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Studies on Management of Pod Borer Complex in Field Bean

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was carried out at S. V. Agricultural College, Tirupati to evaluate the efficacy of selected insecticide molecules against pod borer complex in field bean during *rabi*, 2020-21. The results revealed that among nine insecticide molecules tested for their efficacy against major pod borers, the sprays of spinosad 45 SC @ 0.3 ml/L were found to be most effective against spotted pod borer (82.26 per cent reduction over control), tobacco caterpillar (79.77%), blue butterfly (81.13%) and pea pod borer (81.14%). The next in the order of efficacy were indoxacarb 14.5 SC @ 0.5 ml/L which has recorded 80.45 per cent reduction over control for spotted pod borer, 78.82% for tobacco caterpillar, 79.93% for blue butterfly and 79.79% for pea pod borer whereas flubendiamide 20 WG @ 0.3 g/L has recorded 81.02 per cent reduction over control for spotted pod borer, 77.13% for tobacco caterpillar, 77.41% for blue butterfly and 77.11% for pea pod borer. Similarly, the least per cent pod damage was observed in spinosad @ 0.3 ml/L (37.10%), indoxacarb @ 0.5 ml/L (37.45%) and flubendiamide @ 0.3 g/L (37.98%) which were statistically on par with each other. The results on the effect of pod borer complex management on yield revealed that, among the treatments the

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pod yield was maximum in spinosad 45 SC @ 0.3 ml/L (1347 kg ha^{-1}) followed by indoxacarb 14.5 SC @ 0.5 ml/L (1278 kg ha^{-1}) and both the treatments were at par with each other.

Keywords: Pod borers; spinosad; indoxacarb; flubendiamide.

ABBREVATIONS

% : Per cent
@ : At the rate of
a.i : Active ingredient
CD : Critical Difference
CV : Coefficient of Variation
DAS : Days After Spraying
EC : Emulsifiable Concentrate
et al. : And others
etc. : And so on
g/L : Gram/litre
i.e. : That is
Kg ha^{-1} :Kilogram per hectare
Kg : Kilogram
Ml : Millilitre
ml/L : Millilitre/litre
mm : Millimetre
MT : Million Tonnes
No. : Number
PTC : Pre-Treatment Count
RBD : Randomized Block Design
SC : Suspension Concentrate
SE(m) : Standard Error of mean
SG : Soluble Granule
viz., : Namely
WG : Water-dispersable Granule
WP : Wettable Powder

1. INTRODUCTION

Pulses are second most important dietary component in South Asia after cereals and growing legume pulses enriches soil health because of their nitrogen fixing ability in soil. The only source of protein for poor man in India are pulses. The Indian bean, *Lablab purpureus* (L.) Sweet (Family: Fabaceae) originated from India and its wild form are found all over the sub–continent. It is generally cultivated as annual creeping rainy season herb or a perennial twining herb. In Andhra Pradesh, beans are grown in an area of 12.02 thousand hectares with 139,320 tonnes of total production and 16.90 MT ha^{-1} of total productivity [National Horticulture Board, Ministry of Agri. &FW (DAC&FW), Govt. of India; 2019-20- II Adv. Est.] [1].

The pod borer complex includes spotted pod borer, *Maruca vitrata* (Geyer); pea pod borer, *Etiella zinckenella* (Treitschke); soybean pod borer, *Lampiodes boeticus* (L.) *etc*. These borers cause substantial damage to flowers by webbing and boring into the pods. This pod borer complex, sometimes, incurs a deficit of nearly 54% in field beans in India and hence leading to low productivity in India [2]. Among the pod borer complex, the pod damage due to *M. vitrata* and *L. boeticus* were to the tune of 16.66 and 10.20 per cent, respectively [3]. A lot of insecticides have been found to be effective against the pod borer complex in field bean. Many old insecticides *viz.,* endosulfan, chlorpyrifos that have lost their efficiency or become outdated in recent years owing to insect resistance or residual toxicity are being replaced by new generation compounds that are less harmful to mammals, birds, and fish while still having high insecticidal effectiveness. These new chemicals are less dangerous to natural enemies, honeybees, and other pollinators than previous generations molecules [4]. To solve the drawbacks of conventional insecticides, various new compounds with unique chemistry and modes of action were introduced, necessitating testing their performance and the development of a more simple and cost-effective control method. Hence, the present study was taken up with an aim to evaluate the efficacy of selected insecticide molecules against pod borer complex in field bean.

2. MATERIALS AND METHODS

To study the bio efficacy of selected newer insecticides on pod borer complex, a field experiment was laid out at wetland college farm, S. V. Agricultural College, Tirupati under RBD (Randomized block design) with 10 treatments and three replications including an untreated control. The type of soil is red loamy soil which is suitable for pulse crops. A popular variety, Nandini, was raised in *rabi,* 2020-21 with a spacing of 45 cm ^{x} 15 cm between rows and plants, respectively. For each replication a plot size of 7.5 ^{x} 3m was maintained. Nine selected insecticides *viz.,* emamectin benzoate 5 SG @ 0.4g/L, chlorantraniliprole 18.5 SC @0.3g/L, cyantraniliprole 10.26 OD @ 1.2 ml/L, flubendiamide 20 WG @ 0.3 g/L, indoxacarb 14.5 SC @0.5 ml/L, spinosad 45 SC @ 0.3 ml/L, thiodicarb 75 WP @ 1 g/L, novaluron 10 EC @ 1 ml/L and lambda cyhalothrin 5 EC @ 1 ml/L were assessed in comparison with untreated check against field bean pod borer complex. The treatments were given twice with the help of hand knapsack sprayer of spray volume 200 litres per acre when the pest incidence was seen during the crop growth period. The untreated control is sprayed with water.

