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Research Article

Field efficacy of certain microbial insecticides against *Plutella xylostella* Linnaeus and *Pieris brassicae* Linnaeus under cabbage-crop-ecosystem of Manipur

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ABSTRACT: A field trial was experimented during Rabi, 2014-15 at the Vegetable Research Farm of College of Agriculture, Central Agricultural University, Imphal to evaluate certain microbial pesticides against the diamond back moth, *Plutella xylostella* Linnaeus and the cabbage butterfly, *Pieris brassicae* Linnaeus and their effect on the population of lady bird beetle, *Coccinella septempunctata* Linnaeus in cabbage -crop-ecosystem of Manipur. The results on the efficacy of insecticides against *P. xylostella* and *P. brassicae* revealed that all the insecticidal treatments resulted in significantly suppression of both the pests' incidence. However, bioasp (*Bacillus thuringiensis* var. *kurstaki*) @ 1000 g ha^{-1} was the most effective insecticide against *P. xylostella* with a record of minimum mean leaf damage of 13.32 per cent as against 69.18% in untreated control, closely followed by spinosad 2.5 SC applied @ 500 ml ha^{-1}(14.22% LD) which did not differ significantly from each other. Against *P. brassicae* spinosad 2.5 SC registered significantly the lowest mean leaf damage of 24.30 per cent as against 87.38% in untreated check, closely followed by myco-jaal 10 SC (*Beauveria bassiana*) with a record of 26.59 per cent leaf damage but, differed significantly between them. The highest mean leaf damage incidence (37.47% LD) was noticed in the plots treated with brigade (*Vertcillium lecanii*) applied @ 1250 g ha^{-1}. The results on toxic effect of insecticides on the population of *C. septempunctata* revealed that bioasp (*B. thuringiensis* var. *kurstaki*) @ 1000 g ha^{-1} proved to be the safest insecticide with significantly highest population of 1.99/ 5 plants as against 3.04/5 plants recorded in untreated control, followed by myco-jaal 10 SC (*B. bassiana*) @ 500 ml ha^{-1} (1.61 beetles/ 5 plants) and spinosad 2.5 SC @ 500 ml ha^{-1} (1.51 beetles/ 5 plants) which did not differ significantly from each other. The lowest population *C. septempunctata* (0.55/plants) was observed in the malathion 50 EC @ 500 ml ha^{-1} treated plots. The highest mean cabbage yield (24.77 t ha^{-1}) was harvested from the plots treated with spinosad 2.5 SC with the maximum yield increase over control of 9.37 t ha^{-1} which showed non significant difference with the plots of bioasp (*B. thuringiensis* var. *kurstaki* (23.70 t ha^{-1}) with its yield increase over control of 8.30 t ha^{-1}, whereas verticel (*V. lecanii*) @ 1000 g ha^{-1} treated plots accrued significantly lowest cabbage yield of 19.27 t ha^{-1} with a record of lowest yield increase over control of 3.87 t ha^{-1}. The avoidable yield loss was computed to be 37.82 per cent in the untreated control plots. Application of insecticides resulted in reduction of the mean avoidable loss, which ranged between 4.32 and 22.21 per cent in different insecticidal treatments, the lowest being in bioasp (*B. thuringiensis* var. *kurstaki*) and highest in verticel (*V. lecanii*). The net profit of the insecticidal treatments varied from Rs. 17860.60 (verticel) to Rs. 45621.60 (spinosad) with the cost : benefit ratios ranging between 1:11.99 and 1:43.09, the minimum and maximum being with verticel and myco-jaal 10 SC, respectively.

KEY WORDS: Cabbage, *Coccinella septempunctata*, field evaluation, microbials, *Plutella xylostella*, *Pieris brassicae*

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INTRODUCTION

Cabbage (*Brassicae oleracea* var. *capitata* Linn.) is one of the most important and extensively cultivated vegetable crop because of their nutritional and economical values for producers and consumer point of view, respectively. It is grown for its edible enlarged terminal buds known as head, which is rich source of vitamin A (2000 I.U.), B1 (50 I.U.) and C (124 mg/100gm) and also contains minerals including phosphorus, potassium, sodium, calcium, and iron as well. This crop is a native of West Europe and the Northern shores of the Mediterranean (Yawalkar, 1980). India is second to China in cabbage production. It is grown over an area of 3.12 million ha in the world and 0.331million ha in India (Anonymous, 2010). However, the average productivity of cabbage in India is about 22.0 metric tonne/ha which is less than World's productivity of 22.3 million tonne/ha (Anon., 2010). The productivity is only 10.1 M.T/ha in Manipur as compared to the national productivity of 22.0 metric tonnes/ha (Anon., 2010). Amongst several abiotic and biotic factors responsible for low productivity of cabbage, the damage caused by insect pests which infest the crop from seedlings to harvest is considered as one of the major production constraints.

