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Studies on Efficacy of Cyantraniliprole 19.8% + Thiamethoxam 19.8% W/W FSAs Seed Treatment against Fall Army Worm *Spodoptera frugiperda* (J. E. Smith) on Maize

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ABSTRACT: Fall armyworm is one of the main destructive invasive insect pests in India, which threaten the production of corn starting from the seedling stage to maturity stage. The present work aimed to evaluate the effect of seed treatment on the management of fall army worm (*Spodoptera frugiperda)* at initial stages of maize crop. The experiment was carried out under field conditions at Maize Research Center, Agricultural Research Station, Vijayarai in Andhra Pradesh. The experimentation was executed with seven treatments viz., Cyantraniliprole plus thiamethoxam at the doses of 5.0ml (T2); 6.0ml (T3) and 7.0ml kg^{-1} of seed (T4); T5: thiamethoxam @8.0ml kg^{-1} of seed; T6: cyantraniliprole at 2.4 ml kg^{-1} of seed; T7: carbofuran at 33.0 kg ha^{-1} applied through seed treatment along with T1: untreated control with three replications in a completely randomized design. Seed treatment had no adverse effect on germination of maize and there was no significant difference in plant height of maize among different treatments was found at 10, 20 and 30 days after sowing during two years of study. Higher concentrations of cyantraniliprole + thiamethoxam @ 6.0 and 7.0 mlkg^{-1} recorded the best results among all treatments, with lower percent infestation, and mean whorl damage by the larvae of fall army worm indicating that seed treatment is a viable alternative for controlling *Spodoptera frugiperda* at the early stages of crop growth, by reducing the foliar damage. Significantly higher grain yields were recorded in T4: 5918kg/ha and T3:5322 kg/ha during 2018-19 and T4: 8150 kg/ha T3: 8006 kg/ha was recorded during 2019-20 over other treatments. Lack of awareness on seed treatment at farmer's level is one of the limiting factors in fall army worm management in maize and hence, efforts should be made at farmer's level to adopt the technology.

Keywords: Seed treatment, Cyantraniliprole + thiamethoxam, fall army worm, Maize, *Spodoptera frugiperda.*

INTRODUCTION

In India, maize is as the third most important cereal crop after rice and wheat. Maize has its significance as a source of a large number of industrial products besides its uses as human food, animal feed and fodder. Maize is attacked by more than 40 insect pests during the crop season, including fall army worm. Of these pests, the maize stem borers pink stem borer (*Sesamia inference*), spotted stem borer (*Chilopartellus*), and cob borer (*Helicoverpa*) have long been recognized as major pests, but a more recent invasive species, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), commonly named fall armyworm (FAW), has now become the major insect pest which threaten the production of maize beginning from the seedling stage to cob maturity stage causing substantial yield losses in India and other countries. Though it is major pest on maize but it also attacks more than 85 economically important cultivated crop species such as rice, millets, sorghum, cotton (FAO, 2020), wheat, potato, soybean, cowpea, peanuts, sugarcane and vegetables (CABI, 2017).

Depending on the crop season and the type of hybrid, Fall army worm can reduce corn yields up to 57% by feeding inside the corn whorl, hindering its control by foliar spraying. Dhingra (1985) affirms that seed treatment is an important process and the first effective step for plant protection. The absence of this initial form of protection may have a direct impact on crop yield, with a significant reduction in farmer profitability (Buzzerio, 2010).

There are several chemical groups used in seed treatment, such as methylcarbamates, pyrazole, abamectin, and diamides to control different pests in soyabean and in different crops. At present, seed treatment with neonicotinoid or other insecticides alone or in combination are widely used in integrated pest management systems because of their ease in handling, relatively safe, and cause less pollution. Neonicotinoid seed treatments have shown long-lasting residual activity against aphids (Zhang *et al.* 2016a,b), and have been shown to be effective against stem borers as a seed treatment in maize (Anuradha, 2012). Recently, Insecticides belongs to chemical diamides group are widely used to control pests in many commercial crops worldwide (Adams *et al.,* 2016). Diamides was labeled for use over 10 years ago (2008) (Jeanguenat 2013) and are classified in the group 28 by the Insecticide Resistance Action Committee (IRAC), acting as modulators of ryanodine receptors (IRAC, 2017).Since their commercialization, diamides have been widely used for pest management in various countries, Cyantraniliprole is part of the second generation that are currently labeled for used as seed treatment with a broad spectrum action on lepidopterans, dipterans, coleopterans, hemipterans and thy sanopterans (Foster, 2012).

