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Bhimani AM
Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Jethva DM
Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Kachot AV
Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Patel DS
Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Corresponding Author:
Bhimani AM
Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Standardization of pheromone trap density for mass trapping of Maize fall armyworm, *Spodoptera frugiperda* (J. E. Smith)

Bhimani AM, Jethva DM, Kachot AV and Patel DS

Abstract
A study on the standardization of sex pheromone traps against *S. frugiperda* noted that the sex pheromone traps installed @ 60 and 50 traps/ha recorded the lowest (12.01-16.51% and 12.89-17.26%) percent central shoot damage, larval population (2.37-10.27 and 2.49-10.62 larvae/10 plants), cob damage (12.07 and 13.08%) and moth catches (27.34 and 25.98 moths/trap/week), respectively. The study concluded that a trap density of 50 pheromone traps per hectare was optimal for managing fall armyworm infestation in maize.

Keywords: Maize fall armyworm, pheromone trap, *S. frugiperda*

Introduction
Maize (*Zea mays* L.) is the third most important grain crop in the world, which is widely cultivated all over the world in different agro-climatic zones. Worldwide, it is popularly known as the "Queen of cereals" due to its wider adaptability and highest genetic yield potential among cereal crops. Maize is a storehouse of various nutrients such as carbohydrates, proteins, minerals, vitamins, iron, etc. and particularly supplies high energy of 365 Cal/100g. It serves many purposes such as the source of human food, livestock and poultry feed. Besides this, maize has wider applications in milling industries for starch and oil extraction. Its large-scale application lies in biofuel or ethanol production in many developed countries, especially in the USA and Brazil. Maize originated from central Mexico and is currently one of the most widely distributed crops in the world. It is grown in more than 160 countries of the world and the USA, China, Brazil, Mexico, France and India are the major producers. At the beginning of the 17th century, it was introduced into India from Central America.

In India, maize is cultivated at 9.83 million hectares with a production of 26.26 million tonnes and productivity of 2664 kg/ha. India stands sixth in the world for maize production. Cultivation of maize in India is mostly confined to the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, Karnataka, Madhya Pradesh, Andhra Pradesh and Jammu-Kashmir. Gujarat occupies an area of 0.45 million hectares with a production of 0.80 million tonnes and productivity of 1780 kg/ha (Anon., 2017) [1]. The important districts of Gujarat growing maize are Dahod, Punchmahal, Vadodara, Samantha, Kheda, Banaskantha, Bharuch, Anand and Dang.

The maize plant is attacked by 140 species of insect pests causing a varying degree of damage. However, only about a dozen are quite serious (Sarup *et al*., 1987) [8]. Among these insect pests, only ten species cause serious damage from sowing to storage (Arabjafari and Jalali, 2007). Major pests attacking maize are the maize stem borer, *Chilo partellus* (Swinhoe); European corn borer, *Ostrinia nubilalis* (Hubner) and *Ostrinia furnicalis* (Guenee); Maize shoot fly, *Atherigona soccata* (Rondani); Hairy caterpillar, *Amsacta moorei* (Butler); Bihar hairy caterpillar, *Spilosoma oblique* (Walker); Maize leaf aphid, *Rhopalosiphum maidis* (Fitch); Blister beetle, *Mylabris pustulata* (Thunberg); Maize Jassid, *Zygnidia manaliensis* (Singh); Maize thrips, *Anaphothrips sudanensis* (Trybon); Chafer beetle, *Holotrichia consanguinea* (Blanchard), and Maize weevil, *Myllocerus discolor* (Boheman). Among these, FAW is a newly invasive pest of maize in India.

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is native to America and it is a key pest of maize and many other crops throughout America. *S. frugiperda* was reported for the first time in 2016 in Africa, causing significant damage to maize. This pest was detected for the first time on the Indian subcontinent in mid-May, 2018 in maize fields at the College of Agriculture, (UAHS), Shivamogga. Similar information has also just been released on independent investigations by the National Bureau of Agriculturally Important Microorganisms (NBAIR) under the Indian Council of Agricultural Research (ICAR).

Pheromones can contribute to Integrated Pest Management (IPM) strategies by modifying insect behavior, and mainly by capturing the adult stages of the pest. There are many different ways by which pheromones have been successfully deployed. The use of pheromones in pest control has developed along three main pathways: for the monitoring of insect populations with pheromone-baited traps, for control by mass trapping (using large numbers of traps to reduce pest population levels) and for control by a mating disruption in which a synthetic pheromone is used to permeate the atmosphere so that an insect will be unsuccessful in finding a mate (Campion, 1983) [3].

