



Fall armyworm (*S. frugiperda*) an Emerging Risk for the Expansion of Maize in the Coastal Zone of Bangladesh: A Survey of Farmers' Perception and Practices

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Maize is being promoted as a new *Rabi* season crop for the coastal zone in Bangladesh, but the spread of fall armyworm (*Spodoptera frugiperda*) is an emergent threat that needs to be managed. The prevalence of fall armyworm was surveyed in Patuakhali (Kalapara upazila), Barguna (Amtali upazila) and Khulna (Dacope and Batiaghata upazila) districts in coastal Bangladesh using a structured questionnaire and supplemented by a survey of farmer's awareness of this pest and their current management responses. Adult populations were monitored using pheromone traps and larval populations were counted by sampling maize plants from production fields during October 2019 to April 2020. Of the 120 maize growers, 74% had >10 years farming experience but most were illiterate. They mainly cultivated hybrid maize varieties Miracle, NK 40 and BARI hybrid maize 16. All the respondents opined that different stages of maize plants were infested by fall armyworm from seedling stage. The infestation level of fall armyworm increased during February to March and they sprayed chemical insecticides 2-3 times for the management of this pest. Most of the farmers got pest management information from a pesticide retailer. The number of captured moths in pheromone traps gradually increased from December to March at each coastal district. Larvae of *S. frugiperda* was first observed on the 1st week of January when temperature was low and reached a peak during the 3rd week of March. Increases in maximum temperature and minimum temperature had positive associations with incidence of larvae whereas increasing relative humidity and rainfall exhibited a negative association. In conclusion, maize growers are familiar with *S. frugiperda* and they used chemical insecticides for the management of this pest. *S. frugiperda* control measures need to target the period from January and February.

(*Key words: Fall armyworm, Infestation, Management, Population, Zea mays*)

Over the past ten years, Bangladesh has seen a dramatic growth in the production and cultivation of maize (*Zea mays* L.). Its expansion has accelerated more recently than any other crop in Bangladesh, most likely as a result of its year-round production, high yield, and resistance to extreme heat and other natural calamities. The nation's annual maize production increased from 1,552,000 tonnes in 2010-11 to 4,116,000 tonnes in 2020-21 (BSS, 2022).

However, 2.2 million tonnes were imported in 2020-2021 (USDA, 2021). Due to salt stress, many areas in Bangladesh's coastal region go fallow during the *Rabi* season. Maize has shown promise for growth on the fallow land. However, during dry periods in the

coastal area in Bangladesh, crop cultivation is difficult due to high soil and water salinity, with estimates of fallow land ranging from 40-45% and 30-35% during *Rabi* and *Kharif* seasons, respectively (Rahman *et al.*, 2017). In the coastal and offshore areas of Bangladesh about 0.83 million hectares or 30% of land are arable lands (Rahman, 2012). Maize is relatively a new crop that was introduced in the southern part of Bangladesh. According to Katalyst (2015), the southern disaster-prone coastal regions of Bangladesh are available for introducing summer and winter maize cultivation in areas where fallow land has resulted in low income for farmers. Therefore, in water scarce areas like the coastal regions of Bangladesh, maize could be an alternative

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option in the *Rabi* season for higher productivity and income (Rahman, 2012).

The fall armyworm, *Spodoptera frugiperda* (JE Smith) (*Lepidoptera: Noctuidae*), is the most significant noctuid pest in North and South America and has lately spread to 38 countries (Igyuve *et al.*, 2018; Montezano *et al.*, 2018). It first appeared in Bangladesh in November 2018 and there after expanded to 22 districts before it was identified in May 2019 (CIMMYT, 2020). It was first found on cabbage and maize, in various areas (Palma, 2018) but the fall armyworm (FAW) larvae may feed on more than 100 plant species, including maize, rice, sorghum, millet, sugarcane, vegetable crops, and cotton. They can significantly reduce yields in these plants as well as others. In neighboring states of eastern India (West Bengal and Bihar), FAW was reported to cause significant damage to maize crops: around 40% of crops in Bihar were destroyed by FAW (Manoj 2021; Mohd, 2019). Similarly, in the north-eastern plain zone of Uttar Pradesh, FAW incidence varied from 16-31% of crops (Vinay *et al.*, 2022). Across the northern maize-growing states of India including West Bengal, Vishwanath (2022) reported production decreases due to FAW of 5-10% and additional costs for spraying of Rs. 2,500-3,000 per acre.

