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INSECTICIDE RESISTANCE MONITORING OF FALL ARMYWORM (*Spodoptera frugiperda* J.E. Smith) IN CHITTOOR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Maize (*Zea mays* L.) is considered as queen of the cereals and is one of the most important crop next to rice and wheat in global agriculture. It has very high yield potential and there is no such cereal crop on the earth which has such immense potentiality. Globally it is highly valued for its multiple uses such as food, feed, fodder and raw material for large number of industrial products. Fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) is a dangerous transboundary pest, can cause significant yield losses if it is not managed well in time. Hence bioassay studies were conducted on third instar FAW larvae from F1 population of field collections from chittoor of Andhra Pradesh using diet incorporation assay (IRAC test method) to check the resistance monitoring. The studies on the resistance levels in *S. frugiperda* to five insecticides viz., emamectin benzoate, chlorpyriphos, lambda-cyhalothrin, chlorantraniliprole and spinetoram. revealed the high level of resistance to conventional insecticides like chlorpyrifos (114.8 folds), lambda cyhalothrin (19.4 folds), and low level of resistance to new chemicals like chlorantraniliprole (12.5 folds), spinetoram (10 folds) and emamectin benzoate (3 folds).

KEYWORDS: Fall armyworm, Resistance monitoring, Resistance level.

INTRODUCTION

Maize (*Zea mays* L.) is considered as queen of the cereals and is one of the most important crop next to rice and wheat in global agriculture . It has very high yield potential and there is no cereal on the earth which has so immense potentiality. Globally it is highly valued for its multiple uses such as food, feed, fodder and raw material for large number of industrial products.

Fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) is a dangerous transboundary pest, able to fly over 100 km in one single night (Naganna *et al*., 2020) with a high potential to spread continually because of natural distributional capacity and international trade. FAW can cause significant yield losses if it is not managed well in time. *S. frugiperda* has recently become the new invasive species in both the West and Central Africa where the outbreaks have been recorded for the very first time in early 2016 (Georgen *et al*., 2016). In India it was first reported in Karnataka during May 2018 (Sharanabasappa *et al*., 2018). This rapid spread and difficulty in controlling *S. frugiperda* is due to its high migration ability, high reproductive capacity, absence of diapause, wider host range, suitable tropical climate as well as polyphagous nature.

The development of the dose mortality responses for the insecticides is necessary to provide baseline data for a future resistance monitoring studies for polyphagous pests like *S. frugiperda*. These invaded FAW populations attacked the maize crop in different South Indian states and also different districts of Andhra Pradesh and to control these voracious feeders, farmers spray different groups of pesticides indiscriminately without any label claim. These invaded FAW population which travelled across continents may be exposed to different groups of pesticides and may have some innate capability to tolerate the insecticides. But there is no baseline toxicity data available for this *S. frugiperda* larvae to different insecticides. Therefore, this study on insecticide resistance monitoring of fall armyworm in Chittoor district of Andhra Pradesh is carried out.

MATERIAL AND METHODS

Collection of field population fall armyworm

Roving survey was conducted Chittoor district of Andhra Pradesh during *rabi*, 2021-2022 to know the severity of incidence of Fall armyworm (FAW) on maize and collected the larval populations from three mandals during the survey period to study the resistance monitoring studies among the collected larval population.

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Fifty larvae were collected from each mandal and kept individually in plastic cups and brought to the laboratory for further studies.

Mass multiplication of FAW, *S. frugiperda*

The collected larvae from Chittoor districts were separately reared on artificial diet (Barreto *et al*., 1999) till pupation. Then the pupae were collected and kept in Acrylic rearing chambers of dimensions 26.5 cm × 29.5 cm × 29.5 cm for adult emergence. The cotton swabs dipped in 40 per cent honey solution were arranged as food for emerging adults and Maize seedlings of 5 to 7 days old were kept inside the rearing chambers for egg laying by *S. frugiperda* adults.

The rearing chambers were checked regularly for replacement of honey solution and egg laying by adult moths of FAW. The egg masses were collected and transferred to plastic troughs and allowed for hatching. After hatching the neonates were allowed to feed on fresh sweet corn kernels until they reach third instar and then transferred to artificial diet boxes for individual feeding to avoid cannibalism.

Preparation of stock solutions

Stock solutions of test insecticides were prepared by using the formula (Naveed, 2005) (Table 2).

