

Original Research Article

The Possible Potential of Pheromone Traps Against Invasive Pest *Spodoptera frugiperda*.

Abstract

The *Spodoptera frugiperda* invasive pest was first reported in Karnataka in the year 2018 and now year 2024 spread all over India. Commonly known as the fall armyworm, it is a destructive pest that affects a wide range of crops, particularly maize (corn), but also sorghum, rice, cotton, and various vegetable crops. Agricultural insect pest management is heavily reliant on synthetic pesticides, which do not accomplish long-term pest population reductions, particularly in areas with warm climates and extended growing seasons whereas continuous long-term pheromone-based control reduces population levels of targeted pest species. The lure for lepidopterans is generally based on the sex pheromone emitted by females. Mating disruption, monitoring, and mass trapping are the major techniques of lepidopteran pest management that use female sex pheromones and they can be utilized alone, as in mating disruption or mass trapping, or conjunction with pesticides, entomopathogens, and sterilant.

The *Spodoptera frugiperda* infestation in maize crops by using different densities of Pheromone traps show the average infestation in such as 61%, 51%, 30%, 10%, and control 91.25. % concerning trap densities 8, 16, 24, 32, and Control.

The 10% infestation results highest in maize crop with pheromone traps was an effective component of integrated pest management and often used in conjunction with other control methods such as biological control agents, cultural practices, and selective pesticide applications to manage fall armyworm populations sustainably and effectively.

Key Word: Pheromone traps, Invasive pest, *Spodoptera frugiperda*, Pest Monitoring, Fall armyworm.

INTRODUCTION

Maize (*Zea mays*) is one of the main and popular cereal crops due to its high value as stable food as well as its stover demand for animal feed and fuel and even for construction

purposes (Abebe and Feyisa, 2017). Maize (*Zea mays* L.) is the third most-produced cereal in India, both in terms of area and production, registering the maximum growth rate among food crops (Rakshit and Chikkappa 2018). Over 140 insect species feed on and cause varying degrees of damage to maize crops right from sowing until harvest (Reddy and Trivedi, 2008), and fall armyworm (FAW) *Spodoptera frugiperda* (J. E. smith) is currently the major biotic stress factor in maize crop of Asia and Africa.

Fall armyworm (FAW) is native to tropical and subtropical Americas and is known as a sporadic pest in the United States since 1797. A severe outbreak of FAW on corn and millet was documented in 1912. Fall armyworm is native to the Americas and has been known as a pest in the United States since 1797 and early documents on its management are also available (Walton and Luginbill 1916).

Outside America, Fall Army worm was first noticed in Africa in 2016 and it reached as far as Australia by 2022.

The fall armyworm, *Spodoptera frugiperda*, is a lepidopteran pest that feeds in large numbers on the leaves, stems, and reproductive parts of more than 350 plant species, causing major damage to economically important cultivated grasses such as maize, rice, sorghum, sugarcane, and wheat but also other vegetable crops and cotton. Native to the Americas, it has been repeatedly intercepted at quarantine in Europe and was first reported from Africa in 2016 where it caused significant damage to maize crops. In 2018, *Spodoptera frugiperda* was first reported from the Indian subcontinent (Ganiger et al., 2018; Sharanabasappa Kalleshwaraswamy et al., 2018).

Long an important pest of agriculture in its native New World range, the fall armyworm (FAW) *Spodoptera frugiperda* was first reported in West Africa in early 2016, followed by confirmation across central and sub-Saharan Africa between 2017/2018, Middle East India (2018) and surrounding nations such as Thailand followed by Southern China in early January 2019. Across the native and invasive ranges, FAW individuals have been classified into rice- or corn-preferred strains, either based on the partial mtCOI gene or through the TPI partial gene from the z-chromosome. (Wee et al. 2022)

Agricultural insect pest management is heavily reliant on synthetic pesticides, which do not accomplish long-term pest population reductions, particularly in areas with warm climates and extended growing seasons (Witzgall et al., 2010), whereas continuous long-term pheromone-based control reduces population levels of targeted pest species (Weddle et al., 2009).

This is due to their species-specificity and nontoxicity to nontarget organisms (beneficial organisms), as well as pheromone potency at low population densities (Witzgall *et al.*, 2010). Pheromones aid in pest control techniques by altering insect behavior, and mainly by capturing the adult pest stages to reduce pest populations (Ahmad and Kamarudin, 2011).

