Indian Journal of Entomology Online published Ref. No. e23329 DoI. No.: 10.55446/IJE.2023.1329

SEED TREATMENT WITH INSECTICIDES- A POTENTIAL OPTION AGAINST FALL ARMY WORM *SPODOPTERA FRUGIPERDA* IN MAIZE

Rakesh Kumar Behera[1, 2]*, Murali Mohan K[2] and Prabhu C Ganiger[2]

[1]Division of Entomology, ICAR-Indian Agricultural Research Institutes, New Delhi 110012, India
[2]Department of Agricultural Entomology, University of Agricultural Sciences, Bangalore 560065, Karnataka, India
*Email: rkbehera41@gmail.com (corresponding author): ORCID ID 0000-0003-0208-5311

ABSTRACT

Spraying with insecticides is generally carried out for the management of fall army worm *Spodoptera frugiperda* (J E Smith) in maize. As the pest causes significant damage in the vegetative stages, seed treatment can also be an option. In the present study, seed treatment has been evaluated for its efficacy in comparison with spray in maize. The results suggested that chlorantraniliprole 62.5FS was more effective than presently used seed treatment with cyantraniliprole. In case of foliar spray, spinetoram 11.7SC along with chlorantraniliprole 18.5SC and emamectin benzoate 5SG were found effective. As seed treatment is easy to practice and economical, seed treatment with diamides, particularly chlorantraniliprole 62.5FS might provide a better alternative to foliar sprays during early crop stage. Hence, an integrated strategy involving seed treatment in combination with need-based foliar spray at later crop stages may make management of *S. frugiperda* more efficient.

Key words: Chlorantraniliprole, cyantraniliprole, diamide, emamectin benzoate, field assessment, foliar spray, seed treatment, spinetoram, *Spodoptera frugiperda*, *Zea mays*

With superior adaptation to agroclimatic conditions, maize (*Zea mays* L.) is by far the most widely grown cereal crop. It is grown over an area of 9.86 million ha in India, with a production of 31.51 mt (Anonymous, 2021). The tremendous development in area and output can be attributed to its varied applications for food, feed, and fodder, which have complimented the expansion of the nation's poultry and other agro-based sectors (Anonymous, 2022). However, the fall army worm *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) poses a continual risk to the production of maize. It is a pest with a large host range that includes around 353 host plants (Montezano et al., 2018). The pest infiltrated Asia in 2018 and was first identified on maize in the Indian state of Karnataka the same year (Ganiger et al., 2018). Since then, most of the nations in the Asia-Pacific area, including Australia and New Zealand, have reported this pest (CABI, 2022). *Spodoptera frugiperda* severely damages maize, mostly during the crop's vegetative stage. In the reproductive stage, the caterpillars feed on the cobs, resulting in a direct economic loss (Kasoma et al., 2021). According to predictions, India might lose more than 70,000 tonnes of maize owing to output losses of 5-10% caused by *S. frugiperda* infestation (Suby et al., 2020). In addition, *S. frugiperda* is considered a noxious and economically significant pest of maize because of its difficulties in management. Due of its chemical control is typically used in crops (Kumar et al., 2022). However, since the larvae dwell within the whorl, foliar spray cannot be effective. The likelihood of resistance development increases with insecticide applications, increasing economic cost and environmental risks (Bird et al., 2022). It is crucial to safeguard the crop during the vegetative crop stage since the larvae severely harm young plants. In this regard, treating the seeds with pesticides may provide a genuine option. Seed treatment can protect the crop both in pre and post emergence stages (Lamichhane et al., 2022). Although farmers in India mostly use insecticide spraying as a management strategy against *S. frugiperda*, seed treatment has also been recommended (Anonymous, 2019). In this research the extent of protection provided by seed treatment in comparison with the chemical spray against *S. frugiperda* in maize is evaluated.

