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Field evaluation of insecticides for management of spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) on maize

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Abstract
Management of spotted stem borer, *Chilo partellus* (Swinhoe) on maize by insecticides was conducted in the Agricultural research station, Hagari (Ballari) UAS, Raichur, Karnataka during *Kharif* 2016. The results revealed that, the insecticide viz., imidacloprid 60 FS - chlorantriniliprole 0.4 G, imidacloprid 60 FS - fipronil 0.3 G, imidacloprid 60 FS - carbofuran 3 G were found to be effective molecules against *Chilo partellus.* Next superior treatments in order of priority were chlorantriniliprole 0.4 G > imidacloprid 60 FS + flubendiamide 39.35 SC > fipronil 0.3 G > carbofuran 3 G > flubendiamide 39.35 SC > imdacloprid 60 FS.

Keywords: Insecticides, Maize, Spotted stem borer, *Chilo partellus*

Introduction
Maize or corn (*Zea mays* Linn.) is one of the important cereal crops in the world after wheat and rice and it is cultivated for food, fodder and as raw material for many industries. In India, maize is the third most important food crops after rice and wheat. It is cultivated over an area of 8.69 m ha with a production of 21.80 m t and productivity of 2509 kg ha^{-1}. In Karnataka, maize occupies an area of 1.18 m ha with a production of 3.27 million tones and average productivity is 2773 kg ha^{-1} [1].
Inspite of increase in acreage, maize production in India remained almost stagnant with constant yield level. Biotic stress is one of the major constraints to achieve the attainable yield. Maize is attacked by about 139 species of insect pests with varying degree of damage of which the dozen are quite serious [7]. The lepidopteran pests, particularly the stem borers are the constraint to the productivity of maize in the world. Of these, maize stem borer, *Chilo partellus* in *kharif* season and *Sesamia inferens* in *rabi* season is a major cause of damage to maize crop. Yield losses in different agro climatic regions of India in maize due to *C. partellus* and *S. inferens* ranged from 26.70 to 80.40 and 25.70 to 78.90 percent, respectively [5]. Maize is most vulnerable to *Chilo partellus* (Swinhoe) which causes severe losses to maize crop. It is an important pest in Asian and African countries [3].

Materials and methods
A field experiment was conducted to study the efficacy of various chemicals for spotted stem borer, *Chilo partellus* management at Agricultural Research Station, Hagari (Ballari) during *kharif* 2016. The maize hybrid kaveri 25k55 was used for the experimental purpose. The experiment was designed in RBD with 10 treatments and 3 replications and all the agronomic practices were followed except plant protection measures. In treatments having the seed treatment and foliar spray, first seed treatment was done with imidacloprid at the time of sowing (1hr before sowing) followed by 25 DAS whorl application of carbofuran, chlorantriniliprole and fipronil. Foliar spray was taken at 25 DAS with flubendiamide by using manually operated Knapsack sprayer. Subsequent spraying / whorl application was given at 15 days after first application. The treatment details are described here (Table 1).
Efficacy of the treatments was judged based on the larval population of the stem borers before and after treatment application. Pre count on larval population was taken a day before treatment application on five randomly selected plants by destructive sampling in each plot. Post count was taken at one, three and seven days after application. Percent dead hearts were recorded at 25, 40 and 55 days after sowing. The grain yield from individual treatment was recorded separately and expressed as q ha^{-1}.

Table 1: Treatments details for management of spotted stem borer, *Chilo partellus*

Treat.	Chemicals	Dosage
T1	Imidacloprid 60 FS (seed treatment)	10 ml/kg seeds
T2	Carbofuran 3 G (whorl application @ 25 & 40 DAS)	7.5 kg/ha
T3	Chlorantriniliprole 0.4 G (whorl application @ 25 & 40 DAS)	10 kg/ha
T4	Fipronil 0.3 G (whorl application @ 25 & 40 DAS)	12 kg/ha
T5	Flubendiamide 39.35 SC (spray @ 25 & 40 DAS)	0.15 ml/lit
T6	Imidacloprid 60 FS followed by carbofuran 3 G	10 ml/kg-7.5 kg/ha
T7	Imidacloprid 60 FS followed by chlorantriniliprole 0.4 G	10 ml/kg-10 kg/ha
T8	Imidacloprid 60 FS followed by fipronil 0.3 G	10 ml/kg-12 kg/ha
T9	Imidacloprid 60 FS followed by flubendiamide 39.35 SC	10 ml/kg-0.15 ml/lit
T10	Untreated control (UTC)	--