Stock solution =

$$\frac{\text{Required concentration}}{\text{Per cent of cormulation of insecticide}} \times 100*$$

*Quantity of water taken for the preparation of solution

Stock solution of 100 mL was used for the preparation of desired concentration by serial dilution method. Untreated control was also maintained for each insecticide tested and the mortality data was corrected by using modified Abbotts formula (Abbott, 1925) wherever >10% mortality recorded in the untreated control.

Abbott's formula for corrected mortality =

$$\frac{\text{T - C}}{\text{100 - C}} \times 100$$

T = Mortality in treatment

C = Mortality in control

Bioassay studies with Fall armyworm, *S. frugiperda*

For conducting Bioassay, artificial diet incorporation method was used (IRAC Method, 2020). The stock solution of the insecticides was prepared in 100 ml of distilled water and subsequently, 1 ml of insecticide solution was mixed with 9 ml of diet and allowed to solidify. Then third instar larvae were selected and pre starved separately for 4 hours, then placed into large cell wells containing a cube of the insecticide infused diet. A control diet was maintained without mixing any insecticide. Each treatment was replicated thrice.

Statistical analysis

The larval mortality counts were taken at 24, 48 and 72 hours after treatment. The larvae which did not show any movement and moribund were treated as dead. Data on mortality was subjected to probit analysis (Finney, 1971). LC_{50} and LC_{90} values were calculated using SPSS statistical package.

Assessment of insecticidal resistance in *S. frugiperda*

The degree of development of resistance through different generations was determined by working out LC_{50} values in next generation and thus computing the resistance ratio (RR) by dividing the LC_{50} value of field population with LC_{50} value of the baseline susceptible population (Tabashnik *et al.,* 1987).

Resistance ratio =

$$\frac{LC_{50}\ \text{value of field population}}{LC_{50}\ \text{value of susceptible population}}$$

RESULTS

The results of the survey indicate that higher incidence of fall armyworm was observed in Tirupati rural (63.81%) followed by Chandragiri (62.55%) and byreddipalli (50.46%) (Table 1). The farmers of chittoor district are not much aware of the latest chemicals and mostly they are using the conventional insecticides like neem formulations, chlorpyriphos, profenophos, cypermethrin *etc.,* which are not so effective against FAW in maize.

The LC_{50} values of different insecticides are Chlorpyriphos, 166.51 µg/ml > chlorantraniliprole, 12.48 µg/ml > lambda cyhalothrin, 10.07 µg/ml > Spintoram,

Table 1. List of mandals and villages of Chittoor district of Andhra Pradesh surveyed for the incidence of FAW on maize during *rabi*, 2021-2022

District	Mandal	GPS (Latitude, Longitude)	Per cent incidence
Chittoor	Chandragiri	13.584116^o, 79.32064^o	62.55
	Baireddipalli	13.04959^o, 78.53004^o	50.46
	Tirupati Rural	13.620718^o, 79.372778^o	63.81

4.81 µg/ml > emamectin benzoate, 1.81 µg/ml. (Table 3 and Fig. 2)

Among the different insecticides used the relative resistance ratios was higher for chlorpryiphos (114.8) followed by lambda cyhalothrin (19.4), chlorantraniliprole (12.8), spinetoram (10) and emamectin benzoate (3) (Table 3 and fig. 1). The differences in the levels of resistance of FAW populations may be due to increased spraying frequencies of new chemicals like emamectin benzoate, chlorantraniloprole and spinetoram in maize ecosystem to manage the FAW even at an early vegetative stage till tasselling stage.

The resistance ratios of emamectin benzoate were in accordance with Grace *et al*. (2019) who studied the resistance of *S. litura* from Kurnool district during 2016-2017. The resistance ratios of Lambda cyhalothrin, chlorantraniliprole and cyantraniliprole were in accordance with Zhang *et al*. (2021) who studied the resistance of *S. frugiperda* from different populations of China during 2019. These findings are in collaboration with Song *et al*. (2020) who reported that the spraying frequency of ememectin benzoate increased to 6.83 times during 2019 in west Yunnan since FAW invaded china.

These results are in line with the reports of Zhang *et al*. (2021) who reported the insecticide resistance in FAW from China to different insecticides like 615-1068 folds to chlorpyriphos, 60-388 folds to spinosad, 26-317 folds to lambda cyhalothrin, 13-29 folds malathion, 3-8 folds to emamectin benzoate and 1-2 folds to chlorantraniliprole, respectively.

