

## Field Efficacy of Bio-Pesticides Against Leaf-Eating Caterpillar (*Spodoptera Litura* Fabricius) Infesting Soybean

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### Abstract

Investigations on field efficacy of biopesticides against leaf-eating caterpillar *Spodoptera litura* Fabricius infesting soybean were carried out at Junagadh Agricultural University, Dhari (Gujarat) during *Kharif* 2021 and 2022. Nine biopesticides were evaluated in the field during *kharif*, 2021 and 2022 and maximum per cent larval mortality (59.25 percent) was observed in the treatment of *Beauveria bassiana* 2 x 10<sup>8</sup> cfu/g followed by SNPV 2 % (57.01) and *Bacillus thuringiensis* 0.5% (54.58). Maximum seed yield was registered in plots treated with *B. bassiana* 2 x 10<sup>8</sup> cfu/g followed by SNPV 2 % and *B. thuringiensis* 0.5 %. Maximum (86.93 %) seed yield was increased in the plots treated with *B. bassiana* followed by SNPV 2 % (81.05) and *B. thuringiensis* 0.5 % (65.36 %). The avoidable loss was the lowest (3.15 %) in the treatment of SNPV at 2 % followed by *B. thuringiensis* at 0.5 % (11.54 %) and NSKE at 5 % (15.56 %). The avoidable losses were 16.78 to 21.68 per cent in Neem oil 0.3%, NLE 10.0 % and *Ardusa* leaf extract 10.0 %. The avoidable loss was calculated as 24.82 and 29.37 per cent in treatments of Akada leaf extract 10.0 % and Tulsi leaf extract 10.0 %, respectively. The maximum net realization was obtained in the treatment of *B. bassiana* 2 x 10<sup>8</sup> cfu/g.

**Key words:** *Field efficacy, insecticides, leaf-eating caterpillar, yield*

### Introduction

Soybean [*Glycine max* (L.) Merrill] is one of the important oilseed cash crops of India. It is a unique crop with high nutritional value, thus it is also known as the "Miracle bean, Golden bean, and Crop of the planet". It provides 40% protein, well balanced in essential amino acids; 20% oil, rich in polyunsaturated fats especially Omega 6 and Omega 5 fatty acids; 6-7% total minerals; 5-6% crude fiber and 17-19% carbohydrates (Chauhan and Joshi, 2005). Soybean is known as Soja bean, Soya bean, Chinese pea, and Manchurian bean which belong to family Fabaceae, sub-family Faboideae, and have Eastern Asian origin. Soybean was introduced in India during 1870-80. The soybean crop is one of the remarkable success stories in Indian agriculture. The total area of soybean in India is 121.76 lakh ha with production of 127.20 lakh tons in 2019-20 with an average national yield of 1258 kg/ha. Soybean occupied 42% of India's total oilseeds and 25% of edible oil production. In India,

Madhya Pradesh, Maharashtra, Rajasthan, Gujarat, Telangana, Chhattisgarh, and Karnataka are the leading producers of soybean.

In the world, the total area under soybean cultivation is 120.50 million hectares with a production of 333.67 million tons and productivity of 2404 kg/ha. India is the fifth largest producer of soybean in the world after Brazil, USA, Argentina, and China with the total area under soybean cultivation was 36.60, 30.70, 17.40, and 8.90 million hectares with a production of 122.80, 98.90, 53.80 and 17.00 million tons respectively (Anonymous, 2022). Researchers from different parts of the world and India have confirmed that seed yield and seed quality were being adversely affected by insect pests. Among the insect pests that attack soybean from the early growth up to harvesting time, armyworm, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) is the major defoliating pest and responsible for huge yield losses. Soybean yield loss caused by *S. litura* in untreated area

was about 68% as compare with the yield in treated area with lambda cyhalothrin. Larva is the most destructive stage of *S. litura* in which attacked leaves and pods that plays an important role in the early reproductive phases (Souza *et al.*, 2012; Punithavalli *et al.*, 2014 and Dudhbale *et al.*, 2017). Soybean was introduced in Gujarat as early as 1934. In recent years the top producer of groundnut is witnessing a slow but steady shift towards soybean cultivation. Sabarkantha, Bharuch, Vadodara, Dahod, Panchmahal and Amreli are major districts known for the cultivation of this crop in Gujarat. To avoid the yield losses caused by this destructive pest to encourage the cultivation of soybeans in a large area and to increase the production and productivity of India as well as Gujarat,

The present study aims to evaluate the efficacy of biopesticides for managing *S. litura* in soybean, a critical oilseed crop extensively grown in arid and semi-arid regions. The treatments were applied as foliar sprays, to assess their effectiveness over two consecutive years. This two-year study seeks to validate and provide an effective and economically viable management practices for the

researchers, farmers and policy makers. By recommending sustainable pest management strategies, the study addresses the dual goals of enhancing crop productivity and reducing input costs. Ultimately, it contributes to the broader objectives of sustainable agriculture by reducing chemical dependency and promoting eco-friendly farming practices.

