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Efficacy and Profitability of Selected Organophosphates and Pyrethroids for Control of Tomato Fruitborer *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) in Southwestern Nigeria

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ABSTRACT

Tomato fruitborer - TBF (*Helicoverpa armigera*) larvae cause significant losses in the quality and quantity of tomato fruits due to their boring activities. Most farmers are yet to adopt the use of a single insecticide for the control of TFB but rather use a mix of two or three insecticides due to the speculation of TFB resistance to insecticides in Nigeria. Trials were conducted 2017 and 2020 to evaluate singly, three pyrethroids- Lambda-cyhalothrin, Cypermethrin, Deltamethrin and three organophosphates - Dimethoate, Dichlorvos and Diazinon for efficacy against tomato fruitborer larvae and cost benefit. A susceptible tomato genotype "Kerewa" was used for the trials and were laid in a Randomized Complete Block Design (RCBD) with three replications. From the trials, number of exit holes and tomato fruitborer larvae from infested tomato fruits were significantly lower in treated plots. All the insecticides tested were comparable in efficacies, resulting in significantly lower fruit damage than control in both trials. Yield was higher in treated plots than from untreated control. Cypermethrin application gave highest yield in 2017 and 2020. Highest economic returns were recorded from applications of Dimethoate and Cypermethrin in 2017 but from applications of Deltamethrin and Cypermethrin in 2020. A significant control of *Helicoverpa armigera* was achieved the insecticides tested singly. The highest tomato yield and average economic returns were obtained from application of cypermethrin.

Keywords: Tomato, Tomato Fruitborer, Organophosphates, Pyrethroids, Fruit damage, Fruit yield, cost benefit ratio.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the second most important fruit or vegetable crop after potato in the Solanaceae family (Quinet *et al*., 2019). It is an indispensable commercial vegetable grown worldwide for its benefits. It is a high yielding, warm season, relatively short duration crop with high sensitivity to humidity (Ugonna *et al*., 2015). Nigeria is the 14th largest producer of tomato in the world and the second largest producer of fresh tomatoes in Africa, producing 10.8% of fresh tomatoes in the Sub-sahara Africa (Surechain, 2021). Tomato is one of the vegetables cultivated throughout the year in almost all parts of Nigeria (Umeh *et al*., 2002). The main tomato producing States in the northern parts of Nigeria include Bauchi, Benue, Borno, Kano, Kaduna, Plateau, Jigawa and a few southern States as Delta, Kwara and Oyo (Ugonna *et al*., 2015).

Tomato accounts for about 18% of the average daily consumption of vegetables in

Nigeria. It is among the major vegetables produced and consumed in different forms in Nigeria (Marti *et al*., 2016; Amurtiya and Adewuyi, 2020). Tomato fruits are consumed fresh in salads and essential condiments for sauces, soup, meat or fish dishes. It can be processed into different products such as ketchup, puree, powder and juice (FAOSTAT, 2018). It forms an integral part of the diet of Nigerians, contributing to a healthy and well-balanced diet. It is rich in minerals, vitamins, essential amino acids, sugars, dietary fibres, vitamin B and C, iron and phosphorus (FAOSTAT, 2018). Tomatoes contain many health-promoting bio-active compounds as vitamins, carotenoids (particularly lycopene), ascorbic acid, and phenolic compounds that have a wide range of physiological properties such as anti-inflammatory, anti-allergenic, antimicrobial, vasodilatory, antithrombotic, cardio-protective, and antioxidant effects (Borguini *et al*., 2009; Quinet *et al*., 2019).

Tomato production in Nigeria is constrained by low soil fertility, lack of improved seeds, lack of improved technology, inadequate pest and weed control, high postharvest losses and lack of processing and marketing infrastructure. These constraints are however, compounded by the ravaging incidence of diseases and severe insect pest infestation (Amurtiya and Adewuyi, 2020). Tomato fruitborer –TFB (*Helicoverpa armigera*) is considered the most economically important among the numerous insect pests attacking tomato in Nigeria, (Borisade *et al*., 2017; Rosenya *et al*., 2017). *Helicoverpa armigera* larvae attack growing terminals prior to flowering causing loss of plant uniformity and consequent yield loss to the tune of 35-55%. (Ali *et al*., 2021). Tomato fruitborer larva feeds on leaves, stems, buds, inflorescences, and fruits of tomato causing substantial economic loss of yield and market value especially when fruits are blemished, bored or rotted (Murúa *et al.*, 2014; Sapkal *et al*., 2018). In Nigeria, it has been reported that larval feeding, which causes destruction of several fruits if not controlled, can cause up to 45% crop losses in extreme conditions as a result of reduction in fruit weight, fruit size or total fruit damage (Ali *et al*., 2021; Umeh *et al*., 2002).

