Original Research Article

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

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**Abstract**

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 (Spinosa-45SC at 200g/ha, Bt.k. (Dipel 8L) at 1lit, SlNPV-250LE at 250ml/ha, Spinosa-45SC at 200g/h-SlNPV-250LE at 250ml/ha SlNPV-250LE at 250ml/ha, Spinosa-45SC at 200g/ha-Bt.k.- (Dipel 8L) at 1lit -Bt.k.(Dipel 8L) at 1lit, SlNPV-250LE at 250ml/ha- Spinosa-45SC at 200g/ha- Spinosa 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 Spinosa-45SC at 200g/ha-Spinosa-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 spinosa 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 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 T1 comprising three spray of spinosa 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,
B1, B2 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 10⁸ PIBs/larva (Sajap *et al.*, 2000). Similarly, the sequential spray of biopesticides *viz.*, *SlNPV* 250 LE (1.5 X 10¹² 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 bioefficacy of three biopesticides *viz.*, *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 m² 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).

**Per cent reduction in**

\[
\text{Population} = 100 \times \left[ 1 - \frac{T_a \times C_b}{T_b \times C_a} \right]
\]

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):

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

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

**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 \(T_6\) (SINPV 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. SINPV + Spinosad was found against *S. litura* on cabbage reported by Khattab (2005) found SINPV + Spinosad effective against *S. litura* on cabbage.
The data further revealed that the biopesticides treatment T₃ [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. Ramagouda and Basavanagoud (2001) and Rao and Sitaramiah (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            | 250 LE       | 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 |
|-----------|------------------------------|
| T₁        | Three spray of spinosad 45 SC first at initiation of the pest and subsequent second and third spray was applied at 15 days interval. |
| T₂        | Three spray of SlNPV 250 LE first at initiation of the pest and subsequent second and third spray was applied at 15 days interval. |
| T₃        | 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. |
| T₄        | 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. |
| T₅        | 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. |
| T₆        | 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. |
| T₇        | 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. |
| T₈        | 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. |
| T₉        | 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. |
| T₁₀       | 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)** | | | | |
| | | | 1<sup>st</sup> | 2<sup>nd</sup> | 3<sup>rd</sup> | 1<sup>st</sup> | 2<sup>nd</sup> | 3<sup>rd</sup> | 1<sup>st</sup> | 2<sup>nd</sup> | 3<sup>rd</sup> | 1<sup>st</sup> | 2<sup>nd</sup> | 3<sup>rd</sup> | 1<sup>st</sup> | 2<sup>nd</sup> | 3<sup>rd</sup> |
| *T<sub>1</sub>* | Spinosad | 200g | 2.33 | 51.55 (61.33)* | 55.35 (58.33) | 52.01 (58.33) | 52.95 (58.33) | 53.33 (58.33) | 57.00 (62.11) | 54.40 (62.11) | 54.88 (58.33) | 61.14 (66.67) | 68.08 (67.24) | 62.26 (63.65) | 63.65 (67.24) | 57.00 (70.32) |
| *T<sub>2</sub>* | SINPV | 250ml | 2.66 | 47.68 (54.67) | 49.80 (52.99) | 46.72 (52.99) | 48.04 (53.33) | 48.64 (56.33) | 52.74 (63.33) | 49.22 (57.33) | 50.18 (65.33) | 53.94 (70.32) | 60.77 (70.32) | 56.86 (70.32) | 57.11 (68.08) | 51.72 (66.67) |
| *T<sub>3</sub>* | Bt.K | 1lit | 2.99 | 45.38 (50.67) | 47.68 (54.67) | 44.64 (54.67) | 45.92 (51.57) | 46.53 (52.67) | 49.80 (58.33) | 48.26 (55.67) | 48.22 (55.67) | 49.09 (63.66) | 52.93 (66.67) | 52.35 (61.14) | 51.41 (64.91) | 48.50 (59.09) |
| *T<sub>4</sub>* | Spinosad-SINPV-SINPV | 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 (70.32) | 57.01 (70.77) | 57.26 (64.77) | 53.60 (64.77) |
| *T<sub>5</sub>* | Spinosad-Btk-Btk | 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 (57.33) | 49.22 (64.67) | 53.54 (63.33) | 52.74 (61.78) | 51.83 (60.65) | 51.16 (60.65) |
| *T<sub>6</sub>* | SINPV-SINPV-SINPV | 250ml - 200g/200g | 2.66 | 47.68 (54.66) | 49.61 (58.00) | 46.53 (52.67) | 47.93 (51.11) | 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<sub>7</sub>* | SINPV-Btk-Btk | 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 (63.99) | 52.53 (62.99) | 51.59 (61.44) | 49.30 (57.47) | 49.30 (57.47) |
