Field efficacy of eco-friendly management practices against maize stem borers in spring maize at Rampur, Chitwan

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Article Info

ABSTRACT

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A field experiment was conducted to determine the comparative efficacy of different eco-friendly management practices against maize stem borers, *Chilo partellus* (Swinhoe) and *Sesamia inferens* (Walker) in maize under field condition during spring season for two consecutive years, 2017 and 2018. The experiment was laid out in a randomized complete block design with four replications and seven treatments, namely: i) *Trichogramma chilonis* (Ishii) (egg parasitoids) @ 100000 eggs ha⁻¹, ii) Nimbecidine 0.03% (Neemax)-commercial product of neem @ 3.0 mL L⁻¹ of water, iii) Spinosad 45% SC (Tracer) -bio-insecticide @ 0.5 mL L⁻¹ of water, iv) *Bacillus thuringiensis* 10⁸cfu mL⁻¹ (Mahashakti)-bio-insecticide @ 2 mL L⁻¹ of water, v) maize intercropping with cowpea (1:1 ratio), vi) Chlorpyrifos 20% EC (Dursban)- chemical insecticide @ 2 mL L⁻¹ of water, and vii) Untreated control (without application) at the National Maize Research Program, Chitwan, Nepal. The efficacy study revealed that all the treatments significantly reduced leaf and stem injuries and increased grain yield over untreated check ($p < 0.05$). The treatment, chlorpyrifos 20% EC was found effective with minimum percent infestation in both leaf (5.51%) and stem (1.86%) injury followed by spinosad 45% EC and *T. chilonis* respectively. Similarly, spinosad 45% EC gave significant result with the highest grain yield (4.66 mt ha⁻¹) followed by Chlorpyrifos 20% EC (4.57 mt ha⁻¹) and maize + cowpea intercropping (4.23 mt ha⁻¹) as compared to untreated control (2.91 mt ha⁻¹). Maize + cowpea (1:1) intercropping and release of *T. chilonis* were at par statistically and proved safer to natural enemies as compared to the chemical insecticides.

INTRODUCTION

Maize (*Zea mays* L.) is the second important food crop which occupies 956,447 ha of land with the production of 2,713,635 mt in Nepal (MoALD 2018/19). It contributes 3.15% in national gross domestic product (GDP) and 9.5% in agricultural gross domestic product (AGDP). This crop contributes 25.39% to the total cereal crop production in the country. In spite of diverse cultivation areas and

seasons of maize in Nepal, the productivity of maize is only 2.84 mt ha⁻¹ (MoALD 2018/19). The productivity of maize in Nepal is lower as compared to other developed country; for limiting maize yield, both biotic and abiotic factors have played a major role in Nepal (Achhami et al. 2015). Among the insect pests, maize stem borer complex, *Chilo partellus* (Swinhoe) and *Sesamia inferens* (Walker) and *Chilo suppressalis* (Walker) were major borers found in Nepal (Bhandari et al. 2018; KC et al. 2015). They are major biotic constraints to maize production throughout the country (Sharma and Gautam 2010; Bhandari et al. 2018). The plant damage and grain yield reduction due to these pests ranges 20-87%, and 15-60%, respectively in Nepal (Thakur et al. 2013; Achhami et al. 2015).

Chemical insecticides are the most common way to control these pests in developing countries

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like Nepal but due to destructive environmental effect of chemical insecticides in last decade, researchers have been trying to find alternative to synthetic insecticides. Use of insecticides is not the right choice to control stem borers due to its cryptic feeding behavior, prolonged emergence pattern, multiple generations, nocturnal habits of the adult moths and the protection by the host stem for immature pest stages (Ampofo, 1986). Moreover, extensive use of chemical insecticides directly increases the cost of cultivation and possesses many health hazards (Singh et al. 2018). Bio-control agents, like parasitoid wasps and microbial agents have proved as admissible alternative for chemical pesticides (Shahbaz et al. 2012). Egg parasitism by *Trichogramma chilonis* (Ishii) had been observed to be quite effective in the biological suppression of *Chilo partellus* in maize (Jalali and Singh 2003; Farid et al. 2007). Moreover, stem borer species, their populations, damaging behavior, predators and parasites associated with them are still scarce in Nepal. So this experiment was conducted to manage the stem borers in maize using bio-control agents as well as bio-rational insecticides with cultural practices under field condition.

MATERIALS AND METHODS

Experimental site and design

This experiment was conducted in research field of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal during spring seasons of 2017 and 2018. The research location has latitude 27°40'N, longitude 84° 19' E and 228 meter above sea level. The experiment was carried out in a randomized complete block design along with four replications. The maize variety (Rampur Composite-open pollinated variety) was grown in eight rows of five-meter length with a spacing of 75 cm×25 cm (rows x plants). The agronomic practices for growing crop were carried out as per the recommendations of NMRP.