According to Kumela *et al.* (2018), the insect is evolving into a serious danger that is significantly reducing maize yields. Even plant tissues with a high silica content, such as seedlings, leaves, tassels, cobs, and developing kernels, are consumed by older larvae with stronger mandibles and greater appetites (Goergen *et al.*, 2016). The expected cob infestation was less than 5% for the summer 2019 maize cropping season. During the *Rabi* 2019-20 season, plant infection levels ranged from 20-25% in the early vegetative stage to very little cob infection (CIMMYT, 2020).

In many places of Bangladesh, the recent invasion of the FAW is causing a disastrous infestation of maize (Ullah *et al.*, 2021). Farmers' perception and awareness is very much important to gather information on occurrence, distribution, infestation level and management practices of FAW (Djima, 2018) which helps to minimize the risk for expansion of maize cultivation in the coastal area of Bangladesh. Since there has not yet been any research on the FAW pest status in

coastal regions the present study surveyed its prevalence on farmers' fields and current effective control methods as well as farmers' perceptions of the FAW.

MATERIALS AND METHODS

The field survey was conducted in three coastal maize growing districts of Bangladesh *viz.*, Patuakhali, Barguna and Khulna in the *Rabi* season during October 2019 to April 2020. From the three districts, Kalapara upazila from Patuakhali, Amtali upazila from Barguna, Dacope upazila and Batiaghata upazila from Khulna districts were selected as survey areas. Climate change has a long history in those locations. The KGF-ACIAR project had earlier chosen those sites to boost the coastal areas' cropping intensity. Moreover, three villages were chosen in consultation with the field level officials of the Bangladesh Agricultural Research Institute (BARI) from each of the four upazilas where maize is cultivated and 10 maize farmers were chosen randomly for each of the sample villages for interview. Thus, a total of 120 maize farmers were interviewed. A structured questionnaire was developed for the maize farmers based on the demographic information of the respondents. Questions were asked on FAW of maize for assessing farmers perception as infestation status in maize field, condition of host plant, vulnerable stage of maize, infested plant parts, severity of infestation etc. and also for awareness such as control measure of FAW, more infested month, year-round infestation scenario, frequency of insecticide application, training on modern cultivation practice, safe use of insecticides, integrated pest management, etc.

To monitor the adult moths of FAW, pheromone traps were used in the selected maize fields of the sample locations. Pheromone traps and lures (Z9-Tetradecenyl Acetate: Z11-Hexadecenyl Acetate: Z7-Dodecenyl Acetate) were collected from Ispahany Biotech Company Limited, Gazipur, Bangladesh. Traps were set in the maize field at seedling stages. The pheromone lure was hung at the bottom of the lead of the trap's bucket. To maintain their effectiveness, the pheromone lure was replaced in a trap every four weeks. The incidences of captured moths in the pheromone traps were recorded as per pre-designed data sheet from the fourth week of December, 2019 to the third week of April 2020 during maize cropping seasons.

Besides the monitoring of adult moths of FAW, the monitoring of larvae of FAW was also done in the same sample locations as mentioned above. The maize fields which were maintained free of chemical pesticides were selected for this monitoring study. In each sample location, 10 maize plants were randomly selected in a field following the “W” sampling pattern as recommended by Prasanna *et al.* (2018) and the number of larvae observed per plant was recorded at 7 days intervals. Their population was expressed per plant from the mean of three replications and each replicate of data is a mean of data from 10 plants. All the fully opened leaves and whorls of selected plants were visually observed and number of larvae found were recorded. The maximum and minimum temperature, relative humidity and rainfall were also collected from the weather stations situated at Kalapara (for both Patuakhali and Barguna)

and Dacope (Khulna). The collected data were analyzed using SPSS computer package version 2017.

RESULTS AND DISCUSSION

Demographic profile of the farmers

A total of 120 maize farmers participated in the field survey, of which 54% were 30-45 years old and 35% were above 45 years old. Among the responded farmers, 76% were illiterate, whereas 18% had at least primary level education. Considering the years of experience in crop production, 46% of farmers had 10 or more years of experience, while 23% farmers had up to 5 years of experience (Table 1). So, most of the farmers had 10-25 years' experience in crop production despite high levels of illiteracy.