| *T<sub>8</sub>* | Btk-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<sub>9</sub>* | Btk-Spinosad-Spinosad | 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) | 49.67 (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<sub>10</sub>* | 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 biopesticides 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 SINPV                   | 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-SINPV          | 200g-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          | 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 (59.49) | 48.36 (58.58) | 49.02 (56.99) | 52.93 (63.66) | 52.14 (62.33) | 51.33 (60.99) | 51.31 (60.92) |
| T6 SINPV-Spinosad-Bt.K    | 250ml-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 SINPV-Bt.K             | 250ml              | 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-Bt.K    | 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 – SINPV – Spinosad-Bt.K | 250ml-250ml | 2.66                            | 44.81 (49.66) | 46.72 (53.00) | 44.43 (50.55) | 45.32 (58.11) | 49.67 (65.00) | 53.75 (58.99) | 50.19 (60.70) | 51.18 (67.00) | 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) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 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 | 0.54 2.24 2.46 2.23 2.38 2.41 2.77 2.50 2.63 2.82 2.87 3.10 2.43 **Figures in parentheses are retransformed per cent values, * Days after spray | 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 | 0.54 2.24 2.46 2.23 2.38 2.41 2.77 2.50 2.63 2.82 2.87 3.10 2.43 **Figures in parentheses are retransformed per cent values, * Days after spray | 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 | 0.54 2.24 2.46 2.23 2.38 2.41 2.77 2.50 2.63 2.82 2.87 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 |
| **T1 Spinosad**            | 200g                 | 55.21 | 59.77 | 56.07 | 56.28 | 60.96 | 56.64 |
|                            |                      | (67.44)** | (74.66) | (68.85) | (69.18) | (76.44) | (69.77) |
| **T2 SlNPV**               | 250ml                | 50.05 | 54.28 | 50.85 | 50.83 | 55.21 | 51.55 |
|                            |                      | (58.77) | (65.92) | (60.14) | (60.10) | (67.44) | (61.33) |
| **T3 Bt.K.**               | 1lit                 | 47.16 | 50.11 | 48.39 | 46.52 | 49.62 | 47.89 |
|                            |                      | (53.48) | (58.88) | (55.90) | (52.66) | (58.03) | (55.03) |
| **T4 Spinosad- SlNPV-SlNPV** | 200g-250ml-250ml | 51.74 | 56.30 | 52.80 | 52.68 | 57.25 | 53.79 |
|                            |                      | (61.66) | (69.22) | (63.44) | (63.25) | (70.73) | (65.11) |
| **T5 Spinosad- Bt.K.-Bt.K.** | 200g-1lit-1lit | 49.36 | 53.06 | 51.05 | 49.66 | 53.12 | 51.15 |
|                            |                      | (57.59) | (63.89) | (60.48) | (58.10) | (63.99) | (60.66) |
| **T6 SlNPV-Spinosa-Spinosa** | 250ml-200g-200g | 53.32 | 57.13 | 53.99 | 54.23 | 58.30 | 54.59 |
|                            |                      | (64.32) | (70.55) | (65.44) | (65.83) | (72.40) | (66.43) |
| **T7 SlNPV- Bt.K.-Bt.K.**  | 250ml-1lit-1lit      | 47.80 | 50.95 | 49.14 | 47.76 | 50.85 | 48.89 |
|                            |                      | (54.88) | (60.32) | (57.21) | (54.81) | (60.14) | (56.77) |
| **T8 Bt.K.-Spinosa-Spinosa** | 1lit-200g-200g | 52.36 | 56.21 | 53.04 | 52.88 | 56.78 | 53.45 |
|                            |                      | (62.70) | (69.07) | (63.85) | (63.59) | (69.99) | (64.55) |
| **T9 Bt.K. –SlNPV –SlNPV** | 1lit-250ml-250ml    | 47.77 | 53.57 | 50.20 | 49.75 | 53.93 | 50.69 |
|                            |                      | (54.83) | (64.74) | (59.03) | (58.25) | (65.33) | (59.88) |
| **T10 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 avoidable loss (%) | Gross Return (Rs./ha) | Return of increased yield over control (Rs./ha) | Total expenditure (labour + insecticide) (Rs./ha) | Net profit (Rs./ha) | C:B Ratio | Return over control |
|-------|----------------|----------------------|---------------|-----------------------|----------------------------------------|-------------------------|-----------------------|-----------------------------------------------|-------------------------------------------------|---------------------|------------|---------------------|
| T_1   | Spinosad       | 200g-200g-200g       | 3             | 287.35                | 91.70                                  | 0.00                    | 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 | 200g-250ml-250ml     | 1-1-1         | 272.86                | 77.21                                  | 5.04                    | 409290               | 115815                                        | 5149                                            | 110666              | 1:1.370    |                     |
| T_5   | Spinosad-Bt.k-K | 200g-1lit-1lit      | 1-1-1         | 255.15                | 59.50                                  | 11.20                   | 382725               | 892500                                        | 5249                                            | 84001               | 1:1.281    |                     |