Application methodology

All treatments were applied three times as per schedule. The parasitoid wasps were released at 10 days' interval and first application was done at 10 days after seed sowing (DAS). Bio-rational insecticide, *Bacillus thuringiensis* (Bt) was sprayed one week after egg laying when larvae was being in 1st and 2nd instar stage in the whorl. Other treatments were applied 15 days interval, first sprayed at 10 DAS.

Data collection

Sample plants

In each treatment, middle four rows were evaluated for recording plant damage data. From each treatment, twenty plants were collected for measurement of exist holes and tunnel length. Similarly, five cobs were taken to measure cob diameter and cob length.

Leaf damage measurement

Plant damage was observed visually during the knee high stage (25 DAS) and just before tasseling stage (45 DAS) by counting infected and non-infested ones of all treatments. To ascertain the infestation the plants were examined externally and internally.

Pest incidence was calculated using following formulae:

$$\text{Plant infestation (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Stem damage measurement

The exit holes caused by stem borer complex were counted visually from the sampled plants. The intact leaves on stem were removed and the each stalk was dissected (cut) longitudinally and tunnel length made by stem borer (inside stalk) was recorded.

$$\text{Length of tunneling (\%)} = \frac{\text{Length of tunneling (cm)}}{\text{Total length of stem (cm)}} \times 100$$

Yield and yield attributes

Yield attributing traits namely cob length, Cob diameter; thousand grain weights were measured after harvesting of five sample cobs from each treatment. Cob diameter was measured by using Vernier caliper. Grain yield was calculated at 15% moisture using following below formula (Shrestha et al. 2019):

$$\text{Grain yield} = \frac{\text{Grain yield} \left(\frac{\text{kg}}{\text{plot}} \right) \times \text{selling \%} \times 10 (100 - \text{moisture \%})}{\text{Net plot area (m}^2\text{)} \times 85}$$

Data analysis

The data were entered in Microsoft Excel 2016 and GENSTAT (version 17th edition) was used for analysis of data. The comparison of treatment means for significant difference was carried out at 0.05 probability level (Gomez and Gomez, 1984). The correlation analysis with the weather parameters was carried out.

Weather parameters

Climate and weather can significantly influence the growth and development and distribution of insects. Weather data of experimental period were recorded from the weather station at the National Maize Research Program, Rampur which is presented in Figure 1.

Figure 1. Meteorological data during experimental period (2017 and 2018) at Rampur, Chitwan, Nepal

RESULTS AND DISCUSSION

Foliar damage and dead heart percentage

The incidence of leaf injury and dead heart due to natural infestation of stem borers were recorded 10 days after the application of different

treatment during the year 2017 and 2018 (Table 1 and 2). Statistical analysis of data showed that all treatments were significantly different as compared to untreated control ($p < 0.05$). The lower dead heart (0.66%) and leaf infestation (4.99%) due to maize stem borers were found in plot treated with spinosad 45%SC followed by chlorpyrifos 20% EC (0.93% and 4.85%) and *Trichogramma chilonis* (1.61% and 7.13%) respectively during 2017 (Table 1). Similarly, chlorpyrifos was found to be

Table 1. Effect of different treatments on reduction of plant damage and dead heart incidence by stem borers in maize during spring season, 2017

Treatments	Leaf damage (%)			Stem damage			
	KHS (25 DAS)	BTS (45 DAS)	Mean damage	Dead heart (%)	Exit hole (no.)	Tunnel length (cm)	Stem damage (%)
<i>Trichogramma chilonis</i>	9.63 (3.08) ^{ab}	4.63 (2.08) ^{ab}	7.13 (2.64) ^{ab}	1.61 (1.41) ^{ab}	1.33 (1.19) ^b	5.1 (2.23) ^{ab}	3.32 (1.80) ^{ab}
Nimbecidine 0.03%	11.05 (3.39) ^{bc}	11.59 (3.39) ^{bc}	11.57 (3.4) ^{bc}	5.64 (2.43) ^c	1.75 (1.31) ^{bc}	9.22 (3.00) ^{bc}	6.38 (2.48) ^{bc}
Spinosad 45% SC	7.24 (2.55) ^a	2.74 (1.55) ^a	4.99 (2.18) ^a	0.66 (1.05) ^a	1.58 (1.25) ^{bc}	3.03 (2.35) ^{ab}	2.01 (1.71) ^{ab}
<i>Bacillus thuringiensis</i> 10 ⁸ cfu/ml	8.71 (2.92) ^{ab}	21.64 (4.53) ^d	15.16 (3.83) ^c	4.48 (2.22) ^c	2.75 (1.62) ^c	12.7 (3.47) ^c	8.48 (2.84) ^c
Maize + cowpea (1:1)	8.37 (2.87) ^{ab}	13.27 (3.62) ^c	10.83 (3.3) ^{bc}	2.39 (1.68) ^b	1.73 (1.30) ^{bc}	6.85 (2.60) ^{ab}	4.65 (2.14) ^{abc}
Chlorpyrifos 20% EC	5.95 (2.39) ^a	3.74 (1.88) ^{ab}	4.85 (2.16) ^a	0.93 (1.18) ^{ab}	0.43 (0.60) ^a	1.5 (1.20) ^a	0.94 (0.94) ^a
Untreated control	15.89 (3.95) ^c	27.83 (5.23) ^d	21.86 (3.92) ^d	11.08 (3.48) ^d	4.65 (2.14) ^d	19.65 (4.40) ^d	12.69 (3.53) ^d
Grand mean	9.62 (3.02)	12.20 (3.18)	10.91 (2.94)	3.83 (1.91)	2.03 (1.33)	8.29 (2.75)	5.49 (2.33)
F test	*	**	**	*	**	**	**
CV, %	17.1	21.2	15.0	17.9	18.5	21.4	21.9
LSD _{0.05}	4.450	7.722	0.704	2.008	1.01	5.447	3.706