Although, thiamethoxam mixed with other types of insecticides such as diamides have been used as seed treatment to control early season pests of maize in India and other countries, little information is available on the control efficacy of these registered insecticides against fall army worm or their effects on the natural enemies of FAW, and their impacts on corn growth, development and yield. The present investigation was undertaken to compare the efficacy of different doses of Cyantraniliprole 19.8% + thiamthoxam 19.8% W/W FS and other insecticides used as seed treatments in the control of fall army worm and their impact on yields of corn under natural infestation .The data generated from this research can be used to determine the insecticide with highest efficiency as seed treatment against fall army worm in maize under natural field infestation.

MATERIALS AND METHODS

The experiment was carried out at institutional farm, Agricultural Research Station, Vijayarai during *Rabi* 2018-19 and 2019-20.After seed treatment, the maize seeds were sown in a plot size of 25 $m^2$with a spacing of 75X20cm. For treating maize seed, water and insecticides were mixed at right proportion for each treatment and transferred to the two liters plastic bags and vigorously shaken until complete coverage with the respective insecticides, by following the methodology proposed by Cunha *et al.,* (2015) and then seed are air dried. The experimental was laid with seven treatments with three replicates by following completely randomized design. The following treatments were used: T1 – untreated control without seed treatment, T2 – Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 1.98 g a.i/kg seed (0.99+0.99) or 5.0ml per 1.0 kg^{-1} of seed: T3 – Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @2.38 g a.i./kg seed (1.19+1.19) or @ 6.0ml kg^{-1} of seed; T4- Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @2.78a.i. kg^{-1} seed (1.39+1.39) or @ 7.0ml kg^{-1} of seed; T5- Cyantraniliprole 600FS @1.4 g a.i/ kg^{-1} seed or @ 2.4 ml kg-1 seed ; T6- Thiamethoxam 35 FS @2.4 g.a.ikg^{-1} seed or @ 8.0ml kg^{-1} seed ; T7- Carbofuran 3GR @1000 g a.i./ha @33 kg/ha (Table 1A.): T8 – Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 5.54 g a.i/kg seed (2.77+2.77) or @ 14.0ml kg^{-1} of seed was evaluated for phytotoxicity studies (Table 1B). The crop was raised by following all agronomic practices recommended by Acharya N.G. Ranga Agricultural University. No additional insecticides were applied throughout the growing season of maize crop. Data on germination percentage was calculated at 10 and 20 days after sowing.

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated in each treatment}}{\text{Total number of seeds sown in each treatment}} \times 100$$

Plant height was measured by using measuring scale on randomly selected 10 plants in all the treatments at 10 DAS, 20 DAS and 30 DAS.

Infested maize plants by fall army worm were recorded on whole plot basis at 10, 15, 20 Days after sowing (DAS).

$$\text{Per cent plant infestation (\%)} = \frac{\text{Number of plants damaged by fall army worm}}{\text{Total number of plants in each treatment}} \times 100$$

Foliar damage was recorded from twenty randomly selected plants at 14, 21 and 28 days after sowing based on mean whorl feeding injury in terms of visual score (0-9 scale) (Davis and Williums1992). The cobs in all treatments were harvested by leaving the border rows, shelled and cleaned. Grain yield from the net plot of each treatment was taken, dried, weighed and converted to kg ha^{-1} and are subjected to statistical analysis by using ANOVA.

1A) Treatment Details for Evaluation of Bio-efficacy of Cyantraniliprole 19.8%+ Thiamethoxam % W/W FS in Corn.

Tr. No.	Treatments*	DOSAGE		Remarks
		a.i (g)/ha	Formulation (ml/g)/ha	
T1	Untreated check	—	—	Bio-efficacy
T2	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	1.98 (0.99+0.99)	5.0	Bio-efficacy
T3	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	2.38 (1.19+1.19)	6.0	Bio-efficacy
T4	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	2.78 (1.39+1.39)	7.0	Bio-efficacy
T5	Cyantraniliprole 600FS	1.4	2.4	Bio-efficacy
T6	Thiamethoxam 35 FS	2.4	8.0	Bio-efficacy
T7	Carbofuran 3 GR	1000 g a.i./ha	33 kg/ha.	Bio-efficacy

1B) Treatment details for evaluation of phytotoxicity of cyantraniliprole 19.8%+ thiamethoxam 19.8% w/w FS.

