Relative Abundance and Field Efficacy of Insecticides and Bio-Control Agents Against Stem Borer Species in Rice (Oryza sativa L.)

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ABSTRACT

Background: In India, out of the total loss incurred by different insect pests of paddy, 25 to 30 per cent damage is done by stem borer alone. Many conventional insecticides though have been evaluated against stem borers, yet, most of the chemicals have failed to provide adequate control. Hence, the present study aimed to evaluate the efficacy of some newer molecules of insecticides and bio-control agents.

Methods: Field trials were conducted to record the seasonal incidence and to evaluate the efficacy of insecticides and bio-control agents against the stem borer species in rice during Kharif and Rabi.

Result: Field experiments revealed that during Kharif 2018, chlorantraniliprole 18.5 SC was highly effective with 92.98 and 91.24 per cent reduction of stem borer infestation over control at vegetative and reproductive stages, respectively and recorded a high yield of 5720 kg/ha followed by spinetoram 11.7 SC with 83.16 and 80.82 per cent reduction of stem borer over control at vegetative and reproductive stages, respectively. During Rabi 2019, spinetoram 11.7 SC was highly effective with 92.36 and 93.73 per cent reduction of stem borer infestation over control at vegetative and reproductive stages respectively and recorded a high yield of 4570 kg/ha, followed by chlorantraniliprole 18.5 SC with 84.60 and 91.48 per cent reduction of stem borer at vegetative and reproductive stages, respectively. The difference in the efficacy of insecticides during Kharif 2018 and Rabi 2019, might be due to shift in the species occurrence of stem borer, with a dominant occurrence of yellow stem borer (80.61%) in Kharif 2018 and pink stem borer (70.00%) in Rabi, 2019. The bio-control agent Trichogramma japonicum exerted minimum reduction of stem borer with a low grain yield of 3946.6 kg/ha.

Key words: Bio-control agents, Field efficacy, Insecticides, Seasonal distribution, Stem borer species.

INTRODUCTION

Rice (Oryza sativa L.) belonging to family Poaceae is an important grain crop in the world feeding more than 50 per cent of the human population (Agrawal et al., 2005). The rice crop is subjected to a considerable damage by nearly 300 species of insect pests, among them only 23 species are serious pests of rice (Pasalu et al., 2006). In India, out of the total loss incurred by different insect pests of paddy, 25 to 30 per cent damage is done by stem borers alone (Dhivahar et al., 2003). The yellow stem borer (YSB), Scirpophaga incertulas (Walker) the pink stem borer (PSB), Sesamia inferens (Walker) and the dark headed borer Chilo polychrysus (Meyrick) are the widely distributed pests of the graminaceous crops. The changing climatic scenario with modern cultivation practices in rice crop made pink stem borer to achieve pest status in many rice growing regions of India and causes dead heart and white ear that results in yield reduction (Sampath et al., 2014). The young larva of stem borer primarily enters into the leaf sheath and feeds for two to three days, after which the larva enters the basal part usually 5 to 10 cm above water level and feeds inside the stem causing dying of central shoot known as dead heart at vegetative stage and white ear head is formed by boring at the peduncle node during heading stage of crop growth (Gupta et al., 2006). Each unit increase in white ear damage has a greater impact on rice yield (Jiang et al., 2005).

Many conventional insecticides though have been evaluated against stem borers yet; most of the chemicals have failed to provide adequate control. The changing level of pest demands for new chemical possessing novel insecticidal action. With this in view, the present study has been undertaken to evaluate the efficacy of some newer molecules of insecticides and bio-control agents.
MATERIALS AND METHODS
Field efficacy of insecticides and bio-control agents against stem borer on rice