Results and Discussion

1A) Efficacy of insecticides against spotted stem borer, *Chilo partellus* (I imposition): The pre-treatment population of the stem borer larvae was varied from 3.87 to 7.13 larvae per plant. A significant difference observed between the treatments which were treated with imidacloprid as seed treatment with rest of the treatments (Table 2).

(i) One day after treatment: A day after treatment, the number of larvae per plant varied from 2.73 to 7.53. The treatments with imidacloprid 60 FS - chlorantraniliprole 0.4 G (2.73), imidacloprid 60 FS - fipronil 0.3 G (2.93), imidacloprid 60 FS - flubendiamide 39.35 SC (3.00) were found on par with each other and next best treatment was imidacloprid 60 FS - carbofuran 3 G (3.13). These were followed by imidacloprid 60 FS (4.40), chlorantriniliprole 0.4 G (4.73), fipronil 0.3 G (5.00), carbofuran 3 G (5.07), flubendiamide 39.35 SC (5.13) which were on par with each other. Highest larval population was recorded in an control (7.53).

(ii) Three days after treatment: The number of larvae per plant at three days after treatment varied from 0.80 to 7.20. The treatment with imidacloprid 60 FS - chlorantraniliprole 0.4 G was found superior by recording lowest larval population (0.80). Next best treatments were imidacloprid 60 FS - fipronil 0.3 G (1.33) and were on par with imidacloprid 60 FS - carbofuran 3 G (1.47). This was followed by chlorantriniliprole 0.4 G (1.87) and imidacloprid 60 FS - flubendiamide 39.35 SC (2.07) which were statistically on par with each other. The treatments fipronil 0.3 G, carbofuran 3G, flubendiamide 39.35 SC and imidacloprid 60 FS recorded 2.73, 2.87, 3.80 and 4.73 larvae per plant respectively. Untreated control (7.20) recorded highest larvae per plant compared to rest of the treatments.

(iii) Seven days after t*reatment:* At seven days after treatment, the number of larvae per plant varied from 0.60 to 7.67. The treatment with imidacloprid 60 FS - chlorantraniliprole 0.4 G (0.60) was found to be superior over rest of the treatments by recording lowest larval population. Treatments with imidacloprid 60 FS - fipronil 0.3 G (1.27) and imidacloprid 60 FS - carbofuran 3 G (1.33) were on par with each other and next best treatment was chlorantriniliprole 0.4 G (1.53). This was followed by imidacloprid 60 - FS flubendiamide 39.35 SC (2.00) which is on par with fipronil 0.3 G (2.20) and carbofuran 3G (2.33). The treatment flubendiamide 39.35 SC (2.93) found least effective compared to other treatments. Imidacloprid 60 FS (5.13) differed significantly being inferior to other treatments. Larval population was highest in untreated control (7.67).

1B) Efficacy of insecticides against spotted stem borer, *Chilo partellus* (II imposition): The pre-treatment population of the stem borer larvae was varied from 1.93 to 9.47 larvae per plant. All treatments were significantly superior to the untreated control in recording minimum larval population (Table 3).