The lure for lepidopterans is generally based on the sex pheromone emitted by females (Cork, 2016). Mating disruption, monitoring, and mass trapping are the major techniques of lepidopteran pest management that use female sex pheromones (Silverstein, 1981), and they can be utilized alone, as in mating disruption or mass trapping, or conjunction with pesticides, entomopathogens, and sterilants (El-Sayed *et al.*, 2006).

In this study, we compared the performance of a Pheromone trap density against *Spodoptera frugiperda*. In addition, the efficiency of pheromone trap density that showed the highest captures was evaluated to find trap alternatives for catching *Spodoptera frugiperda* males in corn crops. We assumed that at least one of the densities of the trap number evaluated would have a better performance and efficiency than the number of pheromone traps in catching *Spodoptera frugiperda* males in maize crops in Nashik District Maharashtra India.

MATERIALS AND METHODOLOGY

- **1. Study Area:** - The study was conducted at the four different maize crop agricultural fields in the Vinchur Gavali and Ozar villages of Nashik districts. They were selected to conduct the study in farmer's cropland. The temperature and humidity in Nashik district were 28.5 and 83.3. and suitable to carry out the experimental study.

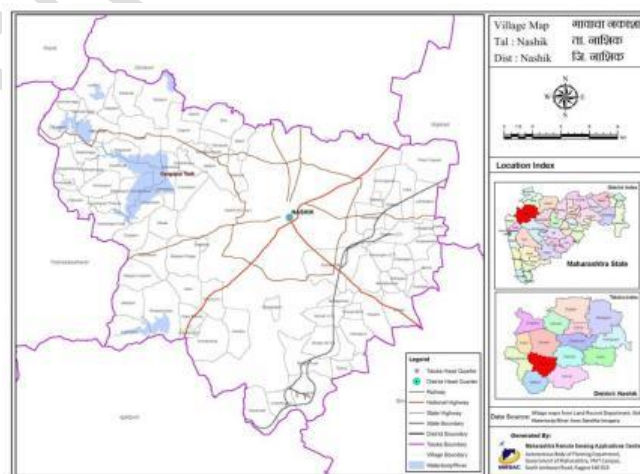


Figure 1. a. Map of Study area Nashik District.

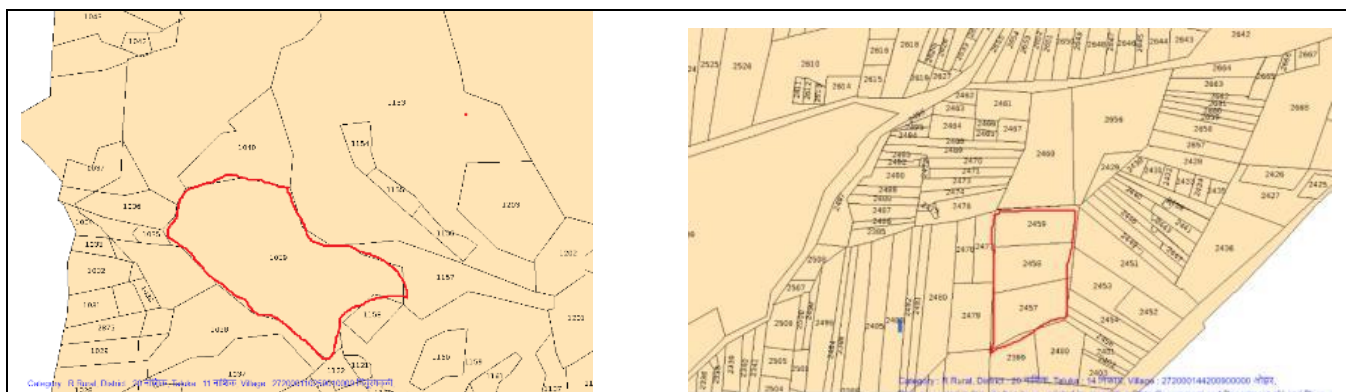


Figure 1.b) Map of study area Vinchur Gavali 1.c) Map of study area Ozar, Village of Nashik district.

2. SEX Pheromone lure of *Spodoptera frugiperda*.

The sex pheromone was lured in this experiment to target the adult male moths. All traps in seasons were baited with the sex pheromone optimized by (Cruz-Esteban et al.,2020) with a red rubber dispenser.

