



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 1483-1489
Received: 25-04-2026
Accepted: 30-05-2026

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Evaluation of PDKV *Bacillus thuringiensis* formulations for sustainable management *Leucinodes orbonalis* (Guenée) on brinjal

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7s.6149>

Abstract

Brinjal (*Solanum melongena* L.) is an economically important vegetable crop, but its productivity is severely affected by the shoot and fruit borer, *Leucinodes orbonalis* (Guenée), which causes considerable quantitative and qualitative yield losses. The present study was undertaken to evaluate the field efficacy of PDKV *Bacillus thuringiensis* formulations for the management of *L. orbonalis*. Twenty-five treatments comprising PDKV *Bt* formulations, a commercial *Bt* formulation (Delfin), a chemical check (Chlorpyrifos 20 EC) and an untreated control were evaluated under field conditions. Fruit damage on number and weight basis was assessed at successive pickings, and marketable fruit yield was recorded to determine treatment performance. The treatments differed significantly in their ability to suppress fruit borer infestation and improve fruit yield. Chlorpyrifos 20 EC @ 1 l/ha recorded the lowest cumulative fruit damage on number (20.54%) and weight basis (21.22%) and produced the highest yield (432.84 q/ha). Among the PDKV *Bt* formulations, PDKV SY-4 25% WP @ 1 kg/ha proved to be the most effective, recording cumulative fruit damage of 20.72 and 22.89 per cent on number and weight basis, respectively, with a fruit yield of 429.56 q/ha. PDKV SA-20 25% WP @ 1 kg/ha, PDKV SGd-1 25% WP @ 1 kg/ha, PDKV SY-4 75% SC @ 1 l/ha and commercial *Bt* formulation (Delfin) also provided effective suppression of *L. orbonalis* and statistically at par with the superior treatments. The findings demonstrate that PDKV SY-4 25% WP is a promising *Bt* formulation for reducing fruit damage and enhancing marketable yield of brinjal, offering a potential biological alternative for the sustainable management of *L. orbonalis* under field conditions.

Keywords: Brinjal, *Leucinodes orbonalis*, PDKV *Bt*, fruit damage, marketable yield

Introduction

Brinjal (*Solanum melongena* L.) is one of the most widely cultivated vegetable crops in tropical and subtropical regions and occupies an important place in human nutrition and commercial vegetable production. It cultivated extensively in Asian countries, particularly India, where it contributes substantially to vegetable production and farmer's income (Choudhary and Gaur, 2009; Anonymous, 2025-26)^[2, 4].

Among the insect pests attacking brinjal, the shoot and fruit borer, *leucinodes orbonalis* (Guenée), is regarded as the most destructive species throughout the crop-growing period. The larvae bore into tender shoots during the vegetative stage and subsequently infest developing fruits, resulting in severe yield reduction and deterioration of market quality. Because of its concealed feeding habit, the pest remains protected from direct contact with insecticides, making its management difficult and often causing substantial economic losses under favourable environmental conditions (Alam *et al.*, 2003; Ghosh and Senapati, 2009; Srinivasan, 2008)^[1, 5, 14].

Management of *L. orbonalis* has largely depended on repeated applications of chemical insecticides. However, indiscriminate and frequent use of synthetic insecticides has resulted in problems such as pesticide residues on marketable fruits, adverse effects on beneficial organisms, environmental contamination and the development of insecticide resistance. These concerns have emphasized the need for environmentally safe and sustainable alternatives that can effectively manage the pest while minimizing ecological risks (Srinivasan, 2008; Saha and Chandran, 2021)^[10, 14].

Among the available biological control agents, *Bt* has gained worldwide acceptance as one of the most successful microbial insecticides because of its high insecticidal activity against lepidopteran pests, target specificity and safety to humans, natural enemies and the environment. The insecticidal activity of *Bt* is primarily attributed to *Cry* proteins, which become activated in the alkaline midgut of susceptible larvae, resulting in disruption of gut epithelial cells and eventual larval mortality. Owing to these advantages, *Bt*-based formulations have become an important component of integrated pest management programmes and are widely used as eco-friendly alternatives to conventional insecticides (Schnepf *et al.*, 1998; Bravo *et al.*, 2011; Sanahuja *et al.*, 2011) [3, 12, 13].