Field trials were conducted at the experimental farm of Department of Plant Protection, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli District, Tamil Nadu, India for the management of rice stem borers in a Randomised Block Design (RBD) during Kharif, 2018 and Rabi, 2019 on the rice variety TRY 3 with eleven treatments and three replications. The plot area was 15 m². The standard agronomic practices recommended by Tamil Nadu Agricultural University were adopted except the plant protection maerasures. The insecticides from classes viz., neo-nicotinoids (dinotefuran), spinosyns (spinetoram), avermectins (emamectin benzoate), anthranilic diamides (flubendiamide, chlorantraniliprole), organophosphates (chlorpyriphos), carbamates (cartap hydrochloride), botanicals (NSKE) and bio-control agents (Trichogramma japonicum Ashmead, Bacillus thuringiensis Berliner and Pseudomonas fluorescens) were used along with an untreated control. The spray application was done using a hand operated knapsack sprayer with a spray fluid of 500 l/ha and the granular insecticide was applied by mixing with sand. The first application of treatments was imposed at 30 days after transplanting (DAT) and second application at 60 DAT. During spraying utmost care was taken to prevent the drift of insecticides. T. japonicum egg cards (Tricho cards) were tagged in the respective plots. The observations on dead heart were recorded from ten randomly chosen hills/plot a day before treatment and 3, 5, 7, 15 and 21 days after imposing the treatments and white ear was recorded on 3, 5, 7, 15 and 21 days after imposing the treatments. The grain yield was recorded for each plot and expressed in kg/ha.

The damage percentage was calculated by adopting the formula developed by Heinrichs et al. (1985)

Dead heart (%) = (No. of dead hearts/Total no. of tillers) × 100

White ear (%) = (No. of white ear/Total no. of productive tillers) × 100

Seasonal distribution of stem borer species in rice

The seasonal incidence of stem borer species was also assessed by cutting open the tillers expressing dead heart and white ear at weekly intervals during Kharif, 2018 and Rabi, 2019. The collected larvae were sorted out according to the identification characters and the occurrence of stem borer species was assessed and the relative abundance of each rice stem borer species was calculated using the formula,

Relative abundance (%) = (Total no. of individuals of each species/ Total no. of individuals of all species) × 100

RESULTS AND DISCUSSION
The results clearly revealed that all the treatments were significantly superior in reducing the stem borer infestation during Kharif 2018, in terms of dead heart and white ear and thus increasing the yield (Table 1a and 1b). Among the treatments, chlorantraniliprole 18.5 SC was found to be the most effective in controlling the stem borer as evidenced by dead heart (0.83%) and white ear (1.58%), followed by spinetoram 11.7 SC with dead heart (1.82%) and white ear (3.51%) after 21 days of first and second application, respectively (Table 1 and 2). The bio-control agents were found to be less effective, when compared to the insecticides as evidenced by increased stem borer incidence in B. thuringiensis in terms of dead heart (4.05%) and white ear (6.73%) followed by P. fluorescens and T. japonicum (Table 1a and 1b). The maximum grain yield was recorded in chlorantraniliprole (5720 kg/ha) followed by spinetoram (5206 kg/ha) and flubendiamide (5200 kg/ha) as against 3326.6 kg/ha in the untreated control (Table 1b).

During Rabi 2019, the results clearly revealed that all the treatments were significantly superior in reducing the stem borer infestation in terms of dead heart and white ear and thus increasing the yield (Table 2a and 2b). Among the treatments, spinetoram 11.7 SC @ 375 ml/ha was found to be the most effective in controlling the stem borer as evidenced by dead heart (1.28%) and white ear (1.56%), followed by chlorantraniliprole 18.5 SC @ 150 ml/ha with dead heart (2.21%) and white ear (1.90%) and flubendiamide 39.35 SC @ 50 ml/ha with dead heart (3.43%) and white ear (2.26%), after 21 days of first and second application, respectively. The bio-control agents were less effective, when compared to the insecticides as evidenced by increased stem borer incidence in B. thuringiensis in terms of dead heart (8.49%) and white ear (7.62%) followed by P. fluorescens and T. japonicum. The maximum yield was obtained in the effective treatment spinetoram 11.7 SC (4570 kg/ha) followed by chlorantraniliprole 18.5 SC (4323.33 kg/ha) and flubendiamide 39.35 SC (4196.67 kg/ha) in Rabi, 2019 (Table 2b).

The relative abundance of stem borer species revealed the presence of YSB as dominant (80.00 %) as against PSB (20.00 %) in Kharif, 2018 (Table 3) when dead heart/ white ear was cut opened. Results obtained during Rabi, 2019 expressed the presence of PSB (75.00 %) as against YSB (19.12 %) and DHB (5.88 %). It clearly indicated the dominance of YSB during Kharif, 2018 and PSB during Rabi, 2019.

