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Relative Efficacy and Economics of Bio-pesticides against *Spodoptera litura* (Fab.) on Cabbage

G.C. Jat[1*], R. Swaminathan[1], P.C. Yadav[1], Swati[2], H.L. Deshwal[3], Suman Choudhary[4] and Suresh Kumar Yadav[1]

[1]Department of Entomology, [2]Department of Molecular Biology and Biotechnology, Rajasthan College of Agriculture, (MPUAT) Udaipur, (Rajasthan) 313001, India
[3]Department of Entomology, College of Agriculture and Agriculture Research Station, (SKRAU) Bikaner, (Rajasthan), India
[4]Department of Entomology, SKN College of Agriculture, (SKNAU) Jobner, Jaipur (Rajasthan) 303329, India
**Corresponding author*

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A B S T R A C T

The field experiment on "Relative efficacy and economics of bio-pesticides" was conducted during 2012-13 and 2013-14 at Horticulture farm and Department of Entomology Rajasthan College of Agriculture, (MPUAT) Udaipur (Rajasthan) during *rabi* 2012-13 and 2013-14. The relative efficacy of three biopesticides *viz*.,Spinosad, *Bt.k*. and *SlNPV* in alone and in different combinations in nine different schedule (Spinosad-45SC at 200g/ha, *Bt.k.* (Dipel 8L) at 1lit, *SlNPV*-250LE at 250ml/ha, Spinosad-45SC at 200g/h-*SlNPV*-250LE at 250ml/ha *SlNPV*-250LE at 250ml/ha, Spinosad-45SC at 200g/ha-*Bt.k.*-(Dipel 8L) at 1lit -*Bt.k*-(Dipel 8L) at 1lit., *SlNPV*-250LE at 250ml/ha- Spinosad-45SC at 200g/ha- Spinosad 45SC at 200g/ha, *SlNPV*-250LE at 250ml/ha *Bt.k.*- (Dipel 8L) at 1lit-*Bt.k.*. (Dipel 8L) at 1lit, *Bt.k.*- (Dipel 8L) at 1lit Spinosad-45SC at 200g/ha-Spinosad-45SC at 200g/ha, *Bt.k.*- (Dipel 8L) at 1lit-*SlNPV*-250LE at 250ml/ha-*SlNPV*-250LE at 250ml/ha) was evaluated against *S. litura* revealed that treatment schedule comprising three spray of spinosad 45 SC at 200g/ha at 15 days interval was found most effective in reducing larval population up to 80.33 and 80.88 per cent during 2012-13 and 2013-14, respectively. It also recorded that higher head yield of 287.35 and 291.15 q ha^{-1} during *rabi* 2012-13 and 2013-14, respectively. The treatment schedule comprising three spray of *Bt.k.* (Dipel 8L) at 1 lit/ha at 15 days interval was found least effective which caused the minimum reduction of larval population with the mean of 56.09 and 55.24 per cent during *rabi* 2012-13 and 2013-14, respectively. The highest benefit: cost ratio of 1.419 and 1.407 was recorded in treatment schedule T_1 copmprising three spray of spinosad 45SC at 200g/ha at 15 days interval during *rabi* 2012-13 and 2013-14, respectively.

Introduction

Cruciferous vegetables have an important place among *rabi* crops grown in India. Cabbage, *Brassica oleracea* var. *capitata* (Linn.), is a popular vegetable that is grown in all the states of India and has appreciable nutritional and economic value. Cabbage is used as salad, boiled vegetable, in curries and pickles; it is rich in minerals and vitamin A,

