



Population Dynamics and Integrated Pest Management of the Fall Armyworm (FAW) *Spodoptera frugiperda* (JE Smith; Lepidoptera: Noctuidae) on Maize in Rivers State, Nigeria

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Abstract

Population dynamics and integrated pest management investigations of the fall armyworm (FAW) on maize conducted at the Faculty of Agriculture Teaching and Research farm, University of Port Harcourt, Rivers State Nigeria, made notable findings for the effective management of this notorious pest. This study involved 3 maize varieties namely Bende White (a local white variety), Oka (a local yellow maize) and Oba Super 98 (an improved white variety); two cropping patterns i.e. sole maize, and maize-yam intercrop; pheromonal trapping and pesticide (Kartodim 315EC). Pesticide applications were at 3 different phases (2WAP, 4WAP, and zero application as control, respectively). The pheromonal trap catches aided tracking of the pest's population dynamics over the study duration showing the arrival times, build-up, peaks and falls. There was no significant difference in FAW populations between sole and intercrop plots; although 3 population peaks were found in maize-yam intercrop (at day 5, 7 and 17) against 2 peaks (day 4 and 15) in the sole maize. Oka variety showed significantly higher mean maize ear damages from FAW attacks (6.36 ± 2.45), compared to Bende (5.71 ± 2.87) and Oba 98 (4.77 ± 2.64) ($p < 0.05$), implying that Oba 98 may be the best maize variety for cultivation in this locality.

Keywords: Population dynamics; Fall armyworm (FAW), *Spodoptera frugiperda*, cropping pattern, pheromone trap

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INTRODUCTION

Maize is the second most important cereal crop in the world. It significantly contributes to the total production of cereal grains as food, feed, and as a trade (Pingali, 2001). It is the most important staple cereal crop (Pandey, 1998) grown by small farm

holders in sub-Saharan Africa (SSA) (Macauley, 2015). Maize has become very popular because it has a higher yield, easier to process, digests relatively faster and is cheaper to grow compared to other cereals (Jaliya *et al.*, 2008). It forms a large part in the diet of many and a source of raw material for animal feed production industries (Abdulraham and Kolawole, 2006).

Because of its capacity to reduce current food insecurity and combat poverty,

maize is regarded as being of utmost importance in developing countries. According to estimates, 130 million poor farm households, over 900 million poor consumers, and roughly one-third of malnourished children prefer it as a primary food (IITA, 2010). Absence or shortage of maize in sub-Saharan Africa perpetually leads to famine and starvation.

According to projections, maize will overtake other crops as the most widely grown crop by 2025, and by 2050, the demand for it in developing nations will have doubled (IITA, 2010). Although maize is a promising crop that has the potential to end hunger and food insecurity, its production in SSA is significantly impacted by socioeconomic factors such as small parcels of land, a lack of sufficient capital, a labor shortage, and a lack of modern equipment to facilitate farming operations (VIB, 2017) in addition to newly emerging invasive diseases and pest insects (CIMMYT, 2019). The presence of insect pests greatly affect maize production and may lead to total failure in terms of yield and quality (Sanchez *et al.*, 1997). Losses caused by insect pests are a significant obstacle to achieving global food security. Addressing the problem of crop loss due to insect pest damage is vital since it is a critical barrier to meeting the food demands from the world's ever-growing population (Berenbaum, 1995).

Despite aggressive chemical management, insect pests still destroy about 14% of all food productions (Gemenchu *et al.*, 2011). Insect pests are economically important in food production as they are the most likely originators of food crisis (Adedire, 2011) thereby reducing the possibility of food security worldwide. The world population is constantly increasing and so is the demand for food, therefore it is necessary to address the challenges of crop losses due to insect pest damages (Berenbaum, 1995). One of the major pests of

maize is fall armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith); an invasive pest which continues to be a great threat to successful cultivation of the crop in Nigeria.