Pre-treatment observations on larval population were taken from 10 randomly selected plants one day before the insecticide application and 1, 3, 7 and 15 days after the spray. The observations on pod damage were recorded on 10 randomly selected plants in each treatment by counting total number of pods and number of pods damaged by the pod borers. The per cent pod damage was worked out by using following formula.

$$Per\ cent\ pod\ damage = \frac{Number\ of\ damaged\ pods\ per\ 10\ plants}{Total\ number\ of\ pods\ per\ 10\ plants} \times 100$$

Pods were harvested from each plot separately treatment wise. Finally, pods from each plot were weighed to record the yield of field bean and the yield was recorded as kg/plot obtained from each treatment and was finally converted to Kg ha^{-1}. Data recorded on pod borer population and pod damage was subjected to statistical analysis using SPSS statistical package to draw the conclusions. Per cent reduction of pod borer complex population in treatments over control plots was estimated by using the formula given by Abbot [5].

$$Population\ reduction\ over\ control\ (\%) = \frac{Population\ in\ untreated\ check - Population\ in\ treatment}{Population\ in\ untreated\ check} \times 100$$

The yield data in different treatments was also recorded to observe the effect of treatments on yield.

3. RESULTS AND DISCUSSION

3.1 Efficacy of Insecticidal Treatments against Larvae of *Maruca vitrata*

Though there was a uniform distribution of spotted pod borer, *M. vitrata* larvae a day before insecticidal application, significant differences in the efficacies of insecticides were noticed at 1, 3, 7 and 15 days after both the insecticidal sprays. A perusal of results on cumulative efficacy of two sprays against spotted pod borer revealed that all the treatments were superior to control in reducing the larval population at 1, 3, 7 and 15 days after spraying (Table 1). At 1 DAS (Days After Spraying), highest percent reduction of larval population was observed in flubendiamide @ 0.3 g/L (78.36 %) followed by emamectin benzoate @ 0.4 g/L (77.78 %), chlorantraniliprole @ 0.3 ml/L (76.02 %) and cyantraniliprole @ 1.2 ml/L (76.02 %) which were on par with each other. At 3 and 7 DAS, the treatments *viz.,* spinosad @ 0.3 ml/L (86.19 % & 89.22 %), indoxacarb @ 0.5 ml/L (85.59 % & 85.62 %) were found superior to rest of the treatments and were on par with each other. At 15 DAS, the treatments spinosad @ 0.3 ml/L (87.50 %) and indoxacarb @ 0.5 ml/L (80.45 %) were found superior to rest of the treatments. Lambda cyhalothrin @ 1.0 ml/L was found least effective in reducing *M. vitrata* larval population when compared to above treatments with 56.14, 53.15, 58.17 and 56.41 per cent reduction over control at 1, 3, 7 and 15 days after spraying, respectively.

The overall mean efficacy of four observations recorded at one, three, seven and fifteen days after two sprays indicated that the plots treated with spinosad @ 0.3 ml/L and indoxacarb @ 0.5 ml/L recorded highest reduction of *M. vitrata* larval population and remained significantly superior over all the other treatments with 82.26 and 81.02 per cent reduction over control, respectively which were at par with each other followed by flubendiamide @ 0.3 g/L (79.78 %) which was on par with indoxacarb @ 0.5 ml/L. The next best treatments in the descending order of efficacy were emamectin benzoate @ 0.4 g/L (77.09 %), chlorantraniliprole @ 0.3 ml/L (75.48 %), cyantraniliprole @ 1.2 ml/L (71.78 %), novaluron @ 1.0 ml/L (67.81 %) and thiodicarb @ 1.0 g/L (63.51 %). Lambda cyhalothrin @ 1.0 ml/L with 55.93 per cent reduction over control was least effective in reducing *M. vitrata* larval population when compared to above treatments which is statistically different from others (Table 1).

3.2 Efficacy of Insecticidal Treatments against Larvae of *Spodoptera litura*

Though there was a uniform distribution of tobacco caterpillar, *S. litura* a day before insecticidal application, significant differences in the efficacies of insecticides were noticed at 1, 3, 7 and 15 days after both the insecticidal sprays. A perusal of results on cumulative efficacy of two sprays against tobacco caterpillar revealed that all the treatments were superior to control in reducing the larval population at 1, 3, 7 and 15 days after spraying (Table 2). At 1 DAS (Days After Spraying), highest percent reduction of larval population was observed in cyantraniliprole @ 1.2 ml/L (74.85 %), followed by emamectin benzoate @ 0.4 g/L (73.99 %), chlorantraniliprole @ 0.3 ml/L (73.62 %) and flubendiamide @ 0.3 g/L (72.52 %) which were on par with each other. At 3 DAS, the treatments spinosad @ 0.3 ml/L (84.63 %) and indoxacarb @ 0.5 ml/L (82.85 %) were found superior to rest of the treatments and were on par with each other. At 7 and 15 DAS, the treatments *viz.,* spinosad @ 0.3 ml/L (86.99 % & 84.63 %), indoxacarb @ 0.5 ml/L (80.82 % & 81.14 %) were found superior to rest of the treatments. Lambda cyhalothrin @ 1.0 ml/L was found least effective in reducing *S. litura* larval population when compared to above treatments with 61.96, 56.67, 56.58 and 56.33 per cent reduction over control at 1, 3, 7 and 15 days after spraying, respectively.