Materials and Methods

The evaluation of different trap densities for managing *S. frugiperda* was investigated in this study. The aim was to determine the most efficient trap density for mass trapping of *S. frugiperda* moths. The experiment was carried out in farmer's field of Targhadia village in Rajkot district during *Kharif*, 2020 and 2021.

Treatment details

Sr. No. Treatments

1. 40 Sex pheromone traps/ha
2. 50 Sex pheromone traps/ha
3. 60 Sex pheromone traps/ha

Methodology

The present experiment was carried out on the farmers' field of Targhadia village in Rajkot district for the standardization of pheromone traps against fall armyworms in maize. The different numbers of pheromone traps (40, 50, and 60/ha) were installed for mass trapping after 15 days of sowing in the maize field. The average number of male moths caught in the trap was recorded at weekly intervals up to the harvesting of the maize crop from each pheromone trap. An isolation distance of 1 km was maintained between each location. Additionally, the pheromone septa were replaced every 40 days with new ones to ensure that the trap's effectiveness was not compromised. From each location, 20 different spots were selected randomly and from each spot 10 plants were selected for recording observation.

Observations recorded

a) Percent central shoot damage/10 plants

The observations on percent central shoot damage were recorded at 30, 45 and 60 days after sowing.

b) Number of larvae/10 plants

The number of larvae per 10 plants was recorded at 30, 45 and 60 days after sowing.

c) Percent cob damage

The percent cob damage was recorded at each picking from each plant and the average of all the pickings was calculated.

d) Number of moth catches/trap/week

The population was monitored by deploying five pheromone traps/ha. The number of moths caught per trap was observed and recorded at weekly intervals, starting from the installation of traps and up to the harvesting of the crop from each plot. The average data recorded during observations were transformed using square root transformation and subjected to statistical analysis.

Results and Discussion

Percent shoot damage

First year (2020-21)

The data presented in Table 1 showed that the lowest (15.93%) percent shoot damage was registered in the plot regulated with 60 pheromone traps/ha, which was statistically at par with 50 pheromone traps/ha (17.11%) after 30 days of installation. However, the treatment of 40 pheromone traps/ha was found least effective in which the highest (28.94%) percent shoot damage was recorded.

After 45 days of sex pheromone installation, the lowest (14.38%) percent of shoot damage was recorded in the plot executed with 60 pheromone traps/ha. However, this treatment was significantly proportionate with the plot administered with 50 pheromone traps/ha (15.44%). The highest (25.41%) percent shoot damage was counted in the plot governed with 40 pheromone traps/ha.

The plot governed with 60 pheromone traps/ha was assessed with the lowest (11.94%) percent of shoot damage after 90 of installation, which was statistically at par with 50 pheromone traps/ha (12.64%). The highest (18.66%) percent shoot damage was counted in the plot governed with 40 pheromone traps/ha.

Table 1: Effect of sex pheromone traps on percent central shoot damage due to fall armyworm, *S. frugiperda* in maize

Sr. No.	Treatments	Percent central shoot damage/plant								
		30 DAS			45 DAS			60 DAS		
		2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	40 Sex pheromone traps/ha	33.12 (28.94)	34.63 (31.35)	33.88 (30.15)	30.91 (25.41)	29.92 (23.94)	30.42 (24.68)	26.29 (18.66)	25.73 (17.88)	26.01 (18.27)
T_2	50 Sex pheromone traps/ha	25.15 (17.11)	25.38 (17.40)	25.27 (17.26)	23.89 (15.44)	23.56 (15.01)	23.73 (15.23)	21.67 (12.64)	22.05 (13.13)	21.86 (12.89)
T_3	60 Sex pheromone traps/ha	24.29 (15.93)	25.14 (17.09)	24.72 (16.51)	23.07 (14.38)	23.35 (14.73)	23.21 (14.56)	21.07 (11.94)	21.17 (12.08)	21.12 (12.01)
S.Em.±		0.61	0.59	0.54	0.40	0.41	0.47	0.31	0.38	0.42
C.D. at 5%		1.78	1.71	1.58	1.14	1.20	1.36	0.89	1.09	1.23
C.V.%		6.78	6.05	6.41	5.04	5.77	5.41	5.16	5.83	5.50

Y									
S.Em.±	-	-	0.33	-	-	0.26	-	-	0.23
C.D. at 5%	-	-	NS	-	-	NS	-	-	NS
Y X T									
S.Em.±	-	-	0.57	-	-	0.44	-	-	0.40
C.D. at 5%	-	-	NS	-	-	NS	-	-	NS

*Figures in parenthesis are original values, while outside are arcsine transformed. DAS-Days after Sowing.