Fall armyworm (FAW), is a polyphagous and highly migratory pest belonging to the order Lepidoptera (Family: Noctuidae). It survives on over 80 plant species; maize, sorghum, rice and wheat included. FAW is a native of the Americas and has gained recognition as one of the most severe maize pests that harms agriculture globally and costs considerable sums of money (Sarmiento *et al.*, 2002; Pogue, 2002). Sometime in 2016, when it was first noted in central and western Africa, it unexpectedly invaded Africa (Goergen *et al.*, 2016). It poses a threat to food security and spreads swiftly over sub-Saharan Africa (Day *et al.*, 2017; Devi, 2018).

Its wide host range, high rate of reproduction, crave for maize, which is widely grown in Africa, and capacity to move over great distances have all contributed to FAW's fast expansion across Africa from the time of its invasion to the present (Rose *et al.*, 2012). According to estimates, the spread of FAW into Africa will pose a long-term threat to a number of significant crops because it will enhance the diversity of lepidopteran pests that attack cereal crops and have a detrimental effect on the continent's agricultural output and food security (Midega *et al.*, 2018).

Nigeria's maize fields have been the target of fall armyworm invasion that has caused tremendous alarm due to the danger posed to the country's food security. The pest's rapid expansion following its discovery in Nigeria is unmistakable proof that it must be controlled since it poses a threat to nearby nations and consequently, a significant challenge to smallholder farmers. Although farmers have tried to use the insecticides that are available, their efforts have not been very

successful or cost-efficient (Kumela *et al.*, 2018).

Many farmers rely on laborious mechanical control measures (hand crushing the larvae and eggs, inserting sand and ashes in leaf whorls), farmer-to-farmer counseling, and suggestions from extension services (Baudron *et al.*, 2019; Kumela *et al.*, 2019). For women, who make up the majority of human labor in smallholder agricultural systems, these techniques are labor-intensive, time-consuming, and demanding. Extension services and results from research are directing farmers to use integrated pest management (IPM) to manage FAW. The aim is to reduce harm from chemicals to people and the environment, while effectively targeting the pest (Day *et al.*, 2017).

The combination of varietal resistance, cropping pattern, pesticide and pheromone traps is an integrated pest management strategy; a system approach to reduce pest damage to tolerable levels through diverse techniques. This study was therefore intended to evaluate the efficacy of intercropping maize and yam in combating fall armyworm; succinctly aimed at determining the effect of integrated management technique as a possible management strategy against the menace of *Spodoptera frugiperda* in maize-yam intercrop. This management system was adopted because it is eco-friendly and helps in sustainable production.

MATERIALS AND METHODS

Geographical description of study area

The study was carried out at the Faculty of Agriculture Teaching and Research farm, University of Port Harcourt, Rivers State in the tropical rain forest zone of Southern Nigeria within latitude 4° 45' N and longitude 6° 50' E. The location is elevated approximately 20m above sea level with variable annual rainfall between 2000mm to

2680mm. The peak months for the rainfall are June and September, basically creating a bimodal trend. The long rainy season ran from April to August while the short rainy season ran from late August to October. With isolated rainfalls here and there, the dry season lasted from November to March. The mean minimum and maximum monthly temperatures, respectively, were from 20°C to 23°C and 28°C to 33°C (Eludoyin *et al.*, 2015).

Experimental materials

Three maize varieties were used for this experiment; local white maize (Bende-White), local yellow maize (Oka) and Oba Super 98 (an improved variety obtained from Agricultural Development Program (ADP), Port Harcourt). The white and yellow maize varieties were bought from Aluu Boundary market in Port Harcourt.

Land preparation and experimental design

A well leveled flat, dry land was used for this research. The land was cleared by hand and debris was handpicked. Planting area was mapped out and measured using a measuring tape, twine and pegs. The land was divided into 12 main plots measuring 102 m² each and spaced out on a total land area of 1877 m². The study was conducted using a factorial design where cropping pattern was the main factor, and maize variety a sub plot factor; and pheromone with chemical application as a sub-sub plot factor. Each treatment plot was replicated three times and laid out in a split-split plot design. Two cropping systems were adopted for the experiment; sole crop and intercrop. Among the 12 plots were 6 plots containing maize alone (sole crop) and 6 plots containing maize and yam (intercrop). The intercropped plots had two yam cultivars growing prior to when maize seeds were planted. The yam cultivars; Ada Onitsha (with purple vines) and Ogoja

(with green vines) were grown with a planting distance of 1m by 1m between rows and stands. On each plot, the three maize varieties were planted following a sequential pattern at a planting distance of 0.25m by 0.75m. Planting depth was 2-3cm with three seeds per hole.

