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Evaluation of different insecticidal application strategies against stem borer, *Chilo partellus* swinhoe infesting maize

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Abstract
To select best insecticidal application strategy for the management of stem borer, *Chilo patellus* Swinhoe in maize, a field experiment was conducted during *kharif*, 2016 and 2017 at Agricultural Research Station, Anand Agricultural University, Sansoli, Gujarat. Among all the tested insecticidal application strategies *viz.*, soil application, seed treatment and leaf whorl application, seed treatment with imidacloprid 600 FS, 8 ml/kg seed and thiamethoxam 30 FS, 8 ml/kg seed found most effective and economical in managing the pest by registering the lowest plant damage, leaf injury scale, number of larvae, number of pupae, stem tunnelling and the highest plant height, grain and fodder yield. Hence, seed treatment should be used as components for Integrated Pest Management (IPM) plans for the effective and economical management of stem borer in maize.

Keywords: *Chilo partellus*, insecticidal application strategies, maize, management, stem borer, yield

Introduction

Maize, *Zea mays* L. is the third most important cereal grain after wheat and rice globally, which is also called the “Queen of Cereals” because of its highest genetic yield potential [12]. Indian cultivation of maize cover over 9.86 million hectares of area with production of 26.26 million tonnes with productivity of 2664 kg/ha [2]. In Gujarat, it occupies 4.00 lakh hectares of area producing 6.65 lakh tonnes with a productivity of 1663 kg/ha of maize [3]. Maize is a traditional crop that is generally cultivated as a source of food, feed and fodder. Demand of maize crop is increasing in higher amount every year due to the higher nutritional benefits. Nutritionally, maize grains have 10% protein, 4% oil, 70% carbohydrate, 2-3% crude fibers, besides having Vitamin A and E, nicotinic acid and riboflavin but its protein Zein is deficient in tryptophan and lysine among essential acids and is deficient in calcium [13]. One of the major reasons for the decline in maize productivity is due to the insect pest infestation. It is attacked by about 140 species of insect pests causing varying degree of damage throughout the crop period [4]. Of these, maize stem borer, *Chilo partellus* Swinhoe is one of the most important pest which causes 26.7 to 80.4 per cent yield loss in different agro-climatic zones of India [17]. Larva attacks on all aerial part of plants (ears, tassels, stems and stalks) by boring into them. The new emerging leaves showed typical “shot-hole” as its initial symptoms. Larval damage causes formation of dead hearts (death of central growing tip), exit holes and tunnel in main stem that causes stunted plant growth and favours secondary infection of fungus and bacteria [16, 20].

Being an internal borer, this pest is difficult to control with single method of pest control practices. For effective management of stem borers infesting maize, effective chemicals and their timing of application (early whorl stage) is significant as this pest is an internal feeder and control at later stage offers narrow scope for chemical control [18]. The efficacy of insecticides in the management of borer can be increased many fold by its application at the right stage [7]. Carbofuran 3 G applied at the base of plants was more effective for a longer period to suppress the pest [14]. The tunnel length caused by *C. partellus* was relatively lower in carbofuran treated plots [6]. Whorl application with granular formulations of Carbofuran 3G was effective against *C. partellus* [5]. Insecticide used as seed dressing were better than insecticide used as granules and foliar sprays in the management of maize stem borer [14].

Among other management strategies, chemical control has its own effectiveness due to its rapid knock down effect [24]. The lethal damage of *C. partellus* to maize crop arouses the significance of its valuable control with these agrochemicals. A number of formulations of insecticides such as granular, seed dresser and foliar are available in the market to manage *C. partellus*. There is need to formulate the schedules of insecticide application as a best chemical component in IPM besides insecticide resistance management strategy. Therefore, the present study was designed to evaluate the different insecticidal application strategies (seed treatment, soil and leaf whorl application) against *C. partellus* under field conditions.

