Research Article

FIELD EFFICACY OF SELECTED INSECTICIDES AGAINST FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J.E. SMITH) IN MAIZE

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ABSTRACT

Action research was conducted to evaluate five selected commercial formulations of insecticides against newly introduced fall armyworm *Spodoptera frugiperda* (J.E. Smith) at Gaindakot of Nepal. Experiments were superimposed at hotspots in maize field with replicated RCB design during June 2019. The treatments included were Spinosad, Chlorantraniliprole, Emamectin benzoate, Imidacloprid and Azadirachtin along with non-treated control and applied in natural infestation of fall armyworm. On the basis of percent plant infestation with live larvae, percent plants with foliar damage by larvae and its damage score, Spinosad, Chlorantraniliprole and Emamectin benzoate were found promising for *S. frugiperda* management in maize, though Imidacloprid and Azadirachtin were also found effective statistically.

Key words: *Azadirachtin, chlorantraniliprole, emamectin benzoate, Spodoptera frugiperda, spinosad.*

INTRODUCTION

Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is an invasive insect pest of maize in Nepal. The *S. frugiperda* had been reported for the first time in Nepal from Gaindakot of Nawalpur district (N 27°42'16.67", E 084°22'50.61") in May 2019. Since then the insect has been spread into various maize growing agro-ecological zones of Nepal. The insect has been recorded from southern plain areas below 100 m above sea level to northern high hills of 1700 m above sea level (Bajracharya *et al*., 2019). *S. frugiperda* has very wide host range and 353 plant species has been recorded as larval host belonging to 76 plant families including major hosts from Poacaea, Asteraceae and Fabaceae (Debora, 2018). Maize is a preferred host and it can cause major damage to cultivated sorghum, rice, wheat, finger millet, sugarcane, cabbage, beet, groundnut, soybean, onion, cotton, tomato, potato and many fodder grasses (Prasanna *et al*., 2018). Fall armyworm larvae feed on vegetative as well as reproductive parts of maize including leaf, whorl, tassel and cob. This pest is strong flier with migratory and localized dispersal habit. Yield losses of maize, by

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feeding of *S. frugiperda* larvae were estimated, 20.15 percent in African countries (Abrahams *et al*., 2017) and 34 percent in Brazil (Cruz *et al*., 1999).

Female moth of fall armyworm lays more than 1000 eggs in multiple clusters covered with abdominal hairs mainly on lower surface of maize leaves (ICAR-IIMR, 2018). Newly born larvae aggregate near egg masses; however, after some time larvae aggressively disperse through crawling and ballooning from hatching site within and across adjacent plants and start feeding on lower surface of young leave. Young larvae feeding on green tissue from lower surface of maize leaves do not consume upper epidermis resulting into elongated papery window like damage symptoms (ICAR-IIMR, 2018). Third instar and above larvae cause ragged edged round or oblong holes on maize leaves and size of holes increase with growth of larvae. As larvae grow, they start to feed inside the whorl of maize plant and deposit fecal matter in the whorl. At reproductive stage of maize plant both tassels and maize cobs along with silk are found damaged by larvae of fall armyworm. *S. frugiperda* is a destructive insect pest of maize and new to farmers and plant protectionist in Nepal thus lacking appropriate and immediate management techniques against this pest. In such context, farmers in infected areas of Nepal were spraying various highly toxic insecticides like cocktail formulation of Chloropyriphos 50% and Cypermethrin 5% which were readily available in local market under various trade names. Farmers were using high doses of various insecticides with frequent applications. The primary management strategies for *S. frugiperda* in its Native American countries are use of genetically modified Bt maize and various recommended synthetic insecticides sprays. Many insecticides recommended against fall armyworm in other countries were either not registered in Nepal or not easily available in local market. Considering all these facts some selected insecticides including insecticides with novel mode of action were evaluated against fall armyworm which was available in local market. This paper highlights the field efficacy of selected insecticides against fall armyworm which would be one of the components of integrated management of this insect pest in future.