This lure is containing a 4-component such as: -

1. (Z)-9-tetradecen- 1-ol acetate, (Z9-14Ac)
2. (Z)-7-dodecen1-ol acetate, (Z7-12Ac)
3. (Z)-9-dodecan-1-ol acetate, (Z9-12Ac) and
4. (Z)-11-hexadecen-1-ol acetate, (Z11-16Ac).

However, several biological factors, including insect size, flight ability, female population density, and host plant habitat (Knight and Croft 1987; Kondo et al. 1993; Williams and Jonusas 2019); as well as environmental factors, such as rainfall, relative humidity, temperature, and wind speed and direction (Pitcairn et al. 1990; Delisle et al. 1998), among others, can affect a trap's efficiency in catching insects, rendering it necessary to carry out rigorous evaluations in the field (Malo et al. 2018; Whitfield et al.2019).

3. The universal funnel traps.

Universal funnel traps consist of a cap, cage, funnel, Pheromone Lure Dispenser, and Plastic bag.

Source: FAO Guidance Note 3 - Fall armyworm trapping (FAO, 2018).

4. Identifying maize growth stages.

The stages of maize growth were divided into vegetative (V), reproductive stages (R), and harvest stage (H). The stages were then simplified to; a) VE – V7 stages (early Whorl) b) V8 – V15 stages (Late Whorl), c) R1 - R3 stages (Reproductive), and d) H - harvest stage. Notably, rather than counting the total number of leaves, the V stages (vegetative stage) of the maize were determined by the proportion of leaves with a leaf collar.

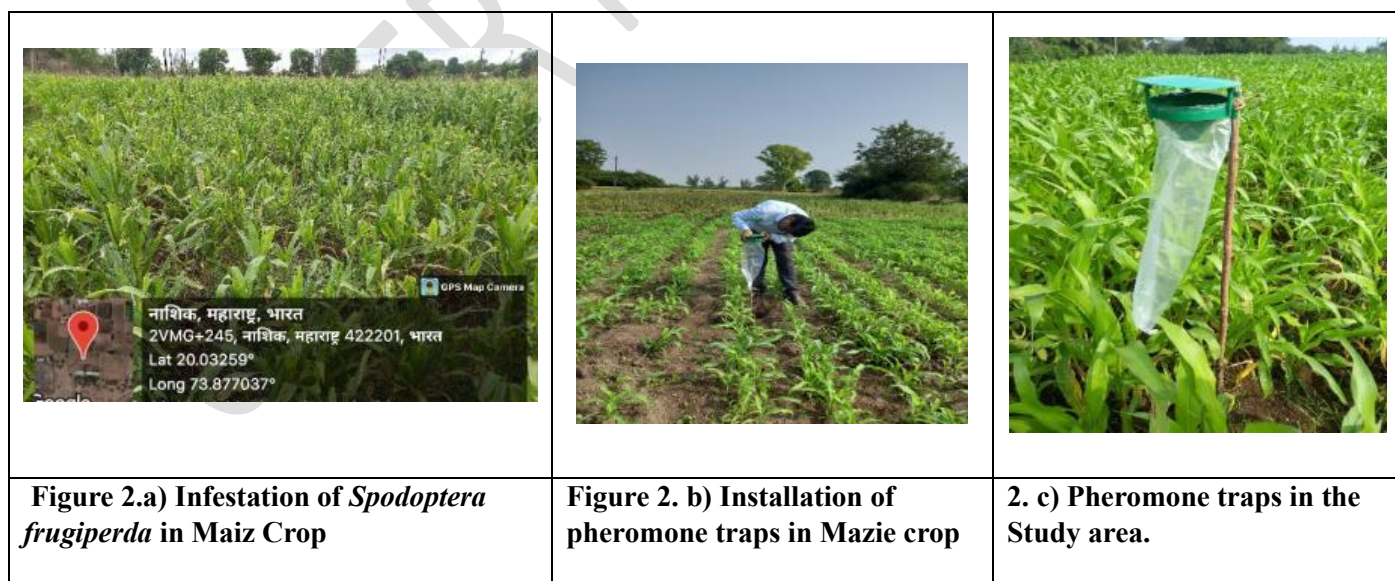
Maize crop growth stage was sampled at different maize phenological stages as shown on

Table 1: Maize phenological stages used for installation of pheromone traps.