B_1, B_2 and C. The more important insect pests that infest cabbage crop are the tobacco caterpillar (*Spodoptera litura* Fab.), diamond back moth (*Plutella xylostella* L.), cabbage semilooper (*Trichoplusia ni* Hubner), painted bug (*Bagrada hilaris* Burmeister and *Bagrada cruciferarum* Kirk.), cabbage butterfly (*Pieris brassicae* L.), flea beetle (*Phyllotreta cruciferae* Goeze), aphids (*Lipaphis erysimi* Kalt. and *Brevicoryne brassicae* L.), Cabbage leaf webber (*Crocidolomia bionotalis* Zell) and the mustard saw fly (*Athalia lugens proxima* Klug.) (Ayyar, 1963; Lall, 1964; Choudhari *et al.,* 2001, and Rao and Lal, 2005). Among these, *Spodoptera litura* (F.) (Lepidoptera: Noctuidae), is a major pest of cabbage. The pest causes damage to an extent of 80-100 per cent in the nurseries under favourable conditions (Chari *et al.,* 1994) and 10-25 per cent to the field crop (Rao and Sitaramaiah, 2001). An eco-friendly alternative to chemical pesticides is the use of bio-pesticides, which encompasses a broad array of microbial pesticides, bio-chemicals derived from micro-organisms and other natural sources, which confer protection against pest damage. The potential benefits to agriculture and public health programmes through the use of bio-pesticides are considerable. India has a vast potential for bio-pesticides. Bio-pesticides, being target pest specific, are presumed to be relatively safe to non-target organisms including human beings. In India, some of the bio-pesticides like Bt, NPV, neem based pesticides and others have already been registered and are in use (Gupta and Dikshit, 2010). Ramaprasad *et al.,* (2000) advocated the use of Biosap (*Bacillus thuringiensis* var. *kurstaki asporogenic*) and Biolep (*B. t.* var. *kurstaki sporogenic*) against *S. litura* in tobacco nurseries. *SlNPV* caused 96 per cent mortality of *S. litura* within a period of 10 days at a dosage of 6 x 10^8 PIBs/larva (Sajap *et al.,* 2000). Similarly, the sequential spray of biopesticides *viz*., SlNPV 250 LE (1.5 X 10^{12} PIB/ha, *Btk* @1.0 kg/ha was effective against *S. litura* in tobacco nurseries (Rao and Sitaramaiah, 2001).

Materials and Methods

Layout and design

The experiment on relative bioefficay of three biopesticides *viz*., Spinosad, *SlNPV and Bt.k.* alone and in different combinations against *S. litura* was conducted at Horticulture farm, Rajasthan College of Agriculture, Udaipur during *rabi* 2012-13 and 2013-14.

The experiment was conducted in the randomized block design (RBD) with ten treatments schedules including control, and each treatment schedule was replicated three time. Each treatment schedule was applied three times at 15 days interval initiating first spray in the last week of December when the pest infestation started *viz*; 30 December and 28 December during *rabi* 2012-13 and 2013-14, respectively (Table 1). The cabbage variety Golden acre was transplanted on *viz.* 30 November and 28 November during *rabi* 2012-13 and 2013-14, respectively. The plot size was 3.60 x 3.60 m^2 with row to row and plant to plant spacing of 45 x 45 cm, respectively.

Bioefficacy of three biopesticides *viz*.; *SlNPV*, spinosad and *Bt.k.* alone and in different combinations (Table 2) was evaluated against *S. litura.* The details of different treatment schedules are as follows:

Management schedule of biopesticides

Pre-calibrated knap sack sprayer was used for spraying the biopesticides care was taken to check the drift of insecticides, by putting polythene sheet screen around each plot at the time of spraying. In all three sprays were applied, first spray was done during the last

week of December during both the years and subsequent second and third sprays were applied at 15 days interval.

Observations

Pretreatment population of *Spodoptera litura* (Fab.) was recorded 24 hours before the scheduled spray. Post treatment population of *S. litura* was recorded on 3, 7 and 10 day after each spray, on 10 plants were selected randomly in each plot.

Statistical analysis

Efficacy of different treatments against the *S. litura* was analyzed by analysis of variance. The population data was corrected by the correction factor for determination of per cent reduction (per cent control) using formula given by Henderson and Tilton (1955) refers it to be modification of Abbott (1925).

$$\text{Per cent reduction in population} = 100 \; x \left[1 - \frac{T_a \; x \; C_b}{T_b \; x \; C_a} \right]$$

Where,

T_a = Number of insects in different treatments after spray

T_b = Number of insects in different treatments before spray

C_a = Number of insects in the untreated check after spray

C_b = Number of insects in the untreated check before spray

The per cent reduction figures were transformed into arc sine values and subjected to analysis of variance.

Crop yield and economics

Healthy cabbage heads were harvested when they reached appropriate marketable size and their weight from each treatment was expressed as marketable yield in quintal per hectare and subjected to analysis of variance. The avoidable loss and increase in yield of cabbage heads over control were calculated for each treatment by the formula given by Pradhan (1964):

$$\text{Increase in yield (\%)} = \frac{\text{Yield in treatment} - \text{yield in control}}{\text{Yield in control}} \times 100$$

$$\text{B: C ratio over Control} = \frac{\text{Return in treatment (Rs./ha)}}{\text{Return in control (Rs./ha) + Cost of insecticides and Labour (Rs./ha)}}$$