Figures in parentheses are Square root transformed values; KHS=knee high stage, BTS= before tasseling stage, DAS= days after sowing

Table 2. Effect of different treatments on reduction of plant damage and dead heart incidence by stem borers in maize during spring season, 2018

Treatments	Leaf damage (%)			Stem damage			
	KHS (25 DAS)	BTS (45 DAS)	Mean leaf damage	Dead heart (%)	Exit hole (No)	Tunnel length (cm)	Stem damage (%)
<i>Trichogramma chilonis</i>	7.3 (2.6) ^{ab}	24.4 (4.7) ^b	15.8 (3.8) ^{bc}	2.54 (1.74) ^b	0.45 (0.66) ^{ab}	4.38 (2.08) ^{ab}	3.13 (1.76) ^{ab}
Nimbecidine 0.03%	15.3 (3.9) ^c	27.8 (5.2) ^{bc}	21.5 (4.6) ^{cd}	5.23 (2.36) ^c	1.1 (1.04) ^{bc}	9.98 (3.14) ^{bcd}	7.01 (2.64) ^{bc}
Spinosad 45% SC	6.8 (2.4) ^{ab}	10.6 (3.2) ^a	8.7 (2.9) ^{ab}	0.55 (0.98) ^a	0.38 (0.52) ^a	2.93 (1.47) ^a	2.11 (1.27) ^a
<i>Bacillus thuringiensis</i> 10 ⁸ cfu/ml	12.5 (3.5) ^{bc}	26.7 (5.2) ^{bc}	19.6 (4.4) ^{cd}	4.34 (2.17) ^c	1.23 (1.09) ^c	12.1 (3.36) ^{cd}	10.57 (3.22) ^c
Maize + cowpea (1:1)	11.4 (3.3) ^{bc}	24.7 (4.9) ^b	18.1 (4.2) ^c	2.28 (1.64) ^b	1.10 (1.0) ^{bc}	8.28 (2.75) ^{bc}	6.02 (2.34) ^{bc}
Chlorpyrifos 20% EC	5.0 (2.2) ^a	7.3 (2.7) ^a	6.1 (2.5) ^a	0.56 (0.98) ^a	0.78 (0.85) ^{abc}	4.10 (1.98) ^{ab}	2.77 (1.63) ^{ab}
Untreated control	15.8 (3.9) ^c	37.1 (6.1) ^c	26.4 (5.1) ^d	9.28 (3.12) ^d	2.28 (1.50) ^d	16.45 (4.03) ^d	8.85 (2.86) ^c
Grand mean	10.6 (3.1)	22.7 (4.5)	16.6 (3.9)	3.54 (1.86)	1.04 (0.95)	8.31 (2.69)	5.78 (2.25)
F test	ns	**	**	*	**	**	*
CV, %	21.2	18.9	17.7	14	26	28	29.3
LSD 0.05	-	11.370	7.716	1.58	0.586	5.301	3.986

Figures in parentheses are Square root transformed values; KHS=knee high stage, BTS= before tasseling stage, DAS= days after sowing

highly effective with lower leaf damage and dead heart followed by spinosad 45% EC and *T. chilonis* during 2018 (Table 2). In combined analysis (Table 3), spinosad was found to be more effective resulting in minimum dead heart (0.60%) and leaf damage (6.86%) as compared to untreated control (10.18%, 24.16%) followed by chlorpyrifos (0.74%, 5.51%) and *T. chilonis* (2.08%, 11.48%) in dead heart and leaf damage respectively. These findings are also in close conformity with the finding of Devananda et al. (2018) who reported

dead heart (0.93%) due to maize stem borer as compared to untreated control (6.95%). Likewise, these findings are also supported by Ahmed et al. (2002) who reported that spinosad was effective to reduce infestation from 10.7% before sprays to 3.1% seven day after first spray and to 0.7% at seven day of second spray. Kumar and Kanta (2011) who reported significantly lower damage caused by the maize stem borer and subsequently increased the grain yield in the plots with where in *T. chilonis* was released @ 100000 eggs ha⁻¹ on 12