The overall mean efficacy of four observations recorded at one, three, seven and fifteen days after two sprays indicated that the plots treated with spinosad @ 0.3 ml/L, indoxacarb @ 0.5 ml/L recorded highest reduction of *S. litura* larval population and remained significantly superior over all the other treatments with 79.77 and 78.82 per cent reduction over control, respectively and both the treatments were at par with each other. The next best treatments in the descending order of efficacy were flubendiamide @ 0.3 g/L and emamectin benzoate @ 0.4 g/L with 77.13 and 75.76 per cent reduction over control, respectively and both the treatments were at par with each other. However, the treatment, flubendiamide @ 0.3 g/L was statistically on par with indoxacarb @ 0.5 ml/L. The next effective treatments were chlorantraniliprole @ 0.3 ml/L (73.59 %) and cyantraniliprole @ 1.2 ml/L (71.92 %), novaluron @ 1.0 ml/L (64.73 %) and thiodicarb @ 1.0 g/L (61.69 %). Lambda cyhalothrin @ 1.0 ml/L with 57.46 per cent reduction over control was least effective in reducing *S. litura* larval population when compared to above treatments which was statistically at par with thiodicarb @ 1.0 g/L (Table 2).

3.3 Efficacy of Insecticidal Treatments against Larvae of *Lampides boeticus*

Though there was a uniform distribution of blue butterfly larvae, *L. boeticus* larvae a day before insecticidal application, significant differences in the efficacies of insecticides were noticed at 1, 3, 7 and 15 days after both the insecticidal sprays. A perusal of results on cumulative efficacy of two sprays against *L. boeticus* revealed that all the treatments were superior to control in reducing the larval population at 1, 3, 7 and 15 days after spraying (Table 3). At 1 DAS (Days After Spraying), highest percent reduction of larval population was observed in emamectin benzoate @ 0.4 g/L (75.30 %) followed by chlorantraniliprole @ 0.3 ml/L (74.70 %), flubendiamide @ 0.3 g/L (73.01 %) and cyantraniliprole @ 1.2 ml/L (72.29 %) which were on par with each other. At 3 and 7 DAS, the treatments *viz.,* spinosad @ 0.3 ml/L (88.69 % & 86.21 %), indoxacarb @ 0.5 ml/L (84.74 % & 82.40 %) were found superior to rest of the treatments. At 15 DAS, the treatments spinosad @ 0.3 ml/L (85.01 %) and indoxacarb @ 0.5 ml/L (81.35 %) were found superior to rest of the treatments and were on par with each other. Lambda cyhalothrin @ 1.0 ml/L was found least effective in reducing *L. boeticus* larval population when compared to above treatments with 60.72, 59.50, 54.93 and 52.18 per cent reduction over control at 1, 3, 7 and 15 days after spraying, respectively.

The overall mean efficacy of four observations recorded at one, three, seven and fifteen days after two sprays indicated that the plots treated with spinosad @ 0.3 ml/L, indoxacarb @ 0.5 ml/L recorded highest reduction of *L. boeticus* larval population and remained significantly superior over all the other treatments with 81.13 and 79.93 per cent reduction over control, respectively and both the treatments were at par with each other. The next best treatments in the descending order of efficacy were flubendiamide @ 0.3 g/L and emamectin benzoate @ 0.4 g/L with 77.41 and 76.30 per cent reduction over control, respectively and both the treatments were at par with each other followed by chlorantraniliprole @ 0.3 ml/L (74.76 %), cyantraniliprole @ 1.2 ml/L (71.77 %), novaluron @ 1.0 ml/L (64.68 %) and thiodicarb @ 1.0 g/L (60.66 %). Lambda cyhalothrin @ 1.0 ml/L with 56.83 per cent reduction over control was least effective in reducing *L. boeticus* larval population when compared to above treatments which is statistically different from others (Table 3).

3.4 Efficacy of Insecticidal Treatments against Larvae of *Etiella zinckenella*

Though there was a uniform distribution of pea pod borer, *E. zinckenella* larvae a day before insecticidal application, significant differences in the efficacies of insecticides were noticed at 1, 3, 7 and 15 days after both the insecticidal sprays. A perusal of results on cumulative efficacy of two sprays against *E. zinckenella* revealed that all the treatments were superior to control in reducing the larval population at 1, 3, 7 and 15 days after spraying (Table 4). At 1 DAS (Days After Spraying), highest percent reduction of larval population was observed in indoxacarb @ 0.5 ml/L (78.27 %) followed by emamectin benzoate @ 0.4 g/L (77.73 %), chlorantraniliprole @ 0.3 ml/L (77.60 %), flubendiamide @ 0.3 g/L (76.80 %) and which were on par with each other. At 3 and 7 DAS, the treatments *viz.,* spinosad @ 0.3 ml/L (89.57 % & 85.77 %), indoxacarb @ 0.5 ml/L (82.00 % & 80.69 %) were found superior to rest of the treatments. At 15 DAS, the treatments spinosad @ 0.3 ml/L (84.38 %) and indoxacarb @ 0.5 ml/L (78.90 %) were found superior to rest of the treatments and were on par with each other. Lambda cyhalothrin @ 1.0 ml/L was found least effective in reducing *L. boeticus* larval population when compared to above treatments with 63.60, 61.14, 58.45 and 55.48 per cent reduction over control at 1, 3, 7 and 15 days after spraying, respectively.