MATERIALS AND METHODS

Three insecticides meant for seed treatment *viz*., cyantraniliprole 19.8% + thiamethoxam 19.8%FS, thiamethoxam 70WS and chlorantraniliprole 62.5FS were used. Cyantraniliprole 19.8% + thiamethoxam 19.8%FS is currently being recommended on *S. frugiperda* in India, while thiamethoxam 70WS has label claim for shoot fly. Chlorantraniliprole 62.5FS is currently under registration for seed treatment against *S. frugiperda* in India. Required quantity of insecticide was diluted in 10 ml of water in separate beakers. Later, 500 g of seeds were treated with each chemical. The seeds were placed in a plastic bag and mixed with chemicals through vigorous agitation for about 15 min to ensure proper coating of seeds. Seeds were then shade dried for two hours and sown in the field. Seeds treated with only water used as control.

Efficacy of seed treatment was assessed in comparison with foliar sprays during rabi 2019-20. This study included seven treatments including control and each treatment was replicated three times following randomized block design. 1 Sweet corn (variety-Sugarita) was grown following all the package and practices recommended by University of Agricultural Sciences, Bangalore. Observations on *S. frugiperda* infestation in the experimental plots were recorded at a weekly interval. The spray with recommended insecticides was given when sufficient infestation was noticed (more than 35%) and it coincided with 21 days after emergence. It was given once during the crop growth, with spray directed towards the whorl region. Observations on extent of foliar damage was recorded on ten randomly selected plants in each replication. Foliage damage % was estimated through visual scoring in a scale of 0-9 following Davis and Williams (1992). Further, comparison on cost of plant protection between sprays and seed treatment was carried out. The data regarding % of leaf damage were subjected to arcsine transformation, and were analysed using one way ANOVA. The % reduction of leaf area damage over untreated control due to seed treatment and after spray of insecticide was determined for estimating efficacy of insecticides by using the Abbott's formula (Abbott, 1925).

RESULTS AND DISCUSSION

No infestation of *S. frugiperda* was noticed at 7 days after emergence (DAE) in the experimental plots. At 14 DAE, the infestation was observed in all the plots and the extent of damage varied from 1.67% to 19.67% (Table 1). Chlorantraniliprole 62.5FS seed treatment resulted in the least leaf damage (1.67%), which was comparable to cyantraniliprole 19.8% + thiamethoxam 19.8%FS (2%). Thiamethoxam seed treatment did not provide any control and showed 17.33% leaf damage which was on par with the control (19.67%). Similar trend was observed in all the sampling days viz.- at 21, 28, 35, and 42 DAE, where the lowest leaf damage was observed in chlorantraniliprole 62.5FS, followed by cyantraniliprole 19.8% + thiamethoxam 19.8%FS. At 21 DAE, when sufficient damage by *S. frugiperda* was noticed (>35%), foliar spraying with insecticides viz., spinetoram 11.7SC, emamectin benzoate 5SG and chlorantraniliprole 18.5SC was carried out. At 7 DAS (which coincided with 28 DAE), lowest leaf damage was recorded in spinetoram 11.7SC (13.67%) followed by chlorantraniliprole 18.5SC (14.33%) and emamectin benzoate 5SG (18.00%). Spinetoram 11.7SC and chlorantraniliprole 18.5SC were found to be on par with each other. Similar pattern was observed at 14 and 21 DAS, where spinetoram 11.7SC was found to be the most effective with lowest leaf damage followed by chlorantraniliprole 18.5SC and emamectin benzoate 5SG.

The % reduction in leaf damage over control in seed treated plots after at 28 DAE showed maximum reduction in chlorantraniliprole 62.5FS seed treatment (58.78%) followed by cyantraniliprole 19.8% + thiamethoxam 19.8%FS seed treatment (39.86%). Likewise, leaf damage reduction at 42 DAE for the seed treated plots revealed that the maximum reduction was found in case of chlorantraniliprole 62.5FS (62.24%) followed by cyantraniliprole 19.8% + thiamethoxam 19.8%FS (46.15%). Thiamethoxam seed treatment recorded 4.20% reduction over untreated control at 42 DAE and did not provide any protection against *S. frugiperda* in maize crop. In case of foliar spray of chemicals, at 7 DAS (at 28 DAE), the reduction over control in leaf damage was 72.30%, 70.95% and 63.51% in spinetoram 11.7SC, chlorantraniliprole 18.5SC and emamectin benzoate 5SG sprayed plots, respectively. The % reduction of leaf damage over control at 21 DAS suggested that spinetoram 11.7SC was the most effective (86.01% reduction) followed by chlorantraniliprole 18.5SC (79.72%) and emamectin benzoate 5SG (59.44%). Analysis of the cost of insecticide treatment suggested that seed treatment with diamides, particularly chlorantraniliprole 62.5FS is economical compared to foliar sprays (Table 1). Though, cost of foliar sprays with emamectin benzoate (per application) was substantially low compared to other insecticides used for foliar sprays, emamectin benzoate treated plots noticed re-infestation within 14 days of spraying. Hence, it may be necessary to repeat the sprays resulting in cost escalations.