Growth Stage	Description
VE	Emergence
V2 – V4	2-4 leaves fully emerged
V5 – V7	5-7 leaves fully emerged.
V8 – V11	8-11 leaves fully emerged
V12 – V15	12-15 leaves
R1 – R2	Tasseling/silking fully formed.
R3	Maturity (drying)
H	Harvest

5. Sex Pheromone Trap setup for *Spodoptera frugiperda*.

Eighty universal funnel traps were used for this study. The four treatments of the experimental field involved the application of the sex pheromone traps randomly placed at 4 different densities of 8, 16, 24, and 32 traps/ha. The life of the lure is 60 days and after days lure is changed. Study sites from 1-4 were visited once in week to check and count the captured male adults of fall armyworm.



6. Statistical analysis

1. The proportion of maize plants that exhibited Fall Army Worm signs of damage as well as the presence /absence of eggs and larvae was determined using equation 1.

$$\text{FAW infestation} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100 \quad (1)$$

The numbers of FAW male moths captured per trap density was converted to percentages of the total number of moths captured within each trap density based on the simplified maize growth stage.

2. Statistical analysis using Microsoft Excel-2021 can be performed using various built-in functions and tools to calculate and plot such as average, percentage, Correlation & graph F tests two sample Variance.

OBSERVATION

After the pheromone traps were setup into maize crop field four treatments of trap densities such as 8, 16, 24, and 32 traps were used against the adult of *Spodoptera frugiperda*. In this experiment observed that the maximum number of males was trapped in mass trapping of males of *Spodoptera frugiperda*. In Figure 3.a) A male adult of *Spodoptera frugiperda* was trapped after setup of a pheromone trap in maize crop 3 – hrs. of installation of traps. Fall armyworm infestation rate by phenology maize growth and trap density.

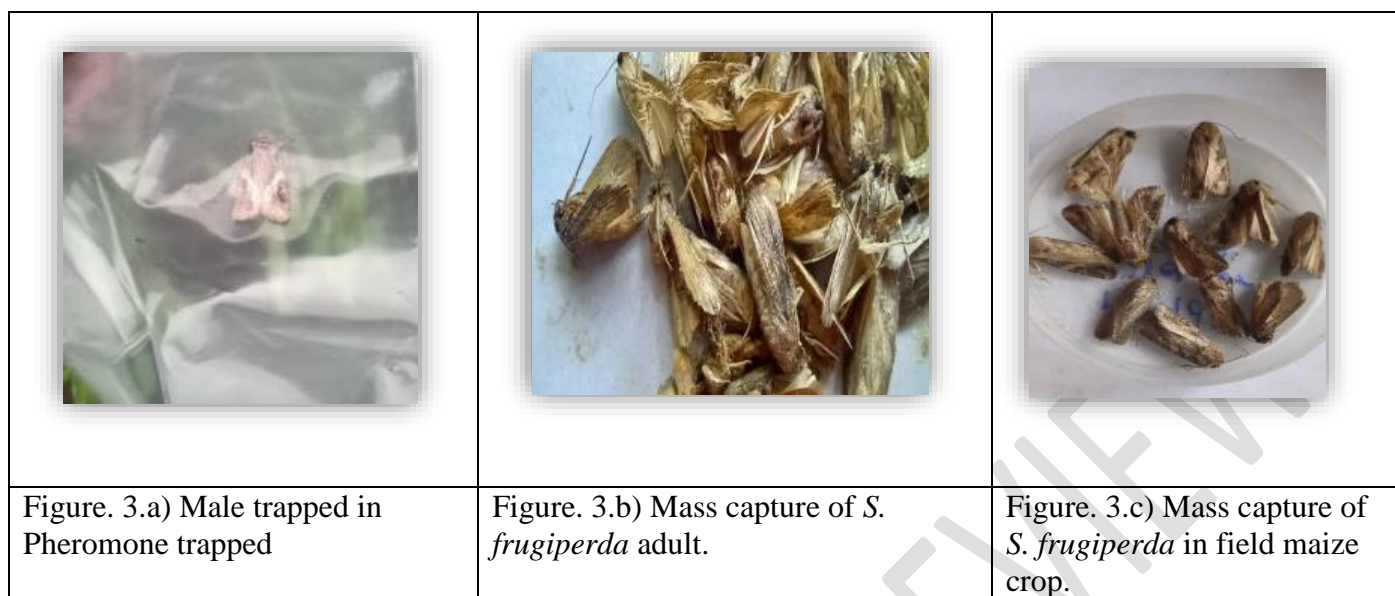


Table 2. Phenology maize growth and trap density and *Spodoptera frugiperda* Adult male Capture.