The present field trial indicated that, chlorantraniliprole @ 150 ml/ha was found to be most effective in controlling the stem borer, followed by spinetoram @ 375 ml/ha and flubendiamide @ 50 ml/ha in Kharif, 2018 (Fig. 1), during which the yellow stem borer was the dominating species (80.61 %) (Fig 3). The efficacy of insecticides evaluated against stem borer in Rabi, 2019, showed that, spinetoram 11.7 SC was the most effective in controlling the stem borer, followed by chlorantraniliprole and flubendiamide (Fig 2), during which the pink stem borer was the abundant species (70.00 %) (Fig 3).

The efficacy of chlorantraniliprole against yellow stem borer in both the sprays was in accordance with the findings...
Table 1a: Field efficacy of insecticides and bio-control agents against stem borer on rice (cv. TRY-3) during vegetative stage (Kharif 2018).

| Treatments                               | Dose (l/ha) | Pre treatment | 3 DAA | 5 DAA | 7 DAA | 15 DAA | 21 DAA | Mean DH (%) | Reduction over control (%) |
|------------------------------------------|-------------|---------------|-------|-------|-------|--------|--------|-------------|---------------------------|
| T1 Dinotefuran 20 SG                     | 150 g (14.60) | (9.75)\textsuperscript{bcdef} | 2.59  | 3.02  | 3.24  | 3.28   | 3.47   | 3.12   | 64.48                        |
| T2 Spinetoram 11.7 SC                    | 375 ml (12.67) | (6.80)\textsuperscript{b} | 4.81  | 1.12  | 1.31  | 1.49   | 1.66   | 1.82   | 1.48                       | 83.16                      |
| T3 Emamectin benzoate 5 SG               | 220 g (14.78) | (8.70)\textsuperscript{bcd} | 6.51  | 2.29  | 2.33  | 2.53   | 2.56   | 2.74   | 2.49                       | 71.66                      |
| T4 Flubendiamide 39.35 SC                | 50 ml (13.25) | (7.45)\textsuperscript{c} | 5.25  | 1.68  | 1.84  | 1.97   | 2.20   | 2.37   | 2.01                       | 76.42                      |
| T5 Cartap hydrochloride 4G               | 25 kg (14.26) | (8.25)\textsuperscript{cd} | 6.07  | 2.06  | 2.13  | 2.15   | 2.44   | 2.56   | 2.27                       | 74.16                      |
| T6 Chlorantraniliprole 18.5 SC           | 150 ml (12.64) | (3.03)\textsuperscript{a} | 4.79  | 0.28  | 0.51  | 0.63   | 0.83   | 0.83   | 0.62                       | 92.98                      |
| T7 Chlorpyriphos 20EC                    | 1.00 l (13.70) | (9.21)\textsuperscript{defg} | 5.61  | 2.56  | 2.70  | 2.82   | 2.87   | 2.93   | 2.78                       | 68.38                      |
| T8 NSKE                                  | 5\% (14.94) | (10.56)\textsuperscript{a} | 6.65  | 3.42  | 3.58  | 3.70   | 3.87   | 5.79   | 4.07                       | 53.66                      |
| T9 Bacillus thuringiensis                | 1.0 l (14.53) | (9.84)\textsuperscript{defg} | 6.29  | 2.92  | 3.04  | 3.40   | 3.47   | 4.05   | 3.38                       | 61.55                      |
| T10 Pseudomonas fluorescens              | 1.0 kg (15.04) | (11.06)\textsuperscript{a} | 6.73  | 3.68  | 3.75  | 3.94   | 5.17   | 7.21   | 4.75                       | 45.89                      |
| T11 Trichogramma japonicum               | 5.0 cc (15.08) | (11.83)\textsuperscript{a} | 6.77  | 4.20  | 5.15  | 5.58   | 6.32   | 8.18   | 5.89                       | 32.96                      |
| T12 Control                              | - - (14.03) | (15.27)\textsuperscript{a} | 5.88  | 6.94  | 7.61  | 8.82   | 9.64   | 10.89  | -                         | -                          |
| SEd                                      | NS          | NS            | 1.01  | 0.96  | 0.82  | 0.51   | 0.43   | -    | -                          | -                          |
| CD (P=0.05)                              | NS          | NS            | 2.29  | 2.00  | 1.70  | 1.05   | 0.89   | -    | -                          | -                          |

In a column, means followed by similar letter(s) are not different statistically (p=0.05) by LSD. Figures in parenthesis are arcsine transformed values.