The use of insecticides has been the major control strategy for *H. armigera* on tomato and other crops in Nigeria due to its preference for highly-valued fruits of tomato (Martin *et al.*, 2005). However, reports from different parts of the world have shown that TFB control with any single insecticide for a long time is quite difficult due to the high polyphagy, wide geographical range, mobility, migratory potential, facultative diapause, high fecundity, propensity to develop resistance to insecticides and larval feeding behaviour (Ballari and Udikeri, 2022; Ahmad, 2007).

Reports from countries such as Spain, Australia, India and Pakistan have shown that *Helicoverpa* spp. has been subjected to heavy selection pressure and have therefore, developed resistance to the major classes of insecticides such as organochlorines, carbamates, organophosphates and pyrethroids (McCaffery, 1998). In Nigeria for instance, Umeh *et al*. (2002) reported that 77% of the tomato farmers in Nigeria who use insecticides to control *H. armigera* reported that insecticides no longer adequately control the pest, thus indicating that there is the likelihood of insecticide resistance development in Nigeria. Also, a field survey conducted in 2013 on major tomato farms in Abeokuta and Ayetoro in Ogun State Nigeria revealed that 80% of tomato farmers use a variety of insecticides either singly or in combination with other insecticides for the management of TFB due to their perception of insecticide resistance in TFB.

There is therefore, a need to conduct an empirical investigation on the farmers speculated TFB resistance to insecticides by screening insecticides commonly used by farmers for TFB control on tomato in Nigeria such as lambda-cyhalothrin, cypermethrin, deltamethrin, dimethoate, dichlorvos (DDVP) and diazinon. It is also important to analyze and compare the cost benefit of using each of the insecticide for the control of TFB. Therefore, the objectives of this study were to:

1. assess the population density of tomato fruitborer larvae in tomato sprayed with the selected six insecticides;
2. assess the TFB induced fruit damage and fruit yield in tomato sprayed with the selected six insecticides; and
3. analyze the cost benefit ratio of selected six insecticides for the control of tomato fruitborer.

MATERIALS AND METHODS

The study was carried out at the Teaching and Research Farm of the Federal University of Agriculture, Abeokut
rainfall of about 963.33 mm, characterized by a bimodal rainfall pattern that peak in June and September with a dry spell in August. The experiment was carried out in the late season between July and October 2017 and repeated in the late season between August and October, 2020. A susceptible tomato genotype, "Kerewa" sourced from FUNAAB/ KNUST/ DfiD/ British Council DelPHE 5 Research Project of FUNAAB was used. Three pyrethroid insecticides (Lambda-cyhalothrin, Cypermethrin and Deltamethrin), and three organophosphates (Dimethoate, Dichlorvos and Diazinon) obtained from agrochemical store were used for the experiment.

Tomato seedlings were established in the nursery by sowing two seeds of "Kerewa" per nursery pot. The nursery pots were arranged under a shed and 50 cl of water was added to seedlings at 24 hours intervals till 3 weeks after sowing (3 WAS). At 3 WAS, tomato seedlings were transplanted from the nursery to the permanent field that was ploughed twice and harrowed once before transplanting tomato seedlings. Two seedlings of tomato were planted on flat at a spacing of 0.5 m by 0.5 m in plots of 2 m x 3 m (6 m^2). Total plot size was 37 x 15 m (555 m^2) while 3 m border was maintained between plots and blocks to minimize insecticide drift across the adjacent plots.

