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Biorational Management of Maize Stem Borer *Chilo partellus* (Swinhoe)

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ABSTRACT

The study on "biorational management of Maize Stem Borer, *Chilo partellus* (Swinhoe) in Farmer's field condition was done from March - August, 2019. Seven maize stem borer management namely; Spinosad 45% SC 0.5 mL L^{-1}; Super-D (Chlorpyriphos 50% EC + Cypermethrin EC) @1.5 mL L^{-1}; Nimbicidine (*Azadirachtin* 300 ppm)) 5 mL L^{-1}; Daman (*Beuveria bassiana*) 3 mL L^{-1}; Kalichakra (*Metarhyzium anisopliae*) @2.5 mL L^{-1}; Emamectin benzoate 6% WP @0.2 g L^{-1} and control were used in Randomized Complete Block Design with three replications. Data were recorded on vegetative growth, damage assessment, yield and yield attributes. The damage assessment recorded at 3, 7 and 12 days after treatment application. There was lower percentage of damaged plant (0.83%) recorded in Spinosad 45% SC sprayed plot. Both stem exit hole and average tunnel length were statistically lower in the plot sprayed with Spinosad 45% SC and Choloropyriphos 50% + Cypermethrin 5% EC. Both insecticides namely Spinosad 45% SC and Choloropyriphos 50% + Cypermethrin 5% EC produced higher grain yield (8670 Kg ha^{-1} and 8620 kg ha^{-1} respectively) of maize as compared to other treatments. Nimbicidine treated plot produced 6900 kg ha^{-1} grain yield which was statistically better than *Beuveria bassiana*, *Metarhyzium anisopliae*, Emamectin benzoate and control. The overall result showed that safer pesticide like Spinosad followed by Nimbicidine are effective for the management of maize stem borer. Rrepeated trails over the seasons and varieties would help to reduce the infestation of maize stem borer.

INTRODUCTION

Maize is most versatile crop that have wider adaptability, high genetic potentials among the food grain crops, diverse in soil, climate, biodiversity, and management practices. The Global productivity of maize is 5920 kg ha^{-1} in 2017 (FAOSTAT 2018) while the maize productivity of Nepal is only 2670 kg ha^{-1} in 2017 (MoALD 2018). The productivity of maize in Nepal is less as compared to the global scenario, this might be due to lack of mechanization, lack of irrigation, attack of insect pest and diseases and lack of commercial farming. Maize stem borer has been reported as a major problem in maize crop. Maize is important cereal crop of Nepal, which grain productlion is reduced by different biotic and abiotic factors (Achhami et al. 2015).

In southern Asia, *Chilo auricilius* (Dudgeon), *Chilo infuscatellus* (Snellen), *Chilo partellus* (Swinhoe), *Chilo polychrysus* (Meyrick), *Chilo suppressalis* (Walker), *Chilo suppressalis* simplex (Butler), *Chilo sacchariphagus* indicus (Kapur), *Chilo supermain* and *Chilo tumidicostalis* (Hampson) are recorded as pests of cereal crops. White grubs (*Phyllophaga* spp. and *Cyclocephala* spp.), stem borers (*C. partellus*), and termites (*Microtermes* spp. and *Macrotermes* spp.) were major maize field insects in all agro-ecologies of Nepal (Poudyal et al. 2001). In Nepalease context, Major pest of maize are *Chilo partellus* (Swinhoe)

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and *Sesamia inferens* (Walker) and *Chilo supresalis* (Walker) (Bhandari et al. 2018; KC et al. 2015). Maize stem borer is one of the most devastating insect pest of maize (Bhandari et al. 2016; Sharma and Gautam 2010). Among 139 species of inesct pest of maize recorded, Chilo partellus is one of the major and cause 90-95% of total damage in Kharib season (Prakash et al. 2017) and 20-80% of damage is recorded by Thakur et al. (2018) in Rampur, Nepal.