*Mean of three replications; DAA - Days After Application, DH - Dead heart.
Table 1b: Field efficacy of insecticides and bio-control agents against stem borer on rice (cv. TRY-3) during reproductive stage (Khanl, 2018).

| Treatments | Dose (/ha) | WE (%)* | Second application | Yield* (%) | Reduction over control (kg/ha) |
|------------|------------|---------|--------------------|------------|-------------------------------|
|            |            | 3 DAA  | 5 DAA  | 7 DAA  | 15 DAA | 21 DAA | Mean WE | Reduction over control (%) |
| T1 Dinotefuran 20 SG | 150 g | (10.02)ab | (10.43)ab | (12.36)abc | (13.05)abc | (13.84)abc | 4.34 | 60.53 | 4906.67 f |
| T2 Spinetoram 11.7 SC | 375 ml | (5.97)b | (6.75)b | (8.13)b | (9.81)b | (10.80)b | 2.17 | 80.82 | 5206.67 b |
| T3 Emamectin benzoate 5 SG | 220 g | (8.31)bc | (9.51)c | (11.48)bc | (11.75)bc | (12.15)bc | 3.47 | 69.64 | 5086.67 d |
| T4 Flubendiamide 39.35 SC | 50 ml | (7.54)bc | (8.29)bc | (8.80)bc | (10.88)bc | (11.32)bc | 2.71 | 75.39 | 5200.00 b |
| T5 Cartap hydrochloride 4G | 25 kg | (8.37)bc | (8.78)bc | (10.34)cd | (11.15)cd | (12.00)cd | 3.14 | 71.43 | 5100.00 c |
| T6 Chlorantraniliprole 18.5 SC | 150 ml | (3.34)a | (4.66)a | (5.62)a | (6.47)a | (7.22)a | 0.96 | 91.24 | 5720.00 a |
| T7 Chlorpyriphos 20EC | 1.0 l | (9.37)c | (10.11)c | (11.64)c | (12.92)c | (15.04)c | 4.02 | 63.46 | 5072.67 e |
| T8 NSKE | 5% | (12.71)bc | (13.12)bc | (14.55)bc | (14.69)bc | (16.50)bc | 6.01 | 45.35 | 4600.00 h |
| T9 Bacillus thuringiensis | 1.0 l | (11.41)bc | (12.82)bc | (13.73)cd | (14.32)cd | (15.04)cd | 5.46 | 50.33 | 4692.67 g |
| T10 Pseudomonas fluorescens | 1.0 kg | (12.95)bc | (13.73)bc | (14.74)bc | (14.86)bc | (16.50)bc | 6.30 | 42.75 | 4107.33 i |
| T11 Trichogramma japonicum | 5.0 cc | (13.52)bc | (14.74)bc | (14.93)bc | (15.12)bc | (18.07)bc | 6.88 | 37.48 | 3946.67 j |
| T12 Control | - | 9.90 | 10.23 | 10.86 | 11.15 | 12.88 | 11.00 | - | 3326.67 k |
| SEd | 1.47 | 1.12 | 1.20 | 0.84 | 0.83 | - | - | 0.03 |
| CD (P=0.05) | 3.05 | 2.33 | 2.48 | 1.73 | 1.72 | - | - | 0.05 |

In a column, means followed by similar letter(s) are not different statistically (p=0.05) by LSD. Figures in parenthesis are arcsine transformed values.

*Mean of three replications; DAA- Days After Application, WE – White ear.
Table 2a: Field efficacy of insecticides and bio-control agents against stem borer on rice (cv. TRY 3) at vegetative stage (Rabi, 2019).