Seed treatment with diamide molecules protected maize crop from *S. frugiperda* for relatively longer

Table 1. Efficacy of insecticides used as seed treatment and foliar spray against *S. frugiperda* in maize crop in Rabi 2019-20

Treatments	% Leaf damage (Average of 10 plants/ replication)						Cost of insecticide/ ha (Rupees)	Total cost/ ha/ application (Rupees)
	7 DAE	14 DAE	21 DAE	28 DAE (7 DAS)*	35 DAE (14 DAS)*	42 DAE (21 DAS)*		
T1: Cyantraniliprole 19.8% + thiamethoxam 19.8%FS (6 ml/ kg seeds or 90 ml/ ha)	0.00	2.00 (0.14) a	19.33 (0.46) b	29.67 (0.58) d	32.00 (0.60) e	25.67 (0.53) d	2503.12	2503.12
T2: Chlorantraniliprole 62.5FS (5.6 ml/ kg seeds or 84 ml/ ha)	0.00	1.67 (0.13) a	14.33 (0.39) a	20.33 (0.47) c	23.33 (0.50) d	18.00 (0.44) c	1050.00	1050.00
T3: #Thiamethoxam 70WS (4g/ kg seeds)	0.00	17.33 (0.43) bc	35.67 (0.64) c	48.00 (0.74) e	50.33 (0.79) f	45.67 (0.74) e	-	
T4: *Spinetoram 11.7SC (0.5 ml/ l or 250 ml/ ha)	0.00	19.00 (0.45) c	36.00 (0.64) c	13.67 (0.38) a	8.33 (0.29) a	6.67 (0.26) a	3687.50	4287.50
T5: *Emamectin benzoate 5SG (0.4 g/ l or 200 g/ ha)	0.00	19.00 (0.45) c	36.33 (0.65) c	18.00 (0.44) b	17.67 (0.43) c	19.33 (0.46) c	3860.00	4460.00
T6: *Chlorantraniliprole 18.5SC (0.4 ml/ l or 200 ml/ ha)	0.00	19.67 (0.46) c	35.67 (0.64) c	14.33 (0.39) a	11.00 (0.34) b	9.67 (0.32) b	1260.00	1860.00
T7: #Untreated control	0.00	19.33 (0.46) c	36.33 (0.65) c	49.33 (0.78) f	52.67 (0.81) g	47.67 (0.76) e	-	
F test	NS	**	**	**	**	**		
SEM (±)	-	0.009	0.004	0.005	0.004	0.007		
CD at p=0.05	-	0.03	0.01	0.01	0.01	0.02		
C.V. (%)	-	4.16	1.15	1.54	1.27	2.37		

DAE= Days after emergence of plants; DAS= Days after spraying; *- Spraying of chemicals at 21 DAE (Spraying cost= Rs. 600/ ha), **- Significant at p= 0.05; NS= Non-significant; Values in parentheses arc sine transformation; Means followed by the same letter in a column do not differ significantly (DMRT, p= 0.05); #- excluded from cost analysis due to ineffectiveness