Second year (2021-22)

The pragmatic data presented in Table 1 indicated that the difference in percent shoot damage at different installation days of sex pheromone traps during 2021-22 was found statistically significant. The percent shoot damage recorded after 30 days of installation of sex pheromone traps revealed that 60 pheromone traps/ha proved to be the most effective treatment with 17.09% shoot damage and it was at par with 50 pheromone traps/ha as it documented 17.40% shoot damage. Installation of 40 pheromone traps/ha was found least effective treatment as it recorded 31.35% shoot damage. The results after 45 days of sex pheromone traps installation showed that the lowest (14.73%) percent shoot damage was recorded in 60 pheromone traps/ha, which was statistically at par with 50 pheromone traps/ha as it texted 15.01% damage. However, installation of 40 pheromone traps/ha counted the highest (23.94%) percent of shoot damage and it was found least effective treatment. The lowest (12.08%) percent shoot damage was figured in the plot treated with 60 pheromone traps/ha after 60 days of sex pheromone traps installation, which was statistically at par with 50 pheromone traps/ha (13.13%). However, the plot governed with 40 pheromone traps/ha confirmed the highest (17.88%) percent of shoot damage.

Pooled (2020-22)

The pooled data on percent shoot damage indicated that the lowest (16.51%) percent shoot damage was recorded in 60 pheromone traps/ha after 30 days of installation, which was statistically at par with the plot managed with 50 pheromone traps/ha (17.26%). Further, the installation of 40 pheromone traps/ha counted the highest (30.15%) percent shoot damage (Table 1). The trend of different trap densities on percent shoot damage was observed to be similar after 45 and 60 days of installation of sex pheromone traps. The treatments of 60 pheromone traps/ha exhibited the minimum (14.56% and 12.01%) percent of shoot damage, which was statistically at par with plot treated with 50 pheromone traps/ha (15.23% and 12.89%) after 45 and 60 days of installation, respectively. Whereas, the installation of 40 pheromone traps/ha resulted in the highest (24.68% and 18.27%) percent shoot damage.

The study indicated that installation of sex pheromone traps @ 60 pheromone traps/ha and 50 pheromone traps/ha exhibited statistically similar low levels of percent shoot damage after 30, 45 and 60 days of installation. The percentage of shoot damage for 60 pheromone traps/ha was 16.51%, 14.56% and 12.01%, respectively while 50 pheromone traps/ha was 17.26%, 15.23% and 12.89%, respectively. Based on these findings, installation of sex pheromone traps @ 60 pheromone traps/ha or 50 pheromone traps/ha are effective treatment options for managing fall armyworm in maize.

Number of larvae per ten plants

First year (2020-21): The number of larvae/10 plants recorded at 60 days after installation of sex pheromone traps during 2021-22 was found significant (Table 2) in all the treatments. The results showed that installation at the rate of 60 pheromone traps/ha conceded the lowest (10.30) number of larvae/10 plants and it was statistically at par with 50 pheromone traps/ha as it enumerated 10.87 number of larvae/10 plants. Installation at the rate of 40 pheromone traps/ha showed the highest (17.86) number of larvae/10 plants and was found comparatively less effective. After 45 days of installation of sex pheromone traps, the lowest (5.69) number of larvae/10 plants was registered in the plot regulated with 60 pheromone traps/ha, which was significantly at par with 50 pheromone traps/ha (6.04). Meanwhile, the highest (14.36) number of larvae/10 plants counted in the plot governed by 40 pheromone traps/ha. Whereas the results showed the rate of 60 pheromone traps/ha conceded the lowest (2.49) number of larvae/10 plants and it was statistically at par with 50 pheromone traps/ha as it enumerated 2.59 number of larvae/10 plants. Installation at the rate of 40 pheromone traps/ha showed the highest (10.20) number of larvae/10 plants and was found comparatively less effective at 90 days after installation.