The overall mean efficacy of four observations recorded at one, three, seven and fifteen days after two sprays indicated that the plots treated with spinosad @ 0.3 ml/L, indoxacarb @ 0.5 ml/L recorded highest reduction of *E. zinckenella* larval population and remained significantly superior over all the other treatments with 81.14 and 79.79 per cent reduction over control, respectively and both the treatments were at par with each other. The next best treatment was flubendiamide @ 0.3 g/L with (77.11 %) followed by emamectin benzoate @ 0.4 g/L (75.38 %), chlorantraniliprole @ 0.3 ml/L (74.11 %), cyantraniliprole @ 1.2 ml/L (68.92 %), novaluron @ 1.0 ml/L (65.02 %) and thiodicarb @ 1.0 g/L (62.34 %). Lambda cyhalothrin @ 1.0 ml/L with 59.50 per cent reduction over control was least effective in reducing *E. zinckenella* larval population when compared to above treatments which is statistically different from others Table 4.

3.5 Effect of Insecticidal Treatments on Per Cent Pod Damage

Though the per cent pod damage due to pod borer complex recorded a day before insecticidal application is uniform, significant differences in the effects of insecticides were noticed at 1, 3, 7 and 15 days after both the insecticidal sprays. A perusal of results on cumulative effect of two sprays on per cent pod damage revealed that all the treatments were superior to control at 1, 3, 7 and 15 days after spraying (Table 5). At 1 DAS (Days After Spraying), lowest percent pod damage was observed in indoxacarb @ 0.5 ml/L (35.76 %) followed by chlorantraniliprole @ 0.3 ml/L (37.23 %), cyantraniliprole @ 1.2 ml/L (37.47 %), flubendiamide @ 0.3 g/L (38.02 %) and which were on par with each other. At 3 and 7 DAS, the treatments *viz.,* spinosad @ 0.3 ml/L (35.36 % & 28.31 %), indoxacarb @ 0.5 ml/L (41.24 % & 37.12 %) were found superior to rest of the treatments. At 15 DAS, the treatments flubendiamide @ 0.3 g/L (37.64 %) and indoxacarb @ 0.5 ml/L (36.41 %) were found superior to rest of the treatments. Lambda cyhalothrin @ 1.0 ml/L was found least effective which recorded high per cent pod damage when compared to above treatments with 61.47, 54.62, 54.69 and 56.25 per cent reduction over control at 1, 3, 7 and 15 days after spraying, respectively.

The overall mean efficacy of four observations recorded at one, three, seven and fifteen days after two sprays indicated that the plots treated with spinosad @ 0.3 ml/L, indoxacarb @ 0.5 ml/L and flubendiamide @ 0.3 g/L recorded highest reduction of per cent pod damage with 37.10, 37.45 and37.98 per cent, respectively and all the treatments were at par with each other. The next effective treatments in descending order of efficacy were emamectin benzoate @ 0.4 g/L (40.95 %), chlorantraniliprole @ 0.3 ml/L (41.42 %), cyantraniliprole @ 1.2 ml/L (43.74 %), novaluron @ 1.0 ml/L (50.18 %) and thiodicarb @ 1.0 g/L (51.17 %). Lambda cyhalothrin @ 1.0 ml/L recorded least per cent pod damage *i.e*., 57.06 per cent which was significantly different from others. However, all the treatments were significantly superior over the control which recorded 61.71 per cent in reducing the pod damage caused by pod borer complex (Table 5).

In the present studies, spinosad 45 SC was found to be the most effective treatment which exhibited highest efficacy on the pod borer complex in field bean. Spinosad is a fermentation metabolite of the actinomycete *Saccharopolyspora spinosa,* a soil-inhabiting microorganism which is a mixture of spinosyns A and D. It kills insects by causing rapid excitation by activation of nicotinic acetylcholine receptors of the insect nervous system, leading to involuntary muscle contractions, prostration, with tremors and paralysis. Spinosad is a contact and stomach poison with some translaminar movement in leaf tissue and is particularly more effective as a broad-spectrum molecule. All these actions might have contributed for the superior efficacy of spinosad. The current results are in conformity with the findings of Jat et al. [6] who revealed that the treatment of spinosad 45 SC (0.01%) proved most effective followed by indoxacarb 14.5 EC (0.01%). The results were also in agreement with that of Rekha and Mallapur [7], Mallikarjuna et al. [8] and Kulheri et al. [9] who found spinosad as highly effective against pod borers. Yadav and Singh [10] reported that spinosad 45 SC and indoxacarb 14.5 SC were the most effective treatments and significantly superior to other treatments with 80.7 and 79.2 per cent larval reduction over control. Mohapatra and Srivastava [11], Chandrayudu et al. [12], Rani and Eswari [13], Kumar and Shivaraju [14] and Sonune et al. [15] have also reported the similar results.

Indoxacarb 14.5 SC was found to be the next best treatment in the control of pod borer complex in field bean with next highest per cent reduction over control. The active ingredients work by inhibiting Na^+ ion entry into nerve cell, resulting in paralysis and death of targeted pests. The primary route of entry is through ingestion of treated foliage with some additional absorption through the pest cuticle. Pests exposed to indoxacarb, stopped feeding in zero to four hours, paralysis and death occurred within 4 to 48 hours. Yadav et al. [16] showed that indoxacarb 14.5 SC and abamectin 1.9 EC were found to be most effective in reducing larval population of *S. litura* and *S. obliqua* whereas, indoxacarb 14.5 SC and emamectin benzoate 5 WG were found significantly better to reduce larval population of *T. ni.*

The next best treatment found showing highest percent reduction of pod borer pest population over control in field bean crop was Flubendiamide 20 WG. Similarly, Selvam et al. [17] reported that Flubendiamide 480 SC recorded the lowest larval population of M. vitrata (2.40 larvae/plant) under field condition. The present findings are also in agreement with findings of Bhoyar et al. [18], Meena et al. [19], Patil et al. [20] and Muthukrishna et al. [21] who reported the higher efficacy of these molecules.