Therefore, the present study was undertaken to evaluate the field efficacy of PDKV *Bacillus thuringiensis* formulations for the management of *L. orbonalis* on brinjal based on fruit damage on number basis and weight basis and marketable fruit yield under field conditions.

Materials and Methods

The field experiment was conducted during the *Kharif* 2025 season to evaluate the field efficacy of PDKV *Bacillus thuringiensis* formulations against the fruit borer, *Leucinodes orbonalis* (Guenée) on brinjal. The experiment was laid out in a Randomized Block Design (RBD) comprising 25 treatments and two replications. Healthy seedlings of brinjal cv. Super Gaurav were transplanted at a spacing of 90 × 60 cm, and all recommended agronomic practices were followed uniformly

throughout the crop season, except for the plant protection treatments under evaluation.

Eleven indigenous PDKV *Bt* isolates previously isolated, characterized and maintained in the Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, were used for the preparation of wettable powder (25% WP) and suspension concentrate (75% SC) formulations. The wettable powder formulations were prepared following the procedure described by Marzaban *et al.* (2021), whereas the suspension concentrate formulations were prepared according to Vimala Devi *et al.* (2015) [15]. The treatments consisted of PDKV-SA-6 25% WP @ 1 kg/ha (T₁), PDKV-SA-6 75% SC @ 1 L/ha (T₂), PDKV-SA-18 25% WP @ 1 kg/ha (T₃), PDKV-SA-18 75% SC @ 1 L/ha (T₄), PDKV-SA-20 25% WP @ 1 kg/ha (T₅), PDKV-SA-20 75% SC @ 1 L/ha (T₆), PDKV-SAK-6 25% WP @ 1 kg/ha (T₇), PDKV-SAK-6 75% SC @ 1 L/ha (T₈), PDKV-SAK-9 25% WP @ 1 kg/ha (T₉), PDKV-SAK-9 75% SC @ 1 L/ha (T₁₀), PDKV-SGd-1 25% WP @ 1 kg/ha (T₁₁), PDKV-SGd-1 75% SC @ 1 L/ha (T₁₂), PDKV-SGn-4 25% WP @ 1 kg/ha (T₁₃), PDKV-SGn-4 75% SC @ 1 L/ha (T₁₄), PDKV-SGn-5 25% WP @ 1 kg/ha (T₁₅), PDKV-SGn-5 75% SC @ 1 L/ha (T₁₆), PDKV-SBn-2 25% WP @ 1 kg/ha (T₁₇), PDKV-SBn-2 75% SC @ 1 L/ha (T₁₈), PDKV-I-3 25% WP @ 1 kg/ha (T₁₉), PDKV-I-3 75% SC @ 1 L/ha (T₂₀), PDKV-SY-4 25% WP @ 1 kg/ha (T₂₁), PDKV-SY-4 75% SC @ 1 L/ha (T₂₂), commercial *Bt* formulation (Delfin) @ 1 kg/ha (T₂₃), Chlorpyrifos 20 EC @ 1 L/ha (T₂₄) and an untreated control (T₂₅).

Table 1: *Bt* strain used

Sr. No.	<i>Bt</i> isolate	Accession no.	Source
1.	PDKV <i>Bt</i> SA-20	ON331908.1	Department of Entomology (Dr. PDKV AKOLA)
2.	PDKV <i>Bt</i> SY-4	ON331906.1	
3.	PDKV <i>Bt</i> SGd-1	ON331905.1	
4.	PDKV <i>Bt</i> SA-6	ON331907.1	
5.	PDKV <i>Bt</i> SA-18	ON209984	
6.	PDKV <i>Bt</i> SBn-2	ON209989	
7.	PDKV <i>Bt</i> SAK-6	ON209985	
8.	PDKV <i>Bt</i> SAK-9	ON209986	
9.	PDKV <i>Bt</i> I-3	ON209990	
10.	PDKV <i>Bt</i> SGn-4	ON209987	
11.	PDKV <i>Bt</i> SGn-5	ON209988	

Application of treatments

Three foliar applications of the respective treatments were given at 15-day intervals, commencing from the initiation of fruit infestation. Spraying was carried out using a knapsack sprayer to ensure uniform coverage. The wettable powder formulations were applied at the rate of 1 kg/ha, whereas the suspension concentrate formulations were applied at 1 l/ha. The commercial *Bt* (Delfin) was applied at 1 kg/ha, while Chlorpyrifos 20 EC was applied at 1 l/ha. Adequate precautions were taken during spraying to avoid drift and contamination between adjacent plots.