MATERIALS AND METHODS

Action research was conducted to evaluate selected five commercial formulations of insecticides against fall armyworm *S. frugiperda*. Superimposed experiment in RCB design was laid at farmers' fields (169 m asl) in Gainndakot of Nawalparasi district during June 2019. Three farmers'fields with 90-100 percent *S. frugiperda* larval infestation were selected for experiment which was used as three replications. The fields were line sown with Dragon hybrid variety of maize and plants were 25-28 days old. The plants were planted at the average spacing of 60cm X 25cm. The fields were divided into 6 plots of size 8m X 6m in each replication. The plant population in each plot was 280-320. Five different insecticides were sprayed in five separate plots and one plot was kept as non-treated control in each replication. All the insecticides were applied adding sticker @ 1ml/ liter of insecticide solution. Each plot was sprayed with three liters of solution at first spray and four liters of solution during second spray and the control was sprayed with sticker solution. The chemicals were sprayed twice on June 5 and June 16 in 11 days interval with the help of knapsack sprayer. The details of treatments with included in the experiment were given in Table 1.

Table 1. List of treatments with their chemical names, formulations, doses and trade names.

SN	Chemical name	Formulation	Dose	Trade name
1	Spinosad	45 % SC	0.3 ml/liter of water	Tracer
2	Chlorantraniliprole	18.5 % SC	0.4 ml/liter of water	Coragen
3	Emamectin benzoate	5 % SG	0.4 g/liter of water	Kingstar
4	Imidacloprid	17.8 % SL	0.3 ml/liter of water	Sumo
5	Azadirachtin	0.15 % EC	5 ml/liter of water	Margo
6	Non-treated control		water	

Observations on various parameters were recorded twice 10 days after first and second spray. Observations were taken from 10 randomly selected plants. The plants were observed for presence or absence of live larvae. The presence or absence of foliar damage on upper four leaves and whorl were recorded. The damage scoring was done in each observed plant with the help of foliar damage scoring scale given in Table 2 which was modified from Davis and Williams (1992). The data collected were converted into "percent plants infested with live larvae" and "percent plants with whorl damage symptoms". The percent data were transformed into arcsine and ANOVA (Analysis of Variance) and DMRT (Duncan's Multiple Range Test) in Genstat Discovery 4 computer software.

Table 2. Scoring scale (0-5) for assessment of foliar damage due to fall armyworm.

Score	Damage symptoms/description
0	No visible feeding symptoms on upper leaves and whorl.
1	Papery window damage symptoms on upper leaves and whorl.
2	Few small holes on upper leaves and whorl.
3	Ragged holes on upper leaves and partially whorl damaged.
4	Whorl and upper leaves extensively damaged.
5	Whorl completely destroyed and plant drying due to extreme defoliation

RESULTS AND DISCUSSION

Percentage of maize plants infested with live larvae of fall army after spraying various insecticides treatments are given in Table 3. All the insecticides were found significantly effective in reducing fall armyworm infestation after both first and second sprays. Spinosad and Chloroantraniliprole were found consistently superior in reducing fall armyworm infestation. Live larvae were not found in maize plants sprayed with Spinosad and Chlorantraniliprole after second spray. Whereas only 3.33 percent plants were found infested with live larvae after first spry of Spinosad and Chlorantraniliprole. Emamectin benzoate benzoate was found as effective as Spinosad and Chlorantrniliprole after second spray with 3.33 percent plant infestation. However, 20 percent plants were found infested with live larvae after first spray of Emamectin benzoate. Imidacloprid and Azadirachtin were found at par in *S. furgiperda* infestation after second spray with 36.67 and 40 percent infested plants. Similarly, 30 and 43.3 percent maize plants were found infested in Imidaclroprid and Azadirachtin sprayed plots respectively after first spray. Maize plants in control plots were found 100 percent infested with live larvae of *S. frugiperda* after both first and second observations.

Table 3. Percentage of plants infested with fall armyworm larvae after insecticides treatments.

Treatments	Percent Plants infested with live larvae	
	AFS*	ASS*
Spinosad	3.33^{a}	0.00^{a}
Chlorantraniliprole	3.33^{a}	0.00^{a}
Emamectin benzoate	20.00^{b}	3.33^{a}
Imidacloprid	30.00^{bc}	36.67^{b}
Azadirachtin	43.33^{c}	40.00^{b}
Non-treated control	100.00^{d}	100.00^{c}
P value	<0.001	<0.001
CV (%)	23.3	22.5

*AFS: After first spray, ASS: After second spray.