(i) One day after treatment: Number of larvae per plant at one day after treatment varied from 1.13 to 9.20. The treatment with imidacloprid 60 FS - chlorantraniliprole 0.4 G (1.13) and chlorantraniliprole 0.4 G (1.40) were found to be at par with each other. These were followed by imidacloprid 60 FS - carbofuran 3G (2.07), imidacloprid 60 FS - fipronil 0.3 G (2.20) which were also found on par with each other but differ significantly with rest of the treatments. The treatments carbofuran 3G and fipronil 0.3 G recorded 2.93 and 3.27 larvae per plant, respectively. The treatments viz. imidacloprid 60 FS - flubendiamide 39.35 SC (3.87), flubendiamide 39.35 SC (4.13) were found to be least effective compared to other treatments. Imidacloprid 60 FS (7.73) differed significantly being inferior to rest of the treatments. However, all treatments recorded lower number of larvae per plant and were significantly superior over the check (9.20).

(ii) Three days after treatment: At three days after insecticide imposition, number of larvae per plant varied from 0.47 to 11.67. The treatment with imidacloprid 60 FS - chlorantraniliprole 0.4 G (0.47) was found to be superior by recording lowest larval population and was on par with chlorantraniliprole 0.4 G (0.87). The treatments imidacloprid 60 FS - fipronil 0.3 G (1.13) and imidacloprid 60 FS - carbofuran 3G (1.27) which were found to be on par with each other and next best treatments were carbofuran 3G (1.53) and fipronil 0.3 G (1.73). The treatments *viz.* flubendiamide 39.35 SC (2.13) and imidacloprid 60 FS - flubendiamide 39.35 SC (2.53) were found to be least effective compared to rest of the treatments. Imidacloprid 60 FS (8.07) differed significantly with former treatments. Untreated check (11.67) had highest larval population.

(iii) Seven days after t*reatment:* During seven days after treatment, the number of larvae per plant varied from 0.47 to 11.67. The treatment with imidacloprid 60 FS - chlorantraniliprole 0.4 G (0.27) was found to be superior by recording lowest larval population and was on par with chlorantraniliprole 0.4 G (0.60). This was followed by imidacloprid 60 FS - fipronil 0.3 G (0.87) and imidacloprid 60 FS - carbofuran 3 G (0.93) which were found to be par with each other but superior over the rest of the treatments. The next best treatments were carbofuran 3 G (1.20), fipronil 0.3 G (1.33) and imidacloprid 60 FS - flubendiamide 39.35 SC (1.40). The treatment flubendiamide 39.35 SC (1.87) was found to be least effective compared to other treatments.

imidacloprid 60 FS (7.20) differed significantly being inferior to other treatments and untreated check recorded 10.93 larvae per plant.

2) Percent dead hearts caused by spotted stem borer, *Chilo partellus*: Effect of insecticides on the percent dead hearts under field condition at 25, 40 and 55 days after sowing is presented in table 4.

(i) At 25 days after sowing: The percent dead heart caused by stem borer was varied from 7.19 to 13.49 percent. Significant difference was observed among the treatments where the seeds were treated with imidacloprid and other treatments (Table 11). The treatment viz. imidacloprid 60 FS - chlorantriniliprole 0.4 G (7.19%), imidacloprid 60 FS - flubendiamide 39.35 SC (7.65%), imidacloprid 60 FS (7.69%), imidacloprid 60 FS - fipronil 0.3 G (8.20%) and imidacloprid 60 FS - carbofuran 3 G (8.28%) which were on par with each other and were superior over rest of the treatments.

(ii) At 40 days after sowing: Similar trend was noticed at 40 DAS, percent dead heart caused by stem borer which ranged from 4.10 to 15.02 percent. The data registered at 40 DAS revealed that imidacloprid 60 FS - chlorantriniliprole 0.4 G recorded minimum percent of dead hearts (4.10%) which was found best among all other treatments followed by imidacloprid 60 FS - carbofuran 3 G (6.49%) which was on par with chlorantriniliprole 0.4 G (6.70%), imidacloprid 60 FS - fipronil 0.3 G (7.32%) and imidacloprid 60 FS - flubendiamide 39.35 SC (7.38%). The treatments viz. fipronil 0.3 G (9.03%), carbofuran 3 G (10.02%), flubendiamide 39.35 SC (10.83%) and imidacloprid 60 FS (11.05%) recorded relatively higher percentage of dead hearts compared to former treatments and untreated check recorded 15.02 percent dead hearts.