## 2. Materials and methods

### 2.1 Experimental materials and design

The study was carried out at Farm of Polytechnic in Agriculture, Junagadh Agricultural University, Dhari, Amreli, Gujarat. GJS 3 variety of soybean was selected for cultivation. Three replications of each treatment were used in the field experiment, which was set up using a Randomized Block Design (RBD). The plot measured Gross plot size: 3.0 x 2.7 m and Net plot size: 2.4 x 1.8 m, and the crop was sown 45 cm x 10 cm spacing. The crop was grown in the experimental field with the application of fertilizers at recommended doses.

**Table. 1: Treatment Details of insecticides used against *S. litura* infesting soybean.**

Tr. No.	Name of insecticides	Trade name and formulation	Conc. (%)	Dose (g or ml/ liter of water)	Source
T <sub>1</sub>	Neem seed kernel extract ( <i>Azadirachta indica</i> )	N.S.K.E.	5 %	500	Virinchi Organics Private Limited, Warangal, Telangana
T <sub>2</sub>	Neem oil ( <i>A. indica</i> )	Nico neem	0.3 %	30	Nico Orgo Manures, Dakor, Gujarat
T <sub>3</sub>	Neem leaf extract ( <i>A. indica</i> )	Prepared in laboratory	10.0 %	1000	Self-prepared
T <sub>4</sub>	Ardusa leaf extract	Prepared in laboratory	10.0 %	1000	Self-prepared
T <sub>5</sub>	Tulsi leaf extract	Prepared in laboratory	10.0 %	1000	Self-prepared
T <sub>6</sub>	Akada leaf extract	Prepared in laboratory	10.0 %	1000	Self-prepared
T <sub>7</sub>	<i>Bacillus thuringiensis</i>	Dipel 8 L	0.5 %	1.0	Lupin Agrochemicals Ltd. Bharuch (Gujarat)
T <sub>8</sub>	SNPV	Biokill-S	2.0 %	250	Ganesh Bio-control System, Rajkot
T <sub>9</sub>	<i>Beauveria bassiana</i>	Biosoft (WP)	2 x 10 <sup>8</sup> cfu/g	40	AgriLand Biotech Ltd., Vadodara, Gujarat
T <sub>10</sub>	Control (unsprayed)	-	-	-	-

## 2.2 Application of treatment

All the recommended agronomical practices were followed. The spraying of biopesticides at mentioned doses was done twice, first at 50 percent flowering stage and second at 50 per cent pod formation stage. The water quantity was 500 lit/ha. The biopesticides were applied by using a knapsack sprayer during evening hours. Care was taken to rinse the sprayer thoroughly before and after each spray with soap, and water to avoid contamination from treatment to treatment.

## 2.3 Observation

The number of larvae was counted from five randomly selected and tagged plants in each plot 24 hours before and 3, 7, and 10 days after spray in each plot during both years of experimentation.

The data was converted into per cent mortality by using the following formula given by Abbott (1925) and modified by Henderson and Tilton (1955) and was subjected to statistical analysis.

$$\text{Corrected per cent mortality} = 100 \times \left( 1 - \frac{T_a \times C_b}{T_b \times C_a} \right)$$

Where,

T<sub>b</sub> = No. of larva observed before treatment.

T<sub>a</sub> = No. of larva observed after treatment.

C<sub>b</sub> = No. of larva observed before treatment in control plot.

C<sub>a</sub> = No. of larva observed after treatment in control plot.

Statistical analysis of data carried out by following the analysis of variance techniques as given by Panse and Sukhatme (1985).

$$\text{Avoidable losses (\%)} = \frac{\text{Yield in treatment which gave the highest yield} - \text{Yield in respective treatment}}{\text{Yield in treatment which gave the highest yield}} \times 100$$

### 2.4.4 Economics

To know the economics of different treatments evaluated against insect pests infesting soybean, an Incremental Cost-Benefit Ratio (ICBR) was worked out. For this purpose, the total cost of treatment per hectare was calculated for each treatment based on the prevailing market price. The increase in yield over control was

## 2.4 Yield, increase in yield over control, avoidable losses, and economics

### 2.4.1 Yield

The yield is an important criterion for comparing the efficacy of different treatments. The soybean crop was harvested at the proper maturity stage *viz.*, the last week of October and the second week of September during 2021 and 2022, respectively. The seeds were separated from soybean plants harvested from each net plot area and weighed treatment-wise. The seed yield in kilogram per hectare was calculated for each treatment and statistically analyzed for interpretation by following standard statistical techniques (Steel and Torrie, 1980).