| Treatment                        | DH (%)* | Reduction over control (%) |
|----------------------------------|---------|-----------------------------|
|                                  | Pre     | First application            |
|                                  | (Dose/ha) | 3 DAA | 5 DAA | 7 DAA | 14 DAA | 21 DAA | Mean DH | | |
| T1 - Dinofuran 20 SG            | 150 g   | 7.37 | 4.70 | 5.18 | 5.40 | 5.60 | 6.80 | 5.54 | 51.23 |
|                                  | (15.75) | (12.52)e | (13.16)f | (13.44)e | (13.69)e | (15.12)e | | |
| T2 - Spinetoram 11.7 SC         | 375 ml  | 8.00 | 0.44 | 0.66 | 0.87 | 1.08 | 1.28 | 0.87 | 92.36 |
|                                  | (16.43) | (3.80)a | (4.66)a | (5.35)a | (5.97)a | (6.50)a | | |
| T3 - Emamectin benzoate 5 SG    | 220 g   | 7.82 | 3.42 | 3.63 | 3.83 | 4.02 | 4.65 | 3.91 | 65.56 |
|                                  | (16.24) | (10.66)d | (10.98)a | (11.29)d | (11.57)d | (12.45)d | | |
| T4 - Fluvalinate 35.35 SC       | 50 ml   | 7.42 | 2.54 | 2.77 | 3.00 | 3.22 | 3.43 | 2.99 | 73.64 |
|                                  | (15.81) | (9.17)c | (9.58)c | (9.97)c | (10.34)c | (10.67)c | | |
| T5 - Cartap hydrochloride 4G    | 25 kg   | 6.83 | 3.87 | 4.09 | 4.30 | 4.49 | 6.32 | 4.61 | 59.35 |
|                                  | (15.11) | (11.35)de | (11.67)d | (11.97)d | (12.23)d | (14.56)de | | |
| T6 - Chlorantraniliprole 18.5 SC| 150 ml  | 6.15 | 1.27 | 1.52 | 1.75 | 1.99 | 2.21 | 1.75 | 84.60 |
|                                  | (14.36) | (6.47)b | (7.08)b | (7.60)b | (8.11)b | (8.55)b | | |
| T7 - Chlorpyriphos 20SC         | 1.0 l   | 6.49 | 4.12 | 5.28 | 5.52 | 5.75 | 6.42 | 5.42 | 52.27 |
|                                  | (14.76) | (11.71)de | (13.28)d | (13.59)e | (13.87)e | (14.68)f | | |
| T8 - NSKE                       | 5%      | 7.67 | 6.93 | 7.57 | 7.74 | 8.35 | 10.29 | 8.18 | 27.96 |
|                                  | (16.08) | (15.26)f | (15.97)e | (16.16)f | (16.80)f | (18.17)g | | |
| T9 - Bacillus thuringiensis     | 1.00 l  | 6.59 | 6.11 | 7.16 | 7.34 | 7.71 | 8.49 | 7.36 | 35.13 |
|                                  | (14.88) | (14.31)f | (15.52)e | (15.72)f | (16.12)f | (16.94)f | | |
| T10 - Pseudomonas fluorescens   | 1.0 kg  | 7.50 | 7.00 | 7.85 | 8.02 | 8.61 | 10.94 | 8.48 | 25.27 |
|                                  | (15.89) | (15.34)f | (16.27)e | (16.45)f | (17.06)f | (19.32)g | | |
| T11 - Trichogramma japonicum    | 5.0 cc  | 8.14 | 7.58 | 8.02 | 9.20 | 10.10 | 11.46 | 9.27 | 18.31 |
|                                  | (16.58) | (15.98)f | (16.45)e | (17.66)g | (18.53)g | (19.79)g | | |
| T12 - Control                   | -       | 8.31 | 9.39 | 10.85 | 11.21 | 12.18 | 13.14 | 11.35 | - |
|                                  | (16.75) | (17.84)g | (19.23)lf | (19.58)h | (20.43)h | (21.25)h | | |
| SEd                             | NS      | 0.68 | 0.96 | 0.60 | 0.55 | 0.58 | - | - |
| CD (P=0.05)                     | NS      | 1.42 | 1.99 | 1.24 | 1.13 | 1.20 | - | - |

*Mean of three replications; Figures in parentheses are arcsine transformed values; In a column means followed by similar letter(s) are not significantly different (p= 0.05) by LSD.

