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EVALUATION OF INSECTICIDAL MIXTURE FORMULATIONS AND SPRAY SCHEDULES ON FALL ARMYWORM (*SPODOPTERA FRUGIPERDA* J.E. SMITH) INFESTATION ON MAIZE PLANTS IN CALABAR.

OGBAN, E. I.[1], OPARAEKE, A. M[2], ODEY, P.O[2].

1 Department of Animal and Environmental Biology, Faculty of Biological Science, University of Cross River State, Calabar.

2 Department of Crop Science, Faculty of Agriculture, Forestry and Wildlife. University of Calabar

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Abstract

A major challenge to increase and sustainable production of maize is its susceptibility to infestation by insect pests in the field. The fall armyworm (FAW), *Spodoptera frugiperda* (J.E.Smith) is a major insect pest of maize in Nigeria and could cause 80 % loss in yield. Field experiment was carried out during the months of March to July, 2021 at the premises of Agricultural Development Project (ADP) Calabar to evaluate the insecticidal mixture formulations and spray schedules on FAW. Plot of 3 x 3m ($9m^2$) were marked out according to the number of treatments while plant spacing for ridge was 25 cm apart, with four rows (ridges) contained in each plot, making 5 treatment combinations replicated 3 times, giving a total of 15 plots. The experiment was laid out in a Randomised Complete Block Design. Treatments consisted of a control, two insecticide mixture formulations (Lambdacyhalothrin + Dimethoate and Cypermethrin + Dimethoate) with two spraying regimes of 4 and 5 times weekly intervals for both combinations. The results showed that maize treated with Cypermethrin + Dimethoate and Lambdacyhalothrin + Dimethoate at 5x weekly sprays schedule, showed significant ($P<0.05$) reduction in maize plant damage compared to the control and the other treatments at 4 x spraying regimes. The lowest maize damage was found in plots treated with Cypermethrin + Dimethoate at 5 x weekly spraying schedule. Maize yield was lowest in control plots, while Cypermethrin + Dimethoate at 5 x weekly spraying schedule had significant ($P>0.5$) increase yield compared to Lambyhalothrin + Dimethoate at 4 times and 5 times weekly spraying schedule respectively.

Keywords: Spodoptera frugiperda Cypermethrin, Lambdacyhalothrin, Dimethoate, Synthetic Insecticide.

1. Introduction

Maize,*Zea mays* L. belongs to the family Poaceae and is a highly valued annual cereal crop of the world (Igyuve *et al.*, 2018). Maize is a major component in the diet of the people of Sub-Saharan Africa and the third most important grain crop in Nigeria, next only to Sorghum and millet (Adegbola, 1990). The popularity and high acceptability of maize have been based on their low cost and versatility in food preparation, (Okonkwo and Okoye, 1996; Huma *et al.*, 2019). For most people in Africa, maize is a staple food for an estimated 50 % of the population where about 80 % of it is consumed while 20 % is utilized in a variety of industrial processes for the production of starch, corn, sweeteners, and ethanol and as delicacies such as *Ogi* (Pap) or *Agidi* (Elegbede, 1998; Agboola and Fayemi, 1999; Owaeye, 2017). Maize's low fats, high complex carbohydrate and moderate vitamins and protein content qualifies it to be selected as a candidate crop for Controlled Ecological Life Support System (CELSS) (Emosairue, 2007). The crop has a high capacity for income generation, poverty alleviation, foreign exchange earnings and provision of raw materials for the animal feed industry (Babatunde *et al.*, 2007; Iken and Amusa, 2014; Abebe and Feyisa, 2014; Samade, 2016). Nigeria is currently the tenth largest producer of maize in the world, and the largest maize producer in Africa (ITTA, 2012; FAO, 2018). Current maize production is below its potential although still higher than that of other major cereal crops. The low yield is attributed to a combination of several production constraints including pest management practices. Arthropod pests are among the key factors contributing to low yields facing maize production today. More than 40 species of insects have been recorded on maize in the field. However, a more recent invasive species, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) commonly named fall armyworm (FAW) is now the major insect pest causing substantial yield losses of maize in Africa and other tropical country (Goergen *et al*, 2016; Day *et al* 2017; CABI, 2017b; 2017c). FAW is native to the tropical region of the western hemisphere from the United States to Argentina. It is a cosmopolitan pest which feeds on all growth stages of maize but most frequently in the whorl of young plants up to 45 days. They feed on foliage, but during heavy infestation, larvae also feed on corn ears. Damage due to this pest attack can reduce corn grain yield up to 20 to 50 per cent in Africa (Early *et al.*, 2018) Annual loss from this pest was estimated at up to 17.7 million tons of maize from 12 African countries, enough to feed tens of millions of people and representing an economic loss of up to US $4.6 billon (FAO, 2018; Silva *et al*., 2018; Togola *et al*., 2018; Prasanna *et al*., 2018; Kumela *et al*., 2019). Armyworm according to Kiprop (2017) is now a permanent challenge to the continent that largely depends on maize, spreading to 28 African countries just a year after it was first reported. In Nigeria, the pest is present in all the states with many workers reporting losses ranging from 20 to 90 % (FAO, IITA 2016; FAO, 2017; 2018). Damaged grains have reduced the quantitative and qualitative nutritional values, impaired germinability, reduced weight and market values (Ukeh*et al*., 2008; FAO, 2018). The devastating loss of field maize to insect attack has therefore necessitated the use of various measures to control this destructive lepidopteran. Methods employed in pest control include the use of botanicals, synthetic pheromones, biological/chemical methods (Ogban, 2015; FAO, 2018; Gilson *et al*., 2018; Bateman *et al.,* 2018). The formulation of plant products into dosage and their adoption for large scale production has not been adequately addressed. Control of FAW over the years is heavily dependent on the use of synthetic fumigants and residual insecticides (Blano *et al*., 2010; 2014). Dramatic successes has been recorded with the use of synthetic insecticides, however, excessive and inappropriate use of synthetic insecticides are associated with a lot of problems ranging from high cost, high mammalian toxicity, development of resistance by the insect, health implications to applicant/user and pollution of environment (Crowe and Booty, 1995; Dike and Mshelia, 1997; Togola *et al.,* 2018; Gutierrex-Moreno *et al.,* 2019; Kumela *et al;* 2019). It is therefore against the importance of this pest, a study was conducted to evaluate the effectiveness of some synthetic chemical formulations and spray schedules against this invasive pest infesting maize.