Kumar and Sarada [22] reported that the pod damage due to pod borer, *H. armigera* was lowest in plots treated with spinosad 45 SC (1.53%), flubendiamide 20 WG (2.46%), chlorantraniliprole 20 SC (2.60%) and emamectin benzoate 5 SG (2.85%) with 88.8, 81.9, 80.9 and 79.1 per cent reduction over control, respectively. Taggar et al. [23] reported that the application of chlorantraniliprole 18.5 SC @ 150 ml ha-1 followed by flubendiamide 480 SC @ 125 ml ha-1 registered significantly the lowest pest population and cumulative pod damage against pod borer complex in pigeonpea. Rashmi et al. [24] reported that chlorantraniliprole 18.5 SC @ 0.15 ml/L followed by spinosad @ 0.15 ml/L and emamectin benzoate @ 0.2 g/L were found to be most effective against the pod borers in field bean. Harshita et al. [25] reported that treatment application of chlorantraniliprole 18.5 SC at 0.2 ml/L and cyantraniliprole 10 OD at 1.2 ml/L showed the least larval population, lowest pod damage against pod borer complex in pigeonpea with higher green pod yield.

3.6 Effect of Insecticidal Treatments on Yield

The overall mean of yield revealed that all the treatments recorded highest pod yield, compared to control. The plots treated with spinosad 45 SC @ 0.3 ml/L recorded the maximum yield of (1347 kg ha^{-1}) followed by indoxacarb 14.5 SC @ 0.5 ml/L (1278 kg ha^{-1}) and both the treatments were at par with each other. The next best treatment was flubendiamide 20 WG @ 0.3 g/L with a yield of 1183 kg ha^{-1} The next treatments in the descending order of yield recorded were emamectin benzoate 5 SG @ 0.4 g/L, chlorantraniliprole 18.5 SC @ 0.3 ml/L, cyantraniliprole 10.26 OD @ 1.2 ml/L and novaluron 10 EC @ 1.0 ml/L with a yield of 1073, 973, 847 and 701 kg ha^{-1}, respectively. However, all the treatments are significantly different from one another. The next treatments were thiodicarb 75 WP @ 1.0 ml/L and lambda cyhalothrin 5 EC @ 1.0 ml/L with a yield of 577 kg ha^{-1} and 491 kg ha^{-1} which were significantly different from one another while control recorded least yield among all of 351 kg ha^{-1} (Table 6).

Spinosad 45 SC was found to be the most effective treatment with highest pod yield. This may be due to its broad-spectrum activity over pod borers and killing of larvae by causing rapid excitation with its unique mode of action. These results were in accordance with Yadav and Singh [10] who reported that the maximum yield in cowpea was recorded in treatment indoxacarb 14.5 SC (11.8 q ha^{-1}) followed by spinosad 45 SC (11.1 q ha^{-1}) which were at par with each other. The present findings are also in agreement with the reports of Mohapatra and Srivastava [11], Chandrayudu et al. [12], Rani and Eswari [13], Kumar and Shivaraju [14] and Sonune et al. [15].

Table 1. Efficacy of different insecticides against spotted pod borer larvae in field bean during *rabi*, 2020-21

S.No.	Treatment	Dose	PTC	Mean no. of larvae per plant and per cent reduction of spotted pod borer larval population over control								Mean per cent reduction
				1 DAS		3 DAS		7 DAS		15 DAS		
				Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	
T_1	Emamectin benzoate 5 SG	0.4 g/L	2.52	0.63	77.78^{a} (61.87)	0.67	75.98^{c} (60.65)	0.53	79.08^{cd} (62.79)	0.63	75.64^{bc} (60.43)	77.09^{c} (61.40)
T_2	Chlorantraniliprole 18.5 SC	0.3 ml/L	2.60	0.68	76.02^{ab} (60.68)	0.68	75.38^{c} (60.25)	0.62	75.82^{d} (60.54)	0.65	75.00^{bc} (60.00)	75.48^{c} (60.32)
T_3	Cyantraniliprole 10.26 OD	1.2 ml/L	2.76	0.68	76.02^{ab} (60.68)	0.83	69.97^{d} (56.77)	0.72	71.90^{e} (57.99)	0.80	69.23^{d} (56.31)	71.78^{d} (57.91)
T_4	Flubendiamide 20 WG	0.3 g/L	2.53	0.62	78.36^{a} (62.28)	0.50	81.98^{b} (64.88)	0.45	82.42^{bc} (65.21)	0.61	76.60^{bc} (61.07)	79.78^{b} (63.28)
T_5	Indoxacarb 14.5 SC	0.5 ml/L	2.55	0.78	72.51^{bc} (58.38)	0.40	85.59^{a} (67.69)	0.37	85.62^{ab} (67.72)	0.51	80.45^{b} (63.76)	81.02^{ab} (64.17)
T_6	Spinosad 45 SC	0.3 ml/L	2.37	0.97	66.08^{e} (54.38)	0.38	86.19^{a} (68.18)	0.28	89.22^{a} (70.83)	0.33	87.50^{a} (69.30)	82.26^{a} (65.09)
T_7	Thiodicarb 75 WP	1.0 g/L	2.62	0.93	67.25^{de} (55.09)	1.10	60.36^{f} (50.98)	0.90	64.71^{f} (53.55)	0.98	62.18^{de} (52.05)	63.51^{f} (52.84)
T_8	Novaluron 10 EC	1.0 ml/L	2.39	0.87	69.59^{cd} (56.53)	0.93	66.37^{e} (54.55)	0.80	68.63^{e} (55.94)	0.87	66.67^{de} (54.74)	67.81^{e} (55.43)
T_9	Lambda cyhalothrin 5 EC	1.0 ml/L	2.70	1.25	56.14^{f} (48.53)	1.30	53.15^{g} (46.81)	1.07	58.17^{g} (49.70)	1.13	56.41^{f} (48.68)	55.93^{g} (48.40)
T_{10}	Untreated check		2.67	2.85	-	2.78	-	2.55	-	2.60	-	-
SEm±					1.35		0.99		1.21		1.76	0.60
CD (5 %)					4.00		2.93		3.61		5.21	1.77
CV (%)					4.49		3.22		3.86		5.78	1.95