The management of the insect pest can be done by different physical, chemical, biological, botanicals and cultural approaches. Neupane et al. (2016) observed highest yield (4520 kg ha^{-1}) and lowest insect score (1) in a plot sprayed with Spinosad 45% EC @ 0.5 mL L^{-1} among seven conventional pesticides, similarly foliar application of Spinosad (0.002%) and Emamectin benzoate result significant reduction of *C. partellus* damage among different botanicals, entomogenous microbes and natural insecticide (Rameash et al. 2012). Mehlhorn et al. (2011) reported that Azadirachtin do not show accumulation effect in plant and there is no adverse effect in water and ground water. In field evaluation of bio agent against *C. partellus* in maize, neemarin @3.0 L ha^{-1} give best result with 17.1% infestation and grain yield of 3032 kg ha^{-1} (Ravindra et al. 2009). *Beuveria bassiana* (Balsamo) and *Metarhizium anisopliae* (Metschnikoff) are potential biocontrol agent that occurs naturally in environment (Karanja et al. 2010). Among various invertebrate fungal pathogens, *Beuveria bassiana* play key role in management of huge number of agricultural, veterinary and fungal pest (Mascarin and Joronski 2016). Vera et al. (2011) reported conidial application of *Beauveria bassiana* to fallen fruits resulted 30-40% infection in Coffee berry borer and reduced subsequent infestation up to 50%. Different management techniques and chemicals are using to control stem borer in Manthali, Ramechhap to control the problems. However, the efficiencies of these methods have not been documented yet. So it is important to find out the suitable management which is cost effective, eco-friendly, and viable to the wider farming situation in Nepal.

MATERIALS AND METHODS

The experiment was conducted at Ramechhap Polytechnic Institute, Manthali, Ramechhap from March- August 2019. The site of experiment was at Manthali Municipality -1, Ramechhap at latitude of 27˚ 38′ N and longitudes of 86˚ 07′ E and at an altitude of 550 meter above mean sea level. The field experiment with 7 replication Spinosad 45% SC 0.5 mL L^{-1}; Super-D (Chlorpyriphos 50% EC + Cypermethrin 5% EC) 1.5 mL L^{-1}; Nimbicidine (*Azadirachtin* 300 ppm) 5 mL L^{-1}; Daman (*Beuveria bassiana*) 3 mL L^{-1}; Kalichakra (*Metarhyzium anisopliae*) 2.5 mL L^{-1}; Emamectin benzoate 6% WP, 0.2 g L^{-1} and control were evaluated against maize stem borer. The experiment was laid in Randomized Complete Block (RCB) design with three replications. The Aditya Hybrid maize was sown in April 2019 in a unit plot of size 3m × 2m with the spacing of 60cm × 25cm.

The experiment was kept under constant supervision during entire crop cycle. All the Agronomic practices were followed. The recommended dose of fertilizer 150:50:40 kg NPK ha^{-1} was applied. The treatments were applied at 20, 35 and 50 days after emergence of maize plant. Different vegetative and reproductive parameters were recorded on sample plant. The leaf damage score was recorded on the basic of 1-9 scoring scale as described by CIMMYT, Mexico (Tefera et al. 2011). The leaf score damage and percentage of infested plant were taken at 3, 7 and 12 days after application of treatment. The data of field experiment was entered in MS-Excel and analyzed in GenStat. ANOVAs were prepared with the guideline in Gomez and Gomez (1984) and critical difference value was calculated at 5 % probability level and treatment was compared by using Duncan's multiple range test (Duncan 1951). In the case of exit hole and tunnel length, the data was not normal. The exit holes and tunnel length obtained in some treatment were found to be 0, So to make the data normal the value was converted to the log value by log(X+1), where X value was the obtained value and log(X+1) value was analyzed with Genstat (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Effect of Insecticide on leaf score damage against maize stem borer

The result of effect of treatment on leaf score damage revealed that there was significantly different leaf score damage among the treatment. The highest percentage of leaf score damage was obtained in controlled plot (2.23) and the least score damage obtained in T2 (Chloropyriphos 50% + Cypermethrin 5% EC) sprayed plot, i.e. 1.25. There was similar level of leaf score damage was obtained in Spinosad, Chlorpyriphos + Cypermethrin and Emamectin benzoate sprayed plot after 3 days of spraying. On the observation there was similar effect of leaf score damage was seen in plot sprayed with *Beuveria bassiana* and *Metarhyzium anisopliae* (Table 1)

Three Days after the spray of insecticide, there was significant difference among the treatment was obtained. The lowest insect leaf score damage (1.25) was obtained in treatment sprayed with Chloropyriphos 50% + Cypermethrin 5% EC followed by 1.27 in treatment sprayed with