Stage of Maize crop	<i>Spodoptera frugiperda</i> Adult male Capture				
	8 traps/ha	16 traps/ha	24 traps/ha	32 traps/ha	Control
Emergence	5 - 6	6-7	8-10	12-16	0
2-4 leaves	8 -9	10-12	11-16	14-20	0
5-7 leaves	10-13	14-17	16-20	22-27	0
8-11 leaves	18-20	20-22	22-25	30-40	0
12-15 leaves	26-30	32-40	60-85	80-95	0
Tasseling	16-18	22-30	40-65	60-75	0
Maturity	12-16	16-24	20-30	25-45	0
Harvest	1-2	3-4	4-5	6-10	0
Total	80- 114	123 -156	181-256	249-328	0

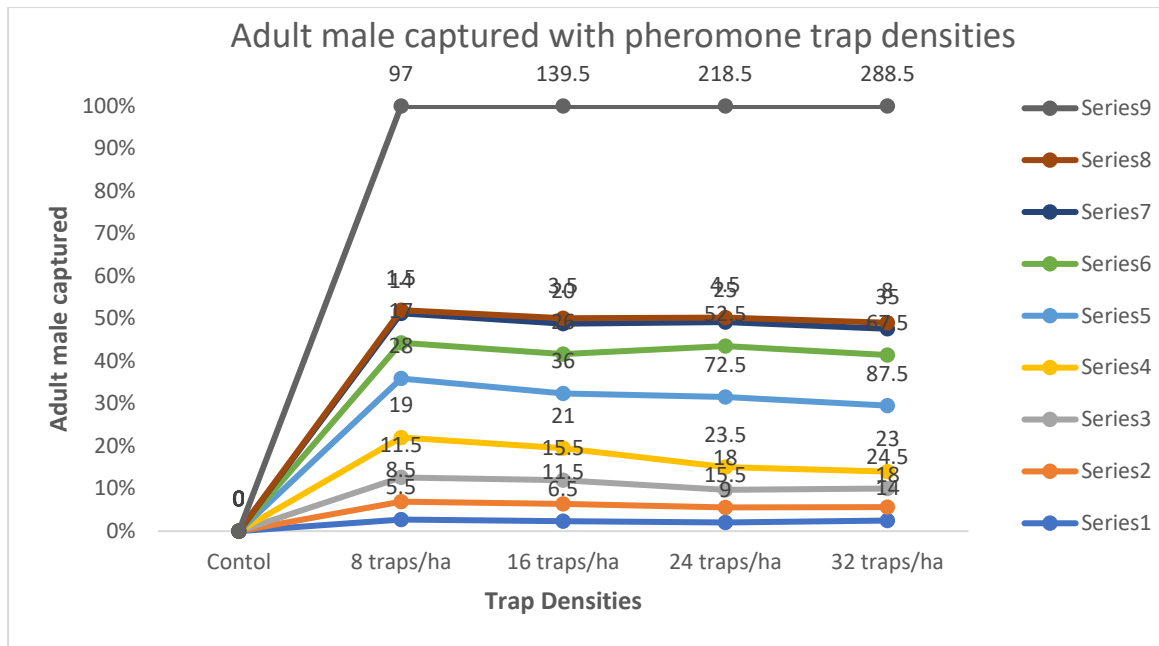
Result

1. Fall armyworm Adult captured compares with the phenological growth stage of maize and Pheromone trap densities.

The fall army worm adult captures were highest at 12-15 leave and low at the emergence and harvest stage to trap densities, 12, 16, 24, and 32 such as 28, 34, 72, and 87. The lowest was 1.5-5.5, 3.5-6.5, 4.5 -9.8-14 captured adult male moth of *Spodoptera frugiperda*.

Table 3. Average of Adult males captured with pheromone traps densities with maize crop growth stages.