(iii) At 55 days after sowing: The percent dead heart caused by stem borer at 55 DAS varied from 2.67 to 21.23 percent. Treatment with imidacloprid 60 FS - chlorantriniliprole 0.4 G recorded minimum percent of dead hearts (2.67%) which was found best among all other treatments, followed by chlorantriniliprole 0.4 G (4.49%). The treatments *viz.* imidacloprid 60 FS - carbofuran 3G (6.62%), imidacloprid 60 FS - fipronil 0.3 G (6.46%), carbofuran 3G (7.31%), imidacloprid 60 FS - flubendiamide 39.35 SC (7.69%) and fipronil 0.3 G (7.79%) which were on par with each other. The treatments viz. flubendiamide 39.35 SC (9.31%) and imidacloprid 60 FS (14.48%) recorded relatively higher percentage of dead hearts compared to former treatments. However, highest percent dead hearts were noticed in over untreated check (21.23%).

3) Grain yield: The treatment imidacloprid 60 FS - chlorantriniliprole 0.4 G recorded higher grain yield of 68.86 q/ha which was on par with imidacloprid 60 FS - fipronil 0.3 G (64.82 q/ha), imidacloprid 60 FS - carbofuran 3 G (62.74 q/ha) and chlorantriniliprole 0.4 G (61.65 q/ha). The next best treatments were fipronil 0.3 G and carbofuran 3 G recorded yield of 58.89 and 57.29 q/ha respectively. These were followed by imidacloprid 60 FS - flubendiamide 39.35 SC (54.41 q/ha) which was on par with flubendiamide 39.35 SC (52.38 q/ha). Seed treatment with imidacloprid 60 FS alone recorded lower seed yield of 36.06 q/ha and that of untreated control was 19.23 q/ha of grain yield (Table 4).

The results were found to be in line with the previous report which stated that chlorantraniliprole 0.4 GR as the best among all the tested insecticides with reduced stem borer infestation [7]. Another report shows that fipronil 0.3 G (12 kg/ha) recorded least larval population (1.8 larvae/plant) compared with other treatments like thiocyclam 4 G (20 kg/ha) and imidacloprid 0.3 G (15 kg/ha) (3.80 and 13.50, respectively) [6]. The results were also found to be in accordance with the previous studies in which it was reported that ef carbofuran 3 G (whorl application) reduce the larval population of 73.50 percent over control [4].

Imidacloprid 60 FS - chlorantriniliprole 0.4 G resulted in lowest percent dead hearts (4.65%). Next to this were imidacloprid 60 FS - carbofuran 3 G (7.13%), imidacloprid 60 FS - fipronil 0.3 G (7.32%). Dead heart damage was significantly high of untreated check (16.64%). The previous articles reported that seed treatment with imidacloprid 60 FS (5ml/kg seed) recorded least dead heart percent (6.50%) compared with thiamethoxam 30 FS (7ml/kg of seed) (8.49%) and untreated check (14.76%) [2]. Similarly chlorantriniliprole 0.4 G recorded zero percent dead hearts over the control (14.8%) against yellow stem borer in rice ecosystem [7]. Another previous article reported that average dead hearts count for carbofuron 3 G were 3.167 percent followed by 4.4 percent for fipronil 4 G over control (22.50%) [9].

Table 2: Evaluation of insecticides on larval population of stem borer, *Chilo partellus* (First insecticide application)