Table 1. The socio-demographic characteristics of the respondents in three districts of coastal Bangladesh

Character	Number of respondents	% of respondents
Age		
Under 30 years	13	10.8
30 - 45 years	65	54.2
Above 45 years	42	35.0
Education		
Primary level	21	17.5
Secondary level	8	6.7
Illiterate	91	75.8
Experience in agriculture		
Up to 5 years	26	23.3
10 - 15 years	55	45.8
16 - 25 years	25	20.0
Above 25 years	13	10.8

Varieties of maize grown at surveyed locations

The ‘Miracle’ variety of maize was most popular and cultivated by 39.2% farmers followed by NK 40 (24.2%), BARI hybrid maize 16 (17.5%), Super shine (13.3%), BMH 9 (5.8%) (Fig. 1).

Farmers' perception regarding the incidence of FAW in maize field

According to the study, 85% of respondents experienced damage from FAW and the maize farmers

were asked to specify part (s) of the maize plant in a field that was infested by the FAW. However, the % age of respondents who reported having suffered damage from FAW from the maize farmers in Dacope, Kalapara, and Amtali was 64%, 12%, and 9%, respectively (Appendix 1). All the farmers (100%) reported that *S. frugiperda* attacked leaves and whorls of maize, 30.8% observed damage on fresh cobs, and 14.2% mentioned infestation of flowers (fresh silk and tassel) (Table 2). Maize growth stages pre-flowering, flowering and post-flowering were

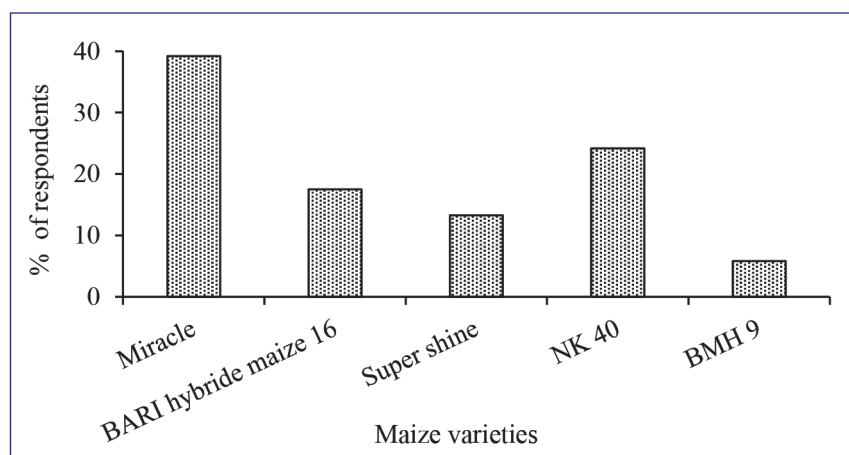


Fig. 1. Maize varieties cultivated in coastal districts of Bangladesh from a survey of 120 farms

all reported by the respondents to be attacked by *S. frugiperda*. But most of respondents (64.2%) considered that the maximum incidence of *S. frugiperda* occurred at pre-flowering stage, followed by flowering (20%) and post-flowering stage (15.8%) of maize. Most of the farmers (64.2%) observed *S. frugiperda* infestation in their maize field for the last two years while 35.8% reported one year of incidence only.

All the respondents (100%) also opined that *S. frugiperda* was the major pest in field during the maize growing period (Table 2) but was not present throughout the year. From the farmers' reports on the incidence of FAW in maize fields, *S. frugiperda* infestation started from seedling stage of maize and continued up to cob stage. Leaves, apical meristem (whorl), silk, tassel and cob were infested by *S. frugiperda* but maximum infestation

Table 2. Farmer's reports of the incidence observed of fall armyworm (FAW) damage or infestation on maize plants during cultivation

Variable	No of respondents	% of respondents
FAW caused damage in maize field		
Yes	103	85.8
No idea	17	14.2
Infested parts of the plant		
Leaves	120	100
Apical meristem (whorl)	120	100
Flowers (fresh silk and tassel)	17	14.2
Fresh cobs	37	30.8
Critical stage of maize for FAW infestation		
Pre-flowering (vegetative stage)	77	64.2
Flowering (tasseling & silking)	24	20.0
Post-flowering (cob initiation)	19	15.8
Fall armyworm incidence in maize field		
One year	43	35.8
Two years	77	64.2
Presence of FAW year around		
Yes	0	0
No	120	100

occurred on leaves and whorls at pre-flowering stage (vegetative stage).