Results and Discussion

Effect of biopesticides on the reduction in *S. litura* population

In the present investigations, based on the mean per cent reduction in larval population of *S. litura* the results showed that T_1 (Spinosad 45 SC @200g/ha - Spinosad 45 SC @200g/ha - Spinosad 45 SC @200g/ha) was most effective in reducing the *S. litura* population upto (70.32% and 72.13%) during *rabi* 2012-13 and 2013-14, on cabbage crop which was followed by T_6 (SlNPV 250LE @ 250ml/ha - Spinosad 45 SC @200g/ha- Spinosad 45 SC @200g/ha) and resulted in 66.77 and 68.24 per cet reduction during *rabi* 2012-13 and 2013-14. The present results are in close agreement with the findings of Gupta (2000), Paliwal and Oommen (2005), Stanley *et al.,* (2006) and Topagi *et al.,* (2010) who reported that spinosad suppressed population of *S. litura*. Mutkule *et al.,* (2009) reported that application of spinosad was superior in suppressing the larval population of *S. litura* infesting groundnut. SlNPV + Spinosad was found against *S. litura* on cabbage reported by Khattab (2005) found SlNPV + Spinosad effective against *S. litura* on cabbage.

The data further revealed that the biopesticides treatment T_3 [*Bt.k.* (Dipel 8L) at 1lit/ha -*Bt.k*. (Dipel 8L) at 1lit/ha- *Bt.k*. (Dipel 8L) at 1lit/ha] was least effective against *S. litura* which gave (56.09% and 55.24%) larval population reduction during *rabi* 2012-13 and 2013-14. Downard (2004) and Prasad and Ahmed (2009) reported that spinosad was highly effective against *S. litura*, similarly Pokharkar *et al.*, (2001) reported that *SlNPV* and *Bacillus thuringiensis* was most effective resulting in maximum larval mortality and it was at par with *SlNPV* and *B. thuringiensis.* Ramegowda and Basavanagoud (2001) and Rao and Sitaramaiah (2001), Hussain *et al.*, (2003) evaluated the efficacy of *SlNPV* and *Bt.k.* that caused significant reduction in *S. litura* population. Jat and Bhardwaj (2005) reported that *Bt.k.* and *SlNPV* was most effective against *S. litura* larval population.

Table.1 Details of the treatments and their dose used for the management of *Spodoptera litura* (Fab)

S. No	Treatments	No. of spray	Formulations	Quantity/dosages(g or ml/ha)
1.	Spinosad	3	45 SC	200
2	*SlNPV*	3	250LE	250
3	*Bt.k.*	3	8L	1000

SlNPV = *Spodoptera litura* Nuclear Polyhedrosis Viruses; *Bt.k.* = *Bacillus thuringiensis var. kurstaki*

Table.2 Management schedule of biopesticides

Treatment	Spray of management schedule
T_1	Three spray of spinosad 45 SC first at initiation of the pest and subsequent second and third spray was applied at 15 days interval.
T_2	Three spray of *SlNPV* 250 LE first at initiation of the pest and subsequent second and third spray was applied at 15 days interval.
T_3	Three spray of *Bt.k.* (Dipel 8L) first at initiation of the pest and subsequent second and third spray was applied at 15 days interval.
T_4	First spray of spinosad 45 SC at initiation of the pest and subsequent second and third spray of *SlNPV* 250 LE was applied at 15 days interval.
T_5	First spray of spinosad 45 SC at initiation of the pest and subsequent second and third spray of *Bt.k.* (Dipel 8L) was applied at 15 days interval.
T_6	First spray of *SlNPV* 250 LE at initiation of the pest and subsequent second and third spray of spinosad 45 SC was applied at 15 days interval
T_7	First spray of *SlNPV* 250 LE at initiation of the pest and subsequent second and third spray of *Bt.k.* (Dipel 8L) was applied at 15 days interval.
T_8	First spray of *Bt.k.* (Dipel 8L) at initiation of the pest and subsequent second and third spray of spinosad 45 SC was applied at 15 days interval.
T_9	First spray of *Bt.k.* (Dipel 8L) at initiation of the pest and subsequent second and third spray of *SlNPV* 250 LE was applied at 15 days interval.
T_{10}	Control

Table.3 Relative efficacy of biopesticides against *S. litura* on cabbage during *rabi* 2012-13