Treatment Number	Treatments*	Dose/ ha (g or ml)	
		a.i	Formulation
T_1	Untreated check	—	—
T2	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	1.98 (0.99+0.99)	5.0
T3	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	2.38 (1.19+1.19)	6.0
T4	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	2.78 (1.39+1.39)	7.0
T8	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	5.54(2.77+2.77)	14.0

Phytotoxicity was assessed by visual observations. Ten plants in each treatment replicated thrice were observed critically at 0^{th}, 1^{st}, 3, 5, 7 and 10 days after germination in T2: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS @ 5.0 ml kg^{-1}, T3: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS @ 6.0ml kg^{-1}, T4: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS @ 7.0ml kg^{-1}, T8: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 14.0 ml kg^{-1} and T1: Untreated Controlforchlorosis & vein clearing , wilting & necrosis, stunting & leaf injury, epinasty and hyponasty and were graded on 0-10 point phytotoxicity scale.

RESULTS AND DISCUSSION

Results obtained during two years of study showed that seed germination was ranged from 93.63 to 97.33% during *rabi*, 2018-19 and 88.33% to 94.67% during *rabi*, 2019-20. Percent germination was statistically insignificant among all the treatments. Hence, Seed treatment had no significant effect on germination (Table 1). Plant height ranged from 12.00 to 15.67 cm; 24.80 cm to 26.07 cm. and 41.00 cm to 48.67 cm at 10, 20 and 30 days after sowing respectively, during 2018-19. Similarly, Plant height ranged between 12.83 to 15.60cm; 22.27 to 28.70 cm and 44.50 to 49.90cm after 10, 20 and 30 days after sowing during 2019-20. No significant difference in plant height among different treatments was found at 10,20 and 30 days after sowing during two years of study. Hence, treatments had no effect on plant height at 10, 20 and 30 days after sowing (Table 2). Our results clearly indicates that seed treatments had no negative influence on the germination percentage and seedling characteristics like height of the corn. Our results closely followed the results of Wilde *et al.* 2007 who reported that neonicotinoid seed treatments cause no differences in crop seedling growth indicators including seed germination, and the primary root length, weight, and height of corn seedlings. No significant variation in germination and plant height was found among seed treated plots of maize with anthranilic diamides (Alam *et al.*, 2020).

Table 1: Effect of seed treatment Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS against germination percentage of maize during 2018-19 & 2019-20.

			% of germination	
Tr. No.	**Treatments**	**Dosage (ml/kg seed)**	**2018-19**	**2019-20**
T1	Untreated check		93.67 (75.57)	93.33 (75.36)
T2	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w F	5	94.33 (78.72)	96.67 (83.85)
T3	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	6	96.00 (81.12)	92.33 (74.66)
T4	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	7	97.00 (81.92)	89.67 (71.58)
T5	Cyantraniliprole 600FS	2.4	94.67 (77.05)	88.33 (70.13)
T6	Thiamethoxam 35 FS	8	94.00 (76.32)	88.67 (70.75)
T7	Carbofuran 3 GR	33 kg/ha.	93.63 (75.48)	94.67 (76.70)
T8	Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS	14	97.33 (82.54)	94.67 (77.75)
	F-test		NS	NS
	CD(P=0.05)		—	—
	CV(%)		8.72	7.33

Table 2: Effect of seed treatment Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS against seedling height of maize during 2018-19 & 2019-20.

			2018-19			**2019-20**		
Tr.No.	**Treatments**	**Dosage**	**Plant Height (in cm.)***			**Plant Height (in cm.)***		
		(ml/kg)	10 DAS	20 DAS	30 DAS	10 DAS	20 DAS	30 DAS
T1	Untreated check		12.67	25.47	44.33	12.83	24.27	47.67
T2	(Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	5	12.83	24.80	41.00	13.93	24.77	48.17
T3	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	6	12.53	25.93	41.43	13.87	25.00	47.23
T4	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	7	14.67	25.73	48.37	13.53	27.17	46.43
T5	Cyantraniliprole 600FS	2.4	12.00	25.40	41.20	14.07	25.30	46.77
T6	Thiamethoxam 35 FS	8	12.00	25.00	38.60	14.87	28.70	44.50
T7	Carbofuran 3 GR	33 kg/ha.	12.42	23.20	41.50	15.13	22.27	48.07
T8	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	14	15.67	26.07	48.67	15.60	23.30	49.90
F-test			NS	NS	NS	NS	NS	NS
CD (P=0.05)			—	—	—	—	—	—
CV(%)			17.92	4.31	15.66	18.1	11.3	5.4