period (Oliveira et al., 2022). Even at 42 DAE which coincided with 21 days after foliar sprays with insecticides, the leaf damage % in chlorantraniliprole 62.5FS seed treatment did not differ significantly to that of emamectin benzoate 5SG sprays. Up to 42 DAE, seed treated with diamide insecticides plots did not show adequate damage to take up any spray. This suggested the long-term residual efficacy of seed treatment. Longer residual efficacy of anthranilic diamides in case of seed treatment viz., cyantraniliprole and chlorantraniliprole had been reported (Pes et al., 2020). Diamides are a novel group of insecticides that act as ryanodine receptor modulators affecting the muscular systems of insects. They primarily act through ingestion and contact action in less than 24 hr resulting in feeding cessation of pests on the treated plants. It may be attributed to the translocative action of diamides. The movement of diamides into leaf tissues can delay or prevent their depletion due to photo-oxidation or rainfall, thus ensuring better residual activity within the plant system (Cameron et al., 2015). Chlorantraniliprole and cyantraniliprole are translocated via xylem when applied to the soil adjacent to roots or through seed treatment (Selby et al., 2017). In the current study, chlorantraniliprole 62.5FS was found more effective compared to cyantraniliprole 19.8% + thiamethoxam 19.8%FS. It can be related to their physiochemical properties. Cyantraniliprole has a greater solubility in water which provides increased mobility in plants, whereas chlorantraniliprole has more residual action (Barry et al., 2015; Selby et al., 2017). Seed treatment with thiamethoxam did not provide satisfactory control against *S. frugiperda.* Poor efficacy of thiomethoxam and other neonicotinoids against *S. frugiperda* had been reported (Triboni et al., 2019).

Previous reports also suggested spinetoram 11.7SC to be highly effective along with chlorantraniliprole

18.5SC and emamectin benzoate 5SG (Dileep Kumar and Murali Mohan, 2020). Anthranilic diamide insecticide group in general exhibits strong activity against lepidopteran caterpillars and possess low toxicity to mammals (Temple et al., 2009). It was observed that chlorantraniliprole had hardly any impact on soil arthropods, beneficial insects, or processes like decomposition, thus having a very suitable ecological profile (Larson et al., 2012). Due to their unique mode of action and minimal impact on beneficial and non-target species, diamides provide a possible alternative (Pes et al., 2020; Cong et al., 2023). *Spodoptera frugiperda* is known to cause significant damage during early crop stage. Hence, protecting crop during initial crop stage is critical. Farmers largely spray insecticides to protect the crop. During the foliar application, the spray needs to be directed to the whorl portion to achieve better control. In comparison to spray, the seed treatment is easy to practice and economical. Hence, seed treatment with diamide insecticides, particularly chlorantraniliprole 62.5FS may provide a better alternative to foliar sprays for the control of *S. frugiperda* during early crop stage.

ACKNOWLEDGEMENTS

The support given by Dr B G Hanumantharaya, Assistant Professor, Department of Horticulture, University of Agricultural Sciences, Bangalore is acknowledged.

FINANCIAL SUPPORT

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

AUTHOR CONTRIBUTION STATEMENT

MK conceived and designed the research. RKB conducted the experiments and analyzed the data. PG provided technical guidance. RKB wrote the manuscript and all authors read and approved the manuscript.

CONFLICT OF INTEREST

No conflict of interest.

REFERENCES

Abbott W S. 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology 18(2): 265-267.

Anonymous. 2019. Directorate of Plant Protection, Quarantine, and Storage. https://ppqs.gov.in/sites/default/files/faw_do.pdf

Anonymous. 2021. Agricultural statistics at a glance 2021. Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Govt of India. https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202021%20(English%20version).pdf

Anonymous. 2022. ICAR-Indian Institute of Maize Research, Department of Agricultural Research and Education, Ministry of Agriculture, Government of India. https://aicrpmaize.icar.gov.in/from-directors-desk. Accessed 7 October 2022

Barry J D, Portillo H E, Annan I B, Cameron R A, Clagg D G, Dietrich R F, Watson L J, Leighty R M, Ryan D L, Mcmillan J A, Swain R S. 2015. Movement of cyantraniliprole in plants after foliar applications and its impact on the control of sucking and chewing insects. Pest Management Science 71(3): 395-403.

Bird L, Miles M, Quade A, Spafford H. 2022. Insecticide resistance in Australian *Spodoptera frugiperda* (J E Smith) and development of testing procedures for resistance surveillance. PLoS ONE 17(2): 0263677.

CABI. 2022. *Spodoptera frugiperda* (fall army worm). Invasive species compendium, CABI. https://www.cabi.org/isc/fallarmyworm. Accessed on 14 July 2022.