Materials and Methods

The field experiment was conducted at Agricultural Research Station, Sansoli of AAU, Anand (Gujarat) during *kharif* 2016 and 2017 in Randomized Block Design with 11 treatments and three replications to evaluate different insecticidal application strategies (seed treatment, soil and leaf whorl application) against *C. partellus* infesting maize (GM-4). The treatments were:

Sr. No.	Name of insecticides	Methods of application	kg a.i/ ha	Dose (kg / ha or ml or g/ kg of seed)
T_1	Carbofuran 3 G	Soil	1.00	33 kg
T_2	Carbofuran 3 G	Leaf whorl	0.24	8 kg
T_3	Phorate 10 G	Soil	1.00	10 kg
T_4	Phorate 10 G	Leaf whorl	0.80	8 kg
T_5	Cartap hydrochloride 4 G	Soil	0.80	20 kg
T_6	Cartap hydrochloride 4 G	Leaf whorl	0.32	8 kg
T_7	Chlorantraniliprole 0.4 G	Soil	0.08	20 kg
T_8	Chlorantraniliprole 0.4 G	Leaf whorl	0.032	8 kg
T_9	Imidacloprid 600 FS	Seed treatment	0.0048	8 ml
T_{10}	Thiamethoxam 30 FS	Seed treatment	0.0024	8 ml
T_{11}	Control	-	-	-

The soil applications of granular insecticides was given one day before sowing of the crop, whereas application of granular insecticides in leaf whorl was applied at 20 and 40 days after sowing (DAS). The maize seeds were treated with respective insecticides as per mentioned rates before 12 hours of sowing [9].

For recording observations on per cent damaged plants/ dead heart, all the plants showing dead-heart formation from net plot area were counted and percent damaged plants/ dead heart was calculated on the basis of total plant stand.

From each net plot area, 10 plants were selected randomly and leaf injury was assessed based on 1 - 9 scale at 20, 30, 40 and 50 DAS. Mean leaf injury score/ plot was calculated based on total leaf injury score divided by total number of plants scored [23].

Scale (1-9)	Description
1	No visible leaf feeding damage
2	Few pin holes on older leaves
3	Several shot-holes injury on a few leaves
4	Several shot-holes injury common on several leaves or small lesions
5	Elongated lesions (> 2 cm long) on a few leaves
6	Elongated lesions on several leaves
7	Several leaves with elongated lesions or tattering
8	Most leaves with elongated lesions or severe tattering
9	Plant dying as a result of foliar damage

The observations on stem tunnelling was recorded from 10 randomly selected plants per plot at the time of harvest by calculating total borer tunneled length divided by plant height of affected plants and multiplied by 100. The number of larvae and pupae were also counted from the plants selected for working out per cent stem tunnelling.

The grain and fodder yield were recorded from each net plot and converted into kg/ha and quintal/ha respectively. The data obtained thus, were subjected to statistical analysis after appropriate transformation (square root and arc sine transformation) to draw valid conclusion [21].

Results and Discussion

Stem borer, *C. partellus* incidence

Based on plant damage

The results presented in Table 1 revealed that the tested insecticides reduced plant damage due to *C. partellus* infestation in all treated plots than untreated control plots till 50 days after sowing during both the years of study. During first year; 20 days after sowing (DAS), the lowest (1.35%) plant damage due to *C. partellus* was observed in the treatment of seeds treated with imidacloprid 600 FS, 8 ml/kg seed and it was at par with thiamethoxam 30 FS, 8 ml/kg seed (1.99%). The treatment of soil application of carbofuran 3 G (33 kg/ha), phorate 10 G (10 kg/ha) and cartap hydrochloride 4 G (20 kg/ha) were at par with each other and stood as next effective treatments for control of the pest. The highest (9.68%) plant damage was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G, 8 kg/ha followed by treatment of leaf whorl application of cartap hydrochloride 4 G and phorate 10 G. More or less similar trend of effectiveness of insecticides was observed after 30, 40, 50 DAS as well as pooled over periods. During second year, the lowest (1.04%) plant damage due to *C. partellus* was observed in the treatment of seeds treated with imidacloprid 600 FS seed and it was at par with thiamethoxam 30 FS (1.69%) seed on 20 DAS followed by treatment of soil application of carbofuran 3 G (3.46%) whereas the highest (8.63%) plant damage was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G, 8 kg/ha. More or less similar trend of effectiveness of insecticides was observed after 30, 40, 50 DAS as well as pooled over periods.

Overall, the results on pooled over years indicated the lowest (2.78%) plant damage noticed in the treatment of seeds treated with imidacloprid 600 FS followed by thiamethoxam 30 FS (3.46%) and soil application of carbofuran 3G (6.61%). Among all the tested insecticides, the highest (11.84%) plant damage was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G.