Table 1. Effect of insecticide on leaf damage score in maize at Manthali, Ramechhap, Nepal, 2019

Treatment	3 days after spray	7 days after spray	12 days after spray
Spinosad 45% SC	1.27^{a} ±0.05	1.34^{a} ±0.05	1.27^{ab} ±0.05
Chloropyriphos 50% + Cypermethrin 5% EC	1.25^{a} ±0.05	1.25^{a} ±0.02	1.17^{a} ±0.05
Nimbicidine	1.38^{b} ±0.08	1.56^{ab} ±0.04	1.46^{bc} ±0.05
Beuveria bassiana, 2×10^{8} cfu/ml	1.73^{b} ±0.09	1.67^{b} ±0.04	1.58^{c} ±0.02
Metarhyzium anisopliae, 2×10^{8} cfu/ml	1.63^{b} ±0.04	1.80^{b} ±0.18	1.66^{c} ±0.16
Emamectin Benzoate 6%	1.28^{a} ±0.13	1.30^{a} ±0.03	1.22^{a} ±0.04
Control	2.23^{c} ±	2.19^{c} ±0.10	2.22^{d} ±0.05
Grand mean	1.54	1.59	1.51
CV, %	4.5	6.7	5.1
LSD $_{0.05}$	0.248	0.300	0.205
F test 5%	**	**	**

Means followed by a same letter within a column are not significantly different by DMRT (α=0.05), CV: coefficient of variation; LSD: least significant difference; **- significant at p=0.01, ns- non significant

Spinosad 45% EC, 1.28 in treatment sprayed Emamectin benzoate, 1.38 in treatment sprayed with Nimbicidine, 1.63 in treatment sprayed with *Metarhyzium anisopliae,* 1.73 in plot sprayed with *Beuveria bassiana* and the highest leaf score damage (2.23) was obtained in control treatment. All the treatments were statistically significant to the control plot. Spinosad 45% EC, Chloropyriphos 50% EC + Cypermethrin 5% EC and Emamectin benzoate 6% Sprayed treatment obtained superior result over other treatment. The similar effect was obtained in a treatment sprayed with Nimbicidine, *Beuveria bassiana* and *Metarhyzium anisopliae.*

Seven days after the spray of insecticide, lowest leaf score damage (1.25) was obtained in a treatment sprayed with Chloropyriphos 50% EC + Cypermethrin 5% EC followed by 1.30 leaf score damage in treatment sprayed with Emamectin benzoate and 1.34 leaf score damage in treatment sprayed with Spinosad 45% SC. 1.56 leaf score damage was obtained in a treatment sprayed with Nimbicidine. There was statistically similar result obtained in those four treatment. *Beuveria bassiana* and *Metarhyzium anisopliae* sprayed treatment obtained statistically similar result, leaf score damage of 1.67 and 1.80 respectively. The control treatment reported the leaf score damage of 2.19. So the treatment here reported statistically low leaf score damage in all treatment over the control plot.

Twelve days after the spray of insecticide, the lowest leaf score damage (1.27) was obtained in treatment sprayed with Chloropyriphos 50% EC + Cypermethrin 5% EC, followed by 1.22 leaf score damage in Emamectin benzoate sprayed plot and 1.27 leaf score damage in treatment sprayed with Spinosad 45% EC. There was similar effect obtained in these three treatment. 1.46 leaf score damage was obtained in treatment sprayed with Nimbicidine and 1.58 leaf score damage was obtained in *Beuveria bassina* sprayed treatment and 1.66 leaf score damage was obtained in *Metarhyzium anisopliae* sprayed treatment. The highest leaf score damage (2.22) was obtained in control treatment. All the treatments were superior in terms of leaf score damage over the control plot at 12 days after the spray of insecticide.