### 2.4.2 The per cent increase in yield over control

The per cent increase in yield over control was calculated by using following formula (Abbott, 1925)

$$\text{Yield increase over control} = \frac{T - C}{C} \times 100$$

Where, T = Yield of respective treatment (kg/ha),  
C = Yield of control (kg/ha)

### 2.4.3 Avoidable losses

Based on soybean seed yield harvested from various treatments under study, the avoidable losses due to insect pests' infestation were calculated by applying the formula of Poul (1976) which is as follows:

calculated by subtracting the yield obtained in the control treatment from the yield obtained in each insecticidal treatment. Then, the gross realization over control was worked out for each treatment based on the increased yield (kg/ha) over control. The net gain (Rs/ha) for each treatment was computed by deducting the insecticidal treatment cost from the gross realization value over

control. The ICBR *i.e.* net gain in rupees per rupee cost of insecticidal treatment was calculated by dividing net gain by the total cost of treatment. This gives values of gross ICBR.

### Results and Discussion

To find out the effectiveness of insecticides against *S. litura* infesting soybean, nine biopesticides were

evaluated in field experiments during *Kharif*, 2021 and 2022. The results of these experiments are presented and discussed herewith.

The periodical data on pest population recorded after 3, 7, and 10 days of each spray, pooled over periods of each spray, and pooled over sprays and The year's results are presented in Tables 2 to 4.

**Table 2: Bio-efficacy of bio-pesticides against *S. litura* infesting Soybean during *kharif*, 2021.**

Tr. No.	Treatments	Conc. (%)	Per cent mortality of <i>S. litura</i> after first spray				Per cent mortality of <i>S. litura</i> after second spray				Pooled over period over spray
			3 DAS	7 DAS	10 DAS	Pooled over period	3 DAS	7 DAS	10 DAS	Pooled over period	
T <sub>1</sub>	Neem seed kernel extract ( <i>A. indica</i> )	5 %	42.31a* (45.30)	46.85abcd (53.22)	41.25a (43.48)	<b>43.47bc</b> <b>(47.33)</b>	43.20ab (46.85)	48.73abc (56.49)	42.01abcd (44.78)	<b>44.64cd</b> <b>(49.37)</b>	<b>44.05cde</b> <b>(48.34)</b>
T <sub>2</sub>	Neem oil ( <i>A. indica</i> )	0.3	44.42a (48.99)	47.84abc (54.95)	43.49a (47.37)	<b>45.25abc</b> <b>(50.44)</b>	43.71ab (47.75)	48.57abc (56.21)	43.17abc (46.69)	<b>45.15bcd</b> <b>(50.26)</b>	<b>45.20cd</b> <b>(50.35)</b>
T <sub>3</sub>	Neem leaf extract ( <i>A. indica</i> )	10.0	41.36ab (43.66)	43.69bcd (47.72)	40.18ab (41.63)	<b>41.75c</b> <b>(44.34)</b>	42.18ab (45.09)	44.58bcd (49.27)	41.37bcd (43.69)	<b>42.71cd</b> <b>(46.01)</b>	<b>42.22de</b> <b>(45.16)</b>
T <sub>4</sub>	Ardusa leaf extract	10.0	33.45bc (30.38)	41.13cd (43.27)	32.81bc (29.36)	<b>35.80d</b> <b>(34.22)</b>	32.64cd (29.10)	42.81cd (46.18)	34.93cd (32.79)	<b>36.80ef</b> <b>(35.88)</b>	<b>36.29f</b> <b>(35.03)</b>
T <sub>5</sub>	Tulsi leaf extract	10.0	31.01c (26.54)	39.23d (40.00)	30.34c (25.51)	<b>33.53d</b> <b>(30.51)</b>	31.63d (27.50)	38.15d (38.16)	33.75d (30.86)	<b>34.50f</b> <b>(32.08)</b>	<b>34.01f</b> <b>(31.29)</b>
T <sub>6</sub>	Akada leaf extract	10.0	40.41ab (42.03)	42.67bcd (45.94)	39.58ab (40.60)	<b>40.89c</b> <b>(42.85)</b>	40.79bc (42.68)	42.72cd (46.03)	40.72bcd (42.55)	<b>41.41de</b> <b>(43.75)</b>	<b>41.15e</b> <b>(43.30)</b>
T <sub>7</sub>	<i>Bacillus thuringiensis</i>	0.5	46.20a (52.10)	49.35ab (57.56)	45.48a (50.84)	<b>47.01ab</b> <b>(53.51)</b>	45.99ab (51.73)	49.66abc (58.10)	45.29ab (50.51)	<b>46.99abc</b> <b>(53.47)</b>	<b>47.00bc</b> <b>(53.49)</b>
T <sub>8</sub>	SNPV	2.0	47.34a (54.08)	50.06ab (58.79)	46.61a (52.81)	<b>48.00a</b> <b>(55.23)</b>	48.53ab (56.16)	52.61a (63.12)	48.39ab (55.90)	<b>49.84ab</b> <b>(58.41)</b>	<b>48.92ab</b> <b>(56.82)</b>
T <sub>9</sub>	<i>Beauveria bassiana</i>	2 x 10 <sup>8</sup> cfu/g	48.38a (55.88)	52.28a (62.56)	47.60a (54.53)	<b>49.42a</b> <b>(57.68)</b>	49.27a (57.43)	54.82a (66.80)	49.93a (58.56)	<b>51.34a</b> <b>(60.98)</b>	<b>50.37a</b> <b>(59.32)</b>
T <sub>10</sub>	Control (unsprayed)	-	-	-	-	-	-	-	-	-	-
S.Em. ±	T		<b>2.80</b>	<b>2.68</b>	<b>2.78</b>	<b>1.59</b>	<b>2.8</b>	<b>3.01</b>	<b>2.85</b>	<b>1.66</b>	<b>1.15</b>
	P		-	-	-	<b>0.91</b>	-	-	-	<b>0.96</b>	<b>0.94</b>
	T x P		-	-	-	<b>2.75</b>	-	-	-	<b>2.88</b>	<b>2.82</b>
C.D. at 5%	T		<b>8.40</b>	<b>8.03</b>	<b>8.33</b>	<b>4.52</b>	<b>8.39</b>	<b>9.02</b>	<b>8.53</b>	<b>4.73</b>	<b>3.22</b>
	P		-	-	-	<b>2.61</b>	-	-	-	<b>2.73</b>	<b>2.63</b>
	T x P		-	-	-	<b>7.83</b>	-	-	-	<b>8.20</b>	<b>7.89</b>
C. V. %			<b>11.65</b>	<b>10.11</b>	<b>11.8</b>	<b>11.15</b>	<b>11.43</b>	<b>11.00</b>	<b>11.58</b>	<b>11.32</b>	<b>11.24</b>