Based on leaf injury scale (1-9)

The perusal of results presented in Table 2 revealed that tested insecticides significantly reduced leaf injury due to *C. partellus* infestation in all treated plots than untreated control plots till 50 days after sowing during both the years of study. During first year, the lowest (1.13) leaf injury scale was observed in the treatment of seeds treated with imidacloprid 600 FS and it was at par with thiamethoxam 30 FS (1.20) on 20 days after sowing (DAS) followed by soil application of carbofuran 3 G (1.60) and phorate 10 G (1.67) whereas the highest (2.47) leaf injury scale was observed in the treatment of leaf whorl application of cartap hydrochloride 4 G which was at par with T_2, T_4 and T_8. After 30 days of sowing, treatment of seeds treated with imidacloprid 600 FS registered the lowest (1.37) leaf injury scale and it was at par with thiamethoxam 30 FS (1.53) whereas the highest (3.57) leaf injury scale was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G followed by T_6, T_4 and T_2. More or less similar trend of effectiveness of insecticides was observed after 40, 50 DAS as well as pooled over periods. During second year, more or less similar trend of effectiveness of insecticides was observed during individual periods as well as pooled over periods.

Table 1: Effect of different insecticidal treatments on stem borer, *C. Partellus* infestation in maize

Insecticides	Method of application	Damaged plants (%)										Pooled over years
		2016					2017					
		20 DAS	30 DAS	40 DAS	50 DAS	Pooled over periods	20 DAS	30 DAS	40 DAS	50 DAS	Pooled over periods	
Carbofuran 3 G	Soil	11.72^{b} (4.13)	14.44^{b} (6.22)	17.47^{b} (9.01)	20.63^{b} (12.41)	16.06^{b} (7.65)	10.72^{b} (3.46)	12.62^{b} (4.77)	15.24^{bc} (6.91)	16.40^{bc} (7.97)	13.74^{b} (5.64)	14.90^{c} (6.61)
Carbofuran 3 G	Leaf whorl	17.44^{cd} (8.98)	18.78^{cde} (10.36)	19.41^{bc} (11.04)	21.27^{b} (13.16)	19.22^{ef} (10.84)	15.20^{cdef} (6.87)	17.47^{de} (9.01)	18.48^{cdef} (10.05)	19.46^{cdef} (11.10)	17.65^{ef} (9.19)	18.44^{fg} (10.01)
Phorate 10 G	Soil	12.91^{b} (4.99)	15.16^{b} (6.84)	18.13^{bc} (9.68)	20.95^{b} (12.78)	16.79^{bc} (8.34)	12.38^{bc} (4.60)	13.38^{bc} (5.35)	16.00^{cd} (7.60)	17.12^{bcd} (8.67)	14.72^{bc} (6.46)	15.75^{cd} (7.37)