Second year (2021-22)

The subsequent year also exhibited a more or less similar trend as observed during the first year but with a slightly decreased population of FAW. The perusal of data presented in Table 2 showed that the lowest (10.23) number of larvae/10 plants was recorded when the traps were installed at the rate of 60 pheromone traps/ha and 50 pheromone traps/ha was found statistically at par with prior treatment, as it conceded 10.37 number of larvae/10 plants. However, installation at the rate of 40 pheromone traps/ha confirmed the highest (16.10) number of larvae/10 plants. The data on the number of larvae/10 plants recorded after 45 days of installation followed the same manner as observed 30 days after the installation of sex pheromone traps wherein, the minimum (3.93) number of larvae/10 plants was recorded in 60 pheromone traps/ha, which was found statistically at par with 50 pheromone traps/ha as it enumerated 4.28 larvae/10 plants. The least (12.56) number of larvae/10 plants was recorded in 40 pheromone traps/ha. After 60 days of installation of sex pheromone traps, the lowest (2.25) number of larvae/10 plants was registered in the plot regulated with 60 pheromone traps/ha, which was significantly at par with 50 pheromone traps/ha (2.38). Meanwhile, the highest (9.25) number of larvae/10 plants counted in the plot governed by 40 pheromone traps/ha.

Table 2: Effect of sex pheromone traps on the number of larvae of fall armyworm, *S. frugiperda* in maize

Sr. No.	Treatments	Number of larvae/10 plant								
		30 DAS			45 DAS			60 DAS		
		2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	40 Sex pheromone traps/ha	4.28 (17.86)	4.07 (16.10)	4.18 (16.98)	3.85 (14.36)	3.61 (12.56)	3.73 (13.46)	3.27 (10.20)	3.12 (9.25)	3.20 (9.73)
T_2	50 Sex pheromone traps/ha	3.37 (10.87)	3.30 (10.37)	3.33 (10.62)	2.55 (6.04)	2.18 (4.28)	2.37 (5.16)	1.76 (2.59)	1.69 (2.38)	1.73 (2.49)
T_3	60 Sex pheromone traps/ha	3.29 (10.30)	3.28 (10.23)	3.28 (10.27)	2.49 (5.69)	2.10 (3.93)	2.29 (4.81)	1.73 (2.49)	1.66 (2.25)	1.69 (2.37)
S.Em.±		0.04	0.04	0.04	0.03	0.05	0.05	0.04	0.02	0.03
C.D. at 5%		0.12	0.12	0.11	0.08	0.15	0.16	0.11	0.06	0.09
C.V.%		3.68	3.45	3.57	5.40	6.56	5.95	3.14	4.43	3.81
Y										
S.Em.±		-	-	0.02	-	-	0.03	-	-	0.02
C.D. at 5%		-	-	0.07	-	-	0.09	-	-	0.04
YXT										
S.Em.±		-	-	0.04	-	-	0.05	-	-	0.03
C.D. at 5%		-	-	NS	-	-	NS	-	-	NS

Figures in parenthesis are original values, while outside is square root transformed. DAS–Days after Sowing.

Pooled (2020-22)

The pooled data presented in Table 2 showed that the lowest (10.27) number of larvae/10 plants was recorded in 60 pheromone traps/ha which was significantly at par with the plot managed with 50 pheromone traps/ha (10.62). Whereas, installation at the rate of 40 pheromone traps/ha resulted in the highest (16.98) number of larvae/10 plants after 30 days of installation. Similar to this, the impact of various sex pheromone trap densities on the number of larvae/10 plants was found to be consistent after 45 and 60 days of installation. The installation of 60 pheromone traps/ha exhibited the lowest (4.81) number of larvae/10 plants which was statistically at par with the plot treated with 50 pheromone traps/ha which recorded 5.16 larvae/10 plants. However, the installation at the rate of 40 pheromone traps/ha resulted in the highest (13.46) number of larvae/10 plants after 45 days of installation. Installation of sex pheromone traps after 60 days, the lowest (2.37) number of larvae/10 plants was registered in the plot regulated with 60 pheromone traps/ha, which was significantly at par with 50 pheromone traps/ha (2.49). Meanwhile, the highest (9.73) number of larvae/10 plants counted in the plot governed by 40 pheromone traps/ha.