\* Arcsine transformed value & Figures in parentheses are retransformed value, DAS- Days after spraying

**Table 3: Bio-efficacy of bio-pesticides against *S. litura* infesting Soybean during kharif-2022.**

Tr. No.	Treatments	Conc. (%)	Per cent mortality of <i>S. litura</i> after first spray				Per cent mortality of <i>S. litura</i> after second spray				Pooled over period over spray
			3 DAS	7 DAS	10 DAS	Pooled over period	3 DAS	7 DAS	10 DAS	Pooled over period	
T <sub>1</sub>	Neem seed kernel extract ( <i>A. indica</i> )	5 %	40.09ab* (41.28)	48.80 abcd (56.61)	43.17ab (46.82)	<b>44.02bc</b> <b>(48.29)</b>	45.01ab (50.02)	46.99a (53.46)	40.97ab (42.98)	<b>44.32bc</b> <b>(48.81)</b>	<b>44.17cd</b> <b>(48.55)</b>
T <sub>2</sub>	Neem oil ( <i>A. indica</i> )	0.3	42.22a (45.16)	49.94abc (58.58)	45.43a (50.75)	<b>45.87abc</b> <b>(51.52)</b>	47.23ab (53.88)	49.18a (57.26)	43.25a (46.94)	<b>46.55abc</b> <b>(52.70)</b>	<b>46.21bc</b> <b>(52.11)</b>
T <sub>3</sub>	Neem leaf extract ( <i>A. indica</i> )	10.0	39.12ab (39.81)	45.75bcd (51.31)	42.15ab (45.03)	<b>42.34c</b> <b>(45.36)</b>	44.01ab (48.28)	45.96ab (51.67)	39.93ab (41.19)	<b>43.30c</b> <b>(47.03)</b>	<b>42.82cd</b> <b>(46.20)</b>
T <sub>4</sub>	Ardusa leaf extract	10.0	30.99bc (26.51)	43.22cd (46.89)	34.92bc (32.77)	<b>36.38d</b> <b>(35.18)</b>	34.61cd (32.26)	36.49bc (35.37)	32.53bc (28.92)	<b>34.55d</b> <b>(32.16)</b>	<b>35.46c</b> <b>(33.66)</b>
T <sub>5</sub>	Tulsi leaf extract	10.0	28.41c (22.64)	41.34d (43.62)	32.29c (28.53)	<b>34.01d</b> <b>(31.29)</b>	33.64d (30.69)	35.71c (34.07)	29.75c (24.63)	<b>33.04d</b> <b>(29.73)</b>	<b>33.53c</b> <b>(30.51)</b>
T <sub>6</sub>	Akada leaf extract	10.0	38.17ab (38.19)	44.74bcd (49.54)	41.54ab (43.98)	<b>41.48c</b> <b>(43.87)</b>	42.64bc (45.88)	44.59abc (49.28)	39.33ab (40.17)	<b>42.18c</b> <b>(45.09)</b>	<b>41.83d</b> <b>(44.48)</b>
T <sub>7</sub>	<i>Bacillus thuringiensis</i>	0.5	44.00a (48.26)	51.44ab (61.15)	47.42a (54.22)	<b>47.62ab</b> <b>(54.57)</b>	49.72ab (58.21)	51.75a (61.67)	45.23a (50.40)	<b>48.90ab</b> <b>(56.79)</b>	<b>48.26ab</b> <b>(55.68)</b>
T <sub>8</sub>	SNPV	2.0	45.15a (50.27)	52.18ab (62.41)	48.52a (56.12)	<b>48.62ab</b> <b>(56.30)</b>	50.37ab (59.32)	52.36a (62.70)	46.33a (52.32)	<b>49.68ab</b> <b>(58.13)</b>	<b>49.15ab</b> <b>(57.22)</b>
T <sub>9</sub>	<i>Beauveria bassiana</i>	2 x 10 <sup>8</sup> cfu/g	46.17a (52.05)	54.43a (66.16)	49.55a (57.91)	<b>50.05a</b> <b>(58.77)</b>	51.14a (60.63)	53.15a (64.04)	47.35a (54.10)	<b>50.55a</b> <b>(59.63)</b>	<b>50.30a</b> <b>(59.20)</b>
T <sub>10</sub>	Control (unsprayed)	-	-	-	-	-	-	-	-	-	-
S.Em. ±	T		<b>2.85</b>	<b>2.72</b>	<b>3.06</b>	<b>1.66</b>	<b>2.79</b>	<b>3.28</b>	<b>3.11</b>	<b>1.77</b>	<b>1.21</b>
	P		-	-	-	<b>0.96</b>	-	-	-	<b>1.02</b>	<b>0.99</b>
	T x P		-	-	-	<b>2.88</b>	-	-	-	<b>3.07</b>	<b>2.97</b>
C.D. at 5%	T		<b>8.55</b>	<b>8.15</b>	<b>9.18</b>	<b>4.73</b>	<b>8.38</b>	<b>9.84</b>	<b>9.31</b>	<b>5.03</b>	<b>3.40</b>
	P		-	-	-	<b>2.73</b>	-	-	-	<b>2.91</b>	<b>2.78</b>
	T x P		-	-	-	<b>8.19</b>	-	-	-	<b>8.72</b>	<b>8.33</b>
C. V. %			<b>12.54</b>	<b>9.81</b>	<b>12.39</b>	<b>11.50</b>	<b>10.93</b>	<b>12.29</b>	<b>13.28</b>	<b>12.16</b>	<b>11.84</b>