Sl. No.	Treatment	Dosage	Number of larvae per plant				Mean	Percent reduction over control
			First imposition					
			1 DBT	1DAT	3DAT	7 DAT		
1	Imidacloprid 60 FS	10 ml/kg seeds	4.33 (2.20) ^{a}	4.40 (2.21) ^{bc}	4.73 (2.29) ^{g}	5.13 (2.37) ^{f}	4.65	35.86
2	Carbofuran 3 G	7.5 kg/ha	6.87 (2.71) ^{b}	5.07 (2.36) ^{c}	2.87 (1.82) ^{e}	2.33 (1.68) ^{d}	4.29	40.83
3	Chlorantriniliprole 0.4 G	10 kg/ha	7.13 (2.76) ^{b}	4.73 (2.28) ^{c}	1.87 (1.54) ^{cd}	1.53 (1.43) ^{bc}	3.82	47.31
4	Fipronil 0.3 G	12 kg/ha	6.40 (2.63) ^{b}	5.00 (2.35) ^{c}	2.73 (1.79) ^{e}	2.20 (1.64) ^{d}	4.08	43.72
5	Flubendiamide 39.35 SC	0.15 ml/ lit	6.07 (2.56) ^{b}	5.13 (2.37) ^{c}	3.80 (2.07) ^{f}	2.93 (1.85) ^{e}	4.48	38.20
6	Imidacloprid 60 FS - Carbofuran 3 G	10 ml/kg - 7.5 kg/ha	4.27 (2.18) ^{a}	3.13 (1.89) ^{ab}	1.47 (1.40) ^{bc}	1.33 (1.35) ^{b}	2.55	64.82
7	Imidacloprid 60 FS - Chlorantriniliprole 0.4 G	10 ml/kg - 10 kg/ha	3.93 (2.10) ^{a}	2.73 (1.79) ^{a}	0.80 (1.14) ^{a}	0.60 (1.05) ^{a}	2.02	72.13
8	Imidacloprid 60 FS - Fipronil 0.3 G	10 ml/kg -12 kg/ha	3.87 (2.09) ^{a}	2.93 (1.85) ^{a}	1.33 (1.35) ^{b}	1.27 (1.33) ^{b}	2.35	67.58
9	Imidacloprid 60 FS -	10 ml/kg - 0.15 ml/lit	4.13	3.00	2.07	2.00	2.80	61.37

	Flubendiamide 39.35 SC		(2.15) [a]	(1.84) [a]	(1.60) [d]	(1.58) [cd]		
10	Untreated control (UTC)	–	6.60 (2.66) [b]	7.53 (2.84) [d]	7.20 (2.78) [h]	7.67 (2.85) [g]	7.25	–
	S.Em±		0.08	0.11	0.06	0.06		
	CD @ 5%		0.23	0.34	0.19	0.17		

DBT – Day before treatment; DAT – Days after treatment;
Figures in the parenthesis are √x+0.5 transformed values.
Mean followed by the same alphabet in the column do not differ significantly by DMRT.

Table 3: Evaluation of insecticides on larval population of stem borer, *Chilo partellus* (Second insecticide application)

Sl. No.	Treatment	Dosage	Number of larvae per plant				Mean	Percent reduction over control
			Second imposition					
			1DBT	1DAT	3DAT	7DAT		
1	Imidacloprid 60 FS	10 ml/kg seeds	7.07 (2.75) [f]	7.73 (2.86) [f]	8.07 (2.92) [f]	7.20 (2.77) [e]	7.52	27.13
2	Carbofuran 3 G	7.5 kg/ha	4.13 (2.15) [cd]	2.93 (1.85) [c]	1.53 (1.43) [bcd]	1.20 (1.30) [c]	2.45	76.26
3	Chlorantriniliprole 0.4 G	10 kg/ha	2.87 (1.83) [b]	1.40 (1.37) [a]	0.87 (1.16) [ab]	0.60 (1.05) [ab]	1.44	86.04
4	Fipronil 0.3 G	12 kg/ha	4.47 (2.23) [d]	3.27 (1.94) [cd]	1.73 (1.50) [cde]	1.33 (1.35) [cd]	2.70	73.84
5	Flubendiamide 39.35 SC	0.15 ml/ lit	5.67 (2.48) [e]	4.13 (2.15) [e]	2.13 (1.62) [de]	1.87 (1.54) [d]	3.45	66.57
6	Imidacloprid 60 FS - Carbofuran 3 G	10 ml/kg + 7.5 kg/ha	3.13 (1.89) [b]	2.07 (1.60) [b]	1.27 (1.31) [bc]	0.93 (1.19) [bc]	1.85	82.07
7	Imidacloprid 60 FS - Chlorantriniliprole 0.4 G	10 ml/kg + 10 kg/ha	1.93 (1.55) [a]	1.13 (1.27) [a]	0.47 (0.98) [a]	0.27 (0.88) [a]	0.95	90.80
8	Imidacloprid 60 FS - Fipronil 0.3 G	10 ml/kg + 12 kg/ha	3.27 (1.94) [bc]	2.20 (1.64) [b]	1.13 (1.27) [bc]	0.87 (1.16) [bc]	1.87	81.88
9	Imidacloprid 60 FS - Flubendiamide 39.35 SC	10 ml/kg + 0.15 ml/lit	4.80 (2.30) [de]	3.87 (2.09) [de]	2.53 (1.74) [e]	1.40 (1.38) [cd]	3.15	69.48
10	Untreated control (UTC)	-	9.47 (3.15) [g]	9.20 (3.11) [g]	11.67 (3.49) [g]	10.93 (3.33) [f]	10.32	-
	S.Em±		0.09	0.07	0.09	0.08	-	-
	CD @ 5%		0.26	0.20	0.28	0.22	-	-