| T_6   | SlNPV-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     | 250ml-1lit-1lit      | 1-1-1         | 247.85                | 52.20                                  | 13.75                   | 371775               | 78300                                         | 2782                                            | 75518               | 1:1.255    |                     |
| T_8   | Bt.k-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     | 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 |
|-------|------------|----------------------|--------|-----------------------|---------------------------------------|------------------------|----------------------|---------------------------------------------|------------------------------------------|------------------|------------|---------------------|
| T₁    | Spinosad   | 200g-200g-200g       | 3      | 291.15                | 91.05                                 | 0.00                   | 436725               | 136575                                      | 10202                                    | 126373            | 1:1.407    |                     |
| T₂    | SINPV      | 250ml-250ml-250ml    | 3      | 267.10                | 67.00                                 | 8.26                   | 400650               | 100500                                      | 2802                                     | 97698            | 1:1.322    |                     |
| T₃    | Bt.k       | 1 lit-1lit-1lit      | 3      | 244.75                | 44.65                                 | 15.94                  | 367125               | 66975                                       | 2952                                     | 64023            | 1:1.211    |                     |
| T₄    | Spinosad-SINPV-SINPV | 200g-250ml-250ml | 1-1-1 | 276.55                | 76.45                                 | 5.01                   | 414825               | 114675                                      | 5268                                     | 109407           | 1:1.358    |                     |
| T₅    | Spinosad-Bt.k- Bt.k | 200g-1lit-1lit  | 1-1-1 | 258.85                | 58.75                                 | 11.09                  | 388275               | 88125                                       | 5369                                     | 82756            | 1:1.271    |                     |
| T₆    | SINPV-Spinosad – Spinosad | 250ml-200g-200g | 1-1-1 | 283.15                | 83.05                                 | 2.75                   | 424725               | 124575                                      | 7735                                     | 116840           | 1:1.379    |                     |
| T₇    | SINPV-Bt.k - Bt.k | 250ml-lit-lit | 1-1-1 | 251.65                | 51.55                                 | 13.57                  | 377475               | 77325                                       | 2902                                     | 74423            | 1:1.245    |                     |
| T₈    | Bt.k-Spinosad-Spinosad | 1lit-200g-200g  | 1-1-1 | 271.10                | 71.00                                 | 6.70                   | 406650               | 106500                                      | 7785                                     | 98718            | 1:1.320    |                     |
| T₉    | Bt.k-SINPV-SINPV | 1lit-250ml-250ml | 1-1-1 | 254.05                | 53.95                                 | 12.74                  | 381075               | 80925                                       | 2852                                     | 78073            | 1:1.258    |                     |
| T₁₀   | Control    | -                   | -      | 200.10                | 00.00                                 | 31.27                  | 300150               | -                                           | -                                        | -                | -          | -                   |

(1) The present price of insecticides: Spinosad Rs. = 1533/100ml or g, SINPV 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 *SINPV* 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 *SINPV* 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, *SINPV*, 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 virulence of *SINPV* 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 *SINPV*. 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 *SINPV* 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 *SINPV* 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 SINPV 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 SINPV 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 SINPV 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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