Phorate 10 G	Leaf whorl	17.77^{d} (9.31)	19.13^{de} (10.74)	19.73^{bc} (11.40)	21.55^{b} (13.49)	19.54^{ef} (11.19)	16.00^{def} (7.60)	18.08^{de} (9.63)	19.12^{def} (10.73)	20.39^{def} (12.14)	18.40^{fg} (9.96)	18.97^{gh} (10.57)
Cartap hydrochloride 4 G	Soil	14.04^{b} (5.89)	15.99^{bc} (7.59)	19.12^{bc} (10.73)	21.81^{b} (13.80)	17.74^{cd} (9.28)	13.15^{bcd} (5.18)	14.83^{bcd} (6.55)	17.08^{cde} (8.63)	18.12^{cde} (9.67)	15.80^{cd} (7.41)	16.77^{de} (8.32)
Cartap hydrochloride 4 G	Leaf whorl	17.81^{d} (9.36)	19.41^{de} (11.04)	20.07^{bc} (11.78)	22.97^{b} (15.23)	20.06^{f} (11.77)	16.38^{def} (7.95)	18.46^{ef} (10.03)	20.08^{ef} (11.79)	21.29^{ef} (13.18)	19.05^{fg} (10.65)	19.56^{gh} (11.21)
Chlorantraniliprole 0.4 G	Soil	14.44^{bc} (6.22)	16.75^{bcd} (8.31)	19.73^{bc} (11.40)	22.02^{b} (14.06)	18.23^{de} (9.79)	13.97^{bcde} (5.83)	16.40^{cde} (7.97)	17.44^{cde} (8.98)	18.73^{cdef} (10.31)	16.63^{de} (8.19)	17.43^{ef} (8.97)
Chlorantraniliprole 0.4 G	Leaf whorl	18.13^{d} (9.68)	20.01^{e} (11.71)	20.90^{c} (12.73)	22.42^{b} (14.55)	20.36^{f} (12.10)	17.08^{ef} (8.63)	19.12^{ef} (10.73)	21.28^{f} (13.17)	22.14^{f} (14.20)	19.90^{g} (11.59)	20.13^{h} (11.84)
Imidacloprid 600 FS	Seed treatment	6.66^{a} (1.35)	8.11^{a} (1.99)	10.56^{a} (3.36)	13.97^{a} (5.83)	9.82^{a} (2.91)	5.85^{a} (1.04)	6.66^{a} (1.35)	11.78^{a} (4.17)	13.15^{a} (5.18)	9.36^{a} (2.65)	9.59^{a} (2.78)
Thiamethoxam 30 FS	Seed treatment	8.11^{a} (1.99)	8.92^{a} (2.40)	11.62^{a} (4.06)	15.16^{a} (6.84)	10.95^{a} (3.61)	7.48^{a} (1.69)	8.29^{a} (2.08)	12.25^{ab} (4.50)	14.01^{ab} (5.86)	10.51^{a} (3.33)	10.72^{b} (3.46)
Control (Untreated)	-	19.14^{d} (10.75)	24.08^{f} (16.65)	26.65^{d} (20.12)	30.66^{c} (26.00)	25.13^{g} (18.03)	18.14^{f} (9.69)	21.82^{f} (13.82)	24.92^{g} (17.75)	28.21^{g} (22.34)	23.27^{h} (15.61)	24.20^{i} (16.80)
S. Em. ±	Treatment (T)	1.01	0.89	1.02	1.11	0.49	1.02	1.00	1.03	1.02	0.51	0.36
	Period (P)	-	-	-	-	0.30	-	-	-	-	0.31	0.30
	Year (Y)	-	-	-	-	-	-	-	-	-	-	0.15
	T x P	-	-	-	-	0.99	-	-	-	-	1.03	0.71
	P x Y	-	-	-	-	-	-	-	-	-	-	0.30
	T x Y	-	-	-	-	-	-	-	-	-	-	0.50
	T x P x Y	-	-	-	-	-	-	-	-	-	-	1.01
C. V.%		12.16	9.37	9.52	9.07	9.69	13.21	11.38	10.17	9.33	10.97	10.31