The results revealed that the installation of 60 pheromone traps/ha and 50 pheromone traps/ha exhibited statistically similar numbers of larvae/10 plants, with 10.27 and 10.62, respectively after 30 days of installation. Similarly, after 45 ad 60 days of installation, 60 pheromone traps/ha and 50 pheromone traps/ha showed statistically similar results, with 4.81 and 5.16 number of larvae/10 plants, respectively at 45 days whereas at 60 days after installation, the 60 pheromone traps/ha and 50 pheromone traps/ha showed statistically similar results, with 2.37 and 2.49 number of larvae/10 plants, respectively. Overall, the installation of 60 pheromone traps/ha and 50 pheromone traps/ha are effective treatments for reducing the number of larvae in maize.

Percent cob damage

First year (2020-21)

A significant difference was observed in the percent cob damage after the installation of sex pheromone traps (Table 3). The results revealed that the installation of 60 pheromone traps/ha resulted in the lowest (12.21%) percentage of cob damage, which was significantly at par with the plot treated with 50 pheromone traps/ha (13.29%). The installation of 40 pheromone traps/ha resulted in 24.14% cob damage and was comparatively less effective.

Second year (2021-22)

The identical trend was observed in second year installation of sex pheromone traps during 2021-22 (Table 3) wherein, 60 pheromone traps/ha exhibited the minimum (11.92%) percent cob damage and it was found at par with 50 pheromone traps/ha (12.87%). Meanwhile, the plot managed with 40 pheromone traps/ha enumerated the maximum (20.92%) percent cob damage.

Pooled (2020-22)

The pooled data (Table 3) conceded that 60 pheromone traps/ha recorded the lowest (12.07%) percent of cob damage which was significantly at par with the plot administered with 50 pheromone traps/ha as it texted 13.08% cob damage. The plot regulated with 40 pheromone traps/ha registered the highest (22.53%) percent of cob damage.

This study examined the effect of varied pheromone trap densities on the percent cob damage. The results indicated that the installation of 60 pheromone traps/ha recorded the least (12.07%) percentage of cob damage which was statistically equivalent to 50 pheromone traps/ha, demonstrating cob damage of 13.08%. Conversely, the implementation of 40 pheromone traps/ha exhibited the highest (22.53%) percent of cob damage.

Table 3: Effect of sex pheromone traps on percent cob damage due to fall armyworm, *S. frugiperda* in maize

Sr. No.	Treatments	Percent cob damage		
		2020-21	2021-22	Pooled
T_1	40 Sex pheromone traps/ha	30.05 (24.14)	27.88 (20.92)	28.97 (22.53)
T_2	50 Sex pheromone traps/ha	22.17 (13.29)	21.85 (12.87)	22.01 (13.08)
T_3	60 Sex pheromone traps/ha	21.31 (12.21)	21.04 (11.92)	21.18 (12.07)
S.Em. ±		0.49	0.41	0.32
C.D. at 5%		1.42	1.20	0.91
C.V.%		6.31	5.53	5.95
Y				
S.Em. ±		-	-	0.26
C.D. at 5%		-	-	0.74
Y × T				
S.Em. ±		-	-	0.45
C.D. at 5%		-	-	NS

*Figures in parenthesis are original values, while outside are arcsine transformed.

The combined data revealed that 60 pheromone traps/ha and 50 pheromone traps/ha were equally effective in reducing cob damage, with 12.07% and 13.08% damage, respectively. These findings suggest that 60 pheromone traps/ha and 50 pheromone traps/ha are the most effective treatments, as they resulted in the lowest level of damage in both years.

Moth catches

The ensuing dataset furnishes comprehensive details on the average captures of moths obtained from the implementation of pheromone traps, commencing from the flowering phase up to the cessation of maize cultivation, during the 2020-21 and 2021-22 growing seasons.

First year (2020-21)

The assessment of moth trap captures was carried out weekly throughout the cropping season. The population of male moths demonstrated a substantial variation amongst all three treatments as the cropping period progressed. The response of FAW moth captures was statistically significant starting from the first week of installation of pheromone traps. The data represented in Table 4 signposted that the mean number of moths captured in all the respective treatments *viz.*, 40, 50, and 60 pheromone traps/ha was 17.58, 26.06 and 27.42 moth catches/trap/week, respectively.