Treatment	Dose (ml/ha or g/ha)	Pre treatment population/ plant	Mean reduction of *S. litura* population (%) days after sprays												Mean reduction in *S. litura* population (%) (1st +2nd +3rd sprays)
			1st spray (30 Dec. 2012)				2nd spray (14 Jan. 2013)				3rd spray (29 Jan. 2013)				
			*3rd	7th	10th	Mean	3rd	7th	10th	Mean	3rd	7th	10th	Mean	
T_1 Spinosad	200g	2.33	51.55 (61.33)**	55.35 (67.66)	52.01 (62.11)	52.95 (63.70)	53.33 (64.33)	57.00 (70.33)	54.40 (66.11)	54.88 (66.92)	61.14 (76.68)	68.08 (85.99)	62.26 (78.33)	63.65 (80.33)	57.00 (70.32)
T_2 SlNPV	250ml	2.66	47.68 (54.67)	49.80 (58.33)	46.72 (52.99)	48.04 (55.33)	48.64 (56.33)	52.74 (63.33)	49.22 (57.33)	50.18 (58.99)	53.94 (65.33)	60.77 (76.11)	56.86 (70.11)	57.11 (70.52)	51.72 (61.61)
T_3 Bt.K	1lit	2.99	45.38 (50.67)	47.68 (54.66)	44.64 (49.38)	45.92 (51.57)	46.53 (52.67)	49.80 (58.33)	48.26 (55.67)	48.22 (55.56)	49.09 (57.11)	52.93 (63.66)	52.35 (62.66)	51.41 (61.14)	48.50 (56.09)
T_4 Spinosad-SlNPV-SlNPV	200g-250ml-250ml	2.66	51.37 (61.00)	54.95 (67.00)	51.75 (61.66)	52.65 (63.22)	49.80 (58.33)	53.34 (64.33)	49.80 (58.33)	50.94 (60.33)	54.14 (65.66)	60.92 (76.33)	57.01 (70.33)	57.26 (70.77)	53.60 (64.77)
T_5 Spinosad-Bt.k-Bt.k	200g-1lit-1lit	2.33	51.43 (61.11)	55.15 (67.33)	51.95 (62.00)	52.81 (63.48)	47.49 (54.33)	50.58 (59.67)	48.51 (56.11)	48.85 (56.70)	49.22 (57.33)	53.54 (64.67)	52.74 (63.33)	51.83 (61.78)	51.16 (60.65)
T_6 SlNPV-Spinosad-Spinosad	250ml-200g-200g	2.66	47.68 (54.66)	49.61 (58.00)	46.53 (52.67)	47.93 (55.11)	52.53 (62.99)	55.97 (68.66)	54.34 (65.99)	54.27 (65.88)	60.23 (75.33)	67.25 (85.00)	61.80 (77.66)	62.94 (79.33)	54.80 (66.77)
T_7 SlNPV-Bt.K-Bt.K	250ml-1lit-1lit	2.99	47.49 (54.33)	49.60 (57.99)	46.53 (52.66)	47.86 (54.99)	46.72 (53.00)	50.18 (58.99)	48.44 (55.99)	48.45 (55.99)	49.22 (57.33)	53.13 (63.99)	52.53 (62.99)	51.59 (61.44)	49.3 0 (57.47)
T_8 Bt.K-Spinosad-Spinosad	1lit-200g-200g	2.66	45.19 (50.33)	47.36 (54.11)	44.49 (49.11)	45.67 (51.18)	52.66 (62.66)	55.65 (68.11)	53.82 (65.11)	53.91 (65.29)	60.08 (75.11)	67.24 (84.99)	61.58 (77.33)	62.80 (79.14)	53.86 (65.21)
T_9 Bt.K – SlNPV – SlNPV	1lit-250ml-250ml	2.33	45.39 (50.67)	47.48 (54.33)	44.42 (48.99)	45.70 (51.33)	56.67 (48.84)	53.08 (63.90)	49.6 7 (58.11)	50.52 (59.56)	53.75 (64.99)	60.67 (75.99)	56.82 (69.99)	56.99 (70.32)	51.01 (60.40)
T_{10} Control	-	2.99	-	-	-	-	-	-	-		-	-	-		-
S.Em.±		0.13	0.95	0.88	0.87	0.79	0.97	0.95	0.90	0.87	0.98	0.97	0.92	1.02	0.91
C.D at 5%		0.38	2.84	2.64	2.6	2.36	2.92	2.84	2.69	2.59	2.93	2.91	2.75	3.05	2.92

**Figures in parentheses are retransformed per cent values, * Days after spray

Table.4 Relative efficacy of biopesticeds against *S. litura* on cabbage during *rabi* 2013-14

