal. (2021) [14], 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) [15] in their three-year experiment on *Spodoptera litura* and ~~*Helicoverpa*~~ *H.armigera*, noted that there was a lag of two weeks between peak of moths in traps and highest incidence of ~~*Spodoptera*~~*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, ~~*Helicoverpa*~~ *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. Butthe above results are in contrast to Pal etal. (2014) [16] who found that larval count of ~~*Helicoverpa*~~ *H.armigera* in the n^{th} week had significant positive association with the moth catch data of the preceding week i.e. $(n-1)^{th}$ week. Muthukrishnan etal. (2022) [17]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 [18].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 ~~by~~ [19]. The number of ~~*Spodoptera*~~*S.litura* males trapped by pheromones cannot always reflect the population correctly [20]. 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 [21].

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 whichcould 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.

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