Figures in parentheses are angular transformed values
PTC: Pre-Treatment Count
DAS: Days After Spraying
CD values were calculated as per DMRT analysis

Table 2. Efficacy of different insecticides against tobacco caterpillar in field bean during *rabi*, 2020-21

S.No.	Treatment	Dose	PTC	Mean no. of larvae per plant and per cent reduction of tobacco caterpillar population over control								Mean per cent reduction
				1 DAS		3 DAS		7 DAS		15 DAS		
				Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	
T_1	Emamectin benzoate 5 SG	0.4 g/L	1.03	0.35	73.99^{a} (59.33)	0.26	79.92^{bc} (63.38)	0.28	76.99^{c} (61.33)	0.35	73.13^{c} (58.78)	75.76^{c} (60.51)
T_2	Chlorantraniliprole 18.5 SC	0.3 ml/L	0.87	0.36	73.62^{a} (59.09)	0.28	78.65^{c} (62.48)	0.36	70.55^{d} (57.13)	0.36	72.48^{c} (58.36)	73.59^{d} (59.08)
T_3	Cyantraniliprole 10.26 OD	1.2 ml/L	0.80	0.34	74.85^{a} (59.90)	0.33	75.22^{d} (60.15)	0.37	69.45^{d} (56.45)	0.41	68.35^{d} (55.76)	71.92^{d} (58.00)
T_4	Flubendiamide 20 WG	0.3 g/L	0.70	0.37	72.52^{a} (58.38)	0.26	79.92^{bc} (63.38)	0.28	76.71^{c} (61.15)	0.26	80.23^{b} (63.60)	77.13^{bc} (61.43)
T_5	Indoxacarb 14.5 SC	0.5 ml/L	0.77	0.39	71.66^{a} (57.83)	0.23	82.85^{ab} (65.53)	0.23	80.82^{b} (64.03)	0.24	81.14^{b} (64.26)	78.82^{ab} (62.60)
T_6	Spinosad 45 SC	0.3 ml/L	0.63	0.49	63.93^{bc} (53.09)	0.20	84.63^{a} (66.91)	0.16	86.99^{a} (68.85)	0.20	84.63^{a} (66.91)	79.77^{a} (63.27)
T_7	Thiodicarb 75 WP	1.0 g/L	0.90	0.44	67.61^{b} (55.31)	0.54	59.21^{f} (50.31)	0.48	60.41^{f} (51.01)	0.50	61.24^{f} (51.50)	61.69^{f} (51.76)
T_8	Novaluron 10 EC	1.0 ml/L	0.83	0.47	65.64^{bc} (54.12)	0.44	66.20^{e} (54.45)	0.43	65.07^{e} (53.77)	0.47	63.57^{e} (52.87)	64.73^{e} (53.56)
T_9	Lambda cyhalothrin 5 EC	1.0 ml/L	0.73	0.52	61.96^{c} (51.92)	0.57	56.67^{f} (48.83)	0.53	56.58^{f} (48.78)	0.56	56.33^{g} (48.64)	57.46^{g} (49.29)
T_{10}	Untreated check		1.33	1.36	-	1.31	-	1.22	-	1.29	-	-
SEm±					1.49		1.07		0.97		0.63	0.59
CD (5 %)					4.43		3.17		2.88		1.87	1.76
CV (%)					5.10		3.45		3.23		2.09	1.98

Figures in parentheses are angular transformed values
PTC: Pre-Treatment Count
DAS: Days After Spraying
CD values were calculated as per DMRT analysis

Table 3. Efficacy of different insecticides against blue butterfly larvae during *rabi,* 2020-21