Insecticide resistance to FAW has been reported from different American, African and Asian countries which created havoc in maize cultivation and resulted in crop failures, food and nutritional security. The indiscriminate use of insecticide resulted in development of resistance to organophosphate and synthetic pyrethroids in Puerto-Rico (Gutierro-Moreno *et al*., 2019), lambda cyhalothrin, chlorpyriphios (Carvalho *et al*., 2013), lufenuron (Nascimento *et al*., 2016) and spinosad (Okuma *et al*., 2018).

Table 2. Insecticides used for bioassay studies against Fall armyworm, *S. frugiperda*

S. No.	Insecticides	Commercial formulation	Chemical class	IRAC group	Mode of action
1.	Emamectin Benzoate	Gall up 5% SG	Avermectins	6	Chloride channel regulators
2.	Chlorpyrifos	Premain 20% EC	Organophosphates	1B	Cholinesterase inhibitors
3.	Lambda Cyhalothrin	Instant 5% EC	Pyrethroids	3A	Sodium channel modulators
4.	Chlorantraniliprole	Coragen 18% W/W	Diamides	28	Ryanodine receptor activators
5.	Spinetoram	Delegate 11.7% SC	Spinosyns	5	Acetylcholine disruptors

Table 3. The resistance level of fall armyworm, *S. frugiperda* populations collected from Chittoor district of Andhra Pradesh against different insecticides at 72 HAT during *rabi*, 2021-2022

S. No.	Insecticide	LC_{50} (ppm)	95% FL		Slope ± SE	Chi Square	Intercept ± SE	RR**
			Lower limit	Upper Limit				
1	Emamectin Benzoate	1.81	0.88	2.64	2.66 ± 0.25	9.91	-0.68 ± 0.13	3
2	Chlorpyrifos	166.51	131.01	202.38	4.54 ± 0.32	17.46	-10.09 ± 0.74	114.8
3	Lambda Cyhalothrin	10.07	2.68	17.75	1.95 ± 0.17	15.17	-1.96 ± 0.22	19.4
4	Chlorantraniliprole	12.48	6.17	21.46	2.15 ± 0.17	14.88	-2.35 ± .22	12.5
5	Spinetoram	4.81	4.16	5.47	2.70 ± 0.26	4.46	-1.84 ± 0.21	10

** RR-Resistance Ratio; HAT-Hours after treatment

* The baseline LC_{50} values to emamectin benzoate of susceptible strain was taken from Gutierrez-Moreno *et al*. (2018)
* The base line LC_{50} values to chloryriphos of susceptible strain was taken from Yu (1991)
* The base line LC_{50} values to chloryriphos of susceptible strain was taken from Yu (1991)
* The baseline LC_{50} values to chlorantraniliprole of susceptible strain was taken from Gutierrez-Moreno *et al*. (2018)
* The baseline LC_{50} values to spinetoram of susceptible strain was taken from Zhao *et al*. (2020)