Farmers' perception on severity of infestation on maize

About half of the respondents (55.8%) reported that the *S. frugiperda* infestations were high in their maize field, whereas, 31.7% reported that the infestations were very high (Table 3). Location-wise, Amtali,

Kalapara, and Dacope had very high *S. frugiperda* infestations, according to reports from 14%, 10%, and 6% of respondents, respectively (Appendix 1). The infestation level increased during the cropping period; 62.5% respondents reported that the infestation level increased during February to March. On the other hand, 21.7% reported that the infestation level increased later in April, while 15.8% found that the infestation level increased during January to February (Table 3).

Table 3. Severity of infestation on maize reported by the respondents

Variable	No of respondents	% of respondents
Severity of infestation		
Low	0	0
Medium	15	12.5
High	67	55.8
Very high	38	31.7
Severity of infestation increased during the period		
January to February	19	15.8
February to March	75	62.5
April	26	21.7

In all three coastal districts (Patuakhali, Barguna and Khulna), all the respondents reported that *S. frugiperda* was the major pest of the maize that attacked their fields but it did not attack other crops.

Farmers' perception against fall armyworm management

Farmer's information about insect pest of maize and their management practice were presented in Table 4. Chemical insecticides were used by 60.8% of the farmers to control this pest, while the remainder did not use any management practices. Various registered insecticides from different chemical groups were sprayed to control the *S. frugiperda* in the field. Most of the farmers (56.7%) sprayed insecticides three times while 25.8% applied twice and 17.5% sprayed only once (Table 4). Overall, 65.8% of farmers received pest management information from a pesticide retailer, 15% from the On Farm Research Division (OFRD) of Bangladesh Agricultural Research Institute (BARI), 6.7% from the Department of Agriculture Extension (DAE) and 12.5% from other farmers (Table 4).

Training on insect pest management

Different organizations such as DAE, BARI and others were involved in farmers' training on insect pest management at the survey locations (Table 5). However, the majority (80.8%) of the farmers did not receive training from any organization. Among the trained farmers (23), 78.3% received training on production technology and 17.4% received training on safe use of insecticides. Most of trained farmers (13) reported that they participated in BARI conducted training. Six farmers (26.1%) received training conducted by other organizations and 17.4% (4) received DAE conducted training (Table 5). More training on FAW identification and management was provided to the farmers of Dacope. Compared to other locations, they are thus more aware. As a result of improved farmer knowledge and perception, the infestation's severity was lower at Dacope (Appendix 1).

Monitoring of fall armyworm

The number of FAW moths trapped during the 4th

Table 4. Control measures adopted by farmers against fall armyworm at surveyed locations of the coastal area

Variable	No. of respondents	% of respondents
Different control measure against fall armyworm		
Chemical insecticides	73	60.8
Biopesticides	0	0.0
Integrated pest management (IPM)	0	0.0
No management	47	39.2
Frequency of insecticides application		
One time application	21	17.5
Two times application	31	25.8
Three times application	68	56.7
Source of pest management information		
Pesticide retailer	79	65.8
OFRD, BARI	18	15.0
DAE officer	8	6.7
Other farmers	15	12.5

Table 5. Training received by farmers for insect pest management

Variable	No of respondents	% of respondents
Training received by farmers		
Yes	23	19.2
No	97	80.8
Training on		
Safe use of insecticides	5	21.7
Integrated pest management	0	0.0
Production technology	18	78.3
Training organized by		
DAE	4	17.4
BARI	13	56.5
Other organization	6	26.1

week of December was 10, 13 and 8 moths trap⁻¹ wk⁻¹, at Kalapara, Amtali and Dacope, respectively (Fig. 2). The number of captured moths in pheromone trap gradually increased over time at each location. The highest number of moths were captured during the 3rd week of March; values were 30, 32 and 28 moths trap⁻¹ wk⁻¹ at Kalapara, Amtali and Dacope, respectively when maximum mean temperature (27.8°C at Kalapara, 27.8°C at Amtali and 26.5°C at Dacope) was recorded.

Incidence of fall armyworm larvae in maize field in different locations

The highest number of larva (1.97 larvae per plant) was recorded in the maize field of Amtali upazila but values range from (0.06 to 3.31 larvae per plant). Similarly, at Kalapara upazila the average was (1.72 larvae per plant range from 0.03 to 3.09 larvae per plant) (Table 6). The lowest average number of FAW larvae (1.54 larvae per plant) was recorded in the maize field

located at Dacope upazila (range from 0.0 to 2.84 larvae per plant). Seasonal variation of FAW larvae among three locations was also observed in the maize fields. At Dacope upazila, no larva was found in the 4th week of December 2019.