Methods of recording observations

Observations on fruit infestation were recorded from five randomly selected plants in each treatment plot at every picking. Pre-treatment observations were recorded 24 hours before application of treatment spray and post treatment observations were recorded at an interval of 7 days after each treatment and continued till last harvesting of fruits. The numbers and weights of healthy and infested fruits were recorded separately, and the percentage of fruit damage on number and weight basis was calculated using the standard formula described by Mollah *et al.*,

(2023) [8].

$$\text{Per cent of fruit damage (Number basis)} = \frac{\text{No. of damaged fruits}}{\text{Total no. of fruits}} \times 100$$

$$\text{Per cent of fruit damage (Weight basis)} = \frac{\text{Total weight of fruits plucked}}{\text{Weight of damaged fruits}} \times 100$$

Fruit yield from each net plot was recorded at every picking and converted to quintals per hectare for statistical analysis.

$$\text{Fruit yield (q/ha)} = \frac{\text{Fruit yield (kg/plot)} \times 10000 \text{ (m}^2\text{)}}{\text{Plot size (m}^2\text{)} \times 100}$$

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design. Percentage data were transformed before analysis wherever necessary, and treatment means were compared using the Critical

Difference (CD) test at the 5% level of significance following the procedure described by Gomez and Gomez (1984)^[6].

Result and discussion

Effect of PDKV *Bacillus thuringiensis* formulations on fruit damage caused by *Leucinodes orbonalis* on number basis

The efficacy of different PDKV *Bacillus thuringiensis* formulations against *Leucinodes orbonalis* was assessed based on cumulative fruit damage recorded on number basis, and the results are presented in Table 2. Significant differences among the treatments were observed, indicating variable efficacy of the indigenous *Bacillus thuringiensis* formulations in suppressing fruit borer infestation.

Among all the treatments, Chlorpyrifos 20 EC @ 1 L/ha (T₂₄) recorded the lowest cumulative fruit damage (20.54%), followed by PDKV-SY-4 25% WP @ 1 kg/ha (T₂₁) with 20.72 per cent fruit damage. These treatments were statistically at par with commercial *Bacillus thuringiensis* formulation (Delfin) @ 1 kg/ha (T₂₃) (21.52%), PDKV-SA-20 25% WP @ 1 kg/ha (T₅) (23.96%), PDKV-SGd-1 25% WP @ 1 kg/ha (T₁₁) (24.50%), PDKV-SY-4 75% SC @ 1 L/ha (T₂₂) (25.73%), PDKV-SA-20 75% SC @ 1 L/ha (T₆) (26.76%) and PDKV-SGd-1 75% SC @ 1 L/ha (T₁₂) (27.42%). These treatments consistently suppressed fruit infestation throughout the crop period and were significantly superior to the untreated control.

This was followed by treatments T₁₂ PDKV-SGd-1 75% SC @ 1 L/ha, T₁ PDKV-SA-6 25% WP @ 1 kg/ha, T₁₀ PDKV-SAK-9 75% SC @ 1 L/ha, T₂ PDKV-SA-6 75% SC @ 1 L/ha, T₂₀ PDKV-I-3 75% SC @ 1 L/ha and T₉ PDKV-SAK-9 25% WP @ 1 kg/ha recorded cumulative fruit damage of 27.42, 29.91, 30.31, 30.78, 32.30 and 33.47 per cent.

The next effective treatment comprised T₈ PDKV-SAK-6 75% SC @ 1 L/ha, T₁₉ PDKV-I-3 25% WP @ 1 kg/ha, T₇ PDKV-SAK-6 25% WP @ 1 kg/ha, T₃ PDKV-SA-18 25% WP @ 1 kg/ha, T₁₄

PDKV-SGn-4 75% SC @ 1 L/ha, T₁₇ PDKV-SBn-2 25% WP @ 1 kg/ha, T₄ PDKV-SA-18 75% SC @ 1 L/ha and T₁₃ PDKV-SGn-4 25% WP @ 1 kg/ha, which recorded cumulative fruit damage of 34.59, 36.20, 36.29, 36.52, 38.17, 39.57, 40.43 and 41.89 per cent. Although these treatments were comparatively less effective than the superior group, they significantly reduced cumulative fruit damage over the untreated control. The comparatively less effective PDKV *Bt* formulations were T₁₆ PDKV-SGn-5 75% SC @ 1 L/ha, T₁₅ PDKV-SGn-5 25% WP @ 1 kg/ha and T₁₈ PDKV-SBn-2 75% SC @ 1 L/ha, which recorded 43.93, 45.47 and 46.27 per cent cumulative fruit damage, respectively.