Treatment	Dose (ml/ha or g/ha)	Pre treatment population/ plant	Mean reduction of *S. litura* population (%) days after sprays												Mean reduction in *S.litura* population (%) (1st +2nd +3rd spray)
			1st spray (28 Dec. 2012)				2nd spray (12 Jan. 2013)				3rd spray (27 Jan. 2013)				
			*3rd	7th	10th	Mean	3rd	7th	10th	Mean	3rd	7th	10th	Mean	
T1 Spinosad	200g	2.66	52.60 (63.11)**	56.17 (69.00)	53.33 (64.33)	54.01 (65.48)	54.40 (66.11)	58.49 (72.66)	55.76 (68.33)	56.18 (69.03)	62.28 (78.33)	69.51 (87.66)	63.22 (76.66)	64.05 (80.88)	58.15 (72.13)
T2 SlNPV	250ml	2.99	48.44 (55.99)	50.57 (59.66)	47.30 (54.00)	48.76 (56.55)	49.41 (57.66)	53.73 (64.99)	49.99 (58.66)	51.02 (60.44)	54.74 (66.66)	61.82 (77.67)	57.64 (71.33)	57.97 (71.89)	52.51 (62.96)
T3 Bt.K	1lit	3.33	44.99 (49.99)	46.79 (53.11)	44.49 (49.11)	45.42 (50.74)	45.95 (51.66)	49.60 (57.99)	47.49 (54.33)	47.67 (54.66)	48.64 (56.33)	52.53 (62.99)	51.75 (61.66)	50.96 (60.33)	48.01 (55.24)
T4 Spinosad-SlNPV-SlNPV	200g-250ml-250ml	2.99	52.54 (63.00)	56.18 (68.99)	53.14 (64.00)	53.92 (65.33)	50.57 (59.66)	53.80 (65.11)	50.38 (59.33)	51.56 (61.37)	55.02 (67.11)	62.10 (78.11)	58.07 (72.00)	58.34 (72.41)	54.56 (66.37)
T5 Spinosad-Bt.k-Bt.k	200g-1lit-1lit	2.66	52.73 (63.33)	56.58 (69.66)	53.53 (64.66)	54.24 (65.88)	47.29 (54.00)	49.99 (58.66)	47.86 (54.99)	48.36 (55.88)	49.02 (56.99)	52.93 (63.66)	52.14 (62.33)	51.33 (60.99)	51.31 (60.92)
T6 SlNPV-Spinosad-Spinosad	250ml-200g-200g	2.99	48.25 (55.66)	50.25 (59.11)	47.10 (53.66)	48.70 (56.14)	53.33 (64.33)	57.42 (70.99)	53.35 (67.66)	55.40 (67.66)	61.82 (77.66)	69.05 (87.11)	62.05 (77.99)	64.10 (80.92)	55.71 (68.24)
T7 SlNPV-Bt.K-Bt.K	250ml-1lit-1lit	3.33	48.06 (55.33)	50.18 (58.99)	46.91 (53.33)	48.36 (55.88)	46.21 (52.11)	49.67 (58.11)	47.68 (54.66)	47.84 (54.96)	49.02 (56.99)	52.74 (63.33)	52.14 (62.33)	51.27 (60.88)	49.17 (57.24)
T8 Bt.K-Spinosad-Spinosad	1lit-200g-200g	2.99	44.62 (49.33)	46.72 (52.99)	44.42 (48.99)	45.26 (50.44)	53.20 (64.11)	57.01 (70.33)	54.95 (67.00)	55.03 (67.15)	61.60 (77.33)	68.59 (86.66)	61.80 (77.66)	63.83 (80.55)	54.36 (66.04)
T9 Bt.K – SlNPV – SlNPV	1lit-250ml-250ml	2.66	44.81 (49.66)	46.72 (53.00)	44.43 (49.00)	45.32 (50.55)	49.67 (58.11)	53.75 (65.00)	50.19 (58.99)	51.18 (60.70)	54.95 (67.00)	62.03 (78.00)	57.86 (71.66)	58.60 (72.22)	51.45 (61.16)
T10 Control	-	2.66	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00
S.Em.±		**0.29**	**0.75**	**0.82**	**0.74**	**0.80**	**0.80**	**0.92**	**0.83**	**0.88**	**0.94**	**0.89**	**0.95**	**1.04**	**0.81**
C.D. at 5%		**0.54**	**2.24**	**2.46**	**2.23**	**2.38**	**2.41**	**2.77**	**2.50**	**2.63**	**2.82**	**2.67**	**2.86**	**3.10**	**2.43**

**Figures in parentheses are retransformed per cent values, * Days after spray

Table.5 Cumulative efficacy of biopesticides against *S. litura* on cabbage during *rabi* 2012-13 and 2013-14