Table 3. Effect of different treatments on reduction of plant damage and dead heart incidence by stem borers in maize in combined analysis, 2017 and 2018

Treatments	Leaf damage (%)			Stem damage			
	KHS (25 DAS)	BTS (45 DAS)	Mean damage	Dead heart (%)	Exit hole (No)	Tunnel length (cm)	Stem damage (%)
<i>Trichogramma chilonis</i>	8.48 ^{ab}	14.49 ^b	11.48 ^b	2.08 (1.57) ^b	0.89 ^a	4.74 ^{ab}	3.22 ^{ab}
Nimbecidine 0.03%	13.43 ^{cd}	19.67 ^{bc}	16.55 ^c	5.43 (2.39) ^c	1.43 ^b	9.60 ^{cd}	6.70 ^c
Spinosad 45% SC	7.06 ^{ab}	6.65 ^a	6.86 ^a	0.60 (1.01) ^a	0.98 ^{ab}	2.98 ^a	2.05 ^a
<i>Bacillus thuringiensis</i> 10 ⁸ cfu/ml	10.65 ^{bc}	24.17 ^c	17.41 ^c	4.41 (2.20) ^c	1.99 ^c	12.4 ^d	9.53 ^d
Maize + cowpea (1:1)	9.92 ^{bc}	19.02 ^{bc}	14.47 ^{bc}	2.34 (1.67) ^b	1.41 ^b	7.56 ^{bc}	5.34 ^{bc}
Chlorpyrifos 20% EC	5.49 ^a	5.53 ^a	5.51 ^a	0.74 (1.08) ^a	0.60 ^a	2.80 ^a	1.86 ^a
Untreated control	15.85 ^d	32.47 ^d	24.16 ^d	10.18 (3.26) ^d	3.46 ^d	18.05 ^e	10.77 ^d
Grand mean	10.13	17.43	13.78	3.68 (1.89)	1.54	8.30	5.63
F test	**	**	**	*	**	**	*
CV, %	24.3	25.2	21.9	12.2	20.8	26.4	31.6
LSD 0.05	3.654	6.534	4.477	1.342	0.473	3.338	2.715

Figures in parentheses are Square root transformed values; KHS=knee high stage, BTS= before tasseling stage, DAS= days after sowing

that spinosad 45% SC recorded minimum percent

Figure 2. Effect of different treatments on dead heart reduction and increment of maize grain yield in combined analysis, 2017 and 2018

and 15 day old maize crop. *Bacillus thuringiensis*

with 4.41% in dead heart was recorded followed by nimbecidine (5.43 %) as the least effective among the treatments but was significantly superior to untreated control (10.18%) in combined analysis. These findings are in conformity with the findings of Choudhary et al. (2017) who found nimbecidine @ 5 mL L⁻¹ of water with 5.13 percent dead heart.

Tunnel length and exit holes measurement

All the treatments significantly reduced the mean percent of stem tunneling and exit hole numbers in comparison to untreated control ($p < 0.05$) (Table 1, 2 and 3). Based on the tunnel length and exit hole numbers made by borers, the lowest tunnel length and exit hole (1.50 cm, 0.43 in numbers) were recorded in plot treated with chlorpyrifos followed by spinosad (3.03 cm and 1.58 numbers) and *Trichogramma chilonis* (5.10 cm and 1.33 numbers) as compared to untreated control (19.65 cm and 4.65 numbers) during 2017 (Table 1). Similarly, the results revealed that all the

treatments were significantly different as compared to untreated control in 2018. Spinosad 45% SC was found to be more effective resulting with minimum tunnel length (2.93 cm) and exit hole numbers (0.38) made by stem borers which was at par with plot treated by chlorpyrifos 20% EC (4.10 cm and 0.78 numbers) as compare to untreated control (16.45%, and 2.28 numbers). Likewise, the treatment chlorpyrifos showed lowest tunnel length (2.80 cm) and exit hole numbers (0.60) followed by spinosad (2.98 cm and 0.98 numbers) and *T. chilonis* (4.74 cm and 0.89 numbers) in combined analysis of 2017 and 2018 (Table 3). Present findings are falling in line of earlier study by Hegde et al. (2017) who reported that chlorpyrifos 20% EC (seed treatment+ foliar spray) was found effective by recording lowest mean number of larvae per plant. They also found chlorpyrifos 20% EC to be superior in its efficacy against maize stem borers with seed treatment after foliar spray at 40 DAS. Similarly, spinosad 45% SC was found to be the best treatments which could reduce the damage to maize plant by stem borers in terms of less larval

Table 4. Effect of different treatments on grain yield and yield attributing traits during spring season, 2017

