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Field Evaluation of some Newer Insecticides on American Fall Armyworm, *Spodoptera frugiperda* (Smith) and its Natural Enemies on Maize

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ABSTRACT: American fall armyworm (FAW) has becomes a major insect pest on maize crop and causing tremendous yield losses. Farmers are more inclined towards the use of chemical insecticides in controlling FAW on maize crop. So. it is necessary to suggest them the insecticides which will not only control the FAW population efficiently but also maintain a natural balance of FAW and its natural enemies by considering above conditions a study was carried out on "Field evaluation of some newer insecticides on American fall armyworm, *Spodoptera frugiperda* (Smith) and its natural enemies on maize" at the research field of Department of Entomology, Dr. PDKV, Akola, during *kharif* 2019. The treatments included Chlorantraniliprole 18.5SC @ 4 ml/10 L, Spinetoram 11.7 SC @ 9 ml/10 L, Indoxacarb 14.5 SC @10 ml/10 L, Thiamethoxam12.6 ZC+Lambda-cyhalothrin 9.5 ZC @ 2.5 ml/10 L, Dimethoate 30 EC @ 12 ml/10 L, Spinosad 45 SC @ 3 ml/ 10 L, Emamectin benzoate 5 SG @ 4 gm/10 L along with control (no spray). All tested insecticides were found significantly superior and effective against fall armyworm in compare to the control (no spray) and succesfully reduces 70-96.63% population of fall armyworm. Among insecticides spinosad 45 SC @ 3 ml/ 10 L was proved most effective with 96.63% mortality in fall armyworm and it was found to be at par with other insecticidal treatments. During the study natural enemies such as lady bird beetle, spiders and carabid larva are recorded attacking fall armyworm. The effect of the above mentioned insecticides was recorded on these natural enemies also. Tested insecticides showed 40.28-86.27% reduction in population of natural enemies. Spinosad 45 SC @ 3 ml/ 10 L, Emamectin benzoate 5 SG@ 4 gm/10 L and Chlorantraniliprole 18.5 SC @ 4 ml/10 L are found to be comparatively safer to the natural enemies with mortality rate of 40.28-58.08%. On the other side, insecticides like Indoxacarb 14.5 SC @10 ml/10 L, Thiamethoxam 12.6 ZC+Lambda-cyhalothrin 9.5 ZC @ 2.5 ml/10 L, and Dimethoate 30 EC @ 12 ml/10 L showed more mortality in natural enemies in range of 70.83-86.27%. The present findings indicate that the newer insecticides are better option in managing the American fall armyworm on maize and can be included in Integrated Pest Management as one of the chemical components and can be used alternatively.

Keywords: American fall armyworm, maize, Spinosad, Chlorantraniliprole, Emamectin benzoate, natural enemies.

INTRODUCTION

American Fall armyworm, *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) is of origin of South America and has spread in number of countries of Africa, Asia. It is considered as an important invasive pest in India. *S. frugiperda* is a polyphagous insect pest that attacks more than 80 plant species. *S. frugiperda* has becomes a great threat to maize in recent time. *S. frugiperda* is reported infesting maize crop in Karnataka, Tamilnadu and Telangana states of India (Sisodiya *et al.*, 2018). Early instar larvae feeds on epidermal leaf tissue and make holes in leaves. Fall armyworm is able to damage a range of vegetative to reproductive plant structures and causing devastating crop losses. As it disperses rapidly and inflicts widespread damage across multiple crops, FAW poses a serious threat to the food security and livelihood of millions of farming households (Prasanna, 2018). FAW attacks all crop stages of Maize. They defoliate and can kill young plants, whorl damage can result in yield losses and ear feeding can results in grain quality and yield losses (Capinera, 1999). About 4.1 to 17.7 million ton maize yield losses per year is estimated by CABI in 12 maize producing countries without control on FAW (Rwomushana *et al.*, 2018). Native biocontrol agent of *Spodoptera* spp. has a chance to expand their niche by parasitizing *S. frugiperda*, a closely related pest of foreign origin. It is most probable that local bioagents may widen their niche by adapting to *S. frugiperda* and check its population build up and further spread (Sharanabasappa *et al.*, 2019). Hence there is need to identify potential bioagents and to try all possible ways to conserve them in crop ecosystem. In order to control fall armyworm population as well as to conserve natural enemies, it is necessary to look beyond conventional insecticides. Taking in account of the above points an experiment aimed to evaluate the effect of newer insecticides on American fall armyworm as well as on its natural enemies under field conditions on maize crop. This research will be helpful during making IPM strategies for fall armyworm at Akola region.