Notes: Figures in parentheses are retransformed values; those outside are arc sine transformed values. Treatment means with common letter(s) are not significant by DNMRT at 5% level of significance within a column; DAS: Days after sowing.

Table 2: Effect of different insecticidal treatments on stem borer, *C. Partellus* infestation in maize

Insecticides	Method of application	Leaf injury scale (1-9)										Pooled over years
		2016					2017					
		20 DAS	30 DAS	40 DAS	50 DAS	Pooled over periods	20 DAS	30 DAS	40 DAS	50 DAS	Pooled over periods	
Carbofuran 3 G	Soil	1.60^{b}	2.00^{b}	2.53^{b}	2.90^{b}	2.26^{b}	1.63^{b}	2.00^{b}	2.37^{b}	3.23^{b}	2.31^{b}	2.28^{b}
Carbofuran 3 G	Leaf whorl	2.30^{c}	2.90^{d}	3.03^{bc}	3.20^{bc}	2.86^{cde}	2.37^{de}	2.80^{de}	3.23^{de}	4.13^{cde}	3.13^{e}	2.99^{de}
Phorate 10 G	Soil	1.67^{b}	2.13^{b}	2.57^{b}	3.00^{bc}	2.34^{bc}	1.90^{bc}	2.10^{bc}	2.40^{bc}	3.37^{b}	2.44^{bc}	2.39^{b}
Phorate 10 G	Leaf whorl	2.43^{c}	3.03^{de}	3.13^{cd}	3.40^{bcd}	3.00^{de}	2.60^{ef}	3.03^{ef}	3.53^{ef}	4.23^{cde}	3.35^{ef}	3.17^{e}
Cartap hydrochloride 4 G	Soil	1.80^{b}	2.40^{bc}	3.00^{bc}	3.50^{cde}	2.68^{bcd}	2.03^{bcd}	2.20^{cd}	2.67^{bc}	3.60^{bc}	2.62^{cd}	2.65^{c}
Cartap hydrochloride 4 G	Leaf whorl	2.47^{c}	3.37^{ef}	3.57^{de}	3.97^{ef}	3.34^{ef}	2.83^{fg}	3.33^{fg}	3.77^{ef}	4.43^{de}	3.59^{f}	3.47^{f}
Chlorantraniliprole 0.4 G	Soil	1.93^{b}	2.67^{cd}	3.30^{cd}	3.80^{de}	2.93^{de}	2.17^{cde}	2.50^{cd}	2.90^{cd}	3.83^{bcd}	2.85^{d}	2.89^{cd}
Chlorantraniliprole 0.4 G	Leaf whorl	2.37^{c}	3.57^{f}	3.87^{e}	4.47^{f}	3.57^{f}	3.20^{g}	3.67^{g}	3.97^{f}	4.73^{e}	3.89^{g}	3.73^{f}
Imidacloprid 600 FS	Seed treatment	1.13^{a}	1.37^{a}	1.60^{a}	1.87^{a}	1.49^{a}	1.07^{a}	1.13^{a}	1.73^{a}	2.20^{a}	1.53^{a}	1.51^{a}
Thiamethoxam 30 FS	Seed treatment	1.20^{a}	1.53^{a}	1.87^{a}	2.23^{a}	1.71^{a}	1.17^{a}	1.30^{a}	1.87^{a}	2.30^{a}	1.66^{a}	1.68^{a}
Control (Untreated)	-	2.53^{c}	5.00^{g}	5.23^{f}	6.23^{g}	4.75^{g}	3.67^{h}	4.57^{h}	5.03^{g}	5.97^{f}	4.81^{h}	4.78^{g}
S. Em. ±	Treatment (T)	0.12	0.15	0.17	0.19	0.18	0.13	0.15	0.16	0.20	0.08	0.08

	Period (P)	-	-	-	-	0.05	-	-	-	-	0.05	0.11
	Year (Y)	-	-	-	-	-	-	-	-	-	-	0.02
	T x P	-	-	-	-	0.16	-	-	-	-	0.16	0.14
	P x Y	-	-	-	-	-	-	-	-	-	-	0.05
	T x Y	-	-	-	-	-	-	-	-	-	-	0.08
	T x P x Y	-	-	-	-	-	-	-	-	-	-	0.16
C. V.%		10.78	9.66	9.80	9.39	9.94	10.17	9.68	9.17	9.13	9.78	9.79

Notes: Figures in parentheses are retransformed values; those outside are $\sqrt{X+0.5}$ transformed values. Treatment means with common letter(s) are not significant by DNMRT at 5% level of significance within a column; DAS: Days after sowing.

Overall, the results on pooled over years indicated the lowest (1.51) leaf injury scale noticed in the treatment of seeds treated with imidacloprid 600 FS and it was at par with thiamethoxam 30 FS (1.68) followed by soil application of carbofuran 3G (2.28) and phorate 10 G (2.39). Among all the tested insecticides, the highest (3.73) leaf injury scale was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G followed by leaf whorl application of cartap hydrochloride 4 G (3.47).

Based on larval and pupal population

The results presented in Table 3 revealed that the lowest (0.11 larva/plant and 0.21 pupa/plant) larval and pupal population was found in the treatment of seeds treated with imidacloprid 600 FS followed by thiamethoxam 30 FS and soil application of carbofuran 3 G during *kharif*, 2016 whereas the highest (0.94 larva/plant and 0.78 pupa/plant) larval and pupal population was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G followed by cartap hydrochloride 4 G and phorate 10 G. More or less similar trend of effectiveness of insecticides was observed during *kharif*, 2017 as well as pooled over years.

Based on stem tunnelling

The results presented in Table 4 revealed that the lowest (0.72%) stem tunnelling was found in the treatment of seeds treated with imidacloprid 600 FS followed by thiamethoxam 30 FS and soil application of carbofuran 3 G during *kharif*, 2016 whereas the highest (3.38%) stem tunnelling was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G followed by cartap hydrochloride 4 G and phorate 10 G. More or less similar trend of effectiveness of insecticides was observed during *kharif*, 2017 as well as pooled over years.