Agronomic practices

The plants were checked 3 days after planting (DAP) and the seeds which failed to germinate were supplied. Thinning was carried out two weeks after to make it one plant per hole. NPK fertilizer was applied using the ring method at a total of 60 kgN and 60 kgP₂O₅ha⁻¹. The farm was kept clean by regular weeding and the crops were rain fed.

Pesticide Application

Two weeks after planting, a pesticide (Kartodim 315EC) was applied. This pesticide is an emulsifiable concentration containing Lambda Cyhalothrin 15g/l and dimethoate 300g/l and was applied in three different phases; control (no application), 2weeks after planting (WAP) and 4WAP.

Mounting of Pheromone Traps

A synthetic pheromone was used and the active ingredient was 97% (Z)-9-tetradecenyl acetate (z-9-14: Ac), 2% (Z)-7-dodecenyl acetate (Z7-12: Ac), and 1% (Z)-9-dodecenyl acetate (Z9-12: Ac), prepared by Russell IPM with batch number 69/5094, labeled and marketed with the trade name *Spodoptera frugiperda* PH-869-1PR. A white triangular Delta trap a product of Koppert Biological Systems Company based in USA was used and had its base with a sticky pad made of thick paper material. While setting, the sticky surface was placed upward. The pheromone was placed in the middle of the sticky base surface before mounting. Six traps were fixed on bamboo sticks at a height of

1.5m in the sole and intercropped plots. Pheromone was mounted 14 DAP.

Trapped Insect Collections

Data collection on natural populations of the fall army worm (FAW) trapped by the pheromone commenced from the 15th day to the 35th day after planting. Collections were made by hand picking the insects into specimen bottles. All collections were made during the early hours of the morning (6/7.00am). Number of Insect collected was recorded.

Weights of harvested Cobs

Fresh weights of maize ears and cobs were taken immediately after harvest i.e. at commencement of yellowing of maize varieties. Cobs were allowed to dry for 25days under open shade, and then dry weights of the husks, and empty cobs were taken. All fresh and dry weights of ears, cobs, husks etc., were recorded by use of the Electronic Kitchen scale (STARFRIT model 93016)

Stem Harvesting: Exit Holes and Ear damage

Numbers of FAW exit holes found on the ear of each maize variety (i.e. ear damage) in the two cropping systems were recorded. Also, number of tunnels and tunnel lengths were recorded for both cropping patterns of the maize varieties using thread and meter rule.

Statistical Analysis

Data collected on fresh ear weight, fresh cob weight, dry cob weight, dry husk weight, ear damage, number of tunnels and length of tunnels were subjected to analysis of variance (ANOVA) using R software version 4.1.1 base package and Agricolae package (version 1.3-5). New Duncan's multiple range test (NDMRT) was used to separate

significant means from non-significant means at $\alpha = 0.05$.

RESULTS

Population Analysis of Fall Army Worm

There was no significant difference ($p > 0.05$) between fall armyworm population in sole cropped maize and maize-yam intercrop. It was observed in Figure 1 that fall army worm population had three peaks in maize-yam intercrop (Day 5, Day 9 and Day 17) and two peaks in sole cropped maize (Day 4 and

Day 15). Average count was highest in intercropped system with no chemical application (0.40) followed by sole and intercropped system with chemical application two and four weeks having 0.20 average each. Management system with least fall armyworm count average were sole cropping system with chemical application two weeks after planting and sole cropping with no chemical application averaging 0.14 and 0.17 respectively (Table 1).