2. Materials and methods

2.1 Description of study area

The study was carried out at the premises of Agriculture Development Project (ADP) Calabar, between April to July 2021. Calabar has a tropical climate characterized by two distinct seasons, the rainy/wet seasons. The wettest months are in August and September while the dry seasons are experienced more between November to March. Calabar is located in the South-eastern rainforest agro-ecological belt of Nigeria and characterized with high temperature and humidity in the dry and wet seasons respectively. The city of Calabar has a total area of 406km^{2-} and elevation of 32m (150ft) and is a lowland town with no solid rock features. It lies between Latitude 05^0 02' 479" N and Longitude 08^0 21' 954" E. with soils that are characterized with coarse, predominantly sandy, loamy and loamy sand texture and having particle size ranging from 610-850g/kg for sand, 80 to 240 g/kg for clay and 30-150 g/kg for silt.

2.2 Experimental materials and sources

Disinfested maize seeds were obtained from Premier seeds (Nig.) Ltd. Calabar, while treatments used were a formulation of Lambdacyhalothrin + Dimethoate and

Cypermethrin + Dimethoate procured from an Agro Chemical distributor in Calabar. Other materials used were a knapsack sprayer (CP15) collected from the Department of Crop Science, University of Calabar, measuring cylinders, buckets, measuring tape, rope, cutlass, hoe and shovel.

2.3 Land preparation/experimental design

The land was cleared with cutlass, plant residues removed and ploughed manually. The experimental farm measured 27 x 14.5m. Plots were marked out according to the number of treatments and were replicated three times. The size of each plot was 3 x 3m (9m^2) with each plot containing four ridges and the dressed maize plant spacing per ridge, measuring 25cm apart. Hybrid pioneer 3550 seeds were planted at two per hole, three centimetres deep into the ground. After emergence of seedlings, they were thinned to one plant at two weeks, given a plant population of 53,333 plants per hectare. All the crop-raising practices including cultural practices, fertigation and weed management were followed to maintain healthy crops and no insecticide other than those included in the trial were applied. Fertilizer (NPK 15:15:15) was applied first by basal application through side/spot application at the rate 210k g/ha (N=50 kg, P=30 kg and K=30 g) and (N=50 kg, P = 30 g and K=30 kg) at two weeks and 5-6 weeks after sowing respectively. The insecticide formulations were at the rate of 1% (100 ml: 10,000mls water). Insecticide applications were carried out during calm, warm, sunny periods using a high volume knapsack sprayer fitted with a hollow core nozzle and using 500 L per ha. Spraying started two weeks after planting and at weekly intervals till the fifth week, 4x and 5x. Data were recorded before and after each spray.