The experiment was laid-out in a Randomized Complete Block Design (RCBD) with three replications. There were eight treatments: which comprised spraying with (i) Lambda-cyhalothrin (Laraforce 25% EC produced by Jubaili Agrotec) at 0.5 litre/ha (ii) Cypermethrin (Avesthrin 10% EC produced by Eastsun Chemical Co Ltd) at 2.4 litres/ha (iii) Deltamethrin (Deltaforce 12.5g/L EC produced by Jubaili Agrotec) at 0.5 litres/ha (iv) Dimethoate (Dimeforce 40% EC produced by Jubaili Agrotec at 1 litre/ha (v) Dichlorvos (DDVP) (DD force 1000 g/L EC produced by Jubaili Agrotec) at 1 litre/ha (vi) Diazinon (Cobra 60 EC) produced by West African Cotton Company Ltd) at 1litre/ha and (ix) Control (no insecticide application).

Application of the treatments commenced 2 weeks after transplanting (WAT) tomato till fruit maturity at weekly intervals. The insecticides were applied three times during vegetative stage; two times during flowering stage and three times during the fruiting stage between 0700 and 0900 hours. The insecticides were applied with a knapsack sprayer. Weeding was carried out at 2 weeks interval with hoe and no fertilizer was applied throughout the experiment.

Assessment of *H. armigera* larval population density commenced at vegetative stage, 2 WATS till fruit maturity, 9WAP by visual counting on 10 randomly selected tomato plants from the middle row of each plot. This was done at weekly intervals between 0700 and 009 hours. It was based on the number of *H. armigera* larvae found on the leaves, stems, flowers and infested fruits per treatment and on the number of exit holes recorded on damaged fruits per treatment. Harvesting of tomato fruits commenced at 9 WATS and lasted till 12 WATS. At harvest, fruits were collected from the 10 randomly selected tagged tomato plants per replicate and sorted into damaged and undamaged. A tomato fruit was considered damaged by *H. armigera* if it had one or more exit holes. Marketable yield evaluation was based on the weight of undamaged tomato fruits.

Cost benefit ratio for each of the six insecticide was calculated as the additional income per hectare and returns on the additional cost incurred using the formular of Dormon *et al.* (2007).

Cost Benefit ratio =

$$\frac{\text{Additional revenue} - \text{Additional cost}}{\text{Additional cost}} \times 100$$

Additional income (AI) = Additional revenue (AR) – Additional cost (AC)

Additional revenue (AR) = Additional yield (kg) x price/kg

Additional cost (AC) = cost of inputs e. g. cost of insecticide + cost of renting spraying equipment + cost of spraying.

Where: Additional yield = Yt – Yc; Yt = yield of treatment: Yc = yield of control.

All data collected were analysed using analysis of variance (ANOVA) at $P<0.05$. Data on insect counts were square transformed, while data on damage in percentages were arcsine ($\sin^{-1}$) transformed before ANOVA tests. Student Newman Keul's (SNK) was used to separate significant means where found.

RESULTS

Effects of insecticide application on population density of larval Helicoverpa armigera damage and yield of tomato in 2017 and 2020 cropping seasons

The number of *H. armigera* larvae on insecticide-sprayed plots varied significantly with insecticide both in 2017 and 2020 trials (Table 1). The number of *H. armigera* larvae found infesting tomato fruits before and after insecticide application was lower in Cypermethrin-, Lambda-cyhalothrin-, Deltamethrin-, Diazinon-, Dimethoate- and Dichlorvox- treated plots than in the control plots in both trials. However, the densities of larval *H. armigera* obtained in Cypermethrin-, Lambda-cyhalothrin-, Deltamethrin-, Diazinon-, Dimethoate- and Dichlorvox- treated plots were similar to one another in both trials (Table 1). Significantly lower numbers of *H. armigera* were recorded in all the six insecticide-treated plots after application of the insecticides, compared to situation before application, in both trials (Table 1).