The trap density of 60 pheromone traps/ha recorded the highest (18.20 moth catches/trap/week) number of moths captured and was statistically proportionate with the trap density of 50 pheromone traps/ha which noted 17.03 moth catches/trap/week. In contrast, the lowest (12.17 moth catches/trap/week) moth catches transpired in the treatment with a trap density of 40 pheromone traps/ha in July (30th SMW).

Notably, the population of fall armyworm exhibited a gradual increase, culminating in a zenith during the weeks of August to September (36th SMW), with the highest moth captures of 33.37, 31.87 and 22.20 moth catches/trap/week in the 60, 50, and 40 pheromone trap density treatments, respectively. After this period, the population of fall armyworm declined in the latter two weeks of September (38th SMW) with 28.35, 25.04, and 17.82 moth catches/trap/week at 60, 50, and 40 pheromone trap densities, respectively. Subsequently, the population of fall armyworm displayed a gradual decline, and moth captures ceased during the last week of September. The cumulative number of moths captured, from installation until harvest, amounted to 246.78, 234.53 and 158.24 moth catches at 60, 50, and 40 pheromone trap density, respectively.

Table 4: Effect of trap density for mass trapping of moth catches of *S. frugiperda* in maize during 2020-21 (First Year)

Sr. No.	Treatments	Moth catches/trap/week									Total no. of moth catches/trap	Mean no. of moth catches/trap/week
		Standard meteorological week										
		30	31	32	33	34	35	36	37	38		
1.	40 Sex pheromone traps/ha	12.17	14.57	15.08	18.37	18.70	19.80	22.20	19.53	17.82	158.24	4.18 (17.58)
2.	50 Sex pheromone traps/ha	17.03	20.37	24.03	27.06	29.80	30.80	31.87	28.53	25.04	234.53	5.08 (26.06)
3.	60 Sex pheromone traps/ha	18.20	21.03	24.87	28.13	30.93	31.87	33.37	30.03	28.35	246.78	5.21 (27.42)
											S.Em. ±	0.16
											C.D. at 5%	0.45
											C.V.%	9.68

*Figures in parenthesis are original values, while outside values are square root transformed.

Second year (2021-22)

In the succeeding year, a comparable pattern was observed, albeit with a lower population of fall armyworms. The reaction of fall armyworm moth captures was statistically noteworthy, originating from the initial week of pheromone trap installation. The examination of data in Table 5 demonstrated that the average count of moths captured across all treatments of 40, 50, and 60 pheromone traps per hectare was 20.65, 26.36 and 27.72 month catches/trap/week, respectively. The fall armyworm population displayed an incremental rise during the study period, with the highest moth captures recorded in the week of August to September (36th SMW), where the densities of 60, 50, and 40 pheromone traps/ha captured 33.67, 32.17, and 22.50 moths catch/trap/week, respectively.

The population of fall armyworms then declined in the last two weeks of September, with moth captures of 28.65, 25.34 and 18.12 moth catches/trap/week at 60, 50, and 40 pheromone trap densities, respectively. A gradual decline in the population was then observed, and moth captures ceased during the last week of September. The total number of moths captured, from installation until harvest, amounted to 249.48, 237.23 and 160.94 moth catches at 60, 50, and 40 pheromone trap density treatments, respectively.

The highest (18.50 moth catches/trap/week) count of moths captured was observed in the treatment with a trap density of 60 pheromone traps/hectare, which was statistically proportional to the treatment with a trap density of 50 pheromone traps per hectare, which noted 17.33 moth catches/trap/week. In contrast, the lowest (12.47 moth catches/trap/week) number of moth captures was observed in the treatment with a trap density of 40 pheromone traps per hectare in July (30th SMW).

Pooled (2020-22)

The pragmatic data presented in Table 6 were pooled from two years of fall armyworm incidence after the installation of pheromone traps. The results indicated that the trap density of 60 pheromone trap/ha (27.34 moths/trap/week) and 50 pheromone trap/ha (25.98 moths/trap/week) were equally effective for capturing the highest number of moths.