NS-Non-significant ; *Mean of three replications

Percent Plant Infestation by Fall Army Worm: Experimental results showed that the efficacy of the Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS against fall army worm was increased with the increase in concentration of the insecticide. In 2018-19, Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 7.0ml and 6.0 ml/kg seed as seed treatment exhibited excellent efficacy against fall army worm by achieving significantly greater control than was observed in the untreated and other insecticide-treated groups (Table 3 and 4). The results in 2019-20 were similar to those from 2018-19. Percent plant infestation by fall army worm was ranged from 0.51 to 29.29 and 5.30 to 39.14 at 10 DAS and 15 DAS during 2018-19; 10.88 to 34.82 and 22.09 to 53.83 at 10 DAS and 15 DAS respectively during 2019-20.

Lowest percent plant infestation (0.51 & 5.30) was observed in T4: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS@7.0ml/kg seed and T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 6.0ml/kg seed (1.52 & 5.81) at 10 and 15 DAS respectively and both the treatments were at par and significantly different from other treatments during 2018-19. Similar results were found in 2019 -20, showed that lowest percent plant infestation was recorded in T4: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 7.0ml/kg seed. (10.88 & 22.09) significantly followed byT3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 6.0ml/kg seed (14.55 & 26.22) and are significantly different from other treatments at 10 DAS & 15 DAS. Highest percent infestation of fall army worm 29.29, 39.14, 34.82 and 53.83 was recorded in untreated Control at 10 and 15 DAS during 2018-19 & 2019-20 respectively (Table 3).Percent plant infestation by fall army worm was increased

drastically from 15 days after sowing. It ranged between 97.70 to 100.0 during 2018-19 and 94.35 to 100.0 during 2019-20 at 20 DAS. However, no significant difference was foundin percent plant infestation by fall army worm among the treatments at 20 DAS during both the years of our study.

High percent reduction of plant infestation(% ROC) by fall army worm over control was achieved in T4: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS)@ 7.0 ml/kg seed (86.45 %,) followed by T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS)@6.0ml/kg seed (85.15 %) at 15 DAS during 2018-19 and more than 50 % reduction over control was attained in both T4:Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS)@ 7.0 ml/kg seed & T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS)@6.0ml/kg seed during 2019-20 (Table 3).

Table 3: Effect of different doses of Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS on Percent infestation by fall army worm in Maize during *Rabi,* 2018-19 and 2019-20.

S.No.	Treatments	Dosage g a.i/ha	2018-19				2019-20			
			Mean Percent Infestation (%) **							
			10 DAS	15 DAS	% ROC	20 DAS	10 DAS	15 DAS	% ROC	20 DAS
1.	Untreated check	—	29.29 (32.74)	39.14 (38.70)	—	100.00 (90.00)*	34.82 (35.92)	53.83 (47.19)	—	97.42 (82.42)
2.	Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS	5	6.57 (14.30)	11.87 (20.02)	**69.67**	99.90 (88.27)	21.80 (27.71)	37.66 (37.84)	30.04	97.61 (83.15)
3.	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	6	1.52 (5.70)	5.81 (13.79)	**85.15**	98.70 (82.86)	14.55 (22.06)	26.22 (30.73)	51.29	94.49 (78.90)
4.	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS)	7	0.51 (2.36)	5.30 (13.03)	**86.45**	97.70 (81.01)	10.88 (19.06)	22.09 (27.96)	58.96	94.35 (76.48)
5.	Cyantraniliprole 600FS	2.4	4.29 (11.91)	10.35 (18.67)	**73.55**	98.70 (82.30)	21.01 (27.19)	39.43 (38.87)	26.75	95.37 (77.85)
6.	Thiamethoxam 35 FS	8	23.74 (29.04)	35.61 (36.55)	**9.01**	98.50 (86.55)	**27.31** (31.49)	**46.01** (42.69)	**14.52**	**96.96** (80.08)
7.	Carbofuran 3 GR	33 kg/ha.	28.28 (32.06)	38.64 (38.40)	**1.27**	99.60 (90.00)	**31.01 (33.79)**	**50.56** (45.3)	**6.07**	**100.00** (90.0)
	F- Test		Sig	Sig		NS	Sig	Sig		NS
	CD(P=0.05)		6.9	4.96		—	6.03	5.322		—
	CV(%)		20.94	10.78		6.76	11.91	7.65		6.37

DAS: Days after sowing * Arc sine values, ** Mean of three replications, %ROC: Reduction over control