Treatments	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob diameter (cm)	Grain yield (mt ha ⁻¹)	Increase in yield over untreated check (%)
<i>Trichogramma chilonis</i>	154	107 ^{ab}	12.9	4.2	4.10 ^{bc}	31.4
Nimbecidine 0.03%	150	106 ^{ab}	12.2	4.0	3.52 ^{cd}	12.8
Spinosad 45% SC	151	108 ^{ab}	13.0	4.0	4.44 ^{ab}	42.3
<i>Bacillus thuringiensis</i> 10 ⁸ cfu/ml	149	107 ^c	13.0	4.0	3.48 ^{cd}	11.5
Maize + cowpea (1:1)	146	105 ^{ab}	12.2	4.2	4.04 ^{bc}	29.5
Chlorpyrifos 20% EC	161	99 ^a	13.1	4.1	4.82 ^a	54.5
Untreated control	155	101 ^c	12.6	4.2	3.12 ^d	
Grand mean	152	105	12.7	4.1	3.93	
F test	ns	ns	ns	ns	**	
CV, %	7.4	6.1	7.3	5.7	10.9	
LSD 0.05	-	-	-	-	0.639	

Mean in a column followed by the same letters are not significantly different at $P=0.05$.

Table 5. Effect of different treatments on grain yield and yield attributing traits during spring season, 2018

Treatments	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob diameter (cm)	Grain yield (mt ha ⁻¹)	Increase in yield over untreated check (%)
<i>Trichogramma chilonis</i>	199	125 ^{ab}	4.2	13.9	3.90 ^{bc}	44.4
Nimibicidine 0.03%	196	111 ^a	4.3	14.2	3.30 ^{cd}	22.2
Spinosad 45% SC	210	123 ^{ab}	4.4	15.0	4.89 ^a	81.1
<i>Bacillus thuringiensis</i> 10 ⁸ cfu/ml	217	118 ^{ab}	4.2	14.1	3.44 ^{bcd}	27.4
Maize + cowpea (1:1)	217	128 ^c	4.3	14.3	3.88 ^{bc}	43.7
Chlorpyrifos 20% EC	201	114 ^{ab}	4.4	14.1	4.36 ^{ab}	61.5
Untreated control	213	122 ^{ab}	4.3	14.2	2.70 ^d	
Grand mean	207.5	120	4.3	14.2	3.78	
F value	ns	ns	ns	ns	*	
CV, %	7.9	7.8	4.3	5.3	16.5	
LSD 0.05	-	-	-	-	0.924	

Mean in a column followed by the same letters are not significantly different at P=0.05.

density, foliar damage, number of exit holes and stem tunneling reported by Kumar et al. (2017).

Bacillus thuringiensis and nimibicidine

recorded higher tunnel length (12.40 cm and 9.60 cm) and higher exit hole numbers (1.99 and 1.43) and thus proved the least effective among the treatments but were found effective as compared to untreated control (18.05 cm tunnel length and 3.46 number of exit holes) in combined analysis (Table 3). The possible reason was too effective of Bt only for early instar larvae in the field condition but less effective for later instar larvae because they bored into the maize stalk. These results are in line with the findings of Jalali and Singh (2006); Malepati et al. (2018) who found that *B. thuringiensis* was recorded as least effective among the chemical treatments but significant and superior over control. Similarly, the results of lower efficacy of *B. thuringiensis* kurstaki @ 1 g L⁻¹ of water) as compared to deltamethrin had also been reported by Teli et al. (2007). On the contrary, Jose et al. (2008) and Pal et al. (2009) reported that nimibicidine @ 5 mL L⁻¹ of water against maize

stem borers was found effective.

Grain yield and yield attributes

Statistical analysis of data showed that all treatments were significantly similar in plant height, ear height, cob length and cob diameter measurement except for grain yield in the years, 2017 and 2018. The yield obtained from different treatments showed that the highest grain yield (4.82 mt ha⁻¹) was obtained from the plot treated with chlorpyrifos 20% followed by spinosad 45%SC (4.44 mt ha⁻¹) and *Trichogramma chilonis* (4.10 mt ha⁻¹) during 2017 (Table 4). Similarly, the yield obtained from different treatments showed significant with 0.05% during 2018. The highest grain yield (4.89 mt ha⁻¹) was obtained from the plot treated with spinosad 45% SC followed by chlorpyrifos 20% EC (4.36 mt ha⁻¹) *T. chilonis* and

(3.90 mt ha⁻¹) (Table 5). However, all the treated plots yielded higher than the untreated control. Statistical analysis of data showed that only grain yield was significantly different as compare to untreated control in combined analysis (Table 6). The highest grain yield (4.66 mt ha⁻¹)

Table 6. Combined analysis of maize stem borers management with grain yield and yield attributing traits of maize during spring season, 2017 and 2018