MATERIAL AND METHODS

A field study was conducted in *kharif* 2019 at Department of Agricultural Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola on plot size 5.4 × 3 m^2 with spacing 60 × 20 cm and variety Uday (Mahabeej-1114) of maize. Trial was fitted up in a randomized block design consist of 8 treatments along with control (no spray) replicated thrice.

Table 1: Details of treatments.

Treatments		Dose g or ml/10 L water
T1	Chlorantraniliprole 18.5 SC	4 ml
T2	Spinetoram 11.7 SC	9 ml
T3	Indoxacarb 14.5 SC	10 ml
T4	Thiamethoxam12.6ZC+Lambda-cyhalothrin9.5ZC	2.5 ml
T5	Dimethoate 30 EC	12ml
T6	Spinosad 45 SC	3ml
T7	Emamectin benzoate 5% SG	4gm
T8	Control (no spray)	-

Treatments (spraying) were put in as soon as the incidence of FAW was noticed and each treatment was replicated thrice. The pre-treatment observations for *S. frugiperda* (i.e. number of larvae per plant) and for natural enemies were recorded one day before spraying. After treatment completion observations on *S. frugiperda* population were taken on 3^{rd}, 7^{th}, and 10^{th} days after spraying by destructive sampling method (Hardke *et al.,* 2011) on randomly selected five plants per plot. Similarly average population of natural enemies was recorded on randomly selected 5 plants at 3^{rd}, 7^{th}, and 10^{th} days after insecticidal application. This field collected data was subjected to square root transformation before analysis. The square root transformed data was analyzed statistically for its significance by following ANOVA technique for Randomized Block Design (RBD) statistical design and the result were interpreted at 5% level of significance.

Percent reduction in fall armyworm population and natural enemies was calculated by using following formulae:

$$\text{Percent reduction} = \frac{\text{Pre - treatment count} - \text{Population in treatment}}{\text{Pre - treatment count}} \times 100$$

RESULTS AND DISCUSSION

A. Cumulative effects of newer insecticide on S. frugiperda during Kharif 2019

Cumulative data on effects of newer insecticide on *S. frugiperda* for *Kharif* 2019 is presented in Table 2. Pre-treatment count of FAW in experimental plots was found in a range of 1.47-2.37 larvae per plant with no significant difference. According to the final data, all treatments were found superior to control (no spray) and equal with each other in efficacy against american fall armyworm. Amongs all insecticides, Spinosad 45 SC @ 3 ml/ 10 L stands most effective and recorded decline in fall armyworm population as 0.06 larvae per plant from pre treatment count of 1.83 larvae per plant which calculated as 96.63% reduction in pest population. Second best treatment was recorded as Chlorantraniliprole 18.5 SC @ 4 ml/10 L with 94.33% reduction, followed by Emamectin benzoate 5% SG @ 4 gm/10 L (93.67% reduction), Spinetoram 11.7 SC @ 9 ml/10 L (91.67% reduction), Thiamethoxam 12.6 ZC+Lambdacyhalothrin 9.5 ZC @ 2.5 ml/10 L (77.00% reduction), Indoxacarb 14.5 SC @10 ml/10 L (73.33% reduction), and Dimethoate 30 EC @ 12 ml/10 L (70.00% reduction). Significantly higher increase in fall armyworm population was recorded in unprotected plot (control) this was recorded from 2.27 to 11.47 larvae per plant.

Previously, Hardke *et al.* (2011) evaluated cyantraniliprole, chlorantraniliprole, flubendiamide, lambda-cyhalothrin, methoxyfenozide, and novaluron along with control treatment against *S. frugiperda.* Application of Chlorantraniliprole and cyantraniliprole resulted in more than 40% mortality at 28 DAT. The result indicated that newer insecticides are equal to or more efficient against american fall armyworm than traditional insecticides. Burtet *et al.* (2017) reported spinetoram; methomyl+chlorantraniliprole and Avatar (acephate+imidacloprid); and lambda-cyhalothrin + lufenuron and lambda-cyhalothrin + chlorantraniliprole as the most effective insecticides against *Spodoptera frugiperda* larvae in B*t* and non-B*t* maize. Assefa (2018) showed that the use of chlorantraniliprole and cyantraniliprole as seed treatments in soybean reduces the need for foliar sprays against fall armyworm in Ethiopia. Worku and Erabuye (2019) conducted field experiment and concluded that the Profenophos+cypermethrin and spinosad gives maximum mortality of sixth instar larva effectively in the whorls; followed by Profenophos+lambda-cyhalothrin and indoxacarb. The study suggested to spray over the canopy which would be more effective against earlier larval instars since these could not hide in the whorl like those of the sixth instar. Sisay *et al.* (2019) tested nine synthetic insecticides for their efficacy against *S. frugiperda* under field conditions. In the first spraying, the lowest number of live *S. frugiperda* larva was recorded in the spinetoram treated plants. In the second and third sprayings of lambda-cyhalothrin + chlorantraniliprole 5 EC and spinetoram 120 SC, no live larvae were recorded from treated plants. Sharanabasappa *et al.* (2020) evaluated field efficacy of some insecticides against fall armyworm in maize.