Leaf damage: Leaf damage was measured in terms of whorl feeding injury as per Davis scale(0 to 9), all the treatments showed whorl injury rating <5.0and < 4 upto 14 DAS during 2018-19 and 2019-20 respectively and thereafter, the leaf damage increased. Lowest leaf damage was noticed in T4:Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 7.0ml/kg seed with injury ratings of 2.36, 3.26 and 4.09 followed by T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 6.0ml/kg seed with injury ratings of 2.50, 3.44 and 4.26 at 14, 21 and 28 DAS respectively, during 2018-19. Similar trend was noticed during 2019-20 also with a lowest injury rating of 1.69, 2.39 and 2.89 in T4: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 7.0ml/kg seed which are at par with T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 6.0ml/kg seed with injury ratings of 1.93, 2.64 and 3.08. and are significantly different from other treatments.(Table no: 4).Over all mean of leaf damage with a visual score of 3.24 & 3.40 during 2018-19; 2.32 & 2.55 during 2019-20 was noticed in T4: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@7ml/kg seed & T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 6.0ml/kg seed against to untreated control with a score of 5.74 & 4.64 during 2018-19 & 2019-20respectively,which indicates that leaf damage during 2019-20 was higher compared to 2018-19 (Table 4).

Table 4: Effect of seed treatment against mean leaf damage by fall army worm in maize during 2018-19 & 2019-20.

Treatments		Dosage	2018-19				2019-20			
			Mean leaf damage(Score)				Mean leaf damage (Score)			
			14 DAS	21 DAS	28 DAS	mean	14 DAS	21 DAS	28 DAS	Mean
T1	Untreated check	—	4.31	5.57	7.35	5.74	3.43	4.59	5.90	4.64
T2	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	5	3.11	4.25	5.22	4.19	2.42	3.32	3.93	3.22
T3	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	6	2.36	3.44	4.26	3.40	1.93	2.64	3.08	2.55
T4	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	7	2.50	3.26	4.09	3.24	1.69	2.39	2.89	2.32
T5	Cyantraniliprole 600FS	2.4	3.08	4.19	5.12	4.13	2.35	3.23	3.79	3.12
T6	Thiamethoxam 35 FS	8	4.58	5.35	7.14	5.69	3.01	4.15	5.38	4.18
T7	Carbofuran 3 GR	33 kg/ha.	4.20	5.28	6.39	5.29	3.09	4.27	4.08	3.81
F-test			Sig	Sig	Sig		Sig	Sig	Sig	
CD(P=0.05)			0.31	0.59	0.61		0.38	0.55	0.69	
CV(%)			4.99	7.43	6.49		8.28	8.75	9.22	

Lower leaf damage and low percent plant infestation of fall army worm in maize was noticed in cyantraniliprole + thiamethoxam at 7.0 ml and 6.0 ml/kg seed treatments plots. It may be due to the translocation of insecticides and continuous upward conduction of cyantraniliprole + thiamethoxam at 7.0 ml and 6.0 ml/kg seed into leaves of corn plants when applied via seed treatment. The effectiveness of the seed treatment with cyantraniliprole + thiamethoxam against fall armyworm is in accordance with the findings of Pes *et al.,* 2020 who reported that the long residual effect of cyantraniliprole to control *S. frugiperda*,was observed, when applied as seed treatment in maize. Our results are strongly supported by different authors in different crops. Single application of insecticide to seeds can prevent fall army worm throughout the seedling stage because the strong upward conduction of neonicotinoids and anthralinicdiamides (Elbert *et al.,* 2008; Alford and Krupke 2017). Chanda *et al.,* 2021 reported that only 50% of fields with seed-coated maize with fortenza duo got infested with fall army worm against 80% in the control and also reported that fall army worm infestations occurred about two weeks later in fields with seed-coated maize than in untreated maize plots. Thrash *et al*., (2013) reported that the use of chlorantraniliprole and cyantraniliprole as seed treatments reduced the need for foliar sprays against fall army worm in soya bean. Cyantraniliprole seed treatment at a dosage of 2.0 g.a.i kg^{-1} seed significantly reduced *A. ipsilon* infestation compared to chlorantraniliprole and clothianidin seed treatments in corn fields (Zhang *et al*, 2019). Further data obtained in this study shows that the insecticidal treatments thiamethoxam (T6), and Carbofuran (T7) did not differ statistically from the untreated control (T1) and this is in conformity with the report of Albuquerque *et al.,* (2006) that the seed treatment with thiamethoxam did not prevent fall army worm infestation in corn. Further, thiodicarb and clothianid in reduced the number of plants cut or injured by fall army worm, but chlorpyrifos, fipronil and thiamethoxam (Camillo *et al.,* 2005) and kerosene (Portillo *et al.,* 1994) were not effective in laboratory. The application of the insecticide thiamethoxam (Cruiser®) through seed treatment showed the lowest control efficiency of *Spodoptera frugiperda* during the evaluation period in soybean plants(Triboni *et al.,* 2019).