Treatments	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob diameter (cm)	Grain yield (mt ha ⁻¹)	Increase in yield over untreated check (%)
<i>Trichogramma chilonis</i>	146.8	115.9	13.4	4.2	4.00 ^a	37.5
Nimibicidine 0.03%	146.1	108.4	13.2	3.4	3.41 ^b	17.1
Spinosad 45% SC	144.8	115.4	14.0	4.2	4.66 ^a	60.1
<i>Bacillus thuringiensis</i> 10 ⁸ cfu/ml	148.8	112.5	13.6	3.5	3.46 ^b	19.0
Maize + cowpea (1:1)	142.1	116.0	13.2	4.5	4.23 ^a	45.5
Chlorpyrifos 20% EC	154.4	106.1	13.6	4.4	4.59 ^a	57.7
Untreated control	151.2	111.2	13.4	2.9	2.91 ^c	
Grand mean	147.7	112.2	13.5	3.9	3.86	
F value	ns	ns	ns	ns	**	
CV, %	6.1	5.4	4.2	3.4	8.6	
LSD 0.05	-	-	-	-	0.492	

Mean in a column followed by the same letters are not significantly different at P=0.05

Table 7. Effect of different treatments on natural enemies' populations in maize crop in combined analysis, 2017 and 2018

Treatments	Populations of 10 sample plants								
	Coccinellids			Spiders			Rove beetles		
	KHS	BTS	Mean	KHS	BTS	Mean	KHS	BTS	Mean
<i>Trichogramma chilonis</i>	4.3	2.3	3.3	2.5	3.0	2.8	8.2	6.1	7.2
Nimbecidine 0.03%	1.5	1.3	1.4	2.5	2.0	2.3	3.4	2.5	3.0
Spinosad 45% SC	1.3	1.0	1.2	1.8	2.5	2.2	2.1	2.4	2.3
<i>B. thuringiensis</i> 10 ⁸ cfu/ml	2.0	1.5	1.8	2.0	1.3	1.7	3.2	3.4	3.3
Cowpea + Maize (1:1)	5.5	4.3	4.9	7.3	4.5	5.9	8.9	7.7	8.3
Chlorpyrifos 20% EC	0.5	0.8	0.7	0.5	1.0	0.8	0.4	0.6	0.5
Untreated control	3.2	3.0	3.1	3.5	3.2	3.4	5.1	4.2	6.4
Grand mean	2.6	2.0	2.3	2.8	2.5	2.7	4.5	3.8	4.4
SD	1.79	1.26	1.48	2.15	1.20	1.62	3.13	2.40	2.88
SEM±	0.67	0.47	0.56	0.81	0.45	0.61	1.18	0.90	1.08

SD=Standard deviation, SEM=Standard error of mean, KHS=knee high stage, BTS=before tasseling stage

was observed in spinosad 45% SC treated plot followed by chlorpyrifos 20% EC (4.59 mt ha⁻¹) and cowpea and maize intercropping (1:1) (4.23 mt/ha) which was at par with *T. chilonis* (4.00 mt ha⁻¹) in pooled analysis. Spinosad 45% SC had the highest increment in the mean grain yield (60.1%) due to minimum dead heart (0.60%) over the

untreated control followed by chlorpyrifos 20% EC (57.7%) and cowpea+maize intercropping (45.7%) (Figure 2). This finding was supported by Neupane et al. (2016) who reported that spinosad 45% EC @ 0.5 mL L⁻¹ of water sprayed twice first at 15 days after emergence and second before tasseling stage was found effective to control maize stem borer damage with increased yield. Similar observations were also recorded by Singh et al. (2018) who found minimum infestation in treatment with intercropping of maize with cowpea (1:1). Present findings are supported by Kavita et al. (2016) who reported that maize intercropped with cowpea recorded the lowest pinholes, cob damage and the highest grain yield. Similarly, released of *T. chilonis* also found effective for stem borers management which are supported by Kumar et al. (2017) who found effective two field releases of *T. chilonis* @ 125,000 eggs ha⁻¹; Farid et al. (2007) who reported four releases of *T. chilonis* during the cropping season. Likewise, Jalali and Singh (2003) reported that release of *T. chilonis* was found effective and economic against *C. partellus* at early stage of the crop. The present results are in confirmation with the findings of Aggrawal & Jindal (2013) advocating inundative release of *T. chilonis* in Kharif season maize under Punjab conditions to achieve better control. The minimum yield increment was in nimbecidine 0.03% (17.1%) and *B. thuringiensis* (19%); however, these treatments resulted in higher grain yield as compared to untreated control. This results

are supported by Jose et al. (2008) who reported that the percent yield increased over untreated control were 17.2 in nimbecidine and 18.8 in *B.*

thuringiensis treated plot.