Table 5: Effect of trap density for mass trapping of moth catches of *S. frugiperda* in maize during 2021-22 (Second Year)

Sr. No.	Treatments	Moth catches/trap/week									Total no. of moth catches/trap	Mean no. of moth catches/trap/week
		Standard meteorological week										
		30	31	32	33	34	35	36	37	38		
1.	40 Sex pheromone traps/ha	12.47	14.87	15.38	18.67	19.00	20.10	22.50	19.83	18.12	160.94	4.21 (20.65)
2.	50 Sex pheromone traps/ha	17.33	20.67	24.33	27.36	30.10	31.10	32.17	28.83	25.34	237.23	5.11 (26.36)
3.	60 Sex pheromone traps/ha	18.50	21.33	25.17	28.43	31.23	32.17	33.67	30.33	28.65	249.48	5.24 (27.72)
											S.Em. ±	0.15
											C.D. at 5%	0.45
											C.V.%	9.55

*Figures in parenthesis are original values, while outside values are square root transformed.

Comprehensively, the trap density of 40 pheromone trap/ha resulted in the lowest (17.61 moths/trap/week) number of moth catches, suggesting a potential inefficacy of lesser trap density in controlling fall armyworm infestation.

In conclusion, the study found that a trap density of 60 pheromone trap/ha and 50 pheromone trap/ha were equally effective in capturing the highest number of moths (27.34 moths/trap/week and 25.98 moths/trap/week respectively). In contrast, the use of a trap density of 40 pheromone trap/ha resulted in the lowest number of moth catches (17.61 moths/trap/week), indicating that a lesser trap density may not be as effective in controlling fall armyworms infestation.

Table 6: Effect of trap density for mass trapping on moth catches of S. *frugiperda* in maize during 2020-21 and 2021-22

Sr. No.	Treatments	Moth catches/trap/week		Pooled
		2020-21	2021-22	
1.	40 Sex pheromone traps/ha	4.18 (17.58)	4.21 (20.65)	4.20 (17.61)
2.	50 Sex pheromone traps/ha	5.08 (26.06)	5.11 (26.36)	5.10 (25.98)
3.	60 Sex pheromone traps/ha	5.21 (27.42)	5.24 (27.72)	5.23 (27.34)
S.Em. ±		0.16	0.15	0.10
C.D. at 5%		0.45	0.45	0.31
C.V.%		9.68	9.55	9.62
Y				
S.Em. ±		-	-	0.09
C.D. at 5%		-	-	NS
Y × T				
S.Em. ±		-	-	0.16
C.D. at 5%		-	-	NS

*Figures in parenthesis are original values, while outside values are square root transformed.

Looking at the results of trap density against fall armyworm in the present findings, very scanty information is available for trap densities and fall armyworm in any crop rather than maize. So, an attempt is made to support the present findings with the reviews available for other crops. The present results follow the findings of Hall *et al*. (2005) [7], who reported that the highest numbers of FAW were collected at traps during the months of late April and May. Maximum numbers of moths collected during this peak period of moth activity reached 125 per trap per night in a trap baited with a Scenturion lure. Firake *et al.* (2019) [6] suggested that the number of pheromone traps was 5 per acre for regular monitoring of fall armyworm, *Spodoptera frugiperda* (J. E. Smith). Cork *et al*. (2005) [5] observed that 4 traps per 100 m^2 at crop height would catch an optimal number of male moths of *L. orbonalis* in the brinjal crop. The setting of the pheromone trap @ 75 numbers per hectare gave quite substantial protection from *L. orbonalis* in shoot damage (58.35%), fruit damage (33.73%), and yield (28.67%) in brinjal crop (Chatterjee, 2009) [4]. Suthar *et al.* (2019) [9] revealed that out of a total of five different treatments *i.e.* 30, 40, 50 and 60 traps/ha, the highest (250) catches were recorded in 60 traps/ha followed by 50 and 40 traps/ha which reflected on flowers and green boll damage in *Bt* cotton. The current study's findings were consistent with Suthar *et al*. (2019) [9], as both 60 and 50 pheromone traps/ha were statistically equivalent in capturing the highest number of moths.

Conclusion
The overall result on the standardization of sex pheromone traps against *S. frugiperda* noted that the sex pheromone traps installed @ 60 and 50 traps/ha recorded the lowest (12.01-16.51% and 12.89-17.26%) percent central shoot damage, larval population (2.37-10.27 and 2.49-10.62 larvae/10 plants), cob damage (12.07 and 13.08%) and moth catches (27.34 and 25.98 moths/trap/week), respectively. The study concluded that a trap density of 50 pheromone traps per hectare was optimal for managing fall armyworm infestation in maize.

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