Treatment	Dose (ml/ha or g/ha)	Mean reduction of *S. litura* population (%) days after sprays					
		2012-13			2013-14		
		*3rd	7th	10th	3rd	7th	10th
T_1 Spinosad	200g	55.21 (67.44)**	59.77 (74.66)	56.07 (68.85)	56.28 (69.18)	60.96 (76.44)	56.64 (69.77)
T_2 SlNPV	250ml	50.05 (58.77)	54.28 (65.92)	50.85 (60.14)	50.83 (60.10)	55.21 (67.44)	51.55 (61.33)
T_3 Bt.K.	1lit	47.16 (53.48)	50.11 (58.88)	48.39 (55.90)	46.52 (52.66)	49.62 (58.03)	47.89 (55.03)
T_4 Spinosad- SlNPV-SlNPV	200g-250ml-250ml	51.74 (61.66)	56.30 (69.22)	52.80 (63.44)	52.68 (63.25)	57.25 (70.73)	53.79 (65.11)
T_5 Spinosad- Bt.k.-Bt.k.	200g-1lit-1lit	49.36 (57.59)	53.06 (63.89)	51.05 (60.48)	49.66 (58.10)	53.12 (63.99)	51.15 (60.66)
T_6 SlNPV-Spinosa-Spinosad	250ml-200g-200g	53.32 (64.32)	57.13 (70.55)	53.99 (65.44)	54.23 (65.83)	58.30 (72.40)	54.59 (66.43)
T_7 SlNPV- Bt.K.-Bt.K.	250ml-1lit-1lit	47.80 (54.88)	50.95 (60.32)	49.14 (57.21)	47.76 (54.81)	50.85 (60.14)	48.89 (56.77)
T_8 Bt.K.-Spinosad-Spinosad	1lit-200g-200g	52.36 (62.70)	56.21 (69.07)	53.04 (63.85)	52.88 (63.59)	56.78 (69.99)	53.45 (64.55)
T_9 Bt.K. –SlNPV –SlNPV	1lit-250ml-250ml	47.77 (54.83)	53.57 (64.74)	50.20 (59.03)	49.75 (58.25)	53.93 (65.33)	50.69 (59.88)
T_{10} Control	-	0.00	0.00	0.00	0.00	0.00	0.00
S.Em.±	-	0.96	0.93	0.89	0.83	0.87	0.84
C.D at 5%	-	2.55	2.79	2.68	2.48	2.63	2.66

**Figures in parentheses are retransformed per cent values, * Days after spray

Table.6 Comparative economics of biopesticide treatments against *S. litura* on cabbage during *rabi* 2012-13

S.No.	Treatments	Dose (ml/ha or g/ha)	No. of Sprays	Average yield (qt/ha)	Increase in yield over control (qt/ha)	Mean avoidble loss (%)	Gross Return (Rs./ha)	Return of increased yield over control (Rs./ha)	Total expenditure (labour + insecticide)	Net profit (Rs./ha)	C:B Ratio Return over control
T_1	Spinosad	200g-200g-200g	3	287.35	91.70	00.00	431025	137550	10082	127468	1:1.419
T_2	SlNPV	250ml-250ml-250ml	3	263.05	67.40	8.46	394575	101100	2682	98418	1:1.332
T_3	Bt.k	1 lit-1lit-1 lit	3	240.45	44.80	16.32	360675	67200	2832	64368	1:1.220
T_4	Spinosad-SlNPV-SlNPV	200g-250ml-250ml	1-1-1	272.86	77.21	5.04	409290	115815	5149	110666	1:1.370
T_5	Spinosad-Bt.k- Bt.k	200g-1lit-1lit	1-1-1	255.15	59.50	11.20	382725	892500	5249	84001	1:1.281
T_6	SlNPV-Spinosad – Spinosad	250ml-200g-200g	1-1-1	279.45	83.80	2.71	419175	125700	7615	118085	1:1.392
T_7	SlNPV-Bt.k-Bt.k	250ml-1lit-1lit	1-1-1	247.85	52.20	13.75	371775	78300	2782	75518	1:1.255
T_8	Bt.k-Spinosad-Spinosad	1lit-200g-200g	1-1-1	267.85	72.20	6.79	401775	108300	7665	100635	1:1.334
T_9	Bt.k-SlNPV-SlNPV	1lit-250ml-250ml	1-1-1	250.25	54.60	12.82	375375	81900	2732	79168	1:1.267
T_{10}	Control	-	-	195.65	0.00	31.91	293475	-	-	-	-

(1) Present price of insecticides: Spinosad Rs. = 1533/100ml or g, SlNPV Rs. =600/250LE (250ml), Bt. K Rs. = 650/kg or lit
(2) Labour charge @ 147/- per day per labour (2 labour required/spray/day and 6 labour required for 3 spray)
(3) Sale price of cabbage Rs. = 15/kg

Table.7 Comparative economics of biopesticides against *S. litura* on cabbage during *rabi* 2013-14