The treatments consisted of a control; two insecticides formulations (Lambdacyhalothrin +Dimethoate) and (Cypermethrin +Dimetoate) with two spraying regimes (4 and 5 times spraying at weekly interval while the total treatment combination was 5, with each replicated 3 times giving a total of 15 plots (Table 1). The entire experiment was laid out in Randomized Complete Block Design (RCBD).

Table 1: Field layout showing Randomization and Treatment Allocations

C_1S_1	C_1S_2	C_1S_2
C_1S_1	C_2S_1	C_2S_1
C_1S_2	C_2S_1	C_1S_2
C_2S_1	C_2S_2	C_1S_1
C_2S_2	C_1S_2	C_2S_2

KEYS

C_1 = Lambdacyhalothrin + Dimethoate

C_2 = Cypermethrin + Dimethoate

$S_1$and S_2 = 4x and 5x spraying

Treatment combinations for replicate

S/N	INSECTICIDE (CI)	INSECTICIDE (C_2)
	C_1S_1	C_2S_1
	C_1S_2	C_2S_2
	C_1S_1	C_2S_1
	C_1S_2	C_2S_2

3. Data collection

Parameters that were assessed included plant and cob damage (%) per maize yield (metric tonnes/ha)

3.1 Plant damage: Plant damage by fall armyworm larvae were assessed by random sampling of eight plants per plot, showing leaf shredding, whorl distortion with heavy frass and new leaves damage, before and after each spraying. Damage is expressed as:

$$\% \text{ plant damage/plot } = \frac{Total\ No.\ of\ plants\ sampled\ /plot - No.\ of\ \ plant\ undamaged\ /\ \ PC}{Total\ No.\ of\ Plants\ sampled\ per\ plot} x\ \frac{100}{1}$$

$$\text{Cobs damaged/plot (\%) } = \frac{Total\ No.\ of\ cobs\ sampled\ plot\ No.\ of cobs\ undamaged\ /\ \ PC}{Total\ No.\ of\ Plants\ sampled\ per\ plot} x\ \frac{100}{1}$$

3.2 Yield (Ky/Plot): This is determined at harvest. After harvesting and threshing grain were allowed to dry its moisture content between 10-12 % weight and recorded.

Treatment-wise, marketable grain yield was recorded and was pooled and expressed in kg/plot.

4. Data analysis

The data were subjected to analysis of variance (ANOVA) using Gensat (2007) and mean separation using Duncan New Multiple Range Test (DNMRT) at 5 % level of probability. Data on plant cob damage were transformed using Arc sine transformation.

5. Results

The field result (table 2) showed that the various insecticidal treatments reduced significantly ($P \leq 0.05$) the fall armyworm larvae, and by extension maize plant damage, cob damage and increased maize yield ($^{t}/_{ha}$) in all the replications when compared with the control plots.

Furthermore, the results (table 2) revealed that maize treatment with Cypermethrin + Dimethoate and Lambdacyhalothrin + Dimethoate at 5 times weekly spray schedule show significant ($P \leq 0.05$) reduction in maze plant damage compared to same treatment but at 4 times spraying regimes and the control. It can therefore be deduced from the result that higher insecticide efficacy correlated with higher spray schedule

Table 2. Effect of insecticides formulations and spray schedules on plant damge, cob damage and yield of maize.

Treatment	**Spray schedules**	**Plant damage (%)**	**Cob damage (%)**	**Maize grain yield (t/ha**
Control		66.20^{a}	62.88^{a}	0.17^{c}
Lambdacyhalothrin + Dimethoate	4×	34.31^{b}	31.22^{b}	2.59^{d}
Lambdacyhalothrin + Dimethoate	5×	32.59^{c}	26.68^{bc}	2.79^{c}
Cypermethrin + Dimethoate	4×	26.90^{d}	22.91^{c}	4.01^{b}
Cypermethrin + Dimethoate	5×	23.80^{e}	20.10^{c}	4.24^{a}
SE		7.33	2.53	0.083

6. Discussion

The invasion of fall armyworm has forced farmers to deploy massive pesticide spraying programme on maize and sorghum fields as an emergency response to manage pest damage (Gutierrex-Moreno *et al*; 2019; Sisay*et al*; 2019; Day *et al*; 2017).This problem appears to be further compounded by the fact that many uninformed low-resource small holders farmers often apply indiscriminately different types of unregistered and unsafe synthetic insecticides without the slightest caution that chemicals should be used as a last resort in pest management. They are numerous, efficacious and readily available non-chemical control methods such as use of natural enemies, botanical compounds, pheromones and other cultural practices to deter adults. This study provides valuable information about the efficacy of insecticides with novel modes of action to manage fall armyworm. Data from this study indicated that maize plant treated with Lambdacyhalothrin + Dimethoate at 5 × weekly spraying schedule resulted in a significant ($P<0.05$) reduction in maize plant damage compared to the plots treated with Lambdacyhalothrin + Dimethoate at 4× weekly spraying schedule. The result is in agreement with Sisay *et al*; (2019) who recorded lower leaf damage on plot treated with a radiant 120SC, Karate % EC at 5 × weely spraying regime. Similarly, Thumar *et al*. (2020)