Table 1: Mean Effect of Chemicals and Cropping System on Fall Army Worm Count in Maize

Chemical	Sole cropping	Intercropping
SP0	0.17±0.45	0.40±0.74
SP2	0.14±0.36	0.23±0.49
SP4	0.20±0.41	0.20±0.47

SP0 represents control (No chemical application); SP2 represents chemical application at 2 weeks after planting; SP4 represents chemical application at 2 and 4 weeks after planting

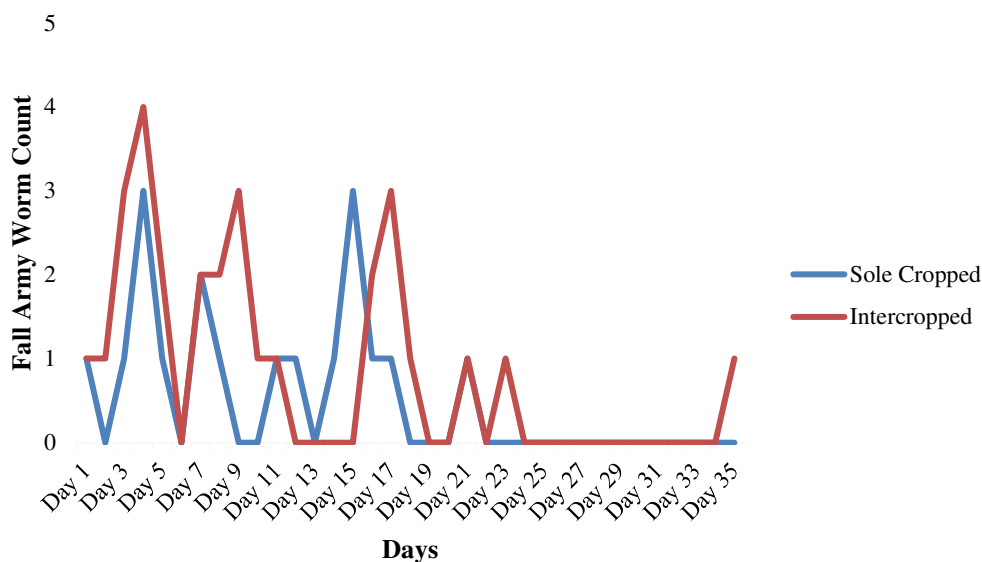


Figure 1: Comparison of Fall Army Worm Population in sole and intercropped maize

Table 2 shows the means of ear damage of maize under the variety main effect, influence of pheromone ~ cropping system ~ chemical application interaction level and full factor (Variety, Pheromone trap, cropping system and chemical application) effect. Among the three varieties used, Oka variety experienced the highest ear damage averaging 6.34 which was significantly highest followed by Bende (5.71) and Oba 98 (4.77). At the pheromone, cropping system and chemical application interaction level, no significant difference in ear damage existed. However, maize intercropped with no chemical application but pheromone trap used had the highest ear damage of 6.36.

This was followed by intercropping ~ no pheromone trap ~ chemical application two weeks after planting (5.80), sole cropping ~ no pheromone trap ~ chemical application 2 and 4 weeks (5.67) and sole crop ~ no pheromone trap ~ no chemical application (5.62) while least three combination at this level were intercrop ~ pheromone trap ~ chemical application two weeks after planting (5.07), intercrop ~ no pheromone trap ~ no chemical application (5.13) and intercrop ~ pheromone trap ~ chemical application two and four weeks after planting (5.18) (Table 2). Also, from the Table, the four factors effect showed highest average ear damage of maize in Bende variety ~ intercrop ~ pheromone trap ~ no chemical application (7.40) and least in Oba 98 variety ~ intercrop ~ pheromone trap ~ chemical application 2 weeks after planting (4.13) although this difference is not significant.