\* Arcsine transformed value & Figures in parentheses are retransformed value, DAS- Days after spraying

**Table 4: Bio-efficacy of bio-pesticides against *S. litura* infesting soybean.**

Tr. No.	Treatments	Conc. (%)	Per cent mortality of <i>S. litura</i>		
			<i>Kharif, 2021</i>	<i>Kharif, 2022</i>	Pooled over years
T <sub>1</sub>	Neem seed kernel extract ( <i>Azadirachta indica</i> )	5 %	44.05cde* (48.34)	44.17cd (48.55)	44.11de (48.45)
T <sub>2</sub>	Neem oil ( <i>A. indica</i> )	0.3	45.20cd (50.35)	46.21bc (52.11)	45.71cd (51.24)
T <sub>3</sub>	Neem leaf extract ( <i>A. indica</i> )	10.0	42.22de (45.16)	42.82cd (46.20)	42.52ef (45.68)
T <sub>4</sub>	Ardusa leaf extract	10.0	36.29f (35.03)	35.46c (33.66)	35.87g (34.33)
T <sub>5</sub>	Tulsi leaf extract	10.0	34.01f (31.29)	33.53c (30.51)	33.77g (30.90)
T <sub>6</sub>	Akada leaf extract	10.0	41.15e (43.30)	41.83d (44.48)	41.49f (43.89)
T <sub>7</sub>	<i>Bacillus thuringiensis</i>	0.5	47.00bc (53.49)	48.26ab (55.68)	47.63bc (54.58)
T <sub>8</sub>	SNPV	2.0	48.92ab (56.82)	49.15ab (57.22)	49.03ab (57.01)
T <sub>9</sub>	<i>Beauveria bassiana</i>	2 x 10 <sup>8</sup> cfu/g	50.37a (59.32)	50.30a (59.20)	50.33a (59.25)
T <sub>10</sub>	Control (unsprayed)	-	-	-	-
<b>S.Em. ±</b>	<b>T</b>		<b>1.15</b>	<b>1.21</b>	<b>0.83</b>
	<b>Y</b>		<b>0.94</b>	<b>0.99</b>	<b>0.96</b>
	<b>T x Y</b>		<b>2.82</b>	<b>2.97</b>	<b>2.89</b>
<b>C.D. at 5%</b>	<b>T</b>		<b>3.22</b>	<b>3.40</b>	<b>2.31</b>
	<b>Y</b>		<b>2.63</b>	<b>2.78</b>	<b>2.67</b>
	<b>T x Y</b>		<b>7.89</b>	<b>8.33</b>	<b>8.03</b>
<b>C. V. %</b>			<b>11.24</b>	<b>11.84</b>	<b>11.54</b>