Based on plant height

The results presented in Table 5 revealed that the maize plant height was significantly higher in all the treatments as compared to control. However, among all the treatments, comparatively higher (172.30 cm) plant height were found in the treatment of seeds treated with imidacloprid 600 FS whereas relatively lower (151.56 cm) plant height was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G. More or less similar trend of effectiveness of insecticides was observed during *kharif*, 2017 as well as pooled over years.

Grain and dry fodder yield

Looking to the overall grain yield of maize, significantly the highest (3281.67 kg/ha and 53.95 q/ha) grain and dry fodder yield was found in the treatment of seeds treated with imidacloprid 600 FS followed by thiamethoxam 30 FS and soil application of carbofuran 3G whereas significantly the lowest (2106.33 kg/ha and 36.35 q/ha) grain and dry fodder yield was observed in the treatment of leaf whorl application of chlorantraniliprole 0.4 G followed by leaf whorl application of cartap hydrochloride 4 G.

Table 3: Effect of different insecticidal treatments on population of stem borer, *C. partellus* in maize

Insecticides	Method of application	No. of larvae/ plant			No. of pupae/ plant		
		***Kharif*, 2016**	***Kharif*, 2017**	**Pooled over years**	***Kharif*, 2016**	***Kharif*, 2017**	**Pooled over years**
Carbofuran 3 G	Soil	0.89^{abc} (0.29)	0.91^{abc} (0.33)	0.90^{bc} (0.31)	0.93^{abc} (0.36)	0.95^{abc} (0.40)	0.94^{abc} (0.38)
Carbofuran 3 G	Leaf whorl	1.01^{cde} (0.52)	1.02^{bcd} (0.54)	1.01^{def} (0.52)	1.01^{bcd} (0.52)	1.09^{cde} (0.69)	1.05^{cdef} (0.60)
Phorate 10 G	Soil	0.91^{abcd} (0.33)	0.93^{abc} (0.36)	0.92^{bcd} (0.35)	0.97^{abcd} (0.44)	1.00^{abcd} (0.50)	0.98^{bcd} (0.46)
Phorate 10 G	Leaf whorl	1.06d^{ef} (0.62)	1.06^{cd} (0.62)	1.06^{f} (0.62)	1.09^{cd} (0.69)	1.17^{def} (0.87)	1.13^{efg} (0.78)
Cartap hydrochloride 4 G	Soil	0.93^{bcd} (0.36)	0.97^{abc} (0.44)	0.95^{cde} (0.40)	0.98^{abcd} (0.46)	1.05^{bcd} (0.60)	1.01^{cde} (0.52)
Cartap hydrochloride 4 G	Leaf whorl	1.14^{ef} (0.80)	1.18^{de} (0.89)	1.16^{g} (0.85)	1.11^{d} (0.73)	1.19^{def} (0.92)	1.15^{fg} (0.82)
Chlorantraniliprole 0.4 G	Soil	0.97^{bcd} (0.44)	1.09^{cde} (0.69)	1.03^{ef} (0.56)	1.05^{bcd} (0.60)	1.12^{cde} (0.75)	1.09^{defg} (0.69)
Chlorantraniliprole 0.4 G	Leaf whorl	1.20^{fg} (0.94)	1.27^{ef} (1.11)	1.23^{g} (1.01)	1.13^{d} (0.78)	1.28^{ef} (1.14)	1.20^{gh} (0.94)
Imidacloprid 600 FS	Seed treatment	0.78^{a} (0.11)	0.79^{a} (0.12)	0.78^{a} (0.11)	0.84^{a} (0.21)	0.84^{a} (0.21)	0.84^{a} (0.21)
Thiamethoxam 30 FS	Seed treatment	0.84^{ab} (0.21)	0.84^{ab} (0.21)	0.84^{ab} (0.21)	0.89^{ab} (0.29)	0.86^{ab} (0.24)	0.87^{ab} (0.26)
Control (Untreated)	-	1.36^{g} (1.35)	1.41^{f} (1.49)	1.38^{h} (1.40)	1.27^{e} (1.11)	1.33^{f} (1.27)	1.31^{h} (1.22)

S. Em. ±	Treatment (T)	0.05	0.06	0.03	0.05	0.06	0.04
	Period (P)	-	-	-	-	-	-
	Year (Y)	-	-	0.01	-	-	0.01
	T x P	-	-	-	-	-	-
	P x Y	-	-	-	-	-	-
	T x Y	-	-	0.05	-	-	0.05
	T x P x Y	-	-	-	-	-	-
C. V.%		8.27	9.33	8.84	8.80	9.21	9.02

Notes: Figures in parentheses are retransformed values; those outside are $\sqrt{X+0.5}$ transformed values. Treatment means with common letter(s) are not significant by DNMRT at 5% level of significance within a column; DAS: Days after sowing.