DAA- Days After Replication, DH – Dead heart.
Table 2b: Field efficacy of insecticides and bio-control agents against stem borer on rice (cv. TRY 3) at reproductive stage (Rabi, 2019).

| Treatment                          | (Dose/ha)   | WE (%)* | Yield (kg/ha)* | Reduction over control (%) |
|------------------------------------|-------------|---------|----------------|---------------------------|
|                                    | Dose/ha     | 3 DAA   | 5 DAA | 7 DAA | 14 DAA | 21 DAA | Mean WE | Reduction over control |
| T1 - Dinotefuran 20 SG             | 150 g       | 3.81    | 4.08  | 4.35  | 4.93   | 5.83   | 4.60    | 69.89           | 2983.33 g       |
|                                    |             | (11.25)ef | (11.65)c | (12.04)e | (12.83)e | (13.97)e |          |                  |
| T2 - Spinetoram 11.7 SC            | 325 ml      | 0.33    | 0.66  | 0.97  | 1.27   | 1.56   | 0.96    | 93.73           | 4570.00 a        |
|                                    |             | (3.29)a | (4.66)a | (5.65)a | (6.47)a | (7.18)a |          |                  |
| T3 - Emamectin benzoate 5 SG      | 220 g       | 1.29    | 1.59  | 1.88  | 2.15   | 2.42   | 1.87    | 87.78           | 3893.33 d        |
|                                    |             | (6.52)c | (7.24)b | (7.88)ab | (8.43)cd | (8.95)cd |          |                  |
| T4 - Flubendiamide 39.35 SC       | 50 ml       | 1.03    | 1.36  | 1.67  | 1.97   | 2.26   | 1.66    | 89.16           | 4196.67 c        |
|                                    |             | (5.83)ab | (6.70)ab | (7.43)bc | (8.07)bc | (8.65)c |          |                  |
| T5 - Cartap hydrochloride 4G      | 25 kg       | 1.56    | 1.79  | 2.03  | 2.25   | 2.47   | 2.02    | 86.78           | 3613.33 e        |
|                                    |             | (7.18)cd | (7.62)b | (8.19)cd | (8.63)cd | (9.04)de |          |                  |
| T6 - Chlorantraniliprole 18.5 SC  | 150 ml      | 0.6     | 1.00  | 1.31  | 1.61   | 1.90   | 1.30    | 91.48           | 4323.33 b1.30   |
|                                    |             | (4.73)ab | (6.57)ab | (7.29)b | (7.92)b |          |          |                  |
| T7 - Chlorpyriphos 20EC           | 1.0 l       | 3.17    | 3.44  | 4.00  | 4.55   | 5.07   | 4.05    | 73.51           | 3190.00 f        |
|                                    |             | (10.26)e | (10.69)c | (11.54)de | (12.32)de | (13.01)e |          |                  |
| T8 - NSKE                          | 5%          | 6.64    | 6.87  | 7.09  | 7.64   | 8.17   | 7.28    | 52.31           | 2293.33 i        |
|                                    |             | (14.93)g | (15.20)d | (15.44)f | (16.05)f | (16.61)f |          |                  |
| T9 - Bacillus thuringiensis       | 1.0 l       | 6.03    | 6.62  | 6.85  | 7.07   | 7.62   | 6.84    | 55.24           | 2606.67 h        |
|                                    |             | (14.22)f | (14.91)d | (15.17)fl | (15.42)fl | (16.02)f |          |                  |
| T10 - Pseudomonas fluorescens     | 1.0 kg      | 6.80    | 7.02  | 7.24  | 7.44   | 9.24   | 7.55    | 50.58           | 2290.00 i        |
|                                    |             | (15.12)fg | (15.36)d | (15.61)fl | (15.83)fl | (17.70)f |          |                  |
| T11 - Trichogramma japonicum     | 5.0 cc      | 7.54    | 7.74  | 7.94  | 8.13   | 8.85   | 8.24    | 46.06           | 2286.67 i        |
|                                    |             | (15.94)g | (16.15)d | (16.37)f | (16.57)fl | (18.29)f |          |                  |
| T12 - Control                     |             | 13.78   | 14.20 | 15.22 | 16.11  | 17.07  | 15.27   | 2116.67 j       |                  |
|                                    |             | (21.79)h | (22.13)e | (22.96)g | (23.68)g | (24.40)g |          |                  |
| SEd                                | 1.56        | 0.57    | 0.99  | 0.73  | 0.64   | -      | -       | 0.11            |                  |
| CD (P=0.05)                        | 3.24        | 1.18    | 2.06  | 1.53  | 1.32   | -      | -       | 0.24            |                  |