S.No.	Treatments	Dose (ml/ha or g/ha)	Sprays	Average yield (qt/ha)	Increase in yield over control (qt/ha)	Mean avoidable loss (%)	Gross Return (Rs./ha)	Return of increased yield over control (Rs./ha)	Total expenditure (labour + insecticide)	Net profit (Rs./ha)	C:B Ratio Return over control
T_1	Spinosad	200g-200g-200g	3	291.15	91.05	0.00	436725	136575	10202	126373	1:1.407
T_2	SlNPV	250ml-250ml-250ml	3	267.10	67.00	8.26	400650	100500	2802	97698	1:1.322
T_3	Bt.k	1 lit-1lit-1 lit	3	244.75	44.65	15.94	367125	66975	2952	64023	1:1.211
T_4	Spinosad-SlNPV-SlNPV	200g-250ml-250ml	1-1-1	276.55	76.45	5.01	414825	114675	5268	109407	1:1.358
T_5	Spinosad-Bt.k- Bt.k	200g-1lit-1lit	1-1-1	258.85	58.75	11.09	388275	88125	5369	82756	1:1.271
T_6	SlNPV-Spinosad – Spinosad	250ml-200g-200g	1-1-1	283.15	83.05	2.75	424725	124575	7735	116840	1:1379
T_7	SlNPV-Bt.k - Bt.k	250ml-1lit-1lit	1-1-1	251.65	51.55	13.57	377475	77325	2902	74423	1:1.245
T_8	Bt.k-Spinosad-Spinosad	1lit-200g-200g	1-1-1	271.10	71.00	6.70	406650	106500	7785	98718	1:1.320
T_9	Bt.k-SlNPV-SlNPV	1lit-250ml-250ml	1-1-1	254.05	53.95	12.74	381075	80925	2852	78073	1:1.258
T_{10}	Control	-	-	200.10	00.00	31.27	300150	-	-	-	-

(1) The present price of insecticides: Spinosad Rs. = 1533/100ml or g, *SlNPV* Rs. =600/250LE (250ml) *Bt.k* Rs. = 650/kg or lit
(2) Labour charge @167/- per day per labor (2 labour required/spray/day and 6 labour required for 3 spray)
(3) Sale price of cabbage Rs. = 15/kg

Mabrouk and Abbas (2002), Basappa and Singh (2003), Kumari and Singh (2009) and Ali *et al.,* (2011) reported that the virulence of *SlNPV* proved most effective against *S. litura* larval population. The results are in conformity with Patil and Hegde (2009) who recorded efficacy of *Bt.k.* and *SlNPV* and found then most effective against *S. litura* larval population. Mandal *et al.,* (2009) recommended three application of spinosad (Success 2.5 SC) at 15 and 30g a.i. for management of *S. litura*. Muthukumar *et al.,* (2007) reported that spinosad at 75g ai/h, Spinosad, Biolep, emamectin benzoate and neem oil proved safer to natural enemies in the cauliflower ecosystem. Newly introduced insecticides such as spinosad, indoxacarb, *SlNPV*, rimon or corzen showed proven efficacy against *S. litura* (Gupta *et al*., 2004; Mohapatra *et al*., 1995; Pramanik and Chatterjee, 2004; Muthukumar *et al*., 2007). Bhutia *et al.,* (2012) reported that the virulenceof *SlNPV* proved most effective against *S. litura* larval population. However, Krishnaiah *et al.,* (1981), Malathi *et al.,* (1999), Sharma (2000) and Chatterjee (2008) reported that *Bt.k.* was effective against *S. litura* larval population. Babu and Krishnayya (1998), reported that the Neem oil, Bt.k. and their combinations were relatively less effective against *S. litura* but were however superior to untreated control.

Effect of biopesticides application on head yield of cabbage

The results showed that the yield of cabbage heads in all the biopesticidal treatments was significantly superior over untreated plots. The highest yield of 287.35 and 291.15q ha^{-1} was obtained from the plots treated with T_1 (Spinosad 45 SC @200g/ha - Spinosad 45 SC @200g/ha - Spinosad 45 SC @200g/ha)and the minimum yield was recorded in T_3 [*Bt.k.* (Dipel 8L) at 1lit/ha - *Bt.k.* (Dipel 8L) at 1lit/ha - *Bt.k.* (Dipel 8L) at 1lit/ha], 240.45 and 244.75 q ha^{-1}, during *rabi* 2012-13 and 2013-14, respectively. The results are in conformity with that of Gupta (2000) who recorded significantly higher yield in spinosad. The present results are also supported from the results of Gupta and Jain (2001) who reported better yield of cabbage heads by the treatment of spinosad. The present results are in agreement with the findings of Prasad and Wadhwani (2005), Kumar and Singh (2009) and Ali *et al.,* (2011) who recorded higher yield of cabbage head obtained from the treatment of *SlNPV*. These findings are in partial agreement with the results of Ashokan *et al.,* (1996) who observed significant increase in yield of cabbage heads from the treatment of *Bt.K*.