Table 4: Effect of different insecticidal treatments on stem tunneling due to stem borer, *C. partellus* in maize

Insecticides	Method of application	Stem tunneling (cm)			Stem tunneling (%)		
		***Kharif*, 2016**	***Kharif*, 2017**	**Pooled over years**	***Kharif*, 2016**	***Kharif*, 2017**	**Pooled over years**
Carbofuran 3 G	Soil	1.83^{ab}	1.50^{abc}	1.67^{ab}	5.62^{abc} (0.96)	5.39^{abc} (0.88)	5.50^{ab} (0.92)
Carbofuran 3 G	Leaf whorl	2.93^{c}	1.97^{c}	2.45^{bc}	7.97^{d} (1.92)	6.28^{bcd} (1.20)	7.13^{bc} (1.54)
Phorate 10 G	Soil	2.30^{bc}	1.80^{cd}	2.05^{ab}	6.67^{bcd} (1.35)	5.97^{abc} (1.08)	6.62^{ab} (1.33)
Phorate 10 G	Leaf whorl	4.37^{d}	2.13^{c}	3.25^{cde}	10.09^{e} (3.07)	6.59^{cde} (1.32)	8.34^{cd} (2.10)
Cartap hydrochloride 4 G	Soil	2.63^{bc}	2.80^{d}	2.72^{bcd}	6.93^{cd} (1.46)	7.42d^{ef} (1.67)	7.18^{bc} (1.56)
Cartap hydrochloride 4 G	Leaf whorl	4.77^{d}	3.47^{d}	4.12^{ef}	10.30^{e} (3.20)	8.49f^{g} (2.18)	9.40^{d} (2.67)
Chlorantraniliprole 0.4 G	Soil	4.27^{d}	3.10^{d}	3.68^{def}	9.70^{e} (2.84)	7.89^{ef} (1.88)	8.79^{cd} (2.34)
Chlorantraniliprole 0.4 G	Leaf whorl	4.83^{d}	4.17^{e}	4.50^{fg}	10.60^{ef} (3.38)	9.58^{g} (2.77)	10.09^{de} (3.07)
Imidacloprid 600 FS	Seed treatment	1.23^{a}	1.13^{a}	1.18^{a}	4.88^{a} (0.72)	4.61^{a} (0.65)	4.74^{a} (0.68)
Thiamethoxam 30 FS	Seed treatment	1.43^{a}	1.30^{ab}	1.37^{a}	5.24^{ab} (0.83)	4.96^{ab} (0.75)	5.10^{a} (0.79)
Control (Untreated)	-	5.77^{e}	5.43^{f}	5.60^{g}	12.16^{f} (4.44)	11.39^{h} (3.90)	11.77^{e} (4.16)
S. Em. ±	Treatment (T)	0.28	0.20	0.34	0.47	0.43	0.55
	Period (P)	-	-	-	-	-	-
	Year (Y)	-	-	0.07	-	-	0.14
	T x P	-	-	-	-	-	-
	P x Y	-	-	-	-	-	-
	T x Y	-	-	0.24	-	-	0.45
	T x P x Y	-	-	-	-	-	-
C. V.%		14.69	13.48	14.33	10.03	10.35	10.19

Notes: Figures in parentheses are retransformed values; those outside are arc sine transformed values. Treatment means with common letter(s) are not significant by DNMRT at 5% level of significance within a column; DAS: Days after sowing.

Table 5: Effect of different insecticidal treatments on plant height and yield of maize