Cabbage is prone to infestation by a number of insect pests consisting sucking and defoliating insects starting from germination to harvesting stage of the crop. In India, a total of 37 insect pests have been reported to feed on cabbage, of which the diamond back moth, *Plutella xylostella* Linneaus, cabbage butterfly, *Pieris brassicae* Linneaus and the mustard aphid, *Lipaphis erysimi* Kaltenbach are the major constraints for profitable cultivation of the crop (Sachan and Gangwar, 1980 and Lal, 1975). Fourteen species of insect pests have been observed to inflict damage in cole crop from seedlings to harvest stage of crop growth in Manipur *viz*., cut worm (*Agrotis ipsilon* Hafner and *Spodoptera litura* Fabricius), pea leaf miner (*Phytomyza atricornis* Meigan), aphids (*Lipaphis erysimi* Kaltenbach, *Brevicoryne brassicae* Linnaeus and *Myzus persicae* Sulzer), diamond backmoth (*P. xylostella*), cabbage butterflies (*P. brassicae*, *P. canidia* and *P. rapae*), Bihar hairy caterpillar (*Spilarctia obliqua* Walker), flea beetle (*Phyllotreta cruciferae* Goeze), pentatomid bug, (*Bagrada cruciferarum* Kirk.) and cabbage semilooper (*Plusia orichalcea* Fabricius), (Ram *et al*., 1981). Out of these, *P. xylostella* and *P. brassicae* are the most important and regular pests of this crop in the State.

Several broad-spectrum synthetic organic insecticides are usually recommended for the effective control of these pests (Sonkar and Desai, 1998). However, these compounds are known to evoke multifarious problems including environmental pollution, health hazards, destruction of beneficial fauna like parasitic, predatory and pollinating insects, resistance to insecticides, resurgence of secondary insect pests etc. Moreover, excessive use of persistent insecticides on vegetable is acquiring a special concern since there is a little time lag between the last application and consumption. In order to counteract the problems caused by conventional synthetic insecticides, the bio-rational materials like microbial insecticides have been found promising in tackling the pest problem (Singh *et al*., 1987, Osman, 1993 and Asokan *et al*., 1996). Owing to wide spectral problems with the use of these insecticides, eco-friendly means like use of microbial insecticides are gaining popularity in Integrated Pest Management (IPM) because of their safety to non-targeted organism and non-biomagnifications in the food chain. Although from other parts of the country, a number of workers had reported on the management of cabbage pests on these aspects, limited attempt had been made in the North east region. Thus, the present investigation on efficacy of certain microbials against *P. xylostella* and *P. brassicae*, and their effect on the population of *Coccinella septempunctata* Linnaeus (predatory coccinellid) in cabbage was undertaken.

MATERIALS AND METHODS

One set of field experiment was conducted during *Rabi season*, 2014-15 at the College of Agriculture, Central Agricultural University, Iroisemba, Imphal, to study the bio- efficacy of certain microbial insecticides against *P. xylostella* and *P. brassicae*, and their effect on the population of, *C. septempunctata* in cabbage var. "Pride of India" under agro-ecological situations of Imphal.

Bio-efficacy of six microbial insecticides, spinosad and malathion against *Plutella xylostella* and *Pieris brassicae*

The field trial was carried out in randomized block design (RBD) with ten treatments including one untreated control and each treatment replicated thrice. For the experiment, seedlings were raised in properly prepared nursery beds. Before sowing, the seeds were treated with Anokhi (Carbendazim 12% + Mencozeb 63%) 75 W.P. @ 2.00 gm/kg of seed in order to make the seeds disinfected from fungal diseases. The locally recommended agronomical practices were adopted for raising the experimental crop under the study the experimental plot was thoroughly ploughed with the help of a tractor one month before transplanting of cabbage seedling and was followed by three cross ploughing by a power-tiller. The soil was then pulverized and the plot was levelled properly.