Table 1: Insecticide type on population density of tomato fruit borer larvae in 2017 and 2020 cropping seasons

Insecticide	2017 Pre-application	2017 Post-application	2020 Pre-application	2020 Post-application
Cypermethrin	5.60b	0.00b	4.76b	0.00b
Lambda-cyhalothrin	4.96b	0.00b	4.32b	1.13b
Deltamethrin	6.48b	0.00b	5.28b	0.00b
Diazinon	2.16b	0.80b	3.20b	1.50b
Dimethoate	5.36b	0.80b	3.60b	0.00b
Dichlorvox	6.64b	1.20b	3.76b	0.00
Control	18.48a	16.80a	12.52a	16.08a
F- value	15.76	7.17	5.93	32.53
P-value	<0.0001	<0.0004	0.0013	<0.0001
CV (%)	26.97	24.26	17.00	19.38
t-statistics	3.019		4.39	

Means followed by the same alphabets along the column are not significantly different from one another according to Student Newman Keul’s (SNK) test ($p > 0.05$).

Fruit damage per plant and fruit damage per plot in Cypermethrin-, Lambda-cyhalothrin-, Deltamethrin-, Diazinon-, Dimethoate- and Dichlorvox- treated plots were statistically similar, and lower than the control plots. There was a significant reduction in fruit damage in insecticide-treated plots compared to the control plots in both trials. The percentage fruit damage in the control plots was 51% times higher than that obtained in the insecticide-treated plots (Table 2). Significantly higher fruit yield was observed in insecticide-treated plots than in the control plots in both trials (Table 3). Significantly heavier fruits were produced in Cypermethrin-treated plot compared to Lambda-cyhalothrin-, Deltamethrin-, Diazinon-, Dimethoate- and Dichlorvox- treated plots in both cropping seasons. However, yield per plot in Cypermethrin-treated plot was significantly similar to those in Lambda-cyhalothrin-, Deltamethrin-, Diazinon-, Dimethoate- and Dichlorvox-treated plots in both trials (Table 3).

A general increase in yield was recorded in insecticide-treated plots compared to the unsprayed control plot in both years (Table 3). However, the increased yield observed from the insecticide-treated plots was significantly higher in Cypermethrin-treated plots relative to others, while the lowest yield was recorded in Dichlorvox-treated plot in 2017. In 2020, however, the increment in yield in all the insecticide-treated plots did not differ significantly from one another (Table 3).

There was a significant increase in the weight of fruits produced from the insecticide-treated plots compared to the control plots in both 2017 and 2020 trials. Fruits produced from Cypermethrin-treated plot were about 200% heavier than the control while those from Dimethoate- and Dichlorvox-treated plots were 83% heavier than the control in 2017. In 2020, the highest yield was produced in Cypermethrin- treated plots, while the lowest was produced in Dichorvox-treated plots. Fruit weight was heavier by about 162% and 65% in Cypermethrin- and Dichorvox-treated plots respectively than the control plot in 2020 (Table 3).

Results of the cost-benefit analysis showed that the profit/marginal returns were positive for all the six insecticides in both trials (Tables 4 and 5). The highest cost/benefit ratio in 2017 was from Dimethoate application followed by Cypermethrin application, while the lowest was obtained with Dichlorvox application in 2020 (Table 4). However, Deltamethrin, Cypermethrin and Lambda-cyhalothrin applications were the most cost-effective, relative to others in 2020 (Table 5). However, on the average, Deltamethrin had the highest cost-benefit ratio followed by Cypermethrin and Lambda-cyhalothrin for both trials.

Table 2: Insecticide type on damage induced by tomato fruit borer larvae in 2017 and 2020 cropping seasons

	2017			2020		
Insecticide	Damage/ plant (g)	Damage/ plot (kg)	%Fruit damage	Damage/ plant (g)	Damage/ plot (kg)	%Fruit damage
Cypermethrin	0.75b	0.018b	2.14b	0.00b	0.00b	0.00b
Lambda-cyhalothrin	0.84b	0.020b	3.30b	0.00b	0.00b	0.00b
Deltamethrin	0.74b	0.018b	3.30b	0.44b	0.011b	1.15b
Diazinon	1.75b	0.042b	5.89b	0.34b	0.008b	0.80b
Dimethoate	2.23b	0.054b	9.15b	0.89b	0.021b	2.31b
Dichlorvox	2.26b	0.050b	8.77b	1.33b	0.032b	4.30
Control	12.50a	0.300a	50.80a	14.34a	0.344b	43.00a

Means with the same alphabets along the column are not significantly different from one another according to Student Newman Keul's (SNK) test ($p > 0.05$).