Stage of Maize crop	Spodoptera frugiperda Adult male Capture				
	Control	8 traps/ha	16 traps/ha	24 traps/ha	32 traps/ha
Emergence	0	5.5	6.5	9	14
2-4 leaves	0	8.5	11.5	15.5	18
5-7 leaves	0	11.5	15.5	18	24.5
8-11 leaves	0	19	21	23.5	23
12-15 leaves	0	28	36	72.5	87.5
Tasselling	0	17	26	52.5	67.5
Maturity	0	14	20	25	35
Harvest	0	1.5	3.5	4.5	8
Total	0	97	139.5	218.5	288.5



Graph 1. Adult males captured with pheromone trap densities.

In all the experimental plots, the 32 traps/ha had the highest captured rates in all the phenological stages except the emergence & harvest stage, while the control plot recorded the lowest (zero) captured in all the phenological stages.

2. Fall armyworm infestation levels by trap density and simplified maize growth stages

Fall armyworm infestation levels were highest in the 8traps/ha plots (61%), while the control plot had the lowest levels of FAW infestations (91.25%). The 16 traps/ha plots had the second-highest levels of FAW symptoms on maize plants (51.5%). The proportion of maizeplants with FAW infestation symptoms in the 8 traps/ha plots was 61 %, while 10.75% of the maize plants in the 32 traps/ha were infested by FAW.

For the 8,16, 24, and 32 traps/ha plots, the late whorl stage recorded lower infestation levels compared to the control simplified stages, however for the 8 traps/ha plot and control plot, it was the early whorl stage. The harvest stage of all the experimental plots showed the highest levels of infection.

Table 4. Trap densities (traps/ha) Fall armyworm infestation (%) concerning Maize crop growth stages.

Maize growth stages	Description	Trap densities (traps/ha) Fall armyworm infestation (%)				
		8 traps/ha	16 traps/ha	24 traps/ha	32 traps/ha	Control
Early whorl (VE – V7)	Emergence, 2-4, & 5-7leaves	58 %	48%	27%	14 %	89 %
Late whorl (V8 – V15)	8-11 & 12-15 leaves	62 %	56 %	33 %	8 %	90 %
Reproductive (R1 - R3)	Tasseling & maturity	64 %	52 %	35 %	9 %	96 %

Harvest	Harvest	60 %	50 %	25 %	12 %	90 %
Average infestation		61 %	51.5 %	30 %	10.75 %	91.2%

Table 5. Pheromone traps densities and captures males of FAW and Average infestation of Mazie crop.

Pheromone Trap density	control	8 traps/ha	16 traps/ha	24 traps/ha	32 traps/ha
Captured male of FAW	0	97	139	218	288
% of Infestation	91.25 %	61 %	51.5 %	30 %	10.75 %

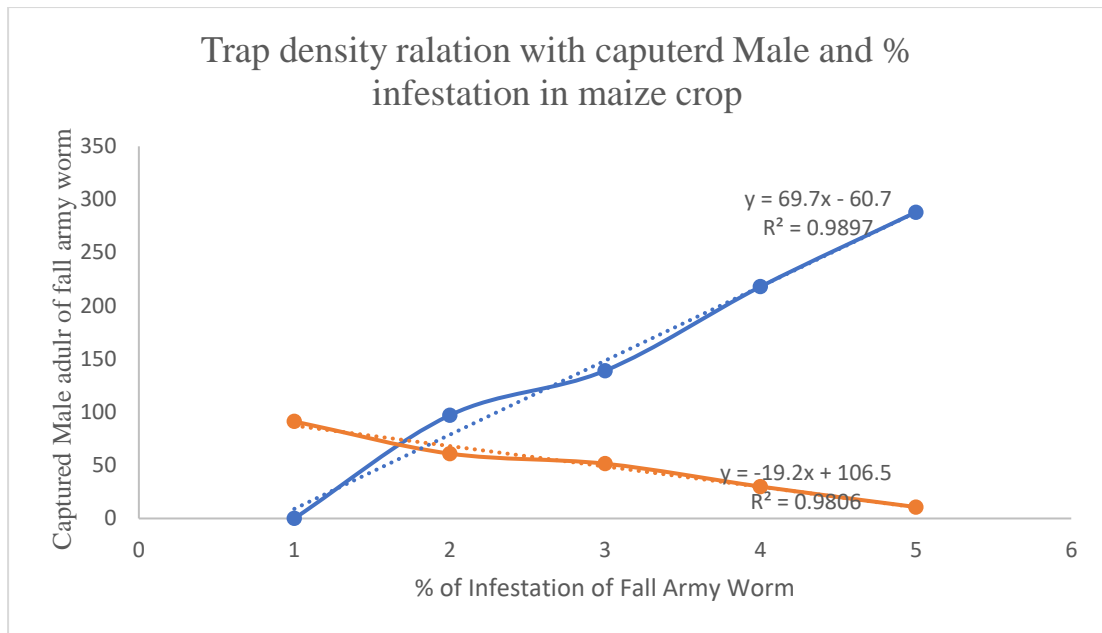
A comparison of the impact of five trap densities on FAW infestation (mean & variance) is shown in Table 4. The F-test Two Sample for Variance indicated that there was a significant difference in FAW infestations between the trap densities ($F = 13.05$, $p < 0.01446$) and F critical one tail 6.3882. FAW infestation levels were highest in 0 and 8 trap/ha density plots, and lowest in the control plot. The 24 and 32 traps/ha density plots had distinct FAW infestation levels.