Fertilizers were applied to the experimental crop @ 100: 80: 60 kg/ha of NPK and urea, single superphosphate and muriate of potash were used as the source of nutrients, respectively. The entire dose of phosphatic and potassic and one-third dose of nitrogen were applied uniformly to all plots as basal dose on the day of last harrowing of the field. The remaining quantity of nitrogen was spitted in two halves and applied by side dressing after one month of transplanting and at the initiation of heading stages. The thirty days old seedling was transplanted at a spacing of 45 x 45 cm in plot size measuring 2 m x 3 cm. Irrigation was given just after transplanting followed as and when necessary. The field was kept free from weeds by three times manual weeding at 30, 60 and 75 days after transplanting. As chemicals are injurious to health of human as well as the environment, for the experiment, chemical method was not adopted for weed management.

Application of insecticides

Spray solution consisting of different insecticides in desired concentrations was prepared separately for each treatment. All the spray treatments were applied by a high volume hand compression knapsack sprayer thrice at weekly intervals commencing from appearance of pests. The volume of the spray liquid was kept at 500 litre/ha. All the insecticides were applied in the evening hours. Care was taken at the time of spraying to avoid drifting of the insecticidal spray solution from one plot to another and to give a thorough coverage of the plants. Plain water was sprayed on the plants of untreated control plots.

Observations recorded

The relative field efficacy of the test insecticides was determined by recording the damaged leaves due to diamond back moth and cabbage butterfly and total leaves at one day before, and 3, 5 and 7 days after each application of insecticides from five randomly selected plants in each plot. The per cent leaf damage was calculated. In order to study the toxic effect of the insecticides to naturally occurring *C. septempunctata*, observations were also recorded on adult population at one day before and 3, 5 and 7 days after each application. The cabbage yield obtained from each plots was recorded and converted to tonnes per hectare.

Determination of avoidable yield loss and cost-benefit ratio

The avoidable yield loss was computed in each treatment by using the formula suggested by Pawar *et al*. (1984).

$$\text{Percent avoidable loss} = \frac{T - C}{C} \times 100$$

Where, T = Yield in most effective treatment
C = Yield in respective treatment

The monetary benefit was estimated by deducting the cost of insecticides, pump hiring and labour charges from the cost of additional yield obtained over untreated control.

The data obtained from the experiment were computed to determine the mean values. The mean values were subjected to statistical analysis after suitable transformation to test significance as per analysis of variance for interpretation of the experimental results.

RESULTS AND DISCUSSION

Bio-efficacy of microbial insecticides against Plutella xylostella Linnaeus and Pieris brassicae Linnaeus on cabbage crop var. "Pride of India"

Effectiveness against *Plutella xylostella*

From the mean leaf damage (LD) data of three sprays over the three post application periods of observation, it is amply clear that all the insecticidal treatments were superior in reducing the damage caused by *P. xylostella* in comparison to untreated control (Tables 1 and 4). However,

Table 1. Efficacy of certain bio-rational insecticides against *Plutella xylostella* in cabbage var. "Pride of India" during Rabi, 2014-15

Treatment	Dose/ha	[1]Mean per cent leaf damage due to *P. xylostella* recorded during			Pooled Mean	DBA	[2]Days after application		
		1st spray	2nd spray	3rd spray			3	5	7
Brigade (*Verticillium lecani*)	1250 g	36.89 (6.11)	32.00 (5.69)	28.89 (5.41)	32.59 (5.74)	88.44 (9.43)	37.35 (6.21)	30.01 (5.25)	30.41 (5.76)
Verticel (*Verticillium lecani*)	1000 g	30.22 (5.53)	35.11 (5.96)	31.56 (5.65)	32.30 (5.71)	84.44 (8.21)	30.10 (5.35)	33.75 (5.82)	33.04 (5.96)
Racer (*Beauveria bassiana*)	1250 g	23.56 (4.88)	18.22 (4.29)	11.11 (3.35)	17.63 (4.17)	91.11 (9.57)	19.43 (4.46)	16.74 (4.45)	14.47 (3.60)
Myco-jaal 10SC (*Beauveria bassiana)*	500 ml	15.11 (3.95)	17.78 (4.28)	12.44 (3.60)	15.11 (3.94)	81.56 (9.05)	15.83 (4.04)	15.07 (3.93)	14.43 (3.85)
Lipel (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	17.78 (4.28)	19.11 (4.43)	12.89 (3.66)	16.59 (4.12)	89.78 (9.50)	17.20 (4.21)	16.68 (4.15)	15.89 (4.01)
Bioasp (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	14.25 (3.74)	15.25 (3.98)	10.15 (3.21)	13.22 (3.64)	91.68 (9.74)	15.25 (3.88)	14.15 (3.49)	10.26 (3.55)
Pacer (*Metarrhizum anisopliae)*	1000 g	27.11 (5.25)	28.44 (5.38)	24.44 (4.99)	26.66 (5.21)	83.33 (9.12)	28.98 (5.95)	26.85 (5.13)	24.15 (4.55)
Spinosad 2.5 SC	500 ml	14.67 (3.89)	16.89 (4.17)	11.11 (3.41)	14.22 (3.82)	90.67 (9.55)	16.27 (4.10)	14.43 (3.61)	11.96 (3.75)
Malathion 50 EC	500 ml	21.78 (4.71)	21.78 (4.71)	20.44 (4.57)	21.33 (4.66)	83.56 (9.16)	22.58 (4.87)	21.98 (4.78)	19.44 (4.33)
Control	Water	69.33 (8.36)	68.89 (8.33)	69.33 (8.36)	69.18 (8.35)	89.73 (9.48)	70.83 (8.97)	69.84 (8.70)	66.88 (7.38)
SEm(±)	-	0.14	0.15	0.22	0.10	0.34	0.11	0.23	0.26
CD(*P*=0.05)	-	0.30	0.31	0.46	0.20	NS	0.22	0.47	0.53