Effect of different treatments on natural enemies

Pooled data of 2017 and 2018 revealed that the rove beetle populations ranged from 0.4-8.9 (25 DAS), 0.6-7.7 (45 DAS) per ten sample plants, coccinellid populations ranged from 0.5 to 5.5 (25 DAS), 0.8 to 4.3 (45 DAS) and spider populations from 0.5 to 7.3 (25 DAS), and 1.0 to 4.5 (45 DAS) were recorded in the same sample plants (Table 7). The highest mean rove beetle, spider and coccinellid populations (8.3, 5.9 and 4.9 per 10 plants) were recorded in cowpea+maize intercropping followed by *Trichogramma chilonis* (7.2, 2.8 and 3.3/10 plant) respectively. The lowest rove beetle, coccinellid and spider mean population (0.5, 0.7 and 0.8 per 10 plants) were recorded in chlorpyrifos 20% EC treated plot followed by spinosad 45% SC treated plot (2.3, 1.2 and 2.2) respectively. The diversity and abundance of spider species were more dominance than coccinellid species in the study area. This study clearly showed that the maize+cowpea intercropping (1:1) and release of *T. chilonis* @ 100,000 eggs ha⁻¹ protected the natural enemies' population as compared to other treatments. The possible reason was to increase biodiversity by providing habitat for a variety of insects; increase the abundance of natural enemies of phytophagous insects such as spiders, parasitic wasps and predators. These findings are in agreement with Ali et al. (2014) as they reported that maize+cowpea (intercropping) and *Trichogramma chilonis* were safe to the spider

population with 4.81, 6.89, 9.42 and 3.58, 5.78, 6.91 spider/5plants at 30, 45, and 60 DAS, respectively. The lowest mean spider and (0.8/10 plants) coccinellid (0.7/10 plants) populations was recorded in chlorpyrifos 20% EC treated plot. The findings of Yadav (2007) are in agreement with the present findings as he reported 50.4 percent reduction in population of coccinellids with endosulfan.

CONCLUSIONS

From the overall results, it can be concluded that spinosad 45% SC@ 0.5 mL L⁻¹ of water was effective against maize stem borers followed by maize+cowpea intercropping (1:1) and *Trichogramma chilonis* @ 100,000 eggs ha⁻¹. These treatments were effective in reducing plant infestation and dead heart formation by stem borers with increased yield as compared to untreated control. Application of chemical insecticides not only increases the cost of production but also disturbs the non-target fauna of beneficial insects. Moreover, using chemicals, these seem environmentally sound approach and offers additional choice of management options for farmers to manage the stem borer infestation in maize production. The treatments, maize+cowpea intercropping and *T. chilonis*, proved safer to natural enemies. Augmentative released of *Trichogramma chilonis* are recommended as a safer alternative to the use of insecticides for the management of maize stem borers.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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REFERENCES

- Achhami, B. B. BK. S. B. Bhandari G. S. (2015) Assessment of maize stem borer damage on hybrid maize varieties in Chitwan, Nepal Journal of Maize Research and Development, 1(1):53-63.
- Aggarwal N. Jindal J. (2013) Validation of bio-control technology for suppression of *Chilo partellus* (Swinhoe) on Kharif maize in Punjab. Journal of Biological Control, 27(4): 278-284.
- Ahmed S. Saleem M. A. Rauf I. (2002) Field efficacy of some bio-insecticides against maize and jowar stem borer, *Chilo partellus* (Pyralidae: Lepidoptera). International Journal of Agriculture and Biology 4:332-334.
- Ali N. Singh G. Singh S. P. Dhaka S. S. Ram M. Tawar K. B. (2014) Efficacy of different management practices against *Chilo partellus* (Swinhoe) in Kharif maize in Western Uttar Pradesh. International Journal of Advanced Research, 2(11): 952-956.
- Ampofo, J. K. O. (1986) Maize stalk borer (Lepidoptera: Pyralidae) damage and plant resistance. Environmental Entomology, 15(6): 1124-1129.
- Bhandari G. Thapa R. B. Giri Y. P. Manandhar H. K. (2018) Effect of planting dates of maize on the incidence of borer complex in Chitwan, Nepal. Journal of Agriculture and Forestry University, 2:107-118.
- Choudhary R. Chandrakar G. Bhardwaj J. R. Khan H. H. Sahu R. (2017) Assessment of the efficacy of neem based insecticides for the management of yellow stem borer, *Scirpophaga incertulas* Walk. In paddy field. Journal of Pharmacognosy and Phytochemistry, 6(5): 1446-1449.
- Devananda K.M. Khanpara A.V. Vaja A. M. (2018) Bio-efficacy of various insecticides against maize stem borer *Chilo partellus* (Swinhoe) Crambidae: Lepidoptera in Junagadh conditions. Journal of Pharmacognosy and Phytochemistry, 7(4):2011-2014.
- Farid A. Khan M.I.N. Khan A. Khattak S. Alamzeb U.K. Sattar A. (2007) Study of maize stem borer *Chilo partellus* (Swinhoe) in Peshawar valley. Pakistan Journal of Zoology, 9: 127-131.