\* Arcsine transformed value & Figures in parentheses are retransformed value

### First Year

During *Kharif, 2021* pooled over periods of first spray indicated that Pooled over periods of first spray revealed that *B. bassiana* recorded the highest (57.68) per cent mortality of *S. litura* and was at par with SNPV (55.23) and *B. thuringiensis* (53.51). The treatments neem oil (50.44), NSKE (47.33), NLE (44.34) and Akada leaf

extract (42.85) were found moderately effective. The lowest mortality was observed in the treatment of Tulsi leaf extract (30.51). While pooled over periods of second spray resulted revealed that *B. bassiana* recorded the highest (60.98) per cent mortality of *S. litura* and was at par with SNPV (58.41) and *B. thuringiensis* (53.47). The treatments neem oil (50.26), NSKE (49.37), NLE (46.01) and Akada leaf extract (43.75) was found moderately

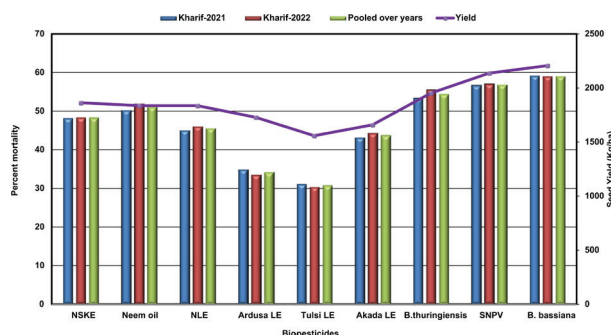
effective. The lowest mortality was observed in the treatment of Tulsi leaf extract (32.08).

The pooled data over periods and sprays (2021) exposed the higher effectiveness of *B. bassiana* (59.32) and SNPV (56.82) and they were significantly superior to all the tested biopesticides. Treatments, *B. thuringiensis* (53.49), neem oil (50.35) NSKE (48.34) and Akada leaf extract (43.30) were proved as equally and mediocre effective against *S. litura*. The least effective treatment was found in the Talsi leaf extract (31.29) followed by the

Ardusa leaf extract (35.03) (Table 4.13). Chandrayudu et al. (2015) at Tirupati, Andhra Pradesh conducted a field trial on the Bio-efficacy of certain botanicals and bio-pesticides against *S. litura* in Rabi groundnut and reported that among the treatments tested NPV (*S. litura*) @ 250 LE per ha and *Bacillus thuringiensis* (Bt) sprays were significantly effective in reducing larval population, leaf damage, This was followed by *Nomuraea rileyi* 1.5x10<sup>13</sup> spores per ml and NSKE @ 5.0 per cent compared to other treatments neem oil @ 2.0 per ml and *Beauveria bassiana* 1.5x10<sup>13</sup> spores per ml respectively

**Table 5: Impact of bio-pesticides on yield and avoidable loses due to *S. litura* infesting soybean.**

Tr. No.	Treatments	Conc. (%)	Seed yield (kg/ha)			Increase in yield over control (%)	Avoidable loss (%)
			Kharif, 2021	Kharif, 2022	Pooled		
T <sub>1</sub>	Neem seed kernel extract ( <i>Azadirachta indica</i> )	5 %	1829abc	1898ab	1863bcd	57.84	15.56
T <sub>2</sub>	Neem oil ( <i>A. indica</i> )	0.3	1906abc	1767b	1836cde	55.55	16.78
T <sub>3</sub>	Neem leaf extract ( <i>A. indica</i> )	10.0	1698abc	1975ab	1836cde	55.56	16.78
T <sub>4</sub>	Ardusa leaf extract	10.0	1636bc	1821b	1728cde	46.41	21.68
T <sub>5</sub>	Tulsi leaf extract	10.0	1489cd	1628b	1559e	32.03	29.37
T <sub>6</sub>	Akada leaf extract	10.0	1636bc	1682b	1659de	40.52	24.82
T <sub>7</sub>	<i>Bacillus thuringiensis</i>	0.5	1975ab	1929ab	1952abc	65.36	11.54
T <sub>8</sub>	SNPV	2.0	2037ab	2238a	2137ab	81.05	3.15
T <sub>9</sub>	<i>Beauveria bassiana</i>	2 x 10 <sup>8</sup> cfu/g	2137a	2276a	2207a	86.93	0.00
T <sub>10</sub>	Control (unsprayed)	-	1157d	1204c	1181f	0.00	46.50
S.Em. ±		T	151.05	138.31	144.81	-	-
		Y	-	-	64.76	-	-
		T x Y	-	-	204.80	-	-
C.D. at 5%		T	448.79	410.94	291.08	-	-
		Y	-	-	130.17	-	-
		T x Y	-	-	411.65	-	-
C. V. %			14.95	13.01	13.96	-	-