Figures in parentheses are angular transformed values; DBA= Day before application; NS=None Significant [1]Composite means of three post treatment observations recorded at 3, 5 and 7 days after application [2]Mean of 3 replications based on 3 applications data bioasp (*Bacillus thuringiensis* var. *kurstaki*) @ 1000 g ha^{-1} treated plots harboured the lowest leaf damage of 13.22% as against 69.18% in untreated control, closely followed by sponosad 2.5 SC @ 500 ml ha^{-1} (14.22% LD), myco-jaal 10 SC (*Beauveria bassiana*) @ 500 ml ha^{-1} (15.11% LD), lipel (*B. thuringiensis* var. *kurstaki*) @ 1000 g ha^{-1}(16.59% LD) and racer (*B. bassiana*) @ 1250 g ha^{-1} (17.63% LD), but differed significantly from each other except between myco-jaal and lipel. Brigade @ 1250 g ha^{-1} was found to be least effective treatment against *P. xylostella* with a record of maximum leaf damage incidence of 32.59 per cent. The mean leaf damage in the rest of insecticidal treatments varied from 21.33 to 32.30 per cent which minimum being noticed in the plots of malathion 50 EC @ 500 ml ha^{-1} and maximum in the plots of verticel (*Verticellium lecanii*) @ 1000 g ha^{-1}.

The effectiveness of spinosad 2.5 SC in cotrolling *P. xylostella* is in accordance with the findings of Vastard *et al*. (2002) who also reported high efficacy of spinosad against DBM. Further, the results obtained in this experiment on the excellent performance of bioasp (*B. thringiensis* var. *kurstaki)* against *P. xylostella*, are in agreement with the results of Garcia (1991); Leibee and Savage (1992); Barros *et al.* (1993); Seal (1995); Asokan *et al.* (1996); Kulkarni *et al.* (1999); Malathi *et al.* (1999); Malathi and Sriramulu (2000); Kalra and Sharma (2000); Biradar and Dhanorkar (2001); Elzen and James (2002) and Abdel-Razek *et al.* (2006) who stated that *B. thuringiensis* var. *kustaki* formulation gave superior results in controlling the diamond back moth population. The results of the two *B. bassiana* formalations (myco-jaal and racer) in suppressing the DBM population also conform to the findings of Ibrahim and Low (1993); Masuda (1998); Shelton *et al*. (1998); Yooon *et al*. (1999); Jun *et al*. (1999); and Alverez and Chirinos (2001) and Abdel-Razek *et al.* (2006) who also observed the superiority of *B. bassiana* products to other insecticides in suppressing the larval population of DBM. The effectiveness of these microbial formulations against DBM might be due to their inherent toxicity to the DBM.

Effectiveness against *Pieris brassicae*

The mean extent of leaf damage of three sprays' data recorded at three time intervals under observation indicated that all the insecticidal treatments proved to be significantly superior over the control in reducing the cabbage butterfly (CB) incidence in all the three post applications periods of observation (Tables 2 and 4). The three sprays'

Table 2. Efficacy of certain bio-rational insecticides against *Pieris brassicae* in cabbage var. "Pride of India" during Rabi, 2014-15