S.No.	Treatment	Dose	PTC	Mean no. of larvae per plant and per cent reduction of blue butterfly larval population over control								Mean per cent reduction
				1 DAS		3 DAS		7 DAS		15 DAS		
				Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	
T_1	Emamectin benzoate 5 SG	0.4 g/L	1.05	0.34	75.30[a] (60.27)	0.36	76.29[c] (60.84)	0.29	79.55[bc] (63.11)	0.37	74.14[bc] (59.44)	76.30[bc] (60.87)
T_2	Chlorantraniliprole 18.5 SC	0.3 ml/L	0.93	0.35	74.70[ab] (59.80)	0.41	73.00[d] (58.69)	0.32	77.17[cd] (61.46)	0.36	74.26[bc] (59.51)	74.76[c] (59.84)
T_3	Cyantraniliprole 10.26 OD	1.2 ml/L	0.87	0.38	72.29[ab] (58.24)	0.47	69.26[e] (56.33)	0.36	74.08[d] (59.40)	0.40	71.66[c] (57.84)	71.77[d] (57.91)
T_4	Flubendiamide 20 WG	0.3 g/L	0.73	0.37	73.01[ab] (58.75)	0.33	78.38[c] (62.31)	0.26	81.81[b] (64.75)	0.33	76.51[b] (61.00)	77.41[b] (61.62)
T_5	Indoxacarb 14.5 SC	0.5 ml/L	0.83	0.40	71.73[bc] (57.67)	0.23	84.74[b] (67.02)	0.25	82.40[b] (65.20)	0.26	81.35[a] (64.41)	79.93[a] (63.39)
T_6	Spinosad 45 SC	0.3 ml/L	0.63	0.49	64.70[e] (53.54)	0.17	88.69[a] (70.35)	0.19	86.21[a] (68.20)	0.21	85.01[a] (67.22)	81.13[a] (64.25)
T_7	Thiodicarb 75 WP	1.0 g/L	0.87	0.47	66.39[de] (53.48)	0.58	61.58[g] (51.70)	0.58	58.38[f] (49.83)	0.62	56.43[d] (48.70)	60.66[f] (51.15)
T_8	Novaluron 10 EC	1.0 ml/L	0.77	0.43	68.67[cd] (55.97)	0.52	65.97[f] (54.31)	0.49	65.16[e] (53.83)	0.58	58.91[d] (50.13)	64.68[e] (53.53)
T_9	Lambda cyhalothrin 5 EC	1.0 ml/L	0.78	0.54	60.72[f] (51.21)	0.62	59.50[g] (50.47)	0.63	54.93[g] (47.83)	0.68	52.18[e] (46.25)	56.83[g] (48.93)
T_{10}	Untreated check		1.38	1.38	-	1.52	-	1.40	-	1.41	-	-
SEm±					1.16		1.09		1.07		1.25	0.73
CD (5 %)					3.45		3.23		3.18		3.72	2.18
CV (%)					3.94		3.53		3.47		4.21	2.43

Figures in parentheses are angular transformed values
PTC: Pre-Treatment Count
DAS: Days After Spraying
CD values were calculated as per DMRT analysis

Table 4. Efficacy of different insecticides against pea pod borer larvae during *rabi,* 2020-21

S.No.	Treatment	Dose	PTC	Mean no. of larvae/plant and per cent reduction of pea pod borer larval population over control								Mean per cent reduction
				1 DAS		3 DAS		7 DAS		15 DAS		
				Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	Mean	Per cent reduction	
T_1	Emamectin benzoate 5 SG	0.4 g/L	1.05	0.28	77.73[a] (61.84)	0.26	78.00[cd] (62.03)	0.32	75.35[c] (60.23)	0.35	70.96[c] (57.39)	75.38[c] (60.25)
T_2	Chlorantraniliprole 18.5 SC	0.3 ml/L	0.77	0.28	77.60[a] (61.75)	0.28	75.71[d] (60.47)	0.35	73.70[c] (59.15)	0.37	69.59[c] (56.53)	74.11[c] (59.41)
T_3	Cyantraniliprole 10.26 OD	1.2 ml/L	0.68	0.36	71.07[b] (57.46)	0.34	70.57[e] (57.15)	0.42	68.11[d] (55.62)	0.41	66.71[c] (54.76)	68.92[d] (56.12)
T_4	Flubendiamide 20 WG	0.3 g/L	0.65	0.29	76.80[a] (63.43)	0.24	79.29[bc] (62.93)	0.30	77.13[bc] (61.43)	0.29	75.89[b] (60.59)	77.11[b] (61.42)
T_5	Indoxacarb 14.5 SC	0.5 ml/L	0.70	0.27	78.27[a] (62.21)	0.21	82.00[b] (64.90)	0.25	80.69[b] (63.93)	0.26	78.90[b] (62.66)	79.79[a] (63.28)
T_6	Spinosad 45 SC	0.3 ml/L	0.67	0.44	65.20[d] (53.85)	0.12	89.57[a] (71.16)	0.19	85.77[a] (67.84)	0.19	84.38[a] (66.72)	81.14[a] (64.26)
T_7	Thiodicarb 75 WP	1.0 g/L	0.87	0.42	66.13[cd] (54.41)	0.42	64.43[fg] (53.39)	0.51	61.25[ef] (51.50)	0.51	58.49[de] (49.89)	62.34[f] (52.15)
T_8	Novaluron 10 EC	1.0 ml/L	0.93	0.39	68.80[bc] (56.04)	0.39	66.29[f] (54.50)	0.47	64.29[de] (53.31)	0.47	61.23[d] (51.49)	65.02[e] (53.74)
T_9	Lambda cyhalothrin 5 EC	1.0 ml/L	0.87	0.46	63.60[d] (52.89)	0.45	61.14[g] (51.44)	0.55	58.45[f] (49.86)	0.54	55.48[e] (48.15)	59.50[g] (50.47)
T_{10}	Untreated check		1.20	1.25	-	1.17	-	1.31	-	1.22	-	-
SEm±					1.18		1.23		1.36		1.52	0.55
CD (5%)					3.50		3.65		4.03		4.53	1.64
CV (%)					3.92		3.95		4.50		5.21	1.84