Influence of Variety, Pheromone Trap, Cropping System and Chemical Use on Ear Damage Yield of Maize

Main effects of pheromone trapping system, variety ~ chemical application and

variety ~ pheromone trap ~ chemical application on ear damage are presented in Tables 3-8 below. Table 3 showed that maize cultivated with no pheromone trap used had ear damage averaging 5.67 which was slightly higher than mean damage values of maize grown under pheromone trap system (5.55). This difference in mean values between pheromone trap and no pheromone trap was not significant. Similarly, no significant difference was observed in the levels of variety ~ chemical application interaction but it is noted that Oka variety with no chemical application had the highest ear damage of 6.58 followed by Oka variety with chemical application two weeks after planting (6.27), Oka variety with chemical application two and four weeks after planting (6.18) while Oba 98 ~ chemical application two weeks after planting, Oba 98 variety ~ chemical application two and four weeks after planting and Oba 98 variety ~ no chemical application had the least damage of 4.53, 4.73 and 5.05 respectively.

At variety ~ pheromone trap system ~ chemical application interaction, no significant difference in their levels combination is observed (Table 3). Oka maize variety cultivated with pheromone trap and no chemical application had the highest ear damage of 6.73 followed by Bende maize variety cultivated with pheromone trap and no chemical application (6.60) and Oka with no pheromone trap and chemical applied two and four weeks after planting (6.53) while least ear damage at this interaction order was observed among Oba 98 variety with pheromone trap and chemical applied two weeks after planting (4.47), Oba 98 variety with no pheromone trap and no chemical applied (4.53) and Oba variety with no pheromone trap and chemical application two weeks after planting (4.60) (Table 3)

Table 2: Influence of Variety, Pheromone Trap System, Cropping System and Chemical Application on Ear Damage Yield of Maize

Variety	Sole Cropping						Intercropping						Mean±SD
	Pheromone Trap			No Pheromone Trap			Pheromone Trap			No Pheromone Trap			
	SP0	SP2	SP4	SP0	SP2	SP4	SP0	SP2	SP4	SP0	SP2	SP4	
BENDE	5.80±2.46	5.73±2.76	5.47±2.92	6.00±2.95	5.93±2.81	5.60±3.22	7.40±3.18	5.07±1.87	5.47±2.88	4.33±1.68	6.33±4.45	5.40±2.32	5.71±2.87^b
OKA	6.67±2.97	6.33±2.50	6.13±2.23	6.27±2.99	6.27±2.09	6.67±2.02	6.80±2.81	6.00±2.45	5.53±3.18	6.60±2.10	6.47±2.26	6.40±2.06	6.34±2.45^a
OBA 98	6.27±2.96	4.80±2.08	5.07±3.17	4.60±2.26	4.60±3.00	4.73±3.10	4.87±3.23	4.13±2.39	4.53±2.90	4.47±2.20	4.60±2.32	4.60±2.06	4.77±2.64^c
Mean±SD	6.24±2.76	5.62±2.49	5.56±2.78	5.62±2.79	5.60±2.70	5.67±2.88	6.36±3.20	5.07±2.33	5.18±2.96	5.13±2.22	5.80±3.22	5.47±2.23	

SP0 represents control (No chemical application); SP2 represents chemical application at 2 weeks after planting; SP4 represents chemical application at 2 and 4 weeks after planting

Table 3: Influence of Variety, Pheromone Trap System, Cropping System and Chemical Application on Ear Damage Yield of Maize

Trap	SP0			SP2			SP4			Mean±SD
	Bende	Oka	Oba 98	Bende	Oka	Oba 98	Bende	Oka	Oba 98	
Pheromone Trap	6.60±2.91	6.73±2.84	5.57±3.13	5.40±2.34	6.17±2.44	4.47±2.22	5.47±2.85	5.83±2.71	4.80±3.00	5.55±2.68
No Pheromone Trap	5.17±2.51	6.43±2.54	4.53±2.19	6.13±3.66	6.37±2.14	4.60±2.63	5.50±2.76	6.53±2.01	4.67±2.59	5.67±2.78
Mean±SD	5.88±2.79	6.58±2.68	5.05±2.73	5.77±3.07	6.27±2.28	4.53±2.42	5.48±2.78	6.18±2.40	4.73±2.78	

SP0 represents control (No chemical application); SP2 represents chemical application at 2 weeks after planting; SP4 represents chemical application at 2 and 4 weeks after planting