Treatment	Dose/ha	[1]Mean per cent leaf damage due to *P. brassicae* recorded during			Pooled Mean	DBA	[2]Days after application		
		1st spray	2nd spray	3rd spray			3	5	7
Brigade (*Verticillium lecani*)	1250 g	24.44 (4.99)	43.93 (6.67)	44.04 (6.89)	37.47 (6.18)	88.55 (9.43)	45.78 (6.80)	34.64 (5.93)	32.00 (5.81)
Verticel *(Verticillium lecani*)	1000 g	31.5 (5.66)	32.00 (5.70)	28.44 (5.38)	30.65 (5.58)	83.33 (9.12)	36.44 (6.08)	28.89 (5.44)	26.64 (5.22)
Racer (*Beauveria bassiana*)	1250 g	35.11 (5.97)	36.62 (6.09)	38.67 (6.26)	36.80 (6.11)	84.44 (8.21)	42.67 (6.57)	35.73 (6.04)	32.00 (5.71)
Myco-jaal 10SC (*Beauveria bassiana*)	500 ml	23.11 (4.86)	26.00 (5.15)	30.67 (5.58)	26.59 (5.20)	81.56 (9.05)	35.11 (5.98)	24.67 (5.08)	20.00 (4.54)
Lipel (*Bacillus thuringiensis* var. *kurstaki)*	1000 g	25.33 (5.08)	29.78 (5.50)	32.89 (5.78)	29.33 (5.45)	89.78 (9.50)	34.22 (5.89)	28.44 (5.38)	25.33 (5.08)
Bioasp (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	28.44 (5.38)	27.78 (5.32)	33.33 (5.82)	29.85 (5.50)	91.11 (9.57)	38.67 (6.16)	29.56 (5.50)	21.33 (4.86)
Pacer (*Metarrhizum anisopliae)*	1000 g	27.11 (5.25)	34.67 (5.93)	45.33 (6.77)	35.70 (5.98)	90.22 (9.52)	43.11 (6.58)	34.67 (5.92)	29.33 (5.46)
Spinosad 2.5 SC	500 ml	23.56 (4.90)	24.00 (4.95)	25.33 (5.08)	24.30 (4.98)	90.67 (9.55)	32.89 (5.78)	23.56 (4.96)	16.44 (4.21)
Malathion 50 EC	500 ml	29.33 (5.46)	31.96 (5.70)	30.22 (5.54)	30.50 (5.57)	83.56 (9.16)	41.33 (6.38)	28.84 (5.48)	21.33 (4.84)
Control	Water	84.89 (9.24)	85.69 (9.28)	91.56 (9.59)	87.38 (9.37)	89.73 (9.48)	90.58 (9.54)	86.89 (9.35)	84.67 (9.23)
SEm(±)	-	0.14	0.15	0.22	0.10	NS	0.11	0.23	0.26
CD(*P*=0.05)	-	0.30	0.31	0.46	0.20	NS	0.22	0.47	0.53

Figures in parentheses are angular transformed values; DBA= Day before application; NS=None Significant [1]Composite means of three post treatment observations recorded at 3, 5 and 7 days after application [2]Mean of 3 replications based on 3 applications data

Table 3. Effect of certain bio-rational insecticides on the population of *Coccinella septempunctata* on cabbage var. 'Pride of India' during Rabi season of 2014-15

Treatment	Dose/ha	[1]Mean population /5 plants recorded during			Pooled Mean	DBA	[2]Days after application		
		1st spray	2nd spray	3rd spray			3	5	7
Brigade (*Verticillium lecani*)	1250 g	1.30 (1.34)	1.20 (1.30)	1.30 (1.34)	1.27 (1.33)	2.67 (1.78)	0.91 (1.19)	1.41 (1.39)	1.49 (1.41)
Verticel (*Verticillium lecani*)	1000 g	1.38 (1.37)	1.53 (1.42)	0.87 (1.17)	1.26 (1.32)	2.62 (1.77)	0.93 (1.20)	1.51 (1.43)	1.34 (1.33)
Racer (*Beauveria bassiana*)	1250 g	0.87 (1.17)	0.90 (1.18)	0.75 (1.12)	0.84 (1.16)	2.04 (1.59)	0.68 (1.11)	0.98 (1.25)	0.86 (1.12)
Myco-jaal 10SC (*Beauveria bassiana*)	500 ml	1.53 (1.42)	1.78 (1.51)	1.52 (1.42)	1.61 (1.45)	3.22 (1.93)	1.20 (1.23)	1.98 (1.78)	1.65 (1.34)
Lipel *(Bacillus thuringiensis* var. *kurstaki)*	1000 g	1.35 (1.36)	1.25 (1.32)	1.50 (1.41)	1.37 (1.36)	2.78 (1.82)	1.22 (1.28)	1.50 (1.42)	1.39 (1.37)
Bioasp (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	1.80 (1.51)	2.07 (1.60)	2.10 (1.62)	1.99 (1.58)	3.47 (1.99)	1.86 (1.53)	1.98 (1.62)	2.13 (1.59)
Pacer (*Metarrhizum anisopliae*)	1000 g	1.00 (1.23)	1.40 (1,34)	0.85 (1.17)	1.08 (1.26)	2.60 (1.77)	0.78 (1.05)	1.51 (1.43)	0.96 (1.31)
Spinosad 2.5 SC	500 ml	1.33 (1.36)	1.44 (1.40)	1.77 (1.53)	1.51 (1.43)	3.16 (1.92)	0.93 (1.35)	1.84 (1.65)	1.47 (1.29)
Malathion 50 EC	500 ml	0.36 (0.94)	0.97 (1.22)	0.33 (0.92)	0.55 (1.03)	2.00 (1.59)	0.41 (0.85)	0.64 (1.25)	0.61 (0.98)
Control	Water	2.22 (1.63)	2.94 (1.86)	3.97 (2.20)	3.04 (1.91)	2.76 (1.83)	2.96 (1.89)	3.11 (1.98)	3.08 (1.82)
SEm(±)	-	0.26	0.35	0.30	0.20	NS	0.17	0.23	0.17
CD(*P*=0.05)	-	0.53	0.71	0.61	0.41	NS	0.35	0.46	0.36