Figures in parentheses are angular transformed values
PTC: Pre-Treatment Count
DAS: Days After Spraying
CD values were calculated as per DMRT analysis

Table 5. Efficacy of different insecticides against per cent pod damage in field bean during *rabi*, 2020-21

S.No.	Treatment	Dose	PTC	Per cent pod damage				Mean
				1 DAS	3 DAS	7 DAS	15 DAS	
T_1	Emamectin benzoate 5 SG	0.4 g/L	62.73	41.57^{b}	41.79^{cd}	40.89^{bc}	40.14^{c}	40.95^{b}
T_2	Chlorantraniliprole 18.5 SC	0.3 ml/L	56.36	37.23^{ab}	39.25^{abc}	42.95^{cd}	43.19^{d}	41.42^{b}
T_3	Cyantraniliprole 10.26 OD	1.2 ml/L	50.06	37.47^{ab}	39.08^{abc}	47.22^{de}	47.16^{f}	43.74^{c}
T_4	Flubendiamide 20 WG	0.3 g/L	46.53	38.02^{ab}	37.87^{ab}	38.49^{bc}	37.64^{a}	37.98^{a}
T_5	Indoxacarb 14.5 SC	0.5 ml/L	52.29	35.76^{a}	41.24^{bc}	37.12^{b}	36.41^{b}	37.45^{a}
T_6	Spinosad 45 SC	0.3 ml/L	52.61	53.51^{cd}	35.36^{a}	28.31^{a}	34.37^{bc}	37.10^{a}
T_7	Thiodicarb 75 WP	1.0 g/L	49.90	51.41^{c}	46.23^{e}	52.08^{fg}	52.93^{f}	51.17^{d}
T_8	Novaluron 10 EC	1.0 ml/L	53.01	56.24^{d}	45.30^{de}	47.68^{ef}	50.63^{f}	50.18^{d}
T_9	Lambda cyhalothrin 5 EC	1.0 ml/L	61.79	61.47^{e}	54.62^{f}	54.69^{g}	56.25^{g}	57.06^{e}
T_{10}	Untreated check		59.18	61.94^{e}	60.17^{g}	61.47^{h}	62.33^{h}	61.71^{f}
SEm±				1.58	1.32	1.53	1.00	0.67
CD (5%)				4.69	3.91	4.53	2.98	1.98
CV (%)				5.77	5.17	5.86	3.77	2.52

Figures in parentheses are angular transformed values

PTC: Pre-Treatment Count; DAS: Days After Spraying; CD values were calculated as per DMRT analysis

Table 6. Yield parameters

S.No.	Treatment	Dose	Yield (Kg ha $^{-1}$)				Mean
			I Picking	II Picking	III Picking	IV Picking	
T_1	Emamectin benzoate 5 SG	0.4 g/L	1298^{cd}	1118^{cd}	994^{cd}	884^{bc}	1073^{c}
T_2	Chlorantraniliprole 18.5 SC	0.3 ml/L	1194de	966^{d}	899^{d}	833^{cd}	973^{d}
T_3	Cyantraniliprole 10.26 OD	1.2 ml/L	1030^{ef}	822^{e}	715^{e}	822^{d}	847^{e}
T_4	Flubendiamide 20 WG	0.3 g/L	1482^{bc}	1242^{bc}	1076^{bc}	930^{ab}	1183^{b}
T_5	Indoxacarb 14.5 SC	0.5 ml/L	1626^{ab}	1355^{ab}	1163^{ab}	967^{a}	1278^{a}
T_6	Spinosad 45 SC	0.3 ml/L	1755^{a}	1426^{a}	1225^{a}	983^{a}	1347^{a}
T_7	Thiodicarb 75 WP	1.0 g/L	865^{gh}	461^{g}	392^{g}	589^{f}	577^{g}
T_8	Novaluron 10 EC	1.0 ml/L	963^{fg}	636^{f}	521^{f}	684^{e}	701^{f}
T_9	Lambda cyhalothrin (Standard Check) 5 EC	1.0 ml/L	602^{h}	458^{h}	385^{h}	521^{g}	491^{h}
T_{10}	Untreated check		592^{h}	279^{i}	290 ^{i}	242^{h}	351^{i}
SEm±			60.33	52.46	30.90	27.38	28.46
CD (5%)			179	156	92	81	84
CV (%)			9.16	10.37	6.99	6.36	5.59

CD values were calculated as per DMRT analysis

Kumar and Sarda [22] revealed that highest seed yield of chickpea was recorded in spinosad 45 SC treated plots (1244.4 kg ha^{-1}) with 121.8 per cent increase over control, followed by chlorantraniliprole 20 SC (1180.5 kg ha^{-1}), flubendiamide 20 WG (1157.4 kg ha^{-1}) and emamectin benzoate 5 SG (1078.7 kg ha^{-1}) with 110.4, 106.3 and 92.2 per cent increase over control, respectively as against the minimum yield of 561.1 kg ha^{-1} in the untreated control.

4. CONCLUSION

Among all the treatments, the treatment spinosad 45 SC @ 0.3 ml/L emerged as the best treatment when compared with the other treatments with highest per cent reduction of pod borer complex, less per cent pod damage and high pod yield due to its unique mode of action and specific target site. The next effective treatment was indoxacarb 14.5 SC @ 0.5 ml/L and was followed by flubendiamide 20 WG @ 0.3 g/L.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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