Insecticides	Method of application	Plant height (cm)			Yield					
					Grain (kg/ha)			Dry fodder (q/ha)		
		2016	**2017**	**Pooled over years**	**2016**	**2017**	**Pooled over years**	**2016**	**2017**	**Pooled over years**
Carbofuran 3 G	Soil	167.23^{a}	170.61^{a}	168.92^{ab}	3116.67^{abc}	3176.67^{ab}	3146.67^{ab}	50.36^{ab}	51.19^{abc}	50.77^{abc}
Carbofuran 3 G	Leaf whorl	162.90^{a}	164.04^{ab}	163.47^{abc}	2858.00^{cde}	2845.00^{abc}	2851.50^{bc}	45.93^{abc}	47.07^{abcd}	46.50^{cde}
Phorate 10 G	Soil	165.23^{a}	166.67^{ab}	165.95^{ab}	3022.33^{abcd}	3010.00^{abc}	3016.17^{ab}	48.76^{ab}	48.19^{abcd}	48.47^{bcd}
Phorate 10 G	Leaf whorl	162.90^{a}	163.46^{ab}	163.18^{abc}	2527.67^{ef}	2748.33^{bc}	2638.00^{c}	41.03^{cd}	44.50^{cdef}	42.76^{e}
Cartap hydrochloride 4 G	Soil	164.24^{a}	166.05^{ab}	165.15^{ab}	2940.67^{bcd}	2753.67^{bc}	2847.17^{bc}	47.18^{abc}	44.97^{bcde}	46.07^{de}
Cartap hydrochloride 4 G	Leaf whorl	154.10^{a}	161.02^{ab}	157.56^{bc}	2237.00^{f}	2198.33^{de}	2217.67^{d}	36.88^{de}	37.90^{efg}	37.39^{f}
Chlorantraniliprole 0.4 G	Soil	160.50^{a}	165.42^{ab}	162.96^{abc}	2685.00^{de}	2603.33^{cd}	2644.17^{c}	43.90^{bc}	41.91^{def}	42.91^{e}
Chlorantraniliprole 0.4 G	Leaf whorl	151.56^{a}	151.40^{bc}	151.48^{c}	2066.00^{f}	2146.67^{de}	2106.33^{d}	35.66^{e}	37.04^{fg}	36.35^{f}
Imidacloprid 600 FS	Seed treatment	172.30^{a}	175.77^{a}	174.03^{a}	3270.00^{a}	3293.33^{a}	3281.67^{a}	53.73^{a}	54.16^{a}	53.95^{a}

Thiamethoxam 30 FS	Seed treatment	169.93[a]	173.47[a]	171.70[a]	3211.67[ab]	3330.00[a]	3270.83[a]	52.25[a]	52.80[ab]	52.53[ab]
Control (Untreated)	-	129.23[b]	139.59[c]	134.41[d]	1660.67[g]	1769.67[e]	1715.17[e]	30.21[f]	31.10[g]	30.65[g]
S. Em. ±	Treatment (T)	7.50	5.21	4.14	135.37	144.58	91.94	1.83	2.33	1.37
	Period (P)	-	-	-	-	-	-	-	-	-
	Year (Y)	-	-	1.95	-	-	42.23	-	-	0.63
	T x P	-	-	-	-	-	-	-	-	-
	P x Y	-	-	-	-	-	-	-	-	-
	T x Y	-	-	6.46	-	-	140.05	-	-	2.09
	T x P x Y	-	-	-	-	-	-	-	-	-
C. V.%		8.12	5.52	6.92	8.71	9.22	8.97	7.16	9.05	8.17

Note: Treatment means with common letter(s) are not significant by DNMRT at 5% level of significance within a column.

It is evident from the results that there are significant differences among the infestation levels of different insecticides and control. The obtained results are in agreement with many research workers [1, 5, 11, 19] who also reported differences among the efficiency of insecticides for the control of maize stem borer. In the present investigation, results indicated that imidacloprid (seed dresser) was prominently effective against maize stem borer in initial days of data recording which is in accordance when same tested with different set of insecticides [10, 19]. Seed dressers (Confidor and Actara) were found considerably more effective as compared to granules and foliar sprays [14]. Seed dressers have longer effects than others and the smaller regression coefficient indicate that the effects were more persistent [14]. It's systemic nature and rapid translocation in plant tissues might be the reason for its quick action during early days of germination [8]. The observed effect of imidacloprid against maize stem borer strengthens as reported elsewhere [15, 22].

Conclusion

In nutshell, all the tested insecticides significantly reduced maize stem borer infestation and have positive effect on maize yield than untreated control. However, considering the stem borer damage and yield; imidacloprid 600 FS and thiamethoxam 30 FS were found highly effective in controlling the stem borer in maize crop. Moreover, soil application of insecticides was also proved effective for management of this pest. It is suggested that farmers may adopt seed treatment component in Integrated Pest Management (IPM) for effective control of maize stem borer.

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