Figures in parentheses are X + 0.5 transformed values; DBS = Day before application; NS=None Significant [1]Composite means of three post treatment observations recorded at 3, 5 and 7 days after application [2]Mean of 3 replications based on 3 applications data

pooled mean leaf damage data indicated that spinosad 2.5 SC applied @ 500 ml ha^{-1} performed significantly better than rest of the insecticidal treatments with a record of minimum mean leaf damage incidence of 24.30 per cent as against 87.38% in untreated check, followed by myco-jaal 10 Sc @ 500 ml ha^{-1} (26.59% LD), lipel (*B. thuringiensis* var. *kurstaki*) @ 1000 g ha^{-1} (29.33% LD) and bioasp (*Bacillus thuringiensis* var. *kurstaki*) @ 1000 g ha^{-1} (29.85% LD), but differed significantly from each other except between lipel and bioasp. The treatments with malathion 50 EC and verticel (*Verticillium lecanii*) were also recorded comparatively lower mean leaf damage of 30.50 and 30.65 per cent, respectively which showed none significant difference between them. The maximum leaf damage incidence (37.47% LD) was observed in the plots treated with brigade (*Verticillium lecanii*) @ 1250 g ha^{-1}. However, all the insecticidal treatments were effective in restricting the infestation due to *P. brassicae* when compared with untreated control.

The results obtained here on the superiority of spinosad in suppression of the butterfly are in conformity with the reports of Rangad *et al*. (2014) who stated that after fifteen days of application it was found spinosad killed maximum number of larvae (97.84%). The efficacy of microbial products against *P. brassicae* on cabbage was also reported with spinosad (Harris and Maclean, 1999 and Klokocar-Smit Zlata *et al*., 2007), *B. thuringiensis* (Lama, 1990; Gupta and Sood, 2003 and Prabhakar and Bishop, 2009) and *B. bassiana* (Sabbour and Sahab, 2005).

Effect on *Coccinella septempunctata* population

The mean of three sprays' pooled data (Tables 3 and 4) revealed that among the evaluated insecticides, bioasp (*Btk*) @ 1000 g ha^{-1} proved to be the safest insecticide to the predatory beetle, *C. septempunctata* with the significantly highest population of 1.99/ 5 plants as against 3.04 / 5 plants recorded in untreated control, followed by myco-jaal 10 SC (*B. bassiana*) @ 500 ml ha^{-1} (1.61 beetles/ 5 plants) and spinosad 2.5 SC @ 500 ml ha^{-1} (1.51 beetles/ 5 plants) which did not differ significantly from each other. The lowest beetle population (0.55 / plants) was observed in the malathion 50 EC @ 500 ml ha^{-1} treated plots. The mean beetle population recorded in lipel (*Btk*) @ 1000 g ha^{-1} (1.37 beetles/5 plants), brigade (*V. lecani*) @ 1250 g ha $^{-1}$ (1.27 beetles/ 5 plants) and verticel (*V. lecani)* @ 1000 g ha^{-1} (1.26 beetles/5 plants), which had none significant difference from one another. In the rest of the insecticidal treatments, the mean population was varied from 0.84 to 1.08/5 planst which minimum being observed in the plots of racer *(B. bassiana)* @ 1000 g ha^{-1} and maximum in Pacer (*Metarrhizum anisoplae*) @ 1000 g ha^{-1} treated plots. However, all the insecticidal treatments recorded significantly lower beetle population as compared to that in untreated control.