Table 4: Influence of Variety, Pheromone Trap System, Cropping System and Chemical Application on Ear Damage Yield of Maize

Chemical	Sole cropping			Intercropping			Mean±SD
	Bende	Oka	Oba 98	Bende	Oka	Oba 98	
SP0	5.90±2.67	6.47±2.93	5.43±2.73	5.87±2.94	6.70±2.44	4.67±2.72	5.84±2.79
SP2	5.83±2.74	6.30±2.26	4.70±2.53	5.70±3.42	6.23±2.33	4.37±2.33	5.52±2.70
SP4	5.53±3.03	6.40±2.11	4.90±3.09	5.43±2.57	5.97±2.67	4.57±2.47	5.47±2.71
Mean±SD	5.76±2.79	6.39±2.43	5.01±2.78	5.67±2.97	6.30±2.47	4.53±2.49	

SP0 represents control (No chemical application); SP2 represents chemical application at 2 weeks after planting; SP4 represents chemical application at 2 and 4 weeks after planting

Table 4 below shows the mean effect of fall army worm management systems and maize varieties on ear damage at chemical application main effect, variety ~ cropping system, and variety ~ cropping system ~ chemical application interactions. Factorial analysis showed no significant effect in the various levels of these main and interaction level. No chemical application had the highest ear damage of 5.84 while chemical application two weeks after planting and chemical application two and four weeks after planting had 5.52 and 5.47 respectively. At variety ~ cropping system interaction, maximum ear damage is seen in Oka variety ~ sole cropping (6.39) followed by Oka ~ intercropped (6.30), Bende ~ sole cropped (5.76), Bende ~ intercropped (5.67), Oba 98 ~ sole cropped (5.01) and least in Oba 98 ~ intercropped (4.53).

Averaging 6.70 in ear damage, intercropped Oka variety with no chemical application had the most ear damage index among other factor levels combination at variety ~ cropping system ~ chemical application interaction order (Table 4). This was followed by Oka ~ sole cropped ~ no chemical application (6.47), Oka ~ sole cropped ~ chemical application two and four weeks after planting (6.40) and Oka ~ sole cropped ~ chemical application two weeks after planting (6.30). Least three combinations were Oba 98 ~ intercropped ~ chemical application two weeks after planting (4.37), Oba 98 ~ intercropped ~ chemical application two and four weeks after planting (4.57) and Oba 98 ~

intercropped ~ no chemical application (4.67) (Table 4).

From Table 5 below, mean values of cropping system main effect, variety ~ pheromone trapping and variety ~ pheromone ~ cropping system is presented. The Table shows that there is no significant difference in cropping system main effect, variety ~ pheromone trapping and variety ~ pheromone ~ cropping system interactions on ear damage of maize. The result indicated that average ear damage of maize was slightly higher in sole cropping system (5.72) than intercropped system (5.50). Among the various combination of variety ~ pheromone trap interactions, Oka with no pheromone trap had the highest average ear damage of 6.44 followed by Oka with pheromone trap (6.24), Bende ~ pheromone trap (5.82) and least three in Oba 98 with no pheromone trap (4.60), Oba with pheromone trap (4.94) and Bende with no pheromone trap (5.60).

Also, as shown in Table 5, Oka intercropped with no pheromone trap had the highest ear damage of 6.49 amongst all other treatment combinations of variety ~ cropping system ~ pheromone trapping system order of interaction. Next to this is Oka solely cropped with no pheromone trap (6.40) and Oka sole cropped with pheromone trap (6.38). Least among these were Oba 98 intercropped with pheromone trap (4.51), Oba 98 intercropped with no pheromone trap (4.56) and Oba 98 sole cropped with no pheromone trap (4.64) (Table 5).