Table 2: Cumulative effect of 1st, 2nd and 3rd spray of newer insecticides against *S. frugiperda*.

Sr. No.	Treatment	Doseg or ml/10 L water	Infestation of fall armyworm				Percent reduction in population
			PTC	3 DAS	7 DAS	14 DAS	
1.	Chlorantraniliprole 18.5 SC	4 ml	2.11 (1.76)	2.37 (1.84)	1.93 (1.71)	0.12 (1.06)	94.33
2.	Spinetoram 11.7 SC	9 ml	1.95 (1.72)	1.91 (1.71)	1.50 (1.58)	0.16 (1.08)	91.67
3.	Indoxacarb 14.5 SC	10 ml	1.89 (1.70)	1.46 (1.57)	1.34 (1.53)	0.50 (1.23)	73.33
4.	Thiamethoxam12.6 ZC +Lambdacyhalothrin 9.5 ZC	2.5 ml	1.67 (1.63)	1.56 (1.60)	1.38 (1.54)	0.38 (1.18)	77.00
5.	Dimethoate 30 EC	12ml	2.37 (1.83)	2.10 (1.76)	1.98 (1.73)	0.71 (1.31)	70.00
6.	Spinosad 45 SC	3ml	1.83 (1.68)	1.93 (1.71)	1.55 (1.60)	0.06 (1.03)	96.63
7.	Emamectin benzoate 5 SG	4gm	1.47 (1.57)	1.22 (1.49)	0.69 (1.30)	0.09 (1.05)	93.67
8.	Control	-	2.27 (1.81)	4.16 (2.27)	12.14 (3.62)	11.47 (3.53)	---
F test			Non-sig	Sig	Sig	Sig	
SE (m) +			0.12	0.12	0.13	0.08	
CD @ 5 %			0.37	0.37	0.40	0.23	
CV (%)			12.42	12.25	12.68	9.20	

*Figures in parentheses are corresponding square root transformation value; *DAS- Days After Spraying; *Pre-treatment count

Table 3: Cumulative effect of newer insecticides on population of natural enemies.

Sr. No.	Treatment	Dosage or ml/10 L water	PTC			3 DAS			7 DAS			14 DAS			Percent reduction in population		
			LLB	Spider	Carabid larvae	LLB	Spider	Carabid larvae	LLB	Spider	Carabid larvae	LLB	Spider	Carabid larvae	LLB	Spider	Carabid larvae
1.	Chlorantraniliprole 18.5 SC	4 ml	0.65 (1.28)	1.67 (1.63)	1.20 (1.48)	0.35 (1.16)	1.26 (1.50)	1.13 (1.46)	0.26 (1.12)	1.1 (1.45)	0.8 (1.34)	0.32 (1.15)	0.70 (1.30)	0.61 (1.27)	50.31	58.08	49.17
2.	Spinetoram 11.7 SC	9 ml	0.59 (1.26)	0.68 (1.30)	0.87 (1.37)	0.36 (1.17)	0.54 (1.24)	0.67 (1.29)	0.24 (1.11)	0.32 (1.15)	0.45 (1.20)	0.32 (1.15)	0.33 (1.15)	0.38 (1.17)	45.08	51.62	56.32
3.	Indoxacarb 14.5 SC	10 ml	1.04 (1.43)	1.06 (1.44)	1.47 (1.57)	0.97 (1.40)	0.85 (1.36)	1.2 (1.48)	0.45 (1.20)	0.28 (1.13)	0.89 (1.37)	0.18 (1.09)	0.15 (1.07)	0.32 (1.15)	82.69	85.85	78.23
4.	Thiamethoxam12.6 % ZC+Lambdacyhalothrin 9.5 ZC	2.5 ml	1.03 (1.42)	0.99 (1.41)	1.20 (1.48)	0.89 (1.37)	0.65 (1.28)	0.98 (1.41)	0.23 (1.11)	0.45 (1.20)	0.56 (1.25)	0.17 (1.08)	0.16 (1.08)	0.25 (1.12)	83.50	83.84	79.17
5.	Dimethoate 30 EC	12ml	1.02 (1.42)	0.98 (1.4)	1.20 (1.48)	0.89 (1.37)	0.76 (1.33)	0.98 (1.41)	0.34 (1.16)	0.34 (1.16)	0.54 (1.24)	0.14 (1.07)	0.17 (1.08)	0.35 (1.16)	86.27	82.76	70.83
6.	Spinosad 45 SC	3ml	0.72 (1.31)	1.55 (1.60)	1.30 (1.52)	0.67 (1.29)	1.45 (1.57)	1.23 (1.49)	0.43 (1.20)	1.32 (1.52)	1.1 (1.45)	0.43 (1.20)	0.87 (1.37)	0.66 (1.29)	40.28	43.87	49.23
7.	Emamectin benzoate 5% SG	4gm	0.73 (1.32)	1.45 (1.57)	1.21 (1.49)	0.64 (1.28)	1.34 (1.53)	1.03 (1.42)	0.32 (1.15)	1.18 (1.48)	0.97 (1.40)	0.40 (1.18)	0.76 (1.33)	0.63 (1.28)	45.34	47.59	47.93
8.	Control	-	0.45 (1.20)	1.24 (1.50)	1.12 (1.46)	0.56 (1.25)	1.47 (1.57)	1.16 (1.47)	0.69 (1.30)	1.54 (1.59)	1.42 (1.56)	1.02 (1.42)	1.61 (1.62)	1.58 (1.61)	-126.67	-29.84	-41.07
F test		-	S	S	S	NS	NS	NS	S	S	S	S	S	S	-	-	-
SE (m) +		-	0.76	0.76	0.76	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.03	-	-	-
CD5%			2.30	2.30	2.30	0.16	0.16	0.16	0.16	0.16	0.16	0.09	0.09	0.09	-	-	-
CV			23.27	23.27	23.27	6.7	6.7	6.7	6.9	6.9	6.9	3.98	3.98	3.98	-	-	-