The results on the safety of the *B. thuringiensis* var. *kurstaki* (*Btk*) to *C. septempunctata* revealed in the present study are in accordance with the findings of Malathi *et al.* (1999) who determined the toxic effect of *Btk* product and neem product, and observed that all the insecticides tested were found to be safe and did not show any adverse effect on the coccinellid population. The safety of *Btk* formulations was also reported by Sharma *et al.* (2000) who observed that all *Btk* formulations were found to be safe and helped in conserving the coccinellid predators.

The least toxicity of *Btk* and *B*. *bassiana* formulations to *C*. *septempunctata* population might be due to their low inherent contact toxic action and minimum residual toxicity, while the higher toxic effect of malathion may be attributed due to its quick knock down contact action nature and maximum residual toxic effect on *C*. *septempunctata*

Effect of microbial insecticides on yield of cabbage crop var. "Pride of India"

Yield of a crop is the interaction product of genetic potential of the variety, effect of prevailing environment and crop management practices including pest management adopted. It is usually expected that the treatment (s) providing good protection of pests is to result in higher yield under an uniform ecological and crop management system. In the present investigation there was clear evidence that all the insecticidal treatments bringing out significant reduction of *P. xylostella and P. brassicae* incidence resulted in significantly higher grain yields in comparison to untreated control. Further, there was a general trend that the extent of grain yield increase was in accordance with the level of control of these pests. The more effective control of *P. xylostella and P. brassicae* by spinosad 2.5 SC, bioasp (*Btk*), myco-jaal 10 SC, lipel (*Btk*) and racer (*B. bassiana*) was manifested by higher production of grain to the increase of 3.87 to 9.37 t ha^{-1} over untreated control (Table 5). The mean yield data recorded during the study period indicated that the highest (24.77 t ha^{1}) being recorded in spinosad 2.5 SC treatment with maximum yield increase over control of 9.37 t ha^{1}, and lowest (19.27 t ha^{1}) in verticel (*V. lecani*) treatment with minimum yield increase of 3.87 t ha^{1} (Ta-

Table 4. Overall effect of insecticides on the extent of leaf damage due to *Plutella xylostella* and *Pieris brassicae* and *Coccinella septempunctata* population, and yield of cabbage during Rabi, 2014-15

Treatment	Dose/ha	[1]Mean per cent leaf damage due to		[2]Mean beetle population of C. *septempunctata/*5 plants	Cabbage Yield (t ha^{-1})
		P. xylostella	*P. brassicae*		
Brigade (*Verticillium lecani*)	1250 g	32.59 (5.74)	37.47 (6.18)	1.27 (1.33)	19.97
Verticel (*Verticillium lecani*)	1000 g	32.30 (5.71)	30.65 (5.58)	1.26(1.32)	19.27
Racer (*Beauveria bassiana*)	1250 g	17.63 (4.17)	36.80 (6.11)	0.84 (1.16)	22.60
Myco-jaal 10SC (*Beauveria bassiana*)	500 ml	15.11 (3.94)	26.59 (5.20)	1.61 (1.45)	22.97
Lipel (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	16.59 (4.12)	29.33 (5.45)	1.37 (1.36)	22.85
Bioasp (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	13.22 (3.64)	29.85 (5.50)	1.99 (1.58)	23.70
Pacer (*Metarrhizum anisopliae*)	1000 g	26.66 (5.21)	35.70 (5.98)	1.08 (1.26)	22.73
Spinosad 2.5 SC	500 ml	14.22 (3.82)	24.30 (4.98)	1.51 (1.43)	24.77
Malathion 50 EC	500 ml	21.33 (4.66)	30.50 (5.57)	0.55 (1.03)	20.03
Control	Water	69.18 (8.35)	87.38 (9.37)	3.04 (1.91)	15.40
SEm (±)	-	0.10	0.11	0.20	0.53
CD = (P = 0.05)	-	0.20	0.22	0.41	1.15