**Fig. 1: Bio-efficacy of bio-pesticides against *S. litura* infesting soybean**

**Table 6: Economics of insecticides used for the control of *S. litura* infesting soybean.**

Biopesticides	Conc. (%)	Total quantity of biopesticides (Lit or kg/ha)	Cost of biopesticides (Rs./ha)	Total Cost of treatment including labour charges (Rs/ha)	Seed yield (kg/ha)	Gross realization (Rs/ha)	Net realization over control (Rs/ha)	Net Profit (Rs/ha)	ICBR
Neem seed kernel extract ( <i>A. indica</i> )	5 %	50	2776	3576	1863	95034	34826	31250	1:8.74
Neem oil ( <i>A. indica</i> )	0.3	3	2050	2850	1836	93656	33448	30598	1:10.74
Neem leaf extract ( <i>A. indica</i> )	10.0	100	2250	3050	1836	93657	33449	30399	1:9.97
Ardusa leaf extract	10.0	100	2250	3050	1728	88148	27940	24890	1:8.16
Tulsi leaf extract	10.0	100	2250	3050	1559	79491	19283	16233	1:5.32
Akada leaf extract	10.0	100	2250	3050	1659	84606	24398	21348	1:7.00
<i>Bacillus thuringiensis</i>	0.5	2	2400	3200	1952	99560	39352	36152	1:11.30
SNPV	2.0	0.5	1680	2480	2137	109004	48796	46316	1:18.68
<i>Beauveria bassiana</i>	2 x 10 <sup>8</sup> cfu/g	4	2560	3360	2207	112546	52338	48978	1:14.58
Control (unsprayed)	-	-	-	-	1181	60208	-	-	-

Note: 1. for one spray 500 liter of solution is required per hectare and two sprays were applied during the cropping season

2. Price of soyabean grain: 51 Rs. /kg, Labour charge (Rs/ha) =400/-

### Second Year

During *Kharif*, 2022 pooled over periods of first spray revealed that *B. bassiana* recorded the highest (58.77) per cent mortality of *S. litura* and was at par with SNPV (56.30) and *B. thuringiensis* (54.57). The treatments neem oil (51.52), NSKE (48.29), NLE (45.36) and Akada leaf extract (43.87) were found moderately effective. The lowest mortality was observed in the treatment of Tulsi leaf extract (31.29). Pooled over periods of second spray revealed that *B. bassiana* recorded the highest (59.63) per cent mortality of *S. litura* and was at par with SNPV (58.13) and *B. thuringiensis* (56.79). The treatments neem oil (52.70), NSKE (48.81), NLE (47.03) and Akada leaf extract (45.09) were found moderately effective. The lowest mortality was observed in the treatment of Tulsi leaf extract (29.73).

The pooled data over periods and sprays (2022) exposed the higher effectiveness of *B. bassiana* (59.20) and SNPV (57.22) and they were significantly superior to all the tested biopesticides. Treatments, *B. thuringiensis* (55.68), Neem oil (52.11) NSKE (48.55) and Akada leaf extract (44.48) were proved as equally and mediocre effective against *S. litura*. The least effective treatment

was found in Talsi leaf extract (30.51) followed by Ardusa leaf extract (33.66) (Table 4.13).

### Pooled over years

Pooled over years analysis (Table 4 and Fig.No.1) indicated that among various biopesticides tested maximum per cent mortality (59.25) was observed in the treatment of *B. bassiana* followed by SNPV (57.01) and *B. thuringiensis* (54.58). Neem oil, NSKE, NLE and Akada leaf extract were found moderately effective with a mortality range between 51.24 and 43.89 per cent. The lowest mortality was observed in the treatment of Tulsi leaf extract (30.90) and it was at par with Ardusa leaf extract (34.33). Chandrayudu *et al.* (2015) reported that among the treatments tested NPV (*S. litura*) @ 250 LE per ha and *Bacillus thuringiensis* (Bt) sprays were significantly effective in reducing larval population. Bangale *et al.* (2020) among the combination of different insecticidal treatments the order of effectiveness was found as *B. bassiana* 0.0035 per cent + chlorantraniliprole 0.003 per cent > *B. bassiana* 0.0035 per cent + indoxacarb 0.004 per cent > *M. anisopliae* 0.0035 per cent + chlorantraniliprole 0.003 per cent > *M. anisopliae* 0.0035 per cent + indoxacarb

0.004 per cent effective in controlling the pest. Dodiya and Barad (2022) recorded the efficacy of biopesticides as a reduction in *S. litura* population was SINPV 250 LE > *B. bassiana* 1% WP > aqueous bidi tobacco dust extract 2% > neem oil 1% > Btk 1% WP > *M. anisopliae* 1% WP > azadirachtin 10000 ppm > *N. rileyi* 1% WP.