Table 6. F-Test Two-Sample for Variances

<i>Statistical parameters</i>	<i>Capture male of FAW</i>	<i>% of Infestation</i>
Mean	148.4	48.9
Variance	12271.3	939.83125
Observations	5	5
df	4	4
F	13.05691846	
P(F<=f) one-tail	0.014462375	
F Critical one-tail	6.388232909	

3. FAW infestation levels and FAW adult male moths captured per trap densities

The graphical presentation of Fall Army Worm infestation and the numbers of Fall Army Worm adult male moths captured by the 8, 16, 24, and 32 trap/ha density plots is illustrated in Graph .2. Overall, the Fall Army Worm infestation rate decreased as the number of Fall Army Worm adult male moths captured per trap densities. No point of intersection was observed between the number of Fall Army Worm adult male moths captured and the number of plants with Fall Army Worm damage symptoms in the four trap densities. From this graphical and statical observation, we conclude that their a positive co-co-correlation between trap density and captured male of Fall Army Worm and a negative co-relation between captured mole of Fall Army Worm and Infestation of Maize crop.



Graph 2. Pheromone Trap density with captured Males and % infestation in maize crop.

DISCUSSION

The results of this study demonstrated that mass trapping using synthetic sex pheromone was ineffective in suppressing Fall Army Worm populations or reducing maize plant infestation symptoms. These results lend support to the assertion that mass trapping should be used as a monitoring and detection tool, together with scouting the fields to assist in determining when pesticides should be used in a manner that is both environmentally and commercially sustainable. Developing mass trapping as an integrated pest management (IPM) package may offer an economic incentive for farmers to adopt this technology.

The *Spodoptera frugiperda* infestation in maize crops by using different densities of Pheromone traps show the average infestation in such as 61%, 51%, 30%, 10%, and control 91.25. % concerning trap densities 8, 16, 24, 32, and Control. The 10% infestation results highest in maize crop with pheromone traps was an effective component of integrated pest management and often used in conjunction with other control methods such as biological control agents, cultural practices, and selective pesticide applications to manage fall armyworm populations sustainably and effectively.

The Fall Army Worm variant in Sub-Saharan Africa (SSA) mainly originated in the USA (Goergen et al., 2016). Nagoshi et al. (2018) reported a fall armyworm variant of the R-biotype that is unique to Africa, having been found in Togo, Kenya, and the Democratic Republic of the Congo (Nagoshi et al., 2018). There is a possibility of genetic variation leading to the Scentry - L105A synthetic lure that was effective in capturing Fall Army Worm adult male moths in the USA (Meagher et al., 2013) was not effective for this population. Genetic explanations for Fall Army Worm trap capture inconsistencies include population isolation caused by the high migratory ability of the FAW leading to differences (lack of homogeneity) with the native population (Andrade et al., 2000), gene drifting that occurs during the expansion of the distribution range from the original habitat (Wakamura et al., 2021) and a significant change in moth pheromone blend when previously unexpressed genes controlling pheromone components become expressed in some females in a population (Roelofs et al., 2002).

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