reported that the highest (24.49%) maize damage was recorded when treated with Chlorpyriphos 20EC. Jerry *et al*., (2020) observed that infestation was highest in the untreated control and lowest in maize plots treated with K-optimal (Lambdacyhalothrin + Acetamiprid). However, this present result is not in agreement with that of Oparaekeand Amatobi (2005) who found that *Marucavibrata* Fab. And *Clavigrallatomentosicolismelegueta* drastically reduced at just 2 × spraying regimes. It could therefore be deduced from the result that two critical factors in maize protection from fall armyworm larvae damage are insecticide effectiveness and excellent coverage of the whole plant. During the crop production 5x application of insecticides schedule provided enough protection against army fall worm and consequently resulted in higher yields compared with the untreated field.

The effectiveness of some chemical insecticides in controlling armyworm cannot be overemphasized (Goergen*et al.,* 2016; Day *et al*; 2017). Previous reports on the control of large populations of this invasive pest using equivalent insecticides other than the ones used in this research indicated that most of the toxic compounds were emamectin benzoate followed by chloranilipole, spinetoram, flubendiamidetriflumuron (a benzoflurea) and pyrethroids. In similar residual bioassay Belay *et al*., (2012) studied the effects of different insecticides for management of fall armyworm larvae using a direct spray over third instar larvae. More than 80 % mortality was observed in chloraniliprole, flubendamide, spinosad, indoxacarb and fenvalerate treatments 96 h after application.

In the present study, the result indicates that the synthetic insecticides used demonstrated the effect of insecticides spraying at higher spraying schedules (5×) in this study resulted in significant ($P \leq 0.05$) reduction in cob damage. This observation is supported by Sisay*et al.*(2019) who reported a significant reduction in cob damage on maize plant treated with Ampligo 150SC (Chlorantraniliprole) Tracer 480SC (Spinosad). Earlier Tumma and Chandrika (2018) had reported that the use of Cyfluthrin, Organophosphate insecticides methyl-parathrin on FAW at diferent spraying rates showed significant reduction on cob damage on sprayed plots compared to the control plots. This present finding is however not in congruent with the report of Thumer*et al.*, (2020) that the highest (25.93%) cob damage was recorded in Chlorpyriphos 20EC treated plots against the fall armyworm on maize.

Sprayed 4× and 5× with Cypermethrin + Dimethoate significantly lower larval infestation and increased maize yield compared to Lambdacyhalothrin is in consonance with Sisay et al (2019) who reported the application of synthetic insecticides, Corgen 200SC (Chlorantraniliprole), Dimethoate 40% significantly ($P>0.05$) increased maize yield on treated plots compared to the untreated plots.

It is not surprising that Cypermethrin + Dimethoate insecticide formulation in this study triggered greater maize yield than the other treatment and the control. Cypermethrin is a synthetic pyrethroid which emulates the properties of pyrethrum, which is naturally extracted from Chrysanthemum flowers. The insecticide goes to work immediately once an insect has come into contact or ingests the ingredient. It could bethe insecticide poison may have interfered with the armyworm's nerve cells leading to paralysis and thereby prevented them from performing normal functions like feeding and grooming hence, the reason a better maize yield was experienced in plots treated with these chemicals.

In the present study, the result indicates that the synthetic insecticides used demonstrated high level of toxicity against the targeted pest. The efficacy of these insecticide formulations is thought to be a function of their chemical composition. Dimethoate, one of the components is a systemic and contact organophosphorous insecticide that acts by inhibiting cholinesterase enzymes involved in transmitting nerve impulses, and it is related to the nerve gases which is among the most toxic of all the pesticides to both invertebrates and vertebrates.

7. Conclusion

Firstly, there is need for low-resource and small-holders farmers in communities to be properly sensitize on the life stages of these invasive pests, methods of scouting them, understanding of the right stages of the crop on which high economic damage may occur, time for management application and implementation and low-cost agronomic practices for sustainable management of the pest. Secondly, it is important to introduce, validate and deploy low-cost environmentally safer and effective technological interventions like single and Pramides-gen-Bt maize) over short, medium and long-term for sustainable management of the fall worm in Nigeria.

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