Table 3: Tomato Fruit yield with insecticide type in 2017 and 2020 cropping seasons

Insecticide	2020				2017			
	Fruit yield/ plant (g)	Fruit yield/ plot (kg)	Fruit yield/ ha (kg)	% increase	Fruit yield/ plant (g)	Fruit yield/ plot (kg)	Fruit yield/ ha (kg)	% increase
Cypermethrin	34.63a	0.82a	1370.70a	197.14a	53.78a	1.29a	2151.20a	182.00a
Lambda-cyhalothrin	24.15bc	0.58a	966.0bc	106.65b	38.63b	0.93a	1550.40b	101.09b
Deltamethrin	28.54b	0.69a	1146.70ab	140.80ab	39.67b	0.95a	1584.30b	102.53b
Diazinon	27.74bc	0.67a	1110.70abc	138.03ab	41.17b	0.99a	1646.7b	112.81b
Dimethoate	21.42c	0.54a	853.30c	83.00b	37.11b	0.89a	1479.90b	97.68b
Dichlorvox	21.56c	0.52a	860.00c	83.17b	31.55b	0.75a	1262.10b	65.03bc
Control	12.15d	0.29b	484.00d	-	19.17c	0.46b	764.70c	-

Means with the same alphabets along the column are not significantly different from one another according to Student Newman Keul's (SNK) test ($p > 0.05$).

Table 4: Cost-benefit ratios of insecticide type for tomato fruit borer control in 2017 cropping season

Items	Cypermethrin	Deltamethrin	Lambda-cyhalothrin	Diazinon	Dimethoate	Dichlorvox
Cost of insecticides (₦)	23,040.00	4,800.00	4,800.00	10,400.00	10,400.00	9,600.00
Cost of renting equipment (₦)	4,000.00	4,000.00	4,000.00	4,000.00	4,000.00	4,000.00
Cost of labour (₦)	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Total cost (₦)	47,040.00	28,800.00	28,800.00	34,400.00	34,400.00	33,600.00
Additional yield (kg/ha)	1282.40	486.80	524.80	526.00	1070.00	440 .40
Revenue at naira (200 ₦ /kg)	264,480.00	33,360.00	104,960.00	105,200.00	214,000.00	88,080.00
Profit (₦)	217,440.00	97, 360.00	96,160.00	70,800.00	179,600.00	54,480.00
Benefit/cost ratio	4.62	3.38	2.64	2.05	5.22	1.62

Additional yield = Yt – Yc; Yt = yield of treatment, Yc = yield of control; Revenue at naira = 200 ₦ /kg X additional yield; Profit = Revenue at naira- Total cost; Cost of insecticide + Cost of renting sprayer + Labour cost = Total cost; Benefit /cost ratio = Profit/total cost

Table 5: Cost-benefit ratios of insecticide type for tomato fruit borer control in 2020 cropping season

Items	Cypermethrin	Deltamethrin	Lambda-cyhalothrin	Diazinon	Dimethoate	Dichlorvox
Cost of insecticides (₦)	23,040.00	4,800.00	4,800.00	10,400.00	10,400.00	9,600.00
Cost of renting equipment (₦)	4,000.00	4,000.00	4,000.00	4,000.00	4,000.00	4,000.00
Cost of labour (₦)	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Total cost (₦)	47,040.00	28,800.00	28,800.00	34,400.00	34,400.00	33,600.00
Additional yield (kg/ha)	1640.00	1480.00	1000.00	1148.80	760.00	400.00
Revenue at naira (200 ₦ /kg)	328,000.00	296,000.00	200,000.00	229,760.00	152,000.00	80,000.00
Profit (₦)	280,960.00	267,200.00	171,200.00	195,360.00	117,600.00	46,400.00
Benefit/cost ratio	5.97	9.27	5.94	5.67	3.42	1.38

Additional yield = Yt – Yc; Yt = yield of treatment, Yc = yield of control; Revenue at naira = 200 ₦ /kg X additional yield; Profit = Revenue at naira- Total cost; Cost of insecticide + Cost of renting sprayer + Labour cost = Total cost; Benefit /cost ratio = Profit/total cost

DISCUSSION

Tomato fruitborer (TFB) caused over 50% fruit damage on tomato in unprotected plots thus confirming its status as a major pest of tomato in Abeokuta, southwestern Nigeria. This was similar to the report of Ogunwolu (1989) from Benue State, Nigeria where fruit damage due to TFB in unprotected plots was 72.4% and 52.2% in 1985 and 1986 respectively, and Mailafiya *et al*. (2014) and Gadhiya *et al.* (2014) who recorded 19-36% and 40-50% tomato fruit damage, respectively.