*Mean of three replications; Figures in parentheses are arcsine transformed values; In a column means followed by similar letter(s) are not significantly different (p=0.05) by LSD; DAA – Days After Application, WE – White ear.
reported by Chatterjee et al. (2016) and Seni and Naik (2017). The results observed were similar to the efficacy of spinetoram 11.7 SC evaluated by Visagie (2016), Karthick et al. (2014) evaluated the efficacy of flubendiamide which coincides with the present finding. Prasad et al. (2014) evaluated the efficacy of flubendiamide 39.35 SC against paddy stem borer whose result was in agreement with the present finding. Deole (2016) reported that, spinosad 45 SC and chlorantraniliprole 18.5 SC were on par and significantly effective in controlling the pink stem borer followed by emamectin benzoate. Cartap hydrochloride 4G was found to be the least effective. The maximum grain yield was obtained in the plots treated with spinosad. Visnupriya and Muthukrishnan (2017) reported that, spinetoram 12 SC @ 45 g a.i./ha was effective against Helicoverpa armigera (Hub.) on okra. Spinetoram 12 SC @ 45 g a.i./ha in combination with buprofezin 25 SC 375 g and spinetoram 12 SC 45 g a.i./ha + urea (2%) were superior and on par in reducing the population to 3.0 and 3.2 per ten plants and registered 81.9 and 80.7 percent reduction and followed by spinetoram 12 SC 45 g + carboxanilid 50 WP 125 g (3.4 / ten plants and 79.5% reduction), respectively over control against Spodoptera litura (Fab.) in onion (Kumar and Muthukrishnan, 2018).

The difference in the efficacy of insecticides for the management of stem borers during Kharif, 2018 and Rabi, 2019, would be due to shift in the species occurrence of stem borer, with a dominant occurrence of pink stem borer

![Fig 1: Field efficacy of insecticides and bio-control agents against stem borer in rice (Kharif, 2018).](image-url1)

![Fig 2: Field efficacy of insecticides and bio-control agents against stem borer in rice (Rabi, 2019).](image-url2)

![Fig 3: Seasonal distribution of stem borer species incidence in rice. YSB – Yellow Stem Borer, PSB – Pink Stem Borer, DHB – Dark Headed Borer.](image-url3)
Table 3: Seasonal distribution of stem borer species in rice.

| Season | Relative abundance (%) | (Dead heart/ white ear) Larval incidence |
|--------|------------------------|------------------------------------------|
|        | YSB  | PSB  | DHB  |                |
| Kharif| 80.00 | 20.00 | 0.00 |                |
| Rabi  | 19.12 | 75.00 | 5.88 |                |

*Mean of weekly observations.

YSB – Yellow Stem Borer, PSB – Pink Stem Borer, DHB – Dark Headed Borer.

(70.00 %) in Rabi, 2019. It can be well supported by the findings that, among the 14 insecticides evaluated for the control of three stem borer species in maize under glass house and field conditions, two of the insecticides, chlornatraniliprole and chlorfenapyr were less effective in controlling *Busseola fusca* (Fuller) and were effective in controlling *Chilo partellus* (Swinhoe) and *Sesamia calamistis* (Hampson) (Visagie, 2016). The bio-control agents were less effective when compared to the insecticides as evidenced by increased stem borer incidence in *B. thuringiensis* in terms of dead heart (4.05%) and white ear (6.73%) followed by *P. fluorescens* and *T. japonicium*. Among the bio-control agents *B. thuringiensis* was effective, followed by NSKE and all the treatments were significantly superior to control. Similar results on the efficacy of NSKE and *B. thuringiensis* was reported against paddy stem borer by Chakraborty (2011).

**CONCLUSION**

The application of chlornatraniliprole 18.5 SC @ 150ml/ha was effective against stem borer, followed by spinetoram 11.7 SC @ 375 ml/ha and flubendiamide 39.35 @ SC 50 ml/ha in Kharif, 2018, when YSB was dominant. Application of spinetoram 11.7 SC @ 375 ml/ha was effective against stem borer, followed by chlornatraniliprole 18.5 SC @ 150ml/ha and flubendiamide 39.35 SC @ 50 ml/ha in Rabi, 2019, when PSB was dominant. It is important to rotate the insecticides of different groups with different mode of action, in the subsequent season, to avoid development of resistance by the stem borer species. Further, it can be emphasised that, species specific recommendation can be made in hot spot areas for effective management of the stem borer species.

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