DBT – Day before treatment; DAT – Days after treatment;
Figures in the parenthesis are √x+0.5 transformed values.
Mean followed by the same alphabet in the column do not differ significantly by DMRT.

Table 4: Influence of various insecticides on percent dead heart and yield in maize

Sl. No.	Treatment	Dosage	Percent dead heart				Percent reduction over control	grain yield (q/ha)
			25 DAS	40DAS	55DAS	Mean		
1	Imidacloprid 60 FS	10 ml/kg seeds	7.69 (16.09) [a]	11.05 (19.38) [d]	14.48 (22.33) [d]	11.07	33.47	36.06
2	Carbofuran 3 G	7.5 kg/ha	13.46 (21.51) [b]	10.02 (18.69) [d]	7.31 (15.53) [bc]	10.26	38.34	57.29
3	Chlorantriniliprole 0.4 G	10 kg/ha	12.22 (20.45) [b]	6.70 (14.92) [bc]	4.49 (12.23) [ab]	7.80	53.12	61.65
4	Fipronil 0.3 G	12 kg/ha	11.54 (19.83) [b]	9.03 (17.44) [d]	7.79 (16.21) [bc]	9.45	43.20	58.89
5	Flubendiamide 39.35 SC	0.15 ml/ lit	12.22 (20.46) [b]	10.83 (19.19) [d]	9.31 (17.70) [cd]	10.78	35.22	52.38
6	Imidacloprid 60 FS - Carbofuran 3 G	10 ml/kg + 7.5 kg/ha	8.28 (16.67) [a]	6.49 (14.71) [b]	6.62 (14.77) [bc]	7.13	57.15	62.74
7	Imidacloprid 60 FS - Chlorantriniliprole 0.4 G	10 ml/kg + 10 kg/ha	7.19 (15.53) [a]	4.10 (11.60) [a]	2.67 (7.69) [a]	4.65	72.05	68.86
8	Imidacloprid 60 FS - Fipronil 0.3 G	10 ml/kg + 12 kg/ha	8.20 (16.59) [a]	7.32 (15.70) [bc]	6.46 (14.58) [bc]	7.32	56.01	64.82
9	Imidacloprid 60 FS - Flubendiamide 39.35 SC	10 ml/kg + 0.15 ml/lit	7.65 (15.91) [a]	7.38 (15.76) [bc]	7.69 (16.10) [bc]	7.57	54.51	54.41
10	Untreated control (UTC)	–	13.49 (21.55) [b]	15.02 (22.75) [e]	21.23 (27.42) [e]	16.64	–	19.23
	S.Em±		0.84	0.85	1.45	-	-	3.14
	CD @ 5%		2.52	2.55	4.34	-	-	9.39

DAS – Days after sowing;
Figures in the parenthesis are arc sin transformed values.
Mean followed by the same alphabet in the column do not differ significantly by DMRT.

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