Percentage of plants with fall armyworm larvae damage symptoms in whorl and upper leaves with their average foliar damage score is given in Table 4. On the basis of damage symptoms on whorl and upper four leaves, Spinosad and Chlorantraniliprole were found superior treatment compared to all other treatments. Damage symptoms were recorded, in less than 20 percent maize plants after first spray which reduced to below 6.67 percent after second spray. The average foliar damage score was 1 with few small papery window damage symptoms. Emamectin benzoate was found second most effective insecticide on the basis of damage symptoms in whorl and upper leaves. Around 43.33 percent of maize plants in Emamectin benzoate treated plots were found damaged by fall armyworm larvae after first spray which reduced to 13.33 percent after second spray. The average damage scoring scale ranged between 1 to 2 with papery widows and few holes in leaves and whorl. Cent percent maize plants were found damaged in control plots and damage score was 4 showing extensive damage in whorl and upper leaves. Imidacloprid and Azadirachtin treated plots recorded less than 83.33 percent of maize plants with damage symptoms with damage score ranged between 2 to 3. However, performance of Imidacloprid and Azadiracthitn was not consistent after first and second sprays and statistically at par with control after second sprays.

Table 4. Percentage of plant with fall armyworm larvae damage symptoms in whorl and upper leaves with their average foliar damage score.

Insecticides	Percent plant with whorl damage symptoms		Average foliar damage score	
	AFS*	ASS*	AFS	ASS
Spinosad	16.67[a]	3.33[a]	1	1
Chlorantraniliprole	20.00[a]	6.67[a]	1	1
Emamectin benzoate	43.33[b]	13.33[b]	1-2	1
Imidacloprid	76.67[c]	60.00[c]	2-3	2
Azadirachtin	70.00[c]	83.33[c]	2	2
Non-treated control	100.00[d]	100.00[c]	4	4
P value	<0.001	<0.001		
CV (%)	14.7	20.8		

*AFS: After first spray, ASS: After second spray.

On the basis of observed parameters; percent plant infestation with live larvae, percent plant with foliar damage by larvae and its damage score, Spinosad and Chlorantraniliprole were found best insecticide to reduce *S. frugiperda* infestation in maize field in Nepal. Sisay *et al*. (2019) also found Spinosad and Chlorantraniliprole were effective in reducing foliar damage of maize compared to the untreated control in green house experiment (Sisay *et al.*, 2019). They also noticed chemical sprays did not affect plant height, stem thickness, or leaf number of maize plants. Similarly, Hardke *et al*. (2011) reported that Chlorantraniliprole is highly effective in bioassay against *S. frugiperda* in laboratory as well as effective in controlling the pest in field sorghum (Hardke *et al.*, 2011). Emamectin benzoate was found second most effective insecticide among treatments on the basis of observed parameters. Emamectin benzoate is a superior insecticide against lepidopteran insect pests (Argentine *et al*., 2002) and it was found very effective against *S. frugiperda* in laboratory conditions when tested in pesticide treated cotton leaves and flowers (Adamczyk *et al*., 1999).

Insecticides: Spinosad, Chlorantraniliprole and Emamectin benzoate could be used in properly and alternately to manage fall armyworm in Nepal in context of lacking well developed IPM package as insect is very new to Nepalese farming community as well as researchers and extension agents. Biological control of the insect with indigenous parasitoids and predators could become important part of sustainable *S. frugiperda* management in hill maize farming community of Nepal in future. Similarly, bio-pesticides developed from indigenous Nuclear Polyhedrosis Virus (NPV), *Bacillus thuringeinsis* (Bt) and fungus species would be important tool of fall armyworm management for commercial maize growers. Cultural practices including proper nutritional and water management need to be developed for integration with chemical and biological management practices. Resistant breeding would be another area need to be exploited in long term management of *S. frugiperda*. Insecticides are not only and ultimate solution for the management of fall armyworm as they are prone to resistant development by insect. The reliance on pesticides to control fall armyworm had led to the development of insecticide resistance in Mexico and displayed different level of resistance with different insecticides: Flubendiamide (500-fold), Chlorantraniliprole (160-fold), Methomyl (223-fold), Thiodicarb (124-fold), Permethrin (48-fold), Chlorpyriphos (47-fold), Zeta-cypermethrin (35-fold), Deltamethrin (25-fold), Triflumuron (20-fold), Spinetoram (14-fold), Spinosad (8-fold), Emamectin benzoate and Abamectin (7-fold) (Morento *et al*., 2018). Thus, IPM package need to be developed for safe and sustainable management of *S. frugiperda* in Nepal.