Cumulative efficacy of biopesticides

The data presented in table 5 reveal that during 2012-13 the treatment schedule comprising three spray of spinosad 45 SC at 200g/ha at 15 days interval was found effective which caused 67.44, 74.66 and 68.85 per cent reduction in larvae population at 3, 7, and 10 days after three spray respectively. It was followed by treatment schedule T_6 comprising spray of SlNPV at 250 LE/ha followed by two spray of spinosad at 200g/ha which caused 64.32, 70.55 and 65.54 per cent reduction at 3,7 and 10 days after three spray, respectively (Table 5). The data on cumulative bioefficacy further revealed treatment *Bt.k.* was the least effective among the treatment. Similar results were also recorded in table 6 revealed that during 2013-14 the treatment schedule comprising three spray of spinosad 45 SC at 200g/ha at 15 days interval was found effective which caused 69.18, 76.44 and 69.77 per cent reduction in larvae population at 3, 7, and 10 days after three spray respectively. It was followed by treatment schedule T_6 comprising spray of SlNPV at 250 LE/ha followed by two spray of spinosad

at 200g/ha which caused 65.83, 72.40 and 66.43 per cent reduction at 3, 7, and 10 days after three spray, respectively. Three spray of *Bt.k.* was the least effective among all the treatment.

Economics of biopesticides treatments

The utility of any biopesticides in the pest management programme is not only evaluated by its relative potency against the target pest and the period for which its application provides protection to the crop, but the economics of the treatments also is a major consideration. Hence, the benefit cost ratio was also worked out in the present investigation. The data revealed that the maximum profit was obtained from the treatment of T_1 (Spinosad 45 SC @200g/ha - Spinosad 45 SC @ 200 gm/ha - Spinosad 45 SC @200g/ha) which gave a benefit:cost ratio of 1.419 and 1.407, during *rabi* 2012-13 and 2013-14, respectively. The minimum benefit cost ratio was found in the treatment of T_3 [*Bt.k.* (Dipel 8L) at 1lit/ha - *Bt.k.* (Dipel 8L) at 1lit/ha - *Bt.k.* (Dipel 8L) at 1lit/ha] which gave a benefit cost ratio of 1.220 and 1.211, during *rabi* 2012-13 and 2013-14, respectively. Contrary to the present findings Pokharkar *et al.,* (2001) reported that treatment of *SlNPV* and *Bt.k.* to sufficient cost benefit ratio with 1:22.40 and 1:20.29, respectively. The present findings are supported by Prasad and Wadhwani (2005) who reported that *SlNPV* gave higher economic return (C: B ratio 1:1.524). The benefit cost ratio of biopesticides was comparatively less due to their higher cost (Table 7).

In the present investigations the relative efficacy of three biopesticides *viz.*, spinosad, *Bt.k.* and *SlNPV* in alone and in nine different schedule combinations was evaluated against *S. litura*. The data for both years (2012-13 and 2013-14) revealed that the treatment schedule comprising three spray of Spinosad 45 SC at 200g/ha first at initiation of the pest and subsequent second and third spray was applied at 15 days interval was most effective in reducing the *S. litura* larval population upto 70.32 and 72.13 per cent during *rabi* 2012-13 and 2013-14, respectively (tables 3 and 4), but the minimum reduction of 56.09 and 55.24 per cent was recorded in treatment schedule comprising three spray of *Bt.k.* (Dipel 8L) at 1lit/ha first at initiation of the pest and subsequent second and third spray was applied at 15 days interval. The highest yield of 287.35 and 291.15 q ha^{-1} was obtained from the plots treated with treatment schedule comprising three spray of Spinosad 45 SC at 200g/ha, whereas, the minimum yield 240.45 and 244.75 q ha^{-1} was recorded in treatment schedule comprising three spray of *Bt.k.* (Dipel 8L) at 1lit/ha, during *rabi* 2012-13 and 2013-14. The increase in yield over untreated control plot was maximum (46.87 and 45.50% during 2012-13 and 2013-14) in the treatment schedule comprising three spray of spinosad 45 SC at 200g/ha; whereas, the lowest increase in yield (22.90 and 22.31% during 2012-13 and 2013-14) in treatment schedule comprising three spray of *Bt.k.* (Dipel 8L) at 1lit/ha. The highest benefit: cost ratio of 1.419 and 1.407 was recorded in the treatment schedule comprising three spray of spinosad 45 SC at 200g/ha and minimum benefit cost ratio of 1.220 and 1.211 was recorded in the treatment schedule comprising three spray of *Bt.k.* (Dipel 8L) at 1lit/ha during *rabi* 2012-13 and 2013-14.

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