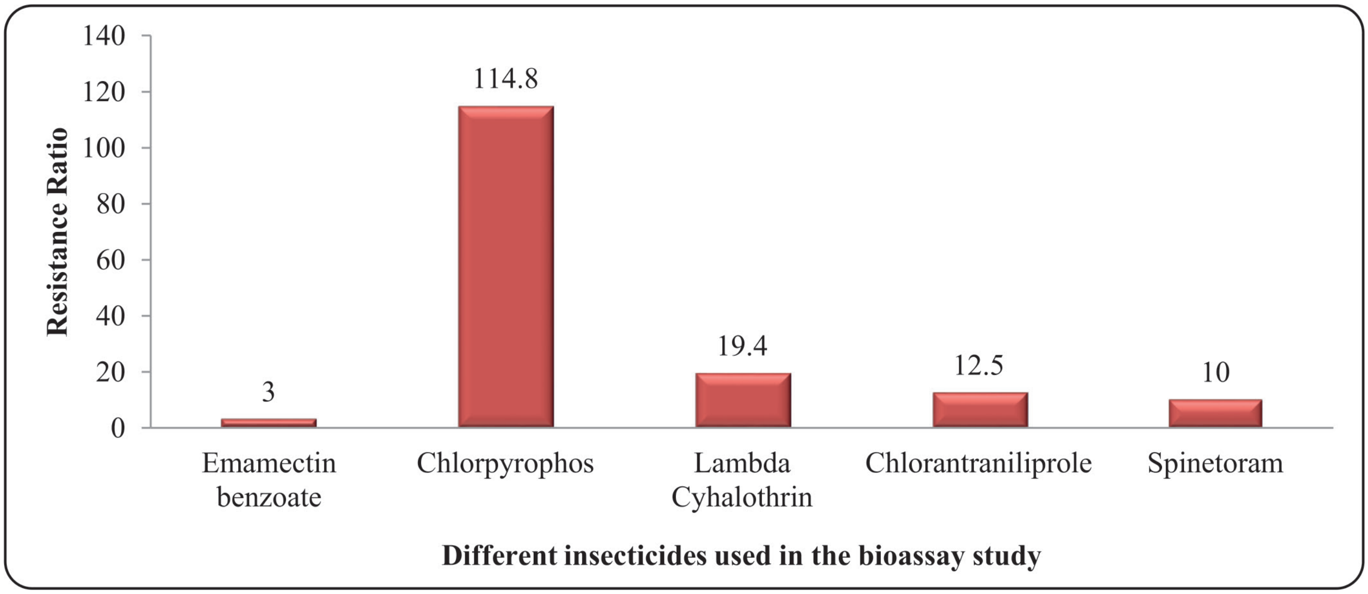

Fig. 1. Relative resistance of fall armyworm, *S. frugiperda* to different insecticides in Chittoor district.

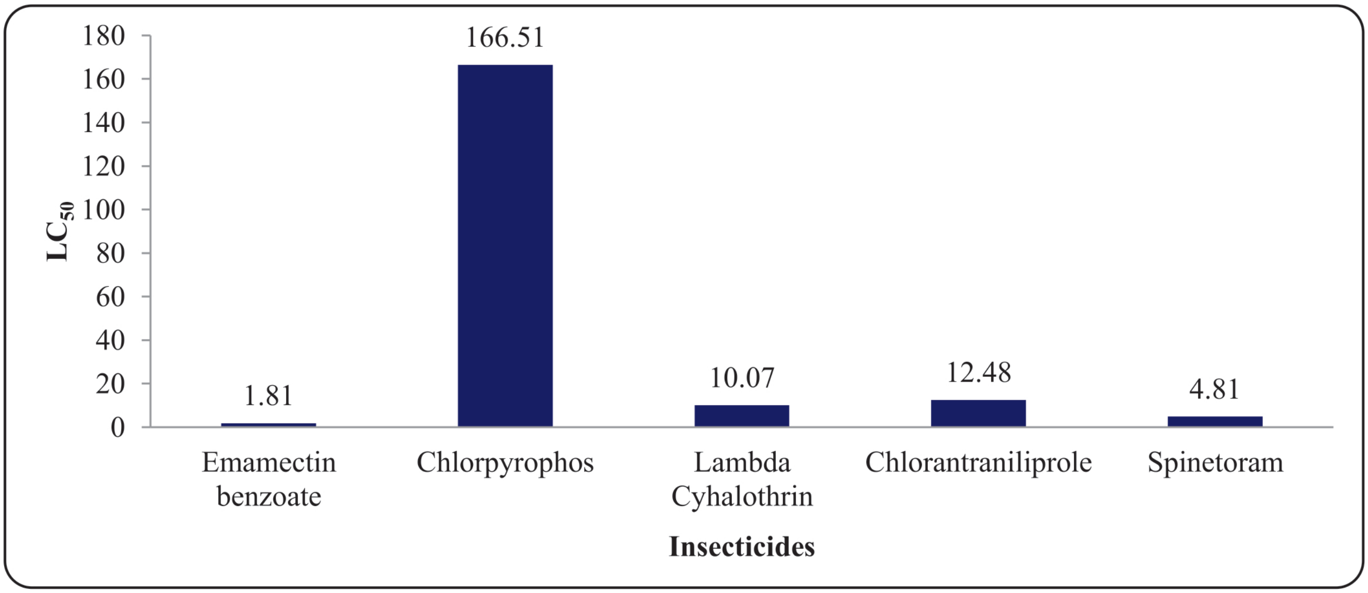

Fig. 2. LC_{50} values of different insecticides used against FAW from Chittoor district.

Fall armyworm, recently introduced transboundary pest into India exhibited insecticide resistance to test insecticides belongs to different groups. This is the first report of resistance development in *S. frugiperda* populations from Andhra Pradesh. The data generated in this study on susceptibility of FAW to different insecticides can be used as a baseline for future IRM studies on *S. frugiperda* populations in Andhra Pradesh. Even though fall armyworm is a new invasive pest it is showing higher level of resistance to different class of insecticides indicating the increased resistance to different class of insecticides.

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