The present finding is also accordance with Neupane et al. (2016) who also reported that lowest insect damage score (1.00) in a plot sprayed with Spinosad 45% SC followed by Choloropyriphos 50% and Cypermethrin 5% EC (1.60). Rauf et al. (2017) also reported minimum number of leaf hole (0.26±0.12) at 3 days after application of Spinosad. Adamu et al. (2015) repoted lowest leaf damage score of 1.00 by maize stem borer in both furrow and basin system of maize applied with

Table 2. Effect of insecticide on Percentage of damaged plant in maize at Manthali, Ramechhap, Nepal, 2019

Treatment	3 Days after Spray	7 Days after Spray	12 Days after Spray
Spinosad 45% SC	3.33^{a} ± 0.83	0.28^{a} ±0.27	0.83^{a} ±0.48
Chloropyriphos 50% + Cypermethrin 5%EC	0.83^{a} ±0.83	0.56^{a} ±0.55	1.11^{a} ±0.55
Nimbicidine	9.17^{b} ± 3.0	2.22^{a} ±0.73	1.94^{ab} ±0.73
Beuveria Bassiana, CFU 2×10^{8}	16.67^{c} ± 3.3	4.72^{b} ±0.27	3.89^{b} ±0.27
Metarhyzium anisopliae, CFU 2×10^{8}	18.33^{c} ±0.83	5^{b} ±0.83	6.94^{c} ±1.21
Emamectin Benzoate 6%	3.33^{a} ±1.66	1.11^{a} ±0.27	1.94^{ab} ±0.27
Control	30.83^{d} ±0.83	10.56^{c} ±1.0	11.67^{d} ±0.96
Grand mean	11.79	3.49	4.05
CV, %	18.9 %	10.4%	5.1 %
$LSD_{0.05}$	4.72	1.977	2.363
F test 5%	**	**	**

Means followed by a same letter within a column are not significantly different by DMRT (α=0.05), CV: coefficient of variation; LSD: least significant difference; Value after ± indicate standard error of mean, **- significant at p=0.01, ns- non significant

Table 3. Effect of insecticide on tunnel stem exit hole, tunnel length and yield in maize at Manthali, Ramechhap, Nepal, 2019

Treatment	Stem exit hole (no.)	Tunnel length (cm)	Grain yield (Kg ha^{-1})
Spinosad 45% SC	0.00 (0.00)[a]	0.00 (0.00)[a]	8670[a] ± 960
Chloropyriphos 50% + Cypermethrin 5% EC	0.00 (0.00)[a]	0.00 (0.00)[a]	8620[a] ±820
Nimbicidine	1.13 (0.65)[c]	2.93 (0.57)[b]	6900[b] ±660
Beuveria Bassiana	1.93 (0.44)[bc]	3.62 (0.65)[b]	4250[c] ±190
Metarhyzium anisopliae	2.67 (0.55)[c]	4.57 (0.74)[bc]	4980[c] ±720
Emamectin Benzoate 6%	0.27 (0.08)[ab]	0.47 (0.17)[a]	5270[c] ±530
Control	4.70 (0.74)[c]	6.60 (0.854)[c]	3780[c] ±400
Grand mean	0.354	0.421	6000.07
CV, %	26.9%	22.5%	14.1 %
$LSD_{0.05}$	0.38	0.182	1470
F test 5%	**	**	**

Means followed by a same letter within a column are not significantly different by DMRT (α=0.05), CV: coefficient of variation; LSD: least significant difference; Value after ± indicate standard error of mean, **- significant at p=0.01, ns- non significant

Chlorpyriphos.

Effect of Insecticide on percentage of damaged plant against maize stem borer

There was highest percentage of damage plant obtained in a plot sprayed with water only, i.e, 30.83% and the lowest percentage of damaged plant was obtained in plot sprayed with Choloropyriphos 50% + Cypermethrin 5% EC. There was no significant difference among the plot sprayed with Choloropyriphos 50% + Cypermethrin 5% EC, Spinosad 45% EC and Emamectin Benzoate 6% in 3 days and 7 days after spraying. Among the biological and botanicals insecticide, for maize stem borer, Spinosad and nimbicidine were found to be effective in this experiment. (Table 2)

3 Days after the spray of insecticide, lowest percentage of infestation (0.83%) was obtained in a treatment sprayed Chloropyriphos 50% EC + Cypermethrin 5% EC followed by 3.33% of infestation in Spinosad 45% SC sprayed plot, 3.33% of infestation in Emamectin Benzoate 6% Sprayed plot. 9.17 % of infestation in Nimbicidine sprayed treatment, 16.67% of infestation in *Beuveria bassiana* sprayed treatment and 18.33% of infestation in *Metarhyzium anisopliae* sprayed treatment. The highest percentage of infestation (30.83%) was obtained in control treatment. All the treatments were statistically significant over the control treatment.