Insecticides: Spinosad, Chlorantraniliprole and Emamectin benzoate are different from traditional insecticides belonging to organophosphate, carbamates and synthetic pyrethroid groups due to their novel mode of action. Spinosad is an insecticide developed from soil bacterium *Saccharopolyspora spinosa*: active component spinosyn act on nicotinic acetyl choline receptor of insect. Chlorantraniliprole belonging to antranilic diamide insecticide affects nervous system of insect through ryanodine receptor of insect muscles. Similarly, Emamectin benzoate isolated from the naturally occurring soil bacteriaum *Streptomyces avermitilis* causes a continuous flow of chlorine ions in the GABA and H-Glutamate receptor sites in insect. Due to their unique mode of actions, if these insecticides are applied in appropriate manner against *S. frugiperda*, development of resistance could be delayed would remain as an effective and important tool of Integrated Pest Management in future for a long period of time.

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LITERATURE CITED

Abrahams, P., T. Beale, M. Cock, N. Corniani, R. Day, J. Godwin, S. Murphy, G. Richards and J. Vos. 2017. Fall armyworm status. Impact and control option in Africa: Preliminary Evidence note. Uk Aid and CABI. 18p.

Adamczyk, J., B.R. Leonard and J.B. Graves. 1999. Toxicity of Selected Insecticides to Fall Armyworms (Lepidoptera: Noctuidae) in Laboratory Bioassay Studies. Florida Entomologist. 82(2): 230-236.

Argentine, J.A., R.K. Jasson, W.R. Halliday, D. Rugg and C.S. Jany. 2002. Potency spectrum and residual activity of four new insecticides under glasshouse conditions. Florida Entomologist. 85(4):552-561. DOI: 10.1653/0015-4040(2002)085 [0552:PSARAO] 2.0.CO;2.

Bajracharya, A.S.R., B. Bhat, P.N. Sharma, P.R. Shashank, N.M. Meshram and T.R. Hashmi. 2019. First record of fall armyworm *Spodoptera frugiperda* (J.E. Smith) from Nepal. Indian Journal of Entomology. 81(3):635-639. DOI: 10.5958/0974-8172.2019.00137.8.

Cruz, E., M.L.C. Figueiredo, A.C. Oliveira and A.V. Carlos.1999. Damage of *Spodoptera frugiperda* (J.E. Smith) in different maize genotypes cultivated in soil in three different levels aluminium saturation. International Journal of Pest Management. 45(4): 293-296.

Debora, M. 2018. Host plant of *Spodoptera furgiperda* (Lepidoptera: Noctuidae) in the Americas. African Entomology. 26(2):286-300.

Hardke, J.T., J.H. Temple, B.R. Leonard and R.E. Jackson. 2011. Laboratory toxicity and field efficacy of selected insecticides against fall armyworm (Lepidoptera: Noctuidae). Florida Entomologist. 94(2):272- 278.

ICAR-IIMR. 2018. Identification and management of fall armyworm *Spodoptera frugiperda*. ICAR-Indian Institute of Maize Research. PAU Campus, Ludhiana, Punjab, India.

Moreno, R.G., D.M. Sanchez, C.A. Blanco, M.E. Whalon, H.T. Santofimio, J.C. Rodriguez-Maciel and C. DiFonzo. 2018. Field-evolved resistance of the fall armyworm (Lepidoptera: Noctuidae) to synthetic insecticides in Puerto Rico and Mexico. Journal of Economic Entomology. 20(10): 1-11. DOI: 10.1093/jee/toy372.

Prasanna, B.M., J.E. Huesing, R. Eddy and V.M. Peschke. 2018. Fall armyworm in Africa: A guide for integrated pest management (1st ed.). CIMMYT, Mexico. 109p.

Sisay, B., T. Tefera, M. Wakgari, G. Ayalew and E. Mendesil. 2019. The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda*, in Maize. Insects. 10(45). DOI: 10.3390/insects10020045.