**Yield, increase in yield over control, avoidable losses, and economics**

**Yield**

The pooled over years data of the first and second year (Table 5) visibly indicated that significantly the highest (2207 kg/ha) yield was obtained from the plots treated with *B. bassiana* and it was at par with SNPV (2137 kg/ha), *B. thuringiensis* (1952 kg/ha) and The plots treated with NSKE, Neem oil, NLE and Ardusa leaf extract produced 1728 to 1863 kg/ha soybean. Among the evaluated biopesticides the lowest (15589 kg/ha) yield was recorded in the plots treated with Tulsi leaf extract followed by Akada leaf extract (1659 kg/ha) compared to the yield of untreated control (1181 kg/ha).

**Increase in yield**

The increase in yield over control ranged from 32.03 to 56.93 per cent due to application of biopesticides. Maximum (86.93 %) seed yield was increased in the plots treated with *B. bassiana* followed by SNPV (81.05 %) and *B. thuringiensis* (65.36 %). NSKE, NLE, Neem oil and Ardusa leaf extract treated plots increased yield between 46.41 and 57.84 per cent. The lowest (32.03 %) increase in yield was obtained in Tulsi leaf extract followed by Akada leaf extract (40.52 %).

**Avoidable losses**

Avoidable loss in yield of soybean was concerned, it varied from 3.15 to 29.37 per cent in different treatments. The avoidable loss was lowest (3.15 %) in the treatment of SNPV followed by *B. thuringiensis* (11.54 %) and NSKE (15.56). The avoidable losses were 16.78 to 21.68 per cent in Neem oil, NLE and Ardusa leaf extract. The avoidable loss was calculated as 24.82 and 29.37 per cent in treatments of Akada leaf extract and Tulsi leaf extract,

respectively. Present study was supported by Sumanjali et al. (2020) evaluated the bio-efficacy of bio-pesticides against *S. litura* in Cabbage and reported that spinosad recorded the highest yield (285.40 q/ha), followed by NSKE which recorded (234.40 q/ha), *Bacillus thuringiensis* (222.70 q/ha) and indoxacarb (222.20 q/ha) respectively.

**Economics**

Economics of various bio-pesticides (Table 6) evaluated against *S. litura* infesting soybean indicated that maximum (Rs 52338/ha) net realization was obtained in the case of *B. bassiana* treatment followed by SNPV (Rs. 48796) and *B. thuringiensis* (Rs 39352). The net realization was Rs. 33449 and 34826/ha in the treatments of NLE and NSKE, respectively. The remaining bio-pesticides (Tulsi leaf extract, Akada leaf extract Ardusa leaf extract and Tulsi leaf extract) recorded (Rs 19283 to 33448) net realization.

Looking at the ICBR, the highest (1:18.68) return was obtained with the treatment of SNPV followed by *B. bassiana* (1:14.58) and *B. thuringiensis* (1:11.30). The ICBR calculated as 1:10.74 and 1:9.97 in treatments of Neem oil and NSKE, respectively. The poor (1:5.32 to 1:8.74) ICBR was recorded with the treatments of Tulsi leaf extract, Akada leaf extract Ardusa leaf extract and Tulsi leaf extract. Choudhary and Shrivastava (2007) reported that among the neem-based products, the application of NSKE at 5 per cent + neem leaf extract at 10 per cent reduced the maximum larval population (51.59%) and recorded a seed yield of 987.66 kg/ ha. However, the ICBR showed that the application of NSKE at 5 per cent (2.44) proved economically most viable amongst the neem-based treatments followed by neem leaf extract at 5 per cent (2.20). Chaudhari et al. (2020) stated that the insecticidal and bio-pesticidal treatments gave significantly higher soybean grain yield over untreated control. Significant maximum grain yield of 26.73 q/ha was recorded in plot treated with an insecticidal spray of chlorantraniliprole and it was at par with flubendamide (26.01 q/ha) and spinosad, *Bacillus thuringiensis* var. *kurstaki* (18.00 q/ha) and SINPV @500 ml/ha (17.51 q/ha) and NSE (Neem seed extract) 5% (16.05 q/ha) found less effective.

## Conclusion

The results of this study clearly demonstrate the significant impact of various treatments on managing *S. litura* in the soybean, particularly highlighting the superior efficacy of *B. bassiana* followed by SNPV and *B. thuringiensis* were found most effective biopesticides among all and proved best in the yield and economics. So present study minimizing reliance on chemical inputs, thereby promoting eco-friendly and sustainable agricultural practices.

## Acknowledgements

The authors are grateful to the working Institution Junagadh Agricultural University, Junagadh (Gujarat) India and we thank the anonymous reviewers for their helpful comments on the manuscript.

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