In 7 days after the application of treatment, the lowest percentage of infestation (0.28%) was obtained in treatment sprayed with Spinosad 45% SC sprayed plot followed by 0.56% in Chloropyriphos 50% EC + Cypermethrin 5% EC sprayed treatment, 1.11% in Emamectin Benzoate sprayed treatment and 2.22% in Nimbicidine sprayed treatment, those four treatment obtained statistically similar percentage of damage. In *Beuveria bassiana* sprayed treatment the percentage of damage was 4.72% and in *Metarhyzium anisopliae* sprayed treatment the percentage of damage was 5%, those two obtained statistically similar percentage of damage at 7 days after the spray of insecticide. The highest percentage of infestation (10.56%) was obtained in control treatment.

In 12 days after the spray of insecticide, the lowest percentage of infestation (0.83%) was obtained in treatment sprayed with Spinosad 45% SC followed by 1.11% of infestation in Chloropyriphos 50% EC + Cypermethrin 5% EC sprayed plot, 1.94% of infestation in Nimbicidine sprayed treatment, 1.94% of infestation in Emamectin benzoate sprayed plot. Those treatment was statistically similar to each other. 3.89% of infestation was obtained in *Beuvaria bassiana* sprayed treatment and 6.94% of infestation was obtained in *Metarhyzium anisopliae* sprayed treatment, in this case *Beuveria bassiana* reported statistically low percentage of infestation over the *Metarhyzium anisopliae* treated plot. The highest percentage of infestation (11.67%) was obtained in a control treatment. Likewise, these findings are also supported by Neupane et al. (2016) they reported lowest percentage of damaged plant (4.32%) in a plot sprayed with Spinosad among the conventional insecticide. These findings match the close confirmation with the findings of Devananda et al. (2018) who recorded minimum damage and dead heart (0.93%) by Maize stem borer in Spinosad 45% SC treated plot. In the above findings, Neembicidine treated plot do well over *Beuveria bassiana* and *Metarhyzium anisopliae* treated plot (1.94% of damaged plant) these findings storongly supported by the findings of Chaudhary et al. (2017) who also recorded lowest percentage spray (5.13%) after 10 days of spray of Nimbicidine (5mL L^{-1}) among other neem based insecticide. Neupane et al. (2016) also reported lowest percentage damage (5.3%) in Spinosad treated plot. Bhandari et al. (2020) recorded minimum percentage of infestation in leaf (5.5%)

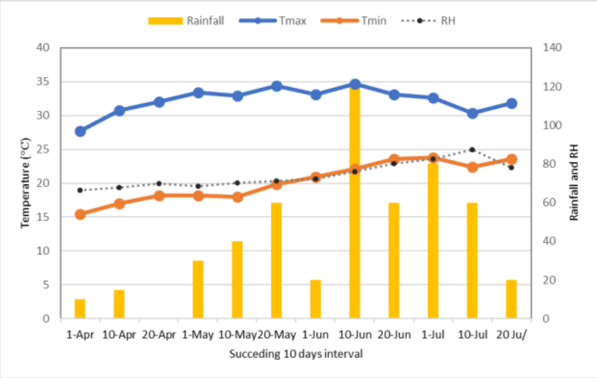

Figure 1. Meteorological data during experimental period (2015-2016) at Manthali, Ramechhap, Nepal.

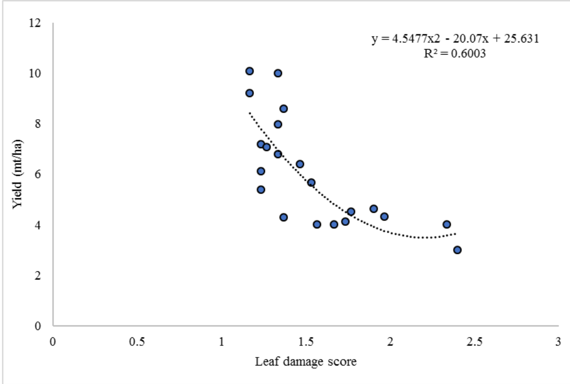

Figure 2. Graph showing relationship between leaf score damage and yield

in Cholorpyriphos 20% EC treated plot followed by Spinosad 45% SC treated plot, which is more similar to this this research.