The reduction in TFB damage and subsequent increase in tomato fruit yield in plots sprayed with Cypermethrin, Lambda-cyhalothrin, Deltamethrin, Diazinon, Dimethoate and Dichlorvox suggested that the insecticides were effective against TFB. Such insecticide effectiveness against TFB population was reported by Khan and Faizullah (1999) and Balikai *et al.* (2001). Similarly, Cypermethrin, Deltamethrin and Lambda-cyhalothrin have been reported to give effective *H. armigera* control (Deshmukh, 2010). However, there have been conflicting reports on the effectiveness of insecticide in the control of TFB in countries other than Nigeria. For instance, Torres -Vila, *et al*. (2002) reported a widespread occurrence of resistance in TFB to popular synthetic pyrethroids in Africa. Similar records of resistance to major chemical families of insecticides such as organochlorines, carbamates, organophosphates and especially pyrethroids by TFB were reported in Spain, Australia, India and Pakistan (Armes *et al*., 1996; McCaffery, 1998).

Also, given that, voracious caterpillars of TFB feed for a short period on the leaves and stems and later bore into the fruits, where they are well-protected, Mehta *et al*. (2010) therefore, opined that TFB control using chemical insecticides may be difficult. However, it was observed in this study that the six insecticides tested reduced the TFB infestation on tomato fruits using the technique of insecticide application aimed at covering the foliage and fruits as completely as possible so that adult *H. armigera* are killed through direct contact.

The significant reduction in fruit damage and multiple-fold increase in fruit yield observed from sprayed plots compared to the control in both trials further confirmed the effectiveness of the insecticides tested against TFB. The highest yields (1370.70 tons/ha and 2151.20 tons /ha) and percentage increase in yield (197.14% and 182%) consistently obtained in cypermethrin-treated plots in both 2017 and 2020 trials indicated that Cypermethrin was more effective than other insecticides tested. This result is consistent with the report of Ogunwolu (1989), Mehta *et al.* (1991), Pampapathy and Basavanagound (2000). The efficacy of Cypermethrin in the control of TFB infestation on chickpea (Jadhav and Suryawanshi, 1998) and major insect pests of vegetable (Abdullah *et al.*, 2001) have all been reported earlier.

The positive cost-benefit ratio of the six insecticides tested implied that the use of insecticides for the control of TFB in tomato for this study is worth the money invested. However, the highest cost-benefit ratio obtained from the plots sprayed with Dimethoate in 2020 suggested that using Dimethoate was cost effective to Cypermethrin while using Deltamethrin was more economically superior to Cypermethrin and Lambda-cyhalothrin in 2017. The six insecticides tested, therefore, achieved effective control of *H.* a*rmigera*, however, Cypermethrin application had the highest fruit yield and higher cost-benefit relative to others.

The status of *H. armigera* as a major pest of tomato in Abeokuta, southwestern Nigeria was established in this study as over 50% yield loss was attributable to *H. armigera* attack in the absence of effective control measures in unprotected plots. The positive impact (efficacy) of lambda-cyhalothrin, deltamethrin, diazinon, dimethoate and dichlorvox in the control of TFB was also revealed in this study contrary to the speculations and reports of insecticide resistance from other countries. However, the significant reduction in fruit damage and multiple-fold increase in fruit yield in plots sprayed with cypermethrin from this study revealed that cypermethrin was the most effective insecticide among several insecticides tested against *H. armigera* on tomato. The high positive cost-benefit ratio obtained from using dimethoate, cypermethrin and lambda-cyhalothrin in the control of TFB showed it was cost effective using these insecticides

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