Note: Figures in parentheses are corresponding square root transformation values., DAS- Day After Spraying

Results showed chlorantraniliprole 18.5 SC as most effective insecticide, followed by emamectine benzoate 5 SG, spinetoram 11.7 SC, flubendiamide 480 SC, indoxacarb 14.5 SC, lambda-cyhalothrin 5 EC and novaluron 10EC.

B. Occurrence of natural enemies in association with S. frugiperda

During the study natural enemies namely, lady bird beetle, carabid larvae and spiders were observed dominantly in association with *S. frugiperda* in maize ecosystem (Plate 2). The population of natural enemies at unprotected plots was recorded. The population of ladybird beetle was observed in range of 0.45 to 1.02 adult and grubs/plant. The population of spider recorded in range of 1.24 to 1.61 spiders/ plant and the population of carabid larvae observed in a range of 1.12 to 1.58 larvae/ plant.

Earlier, Shylesha *et al.* (2018) surveyed the natural enemies of *S. frugiperda*. Survey disclosed the presence of egg parasitoids *viz.*, *Telenomus* sp. and *Trichogramma* sp., solitary larval parasitoid, *Campoletis chloridea*, gregarious larval parasitoid, *Glyptapanteles creatonoti* (Viereck) and *Forficula* sp. (Dermaptera). Sharanabasappa *et al.* (2019) conducted survey in southern India from June to August 2018 and identified three Predators *viz.*, *Forficula* sp, *Hormonia octomaculata*, *Coccinella transversalis*; five larval parasitoid *viz.*, *Coccygidium melleum*, *Campoletis chloridae*, *Eriborus* sp, *Exorista sorbillans*, *Odontepyris* sp.; one entomopathogenic fungi, *viz.*, *Nomuraea rileyi*. Abang *et al.* (2021) recorded two egg parasitoids viz., *Telonemus remus* and *Trichogramma* sp. and four larval parasitoids, *Charops* sp., *C. luteum*, *C. sesamiae* and *C. icipe* in Cameroon.

C. Cumulative effect of newer insecticides on natural enemies of American fall Armyworm

Data on the cumulative effect of newer insecticides on natural enemies is presented in Table 3. Pre-treatment count for lady bird beetle was recorded in range of 0.45 to 1.04 lady bird beetle/ plant, for spider this range was 0.68 to 1.67 spiders/ plant and for carabid larvae this range was 0.87 to 1.47 larvae/ plant. After spraying when final count taken data showed that the test insecticides like Spinosad 45 SC @ 3ml/10 L with 40.28-49.23% of reduction in natural enemies population, Emamectin benzoate 5 SG @ 4gm/10 L with 45.34- 47.93% reduction, Chlorantraniliprole 18.5 SC @ 4 ml/10 L with 49.17-58.08% reduction and spinetoram 11.7 SC with 45.08-56.32% reduction in natural enemies population stand safer to the spiders, carabids and coccinellids in maize ecosystem. Insecticides such as indoxacarb 14.5 SC @10 ml which showed 78.23-85.85% mortality in natural enemies, Thiamethoxam12.6 ZC+Lambdacyhalothrin 9.5 ZC @2.5 ml with 79.17-83.84% mortality, Dimethoate 30 EC@12 ml with 70.83-86.27 % mortality in natural enemies are not suitable for IPM program and application of these chemical insecticides should be avoided if natural enemies are avainable in abundance.