Few larvae (0.05 larvae per plant) were recorded on the 2nd week of January 2020 (winter month of the year), but incidence increased to a maximum 2.84 larvae per

plant on the 3rd week of March 2020 (summer month of the year). Similar trends in larval incidence were observed at Kalapara and Amtali locations. Among three locations, the larval incidences throughout the cropping season were highest in Amtali upazila. Maize plant, weather and age significantly impact egg masses, larval population density, and damage %, with mean daily maximum temperature being the most effective variable. Similar findings also found by Bakrya and Abdel-Bakyb (2023).

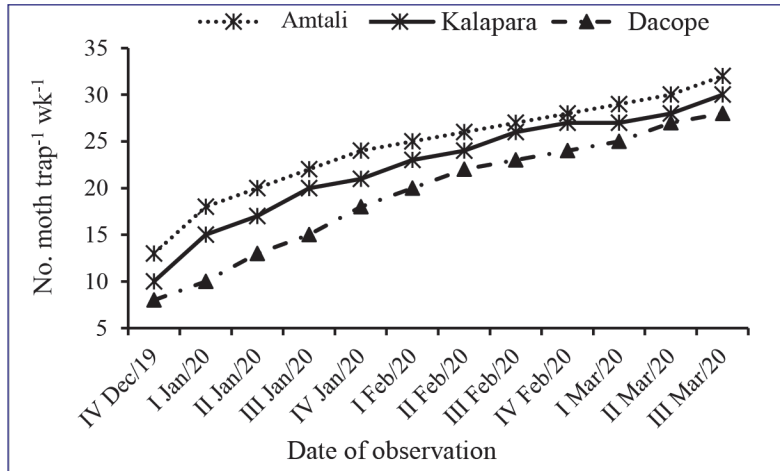


Fig. 2. Mean number of fall armyworm moth captured per trap per week during the cropping seasons of maize at Amtali, Kalapara and Dacope

Table 6. The incidence of fall armyworm larvae on maize fields in Dacope, Kalapara and Amtali district during Rabi season of 2019-2020

Weekly observation	Location-wise weekly mean fall armyworm larval incidence (larvae plant ⁻¹)		
	Dacope	Kalapara	Amtali
4 th week of Dec 2019	0.00	0.03	0.06
1 st week of Jan 2020	0.05	0.08	0.14
2 nd week of Jan 2020	0.14	0.15	0.99
3 rd week of Jan 2020	0.31	0.97	1.31
4 th week of Jan 2020	1.30	1.22	1.79
1 st week of Feb 2020	1.66	2.00	2.17
2 nd week of Feb 2020	2.16	2.24	2.39
3 rd week of Feb 2020	2.29	2.44	2.48
4 th week of Feb 2020	2.49	2.68	2.77
1 st week of Mar 2020	2.56	2.81	3.06
2 nd week of Mar 2020	2.67	2.97	3.19
3 rd week of Mar 2020	2.84	3.09	3.31
Overall mean	1.54	1.72	1.97
Minimum	0.00	0.03	0.06
Maximum	2.84	3.09	3.31
Standard deviation	1.10	1.13	1.09

Weather variations at three survey locations during maize growing season

Differences in weather parameters were observed among the three maize growing regions (Table 7). The maximum mean temperature throughout the cropping season (27.8°C) was recorded in Kalapara and Amtali districts followed by Dacope (26.5°C) while minimum mean (15.7°C) at Dacope region was lower

than at Kalapara and Amtali (16.2°C). In case of mean relative humidity (RH), the maximum RH (71.7%) was recorded in Khulna region followed by Patuakhali and Barguna region (70.8%) (Table 7). The highest mean rainfall (0.85 mm wk⁻¹) was recorded in Patuakhali and Barguna region followed by Khulna region (0.60 mm wk⁻¹) although none of the sites had significant amounts of rainfall (Table 7).