Table 5: Influence of Variety, Pheromone Trap System, Cropping System and Chemical Application on Ear Damage Yield of Maize

Cropping system	Pheromone Trap			No Pheromone Trap			Mean±SD
	Bende	Oka	Oba 98	Bende	Oka	Oba 98	
Sole cropping	5.67±2.66	6.38±2.53	5.38±2.79	5.84±2.94	6.40±2.36	4.64±2.75	5.72±2.72
Inter cropping	5.98±2.83	6.11±2.81	4.51±2.81	5.36±3.10	6.49±2.10	4.56±2.15	5.50±2.74
Mean±SD	5.82±2.74	6.24±2.67	4.94±2.82	5.60±3.01	6.44±2.22	4.60±2.45	

Table 6: Influence of Variety, Pheromone Trap System, Cropping System and Chemical Application on Ear Damage Yield of Maize

Chemical	Pheromone Trap	No Pheromone Trap
SP0	6.30±2.97 ^a	5.38±2.52 ^b
SP2	5.34±2.41 ^b	5.70±2.96 ^{ab}
SP4	5.37±2.86 ^b	5.57±2.57 ^{ab}

SP0 represents control (No chemical application); SP2 represents chemical application at 2 weeks after planting; SP4 represents chemical application at 2 and 4 weeks after planting

Table 6 shows the second order interaction of pheromone trapping system and chemical application. Significant difference existed in the mean ear damage at this level with pheromone trap with no chemical application having significantly highest damage index of 6.30 but statistically similar with no pheromone trap ~ chemical application after two weeks (5.70) and no pheromone trap ~ chemical application two and four weeks after planting (5.57). Combination with the least ear damages were pheromone trap ~ chemical application two weeks after planting (5.34), pheromone trap ~ chemical application two and four weeks after planting (5.37) and no pheromone trap ~ no chemical application (5.38).

Table 7 shows the second order interaction of cropping system and chemical application. No significant difference existed in the mean ear damage at this level, however,

sole cropping with no chemical application had the highest damage of 5.93 while intercropping with no chemical application, sole cropping with chemical application two weeks after planting and sole cropping with chemical application two and four weeks after planting had 5.74, 5.61 and 5.61 respectively with least mean value recorded in intercropping with chemical application two and four weeks after planting (5.32).

Table 8 shows the second order interaction of pheromone trapping system and cropping system. No significant difference existed in the mean ear damage at this level, however, pheromone trap under sole cropping had the highest average of 5.81 followed by no pheromone trap under sole cropping (5.63), pheromone trap under intercropping (5.53) and no pheromone trap under intercropping (5.47).

Table 7: Influence of Variety, Pheromone Trap System, Cropping System and Chemical Application on Ear Damage Yield of Maize

Chemical	Sole cropping	Inter cropping
SP0	5.93±2.78	5.74±2.81
SP2	5.61±2.58	5.43±2.82
SP4	5.61±2.82	5.32±2.61

SP0 represents control (No chemical application); SP2 represents chemical application at 2 weeks after planting; SP4 represents chemical application at 2 and 4 weeks after planting

Table 8: Influence of Variety, Pheromone Trap System, Cropping System and Chemical Application on Ear Damage Yield of Maize

Pheromone	Sole cropping	Inter cropping
Pheromone trap	5.81±2.68	5.53±2.89
No Pheromone trap	5.63±2.77	5.47±2.60

DISCUSSIONS

Pheromone trap has proven to be a useful tool in determining the population dynamics of FAW as postulated by Nandagopal *et al.* (2008) that pheromones are a great tool for keeping an eye on pest numbers which enhances suppression of the pest and provides useful information to influence decisions on the most suitable time to execute effective management methods (Thomas, 2008). It also helps in detecting the presence of fall army worm early enough to influence the establishment of strategies required for assessment of population changes, distribution, reconnaissance, and research (Mc Grath *et al.* 2018). This study clearly revealed FAW population arrival times, build-ups, peaks and falls; and also showed the optimal times for targeting control options to be periods between the build ups and peaks, put succinctly 7-10 days after planting.