Phytotoxicity: The results showed that T2: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 5.0ml/kg seed T3: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS@ 6.0ml/ kg seed T4: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS@ 7.0ml/ kg seed, T8: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 14.0 ml/kg and T1: Untreated Control not shown any phytotoxic symptoms like chlorosis, vein clearing, wilting, necrosis,stunting, leaf injury, epinasty and hyponasty during *rabi*,2018-19 and *rabi*,2019-20. Hence it is safe to use the insecticide in maize without causing phytotoxic symptoms (Table 5).

Table 5: Phytotoxicity data on chlorosis, vein clearing, wilting, necrosis, stunting, leaf injury, e pinasty and hyponasty during 2018-19 and 2019-20.

Tr. No.	Treatments	Dosage (g a.i/ha)	Days of observation					
			0	1	3	5	7	10
T1	Untreated check	—	0	0	0	0	0	0
T2	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	1.98 (0.99+0.99)	0	0	0	0	0	0
T3	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	2.38 (1.19+1.19)	0	0	0	0	0	0
T4	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	2.78 (1.39+1.39)	0	0	0	0	0	0
T8	Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS	5.54(2.77+2.77)	0	0	0	0	0	0

Yield: Significantly higher grain yields were recorded in T4: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS)@7.0ml/kg seed (5918 kg/ha) and T3: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS@ 6.0 ml/kg seed (5322kg/ha) during 2018-19. During *rabi*, 2019-20 highest grain yield of 8150 kg/ha was recorded in T4: Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS@7.0ml/kg seed which is on par with T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 6.0 ml/kg seed (8006 kg/ha) and are significantly different from other treatments. The lowest yield of 2114 kg/ha and 6149 kg/ha was recorded in untreated check during 2018-19 & 2019-20 (Table 6).

Table 6: Effect of seed treatment of Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS on Yield in Maize during 2018-19 & 2019-20.

	Treatments	Dosage (ml/ha)	Yield (Kg/ha)	
			2018-19	2019-20
T1	**Untreated check**	—	2114	6149
T2	**Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS**	5.0	3321	7090
T3	**Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS**	6.0	5322	8006
T4	**Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS)**	7.0	5918	8150
T5	**Cyantraniliprole 600FS**	2.4	3342	7355
T6	**Thiamethoxam 35 FS**	8.0	2576	6171
T7	**Carbofuran 3 GR**	33 kg/ha.	3104	6816
	F-test		Sig	Sig
	CD(P=0.05)		799	647
	CV(%)		12.35	5.1

Higher grain yield was realized in higher doses of insecticide Cyantraniliprole 19.8% + Thiamethoxam 19.8% w/w FS @7.0ml/kg seed and 6.0 ml/kg seed. It can be attributed to the reason that lower percent plant infestation and less foliar damage resulted in more cob weight in these treatments compared to other treatments. During two years of study, yields of maize during 2018-19 were much lower than 2019-20 due to severe leaf damage in 2018 with injury ratings up to 5.57 and 7.35 at 21 DAS and 28 DAS. Yields of T4: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 7.0ml/kg seed and T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 6.0ml/kg seed didn't differ statistically. Hence a lower dose of T3: Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS @ 6.0ml/kg can be recommended as seed treatment for control of fall army worm. Further, it protects the seedlings upto 3-4 weeks after sowing based on leaf damage.

CONCLUSION

Seed treatment with Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 6.0ml/kg seed showed higher efficacy in controlling fall army worm and used as aviable control measure for pest management in corn during early stages of crop growth besides enhancing the grain yield with a favorable safety profile.

FUTURE SCOPE

The use of Cyantraniliprole 19.8%+ Thiamethoxam 19.8% w/w FS@ 6.0ml/kg seed as seed treatment has an impact on the yields of maize by reducing the fall army worm damage at initial stages of maize crop. There is a necessity to widen the research on other early insect pests of maize crop and also its impact on natural enemies of fall army worm in maize ecosystem.

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