Figures in parentheses are angular (*P. xylostella* and *P. brassicae*) and square root (*C. septempunctata*) transformed values; 1Mean per cent leaf damage of three time intervals under observations based on 3 applications' data; 2 Mean beetle population of three time intervals under observations based on 3 applications' data bles 4 & 5). The yield of spinosad 10 SC was followed by bioasp (*Btk*) @ 1000 g ha^{1} (23.70 t ha^{1}) exhibiting yield increase over control of 8.30 t ha^{1} which had none significant difference between them. The mean cabbage yield harvested from the plots of myco-jaal (*B. bassiana*) @ 500 ml ha^{1} (22.97 t ha^{1}) with increase yield of 7.57 t ha^{1}, lipel (*Btk*) @ 1000 g ha^{1} (22.85 t ha^{1} with increase yield of 7.45 t ha^{1}), pacer (*M. anisopliae*) @ 1000 g ha^{1} (22.73 t ha^{1} with the increase of 7.33 t ha^{1}) and racer (*B. bassiana*) @1250 g ha^{1} (22.60 t ha^{1} with yield increase of 7.20 t ha^{1}) and did not differ significantly from one another.

Considering maximum realizable yield in sinosad 2.5 SC treatment (24.77 t ha^{1}) which also afforded maximum protection of the crop from *P. xylostella* and *P. brassicae* infestation, the avoidable yield loss was computed to be 37.83 per cent in the untreated control plots (Table 5). Application of insecticides resulted in reduction of the mean avoidable loss, which ranged between 4.32 and 22.20 per cent in different insecticidal treatments, the lowest being in bioasp (*Btk*) and highest in verticel (*V. lecani*). The cost of inputs including labour charge involved in a treatment and cost of extra yield obtained from such treatment are reflected in cost benefit ratio. The cost of control involved per hectare in various insecticidal treatments ranged between Rs. 858.40 (myco-jaal 10 SC & malathion 50 EC) and Rs. 1489.40 (brigade, verticel, bioasp & bioasp) which resulted in additional monetary benefit of Rs. 17860.60 (verticel) to Rs 45621.60 (spinosad) with the cost benefit ratio ranging from 1:43.09 to 1:11.99, the maximum being in myco-jaal 10 SC and minimum being in verticel treatments, which was mainly due to higher grain yield because of moderate effective control of *P. xylostella* and *P. brassicae*.

Amongst the insecticides evaluated, spinosad 10 SC, bioasp and myco-Jaal afforded more effective in *P. xylostella* and *P. brassicae* control and recorded higher yield with higher cost:benefit ratios, either of these insecticides may be recommended for effective control of these two lepidopterous pests without disturbing the activity of predatory coccinellids, if they can be made easily available to the marginal farmers at subsidized rates or at rates affordable to them. Moreover, these microbial insecticides are comparatively safer to *C. sepetempunctata* in comparison with other insecticides including conventional insecticide.

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Table 5. Cost-benefit ratio of the different insecticidal treatments in diamond back moth control on cabbage during Rabi, 2014-15

Treatment	Dose/ ha	Yield (t/ha)	Increase of yield over control (t/ha)	Avoidable yield loss (%)	Cost of increased yield over control (Rs./ha)	Cost of control (cost of insecticide+ labour charge+sprayer hiring charge) (Rs./ha	Net profit (Rs./ha)	Cost -benefit ratio
Brigade (*Verticillium lecani*)	1250 g	19.97	4.57	19.37	22850.00	1489.40	21360.60	1:14.34
Verticel (*Verticillium lecani*)	1000 g	19.27	3.87	22.20	19350.00	1489.40	17860.60	1:11.99
Racer (*Beauveria bassiana*)	1250 g	22.60	7.20	8.76	36000.00	1058.40	34941.60	1:33.01
Myco-jaal 10SC (*Beauveria bassiana*)	500 ml	22.97	7.57	7.27	37850.00	858.40	36991.60	1:43.09
Lipel (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	22.85	7.45	7.75	37250.00	1058.40	36191.60	1:34.19
Bioasp (*Bacillus thuringiensis* var. *kurstaki*)	1000 g	23.70	8.30	4.32	41500.00	1489.40	40010.60	1:26.86
Pacer (*Metarrhizum anisopliae*)	1000 g	22.73	7.33	8.24	36650.00	1489.40	35160.60	1:23.61
Spinosad 2.5 SC	500 ml	24.77	9.37	0.00	46850.00	1228.40	45621.60	1:37.14
Malathion 50 EC	500 ml	20.03	4.63	19.14	23150.00	858.40	22291.60	1:25.97
Control	Water	15.40	-	37.83	-	-	-	-

Cost of cabbage = Rs. 5/kg Labour charge for two three insecticide applications = Rs. 122.10 x 3 x 3 = Rs.1098.90 Hiring of sprayer for two times = Rs. 50 x 3 = Rs. 150.00

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