Effect of Insecticide on average number of exit holes, average tunnel length and yield at the time of harvest

The highest average number of holes in stem was obtained in a control plot, i.e., 4.7 and lowest average number of hole in stem was obtained in plot sprayed with Chloropyriphos 50% + Cypermethrin 5% EC and Spinosad 45% SC. There was no significant difference in average number of hole in stem at plot sprayed with Chloropyriphos 50% + Cypermethrin 5% EC and Spinosad 45% SC and Emamectin Benzoate 6% 0.2 gm L^{-1}. The bioinsecticide, *Beuveria bassiana* and *Metarhyzium anisopliae* showed effective result over control but not as effective as other insecticides used. (Table 3). The present findings also in accordance with the findings of Bhandari et al. (2020), they also recorded lowest number of exit hole (0.43) and tunnel length (1.5 cm) in Chlorpyrifos 20% EC treated plot followed by Spinosad 45% SC treated plot with 1.58 exit hole and 3.03 cm of tunnel length.

Among all the treatment, highest yield was obtained in a plot sprayed with Spinosad 45 % SC, i.e, 8670 Kg ha^{-1}, and lowest average yield was obtained in a control plot, i.e 3780 kg ha^{-1}. There is similar level of yield was obtained in a plot sprayed with *Beuveria bassiana* and *Metarhyzium anisopliae*, which yield was better than control plot but the effect quite lesser than other insecticides. The Choloropyriphos 50% EC + Cypermethrin 5% EC sprayed treatment obtained yield of 8620 kg ha^{-1}, and Nimbicidine sparyed plot obtained the yield of 6900 kg ha^{-1}, *Beuveria bassiana* sprayed treatment obtained 4250 kg ha^{-1} of yield and *Metarhyzium anisopliae* sprayed treatment obtained 4980 kg ha^{-1} of yield. The findings regarding the yield is also linear to the finding of Bhandari et al. (2020), they also reported highest grain yield (4660 kg ha^{-1}) followed by Chlorpyriphos 20% EC (4570 kg ha^{-1}). Neupane et al. (2016) reported highest grain yield (4520 kg ha^{-1}) in Spinosad treated plot. Dinesh et al. (2018) also recorded highest grain yield (4123 kg ha^{-1}) in Cypermethrin applied plot followed by 3654 kg ha^{-1} of grain yield in Chlorpyrifos applied plot.The yield of neembicidine treated plot is close c onfirmity with the findings of Chaudhary et al. (2017), they reported highest grain yield (4800 kg ha^{-1}) in Nimbicidine sprayed plot among other neem based formulation.

Relationship between leaf score damage and yield

A negative correlation coefficient was obtained between leaf score damage and yield. The maize yield was significantly negative correlated (r = - 0.76) with the leaf damage score. The equation $y = 4.5477x^2 - 20.07x + 25.631$ and $R^2 = 0.6003$ gave the best fit to the figure. That means 60.03 percentage of maize grain yield is defined by leaf score damage of plant. (Figure 2)

On the analysis of biological and botanicals, Spinosad 45% SC was found to be effective in controlling the maize stem borer damage. Spinosad with novel mode of action t is a bio-pesticide derived from fermentation of actinomycete, *Saccharopolyspora spinosa* that leads to disruption of acetyl neurotransmission (Qiao et al. 2007). Galvan et al. (2005) reported the use of insecticide, such as Spinosad and indoxacarb are more toxic to lepidopterans pests, they reported that Spinosad is more toxic to lepidopterans pest when applied at the dose of 10, 25 and 50% FR. Foliar application of Spinosad 240 EC and Emamectin Benzoate 1.9 EC against maize stem borer reduce the population of maize stem borer and *Atherigona soccata* below ETL (Shahzad et al. 2010).

Rameash et al. (2012) reported the foliar application of Spinosad (0.002%) and Emamectin Benzoate (0.002%) were found to be significantly reduced the damage of *Chilo partellus* in field condition. The entomopathogenic fungus result were not effective as other pesticide, the similar result was reported by Maniania (1992).

CONCLUSIONS

Maize stem borer is effectively managed by the safer insecticide 'Spinosad' and botanical insecticide 'Nimbicidine' in comparison to other commonly used chemicals ('Choloropyriphos + Cypermethrin', 'Emamectin benzoate') and organic methods ('Beuveria bassiana', 'Metarhyzium anisopliae'). The maize grain yield can be more than twice (2.3 times) in effectively maize stem borer managed plot as compared to control (no treatment).

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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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