Chemicals such as insecticides are used in the control of fall army worm infestation. Their potentials have been implied (Haase *et al.*, 2015), their effectiveness accounted by 75% of farmers who adopt this method in Mozambique (Canico *et al.*, 2021) and reports on the use of Kartodim 315EC in Nigeria (Kamara *et al.*, 2020). Applications of insecticides have also been reported to improve maize yield (Tanyi *et al.*, 2020), reduce foliar damage (Sisay *et al.*, 2019). These are similar to effects observed in this study as application of Kartodim 315EC insecticide produces higher weight for fresh cob and dry cob weight, and lower ear damage and tunnel length compared to weights and losses from plots without application of the insecticides.

This study showed that maize sown in sole cropping system yielded a better weight metrics than when intercropped with yam. Fresh ear weight of maize shows slightly

better yield was produced in sole cropping system, although not significant, with exception of dry husk weight which is opposed to lower grain yield in control (sole) than intercropped with dwarf beans as reported by Tanyi *et al.* (2020).

Intercropping maize in strips with pigeon pea, cowpea, cassava etc. or repellent plants helps reduce infestation and reproductive activities of fall army worm (Bista *et al.*, 2020). Studies on maize intercropping with legumes has shown that it helps control fall army worm by diversifying parasitoids that infest fall army worm and also adds nitrogen to the soil which improves overall yield as higher number of parasitoids have been found to be related to the increase in biodiversity in intercropped systems (Afrin *et al.*, 2017). Ngangambe and Mwatawala (2020) reported higher incidence of parasitoids of fall army infestation in intercropped fields of maize and cowpea and in a push pull system as compared with sole cropping which is in tandem with findings by Udayakumar (2021). Contrary to this study, Tanyi *et al.* (2020) reported a higher fall army worm infestation in maize fields sown solely (control) as compared with those intercropped with dwarf or climbing beans. Report similar to findings from this research is from Nwanze *et al.* (2021) where fall army worm counts, tunnel number and length were found to be higher in intercropped maize and cassava although yield weight parameters had better produce in intercropped maize as compared with sole maize in this work. No significance in most of the ear yield weight of both cropping system could be attributed to no significant difference in the ear damage measures of sole cropping system (5.72 ± 2.72) and intercropping system (5.50 ± 2.74) although there was significant higher infestation tunnel number and length in intercropped fields.

Varieties of a species are made up of different genetics which can confer resistance and improvement to various attacks and yield measures. Studies have shown various cultivars of maize significantly differing in fresh ear weight, cob length and yield per hectare after exposure to *Bipolaris maydis* (Hussainet *al.*, 2016). The result shows that variations in maize damage by fall army worm have been attributed to different maize varieties (Nwanze *et al.*, 2021) thus suggesting the conveying of the effects to yield losses. Reduction in yield of maize as a result of fall army worm infestations as recorded 15-73% loss in Argentina (Bista, 2020), 20-54% in Kenya (De Groote *et al.*, 2020) and 40-70% yield loss in Africa with losses estimated at 8.2 to 20.5 million tonnes per annum (Day *et al.*, 2017). Nwanze *et al.* (2021) also reported higher yield (Ear weight, cob weight, husk weight) for Oba variety in sole cropped maize but higher yield in Yellow maize variety in intercropped maize with cassava while White maize variety had highest mean for number of tunnel and tunnel length. Length of tunnels observed ranged from 40-45cm as compared to 5-9cm by Nwanze *et al.* (2021). Selection of plant species for intercropping and the purpose of intercropping is important as works has mainly centered on the land equivalent ratio or production (Ikeorgu 2002; Ijoyah, 2011) of maize and yam intercropping.

Amongst the interaction of the various factors, cropping system and variety yield a significant interaction in dry husk weight of maize cob and number of tunnels with sole cropped and Oba producing the highest mean for weight and lowest mean for number of tunnels.

CONCLUSION

The study suggests an ideal time for managing FAW in maize-yam intercrop to be the first week after planting to avoid the pest's

population peaks, and sole maize yielded a better yield metrics than maize-yam intercrop which also suffered higher FAW infestation. Pheromone trap is a useful tool in determining the population dynamics of FAW and a great tool for keeping an eye on pest numbers which enhances suppression of the pest and provides useful information to influence decisions on the most suitable time to execute effective management options.

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