Table 7. Weather variations in three sampled locations during maize growing season

Locations	Seasonal weather factors			
	Mean temperature (°C)		Mean relative humidity (%)	Mean rainfall (mm wk ⁻¹)
	Maximum	Minimum		
Dacope	26.5	15.7	71.7	0.60
Kalapara	27.8	16.2	70.8	0.85
Amtali	27.8	16.2	70.8	0.85

Table 8. Correlation between weather parameters and weekly observations of mean number of larvae of *Spodoptera frugiperda* during Rabi season

Weather parameters	Correlation coefficient value (r)		
	Dacope	Kalapara	Amtali
Max. Temperature	0.893***	0.932***	0.931***
Min. Temperature	0.886***	0.892***	0.897***
Rainfall	-0.589*	-0.445 NS	-0.522 NS
Relative humidity	-0.750*	-0.583*	-0.600*

NS - Non significant; * - Significant at 5%; *** - Significant at 0.1%

Correlation between weather parameters and larval populations of fall armyworm

At Kalapara, the larval population of FAW was highly correlated with maximum temperature ($r = 0.932$; Table 8) and minimum temperature ($r = 0.892$), while it was not correlated with rainfall ($r = -0.445$) and negatively correlated with relative humidity ($r = -0.583$). Similar results also found at Amtali and Dacope (Table 8). Hence, small differences in temperature and to a lesser extent in rainfall and relative humidity (RH) appeared to cause differences in the population of *S. frugiperda* among different locations.

The study found that heavy rainfall can physically remove FAW larvae from plants, but lower rainfall during the Rabi season may have contributed to higher attack rates. Similarly, Archunan *et al.* (2018) who

reported that the positive correlation of lepidopteran pests *Helicoverpa armigera* on tomato with maximum temperature. The study by Nivetha *et al.* (2022) supports the correlation analysis indicating a positive association between maximum temperature and larval incidence of *S. frugiperda*. Manohar (2020) found a strong positive correlation between high temperature and FAW infestation, while also revealing an inverse relationship between rainfall and relative humidity. The study by Anil (2021) found a non-significant negative correlation between rainfall and relative humidity and FAW infestation, supporting the current study.

Farmers' surveys and FAW monitoring data provide crucial information on FAW severity, impact, and incidence in Bangladesh, aiding in identifying high-risk areas and prioritizing interventions. Planning techniques such as using biocontrol agents, dispersing

resistant maize varieties, and spraying insecticides is aided by this information. FAW infection of maize was detected in every survey location. In all areas, the infestation increased in February and March associated with the rise in temperature. When farmers detect the signs of infestation, such as leaf damage, frass, and larvae as the temperature increases, they should take control measures for FAW in maize fields as soon as possible. Hence, seasonal temperature records may be useful to predict the likelihood of severe infestations by FAW in the coastal zone.

CONCLUSION

All the respondents reported that different stages of maize growth were infested by FAW. It was concluded that leaves and whorls were infested by FAW, but most of the respondents reported that FAW incidence occurred in the pre-flowering (late whorl) stage (64.2%). An increase in infestation level from February to March, when temperatures were rising, was reported by 62.5% of respondents. Chemical insecticides were used by most farmers (60.8%) to control this pest, but 39.2% of farmers did not use any management practices. Of the insecticide users, 56.7% of respondents applied insecticides three times. The study suggests that, the population incidence of FAW started in the first week of January and reached peak activity by the third week of March. Increasing maximum and minimum temperatures had a positive association with incidence during December-March, whereas relative humidity and light rainfall exhibited only a week-long negative association. Therefore, temperature plays a major role in the incidence of *S. frugiperda*. Thus, regular monitoring of FAW data and farmers' surveys provide crucial information about its presence and impact in Bangladesh. This helps identify high-risk areas, prioritize interventions, and plan targeted spraying, biocontrol agents, IPM, and resistant maize varieties.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Appendix I. Location wise variation of farmers response on different parameters

Location	Respondent perception on FAW (%)		Incidence of FAW (moths trap ⁻¹ week ⁻¹)		FAW larval incidence and mean temperature		No. farmers training		Severity of infestation (%)				Control measures adopted by farmers (%)	
	Yes	No	December	March	Temp (°C)	No. larva plant ⁻¹	No. of respondents	Percent of respondents	Low	Medium	High	Very high	Yes	No
Amtali	9.1	6.7	13	32	27.8	1.97	5	4.2	0	5.8	24.2	14.2	12.5	19.2
Kalapara	12.5	5.0	10	30	27.8	1.72	7	5.8	0	4.2	18.3	10.8	17.5	11.7
Dacope	64.2	2.5	8	28	26.6	1.54	11	9.2	0	2.5	13.3	6.7	30.8	8.3
Total	85.8	14.2	-	-	-	-	23	19.2	0	12.5	55.8	31.7	60.8	39.2

FAW- Fall armyworm