The above results are in confirmation with previous researchers like Dai-bin *et al*. (2013) reported lambda-cyhalothrin as extremely toxic for hunting spiders, *Xystichus ephippiatus* and can not be used in IPM programs. Emamectin benzoate reduced *X. ephippiatus* population by 58.1-61.4%, but the populations recovered at the end of the experiment. Chlorantraniliprole found relatively safe to *X. ephippiatus*. It reduced *X. ephippiatus* populations by 22.3-33.0%, and the populations totally recovered nine days after application. Saner *et al.* (2014) studied the insecticidal effect on ladybird beetles, *Menochilus sexmaculatus* L. Studies showed lambda cyhalothrin 5 SC (0.96 ladybird beetles /plant) and imidacloprid 17.80 SL (0.92 ladybird beetles /plant) ecofriendly. Wagh *et al.* (2017) showed that the insecticides viz., spinosad 45 SC and abamectin 1.9 EC, chlorantraniliprole 18.5 SC and novaluron 10 EC are safer to the predatory coccinellid beetles and flubendiamide 39.35 SC as moderately toxic to coccinellids.

Plate 1. Fall armyworm larvae and infestation.

Plate 2. Natural enemies observed in association with Fall armyworm on maize.

Whereas, cypermethrin 25 EC was found highly toxic to predatory beetles. Abdullah *et al.* (2019) showed that the Emamectin benzoate and lufenuron can manage *S. litura* also these are relatively safer for beneficial insects as ladybird beetle, *Coccinella septempunctata* L., honeybee, *Apis mellifera* L. and green lacewing, *Chrysoperla carnea* in compared to conventional insecticides, methoxyfenozide, and chlorpyrifos. Similar findings were reported by Soares *et al.* (2019) where the alpha-cypermethrin was found highly toxic to Brazalian wasp, *Protonectarina sylveirae* and paper wasp, *Brachygastra lecheguana* in recommended dose (100%) and sub dose (50%). Whereas, the Novaluron, chlorantraniliprole, spinosad and indoxacarb found safer to *P. sylveirae* and *B. lecheguana* in recommended dose and sub dose.

CONCLUSIONS

Amongs all seven insecticidal treatments, Spinosad 45 SC @ 3 ml/ 10 L was found as the most effective one with 96.63% reduction in pest population. Second best treatment was recorded as Chlorantraniliprole 18.5 SC followed by Emamectin benzoate 5% SG, Spinetoram 11.7 SC, Thiamethoxam 12.6 ZC+Lambdacyhalothrin 9.5 ZC, Indoxacarb 14.5 SC and Dimethoate 30 EC. Natural enemies such as Lady bird beetle, spider and carabid larvae are found in association with different stages of *S. frugiperda* on maize at Dr. PDKV, Akola. The effect of the above mentioned insecticides was recorded on these natural enemies also. Tested insecticides showed 40.28-86.27% reduction in population of natural enemies. Spinosad 45 SC @ 3 ml/ 10 L, Emamectin benzoate 5 SG@ 4 gm/10 L and Chlorantraniliprole 18.5 SC @ 4 ml/10 L are found to be comparatively safer and less detrimental to natural enemies with mortality rate of 40.28-58.08%. On the other side, Indoxacarb 14.5 SC @10 ml/10 L, Thiamethoxam12.6 ZC+Lambda-cyhalothrin 9.5 ZC @ 2.5 ml/10 L, and Dimethoate 30 EC @ 12 ml/10 L showed relatively more mortality in range of 70.83-86.27% which proved them unsuitable for IPM program. Spraying of these insecticides should be avoided if natural enemies are present in abundance. From the present study it can be concluded that, newer insecticides are better option in managing the american fall armyworm on maize and can be included in IPM as one of chemical components and can be use alternatively.

FUTURE SCOPE

Present study will be helpful in selecting safer insecticides for fall armyworm control on maize which eventually will conserve natural enemies and will contribute in development of Integrated Pest Management framework in Maize crop.

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