- Gomez K. A. Gomez A. A. (1984) Statistical procedures for Agricultural research. Wiley Interscience Publications.
- Hegde K. Manjunatha M. Sharanabasappa Kalleshwaraswamy C. M. Adarsha S. K. (2017) Effect of Application of Biopesticides and Insecticides on Stem Borers and Yield of Maize (*Zea mays* L.), International Journal of Pure & Applied Bioscience, 5(1): 42-47. doi: <http://dx.doi.org/10.18782/2320-7051.2527>
- Jalali S. K. Singh S. P. (2003) Determination of release rates of natural enemies for evolving bio-intensive management of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). Shashpa 10: 151-154.
- Jalali S. K. Singh S. P. (2006) Biological control of *Chilo partellus* using egg parasitoid *Trichogramma chilonis* and *Bacillus thuringiensis*. Indian Journal of Agricultural Research, 40 (3): 184-89.
- Jose D. Shekarappa Patil R. K. (2008). Evalaution of biorational pesticides for the management of stem borer, *Chilo partellus* Swinhoe in sweet sorghum. Karnataka Journal Agriculture Science, 21(2): 293-294.
- Kavita H. Manjunatha M. Adarsha S. Sharanabasappa K. (2016) Management of *Chilo partellus* (Swinhoe) and *Sesamia inferens* (Walker) through different intercropping systems and organic manures in maize ecosystem. International Journal of Agriculture Science, 8(7):1053-1056.
- KC G. Karki T. Shrestha J. Achhami B. (2015) Status and prospects of maize research in Nepal. Journal of Maize Research and Development, 1(1): 1-9.
- Kumar G. S. Madhumathi T. Kumar D. S. Kumar V. M. Ahamad M. (2017) Bio-efficacy of different bio-rational insecticides for the management of spotted stem borer, *Chilo partellus* (Swinhoe) in maize (*Zea mays* L.). The Journal of Research ANGRAU, 45(2): 19-30.
- Kumar R. Shera P. Sharma S. Sangha K. (2017) Standardization of release rate of *Trichogramma chilonis* (Ishii) in bio-intensive management of *Chilo partellus* (Swinhoe) in fodder maize. Journal of Biological Control, 31(4): 254-258.
- Kumar V. Kanta U. (2011) Effectiveness of *Trichogramma chilonis* Ishii in the suppression of *Chilo partellus* (Swinhoe) in summer maize. Journal of Biological Control, 25: 92-97.
- Malepati V. D. Simon S. Nagar S. (2018) Bio-rational management of stem borer, *Chilo partellus* in maize. Journal of Pharmacognosy and Phytochemistry, 7(4): 1142-1145.
- MoALD. (2018/19) Statistical Information on Nepalese Agriculture 2075/76 (2018/19). Government of Nepal. Ministry of Agricultural and Livestock Development. Planning & Development Cooperation Coordination Division, Statistics and Analysis Section. Singha Durbar, Kathmandu, Nepal.
- Neupane S. Bhandari G. Sharma S. Yadav S. Subedi S. (2016) Management of stem borer (*Chilo partellus* Swinhoe) in maize using conventional pesticides. Journal of Maize Research and Development, 2(1): 13-19.
- Pal R. Singh G. Prasad C. S. Ali N. Kumar A. Dhaka S. S. (2009) Field evaluation of bio-agents against *Chilo partellus* (Swinhoe) in maize. Annals of Plant Protection Sciences, 17(2): 325-327.
- Shahbaz A. Muhammad A. Sahi S.T. (2012) Potential of parasitoid *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) against the sugarcane stem borer, *Chilo infuscatellus* (Lepidoptera; Pyralidae) under field conditions. International Journal of Biodiversity and Conservation, 4(1): 36-38.
- Sharma P.N. Gautam P. (2010) Assessment of yield loss in maize due to attack by the maize borer, *Chilo partellus* (Swinhoe), Nepal Journal of Science and Technology, 11: 25-30.
- Shrestha J. Subedi S. Timsina K.P. Gairhe S. Kandel M. Subedi M. (2019) Maize Research. ISBN: 978-93-87973-98-5. New India Publishing Agency (NIPA), New Delhi-34, India.
- Singh G. Singh M. J. Verma T. (2018) Management of maize stem borer, *Chilo partellus* (Swinhoe) in Kharif maize with cowpea intercropping. Journal of Entomology and Zoology Studies, 6(3): 1791-1794.
- Teli V. S. Chavan B. P. Ankalkoppe M. N. Khot R. B. Harers P. N. (2007) Evaluation of some insecticides for the control of maize stem borer, *Chilo partellus* (Swinhoe). Journal of Entomological Research, 31(2): 323-26.
- Thakur P. Bhandari G. S. Shrestha J. Achhami B. B. (2018) Effect of Planting Dates and Varieties on Infestation of Maize Stem Borer *Chilo partellus* (Swinhoe). International Journal of Applied Biology, 2(1): 22-28
- Yadav J. B. (2007) Studies on pest complex, their natural enemies and IPM modules on okra

crop in Central U.P. Ph.D. Thesis,

CSAUA&T, Kanpur, India.