Cameron R A, Williams C J, Portillo, H E, Marcon P, Teixeira L A. 2015. Systemic application of chlorantraniliprole to cabbage transplants for control of foliar-feeding lepidopteran pests. Crop Protection 67: 13-19.

Cong Y, Chen J, Xie Y, Wang Y, Cheng C. 2023. Toxicity and sublethal effects of diamide insecticides on key non-target natural predators, the larvae of *Coccinella septempunctata* L. (Coleoptera: Coccinellidae). Toxics 11(3): 270.

Davis F M, N G, S S, Williams W P. 1992. Visual rating scales for screening whorl-stage corn for resistance to fall armyworm. In: Technical bulletin (Mississippi Agricultural and Forestry Experiment Station) 186 pp.

Dileep Kumar N T, Murali Mohan K, Prabhu C G, Mahesh H M. 2020. Safe and cost-effective management of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) using green insecticide baits. International Journal of Chemical Studies 8(5): 106-110.

Ganiger P C, Yeshwanth H M, Muralimohan K, Vinay N, Kumar A R V, Chandrashekara K. 2018. Occurrence of the new invasive pest, fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), in the maize fields of Karnataka, India. Current Science 115(4): 621-623.

Kasoma C, Shimelis H and Laing M D. 2021. Fall armyworm invasion in Africa: implications for maize production and breeding. Journal of Crop Improvement, 35(3): 111-146.

Kumar R M, Gadratagi B G, Paramesh V, Kumar P, Madivalar Y, Narayanappa N, Ullah F. 2022. Sustainable management of invasive fall armyworm, *Spodoptera frugiperda*. Agronomy 12(9): 2150.

Lamichhane J R, Corrales D C, Soltani E. 2022. Biological seed treatments promote crop establishment and yield: a global meta-analysis. Agronomy for Sustainable Development 42(3): 45.

Larson J L, Redmond C T, Potter D A. 2012. Comparative impact of an anthranilic diamide and other insecticidal chemistries on beneficial invertebrates and ecosystem services in turfgrass. Pest Management Science 68(5): 740-748.

Montezano D G, Specht A, Sosa-Gomez D R, Roque-Specht V F, Sousa-Silva J C, Paula-Moraes S V D, Peterson J A, Hunt T E. 2018. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. African Entomology 26(2): 286-300.

Oliveira C, Orozco-Restrepo S M, Alves A C, Pinto B S, Miranda M S, Barbosa M H, Picanco M C, Pereira E J. 2022. Seed treatment for managing fall armyworm as a defoliator and cutworm on maize: plant protection, residuality, and the insect life history. Pest Management Science 78(3): 1240-1250.

Pes M P, Melo A A, Stacke R S, Zanella R, Perini C R, Silva F M A et al. 2020. Translocation of chlorantraniliprole and cyantraniliprole applied to corn as seed treatment and foliar spraying to control *Spodoptera frugiperda* (Lepidoptera: Noctuidae). PLoS ONE 15(4): e0229151.

Selby T P, Lahm G P, Stevenson T M. 2017. A retrospective look at anthranilic diamide insecticides: discovery and lead optimization to chlorantraniliprole and cyantraniliprole. Pest management science 73(4): 658-665.

Suby S B, Soujanya P L, Yadava P, Patil J, Subaharan K, Prasad G S, Babu K S, Jat S L, Yathish K R, Vadassery J, Kalia V K. 2020. Invasion of fall armyworm (*Spodoptera frugiperda*) in India: nature, distribution, management and potential impact. Current Science 119(1): 44-51.

Temple J H, Pommireddy P L, Cook D R, Marçon P, Leonard B R. 2009. Susceptibility of selected lepidopteran pests to rynaxypyr, a novel insecticide. Journal of Cotton Science 13(1): 23-31.

Triboni Y B, Del Bem Junior L, Raetano C G, Negrisoli M M. 2019. Effect of seed treatment with insecticides on the control of *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) in soybean. Arquivos do Instituto Biologico 86: 1-6.

(Manuscript Received: May, 2023; Revised: September, 2023;
Accepted: September, 2023; Online Published: September, 2023)
Online First in www.entosocindia.org and indianentomology.org Ref. No. e23329