Among the indigenous PDKV *Bacillus thuringiensis* formulations, PDKV-SY-4 25% WP @ 1 kg/ha emerged as the most promising formulation for the management of *L. orbonalis* under field conditions. Furthermore, commercial *Bacillus thuringiensis* formulation (Delfin), PDKV-SA-20 25% WP, PDKV-SGd-1 25% WP, PDKV-SY-4 75% SC, PDKV-SA-20 75% SC and PDKV-SGd-1 75% SC were statistically at par with PDKV-SY-4 25% WP. Likewise, PDKV-SY-4 25% WP, commercial *Bacillus thuringiensis* formulation (Delfin), PDKV-SA-20 25% WP, PDKV-SGd-1 25% WP and PDKV-SY-4 75% SC were also statistically at par with the chemical check, Chlorpyrifos 20 EC @ 1 L/ha.

The present result showed that T₂₄ Chlorpyrifos 20% EC @ 1 L/ha recorded the lowest cumulative mean fruit damage with the highest reduction over control is followed by T₂₁ PDKV-SY-4 25% WP @ 1 kg/ha was supported by the finding of Yin (1993)^[16] who determined that spraying of *Bt* emulsion against shoot and fruit borer in brinjal resulted in 78.8-100 per cent control over untreated control. Similarly, Nawale *et al.* (2018)^[9] indicated that the Chlorpyrifos 20EC @ 4gm/lit effective and showed (12.23%) shoot infestation and (9.47%) fruit infestation, and *Bacillus thuringiensis* @ 5gm/lit (15.31%) and (11.48%) respectively.

Table 2: Effect of PDKV *Bacillus thuringiensis* formulation on brinjal fruit damage by *L. orbonalis* on number basis (picking wise)

Treatments	Brinjal fruit damage (%) due to <i>L. orbonalis</i> on number basis after						Cumulative mean fruit damage (%)	Per cent reduction over control
	1 st Spray		2 nd Spray		3 rd Spray			
	1 st Picking	2 nd Picking	3 rd Picking	4 th Picking	5 th Picking	6 th Picking		
T ₁ - PDKV-SA-6 25% WP	35.04 (36.30)	33.04 (35.04)	32.38 (34.68)	29.67 (32.96)	24.34 (29.56)	25.00 (29.99)	29.91 (33.15)	62.44
T ₂ - PDKV-SA-6 75% SC	34.86 (36.14)	34.86 (36.14)	33.47 (35.31)	31.21 (33.94)	26.32 (30.86)	23.95 (29.23)	30.78 (33.68)	61.35
T ₃ - PDKV-SA-18 25% WP	42.15 (40.48)	39.70 (39.04)	40.22 (39.34)	38.46 (38.28)	29.81 (33.07)	28.79 (32.43)	36.52 (37.17)	54.15
T ₄ - PDKV-SA-18 75% SC	48.58 (44.19)	43.02 (40.99)	44.64 (38.84)	45.47 (42.40)	35.22 (36.39)	30.93 (33.79)	40.43 (39.48)	49.24
T ₅ - PDKV-SA-20 25% WP	26.94 (31.24)	27.75 (31.78)	24.69 (29.74)	23.86 (29.20)	21.43 (27.55)	19.07 (25.84)	23.96 (29.28)	69.92
T ₆ - PDKV-SA-20 75% SC	30.23 (33.31)	29.01 (32.57)	28.49 (32.21)	25.94 (30.60)	23.38 (28.92)	23.47 (28.90)	26.76 (31.12)	66.41
T ₇ - PDKV-SAK-6 25% WP	38.48 (38.30)	40.61 (39.58)	41.01 (39.80)	38.17 (38.14)	30.44 (33.45)	29.01 (32.57)	36.29 (37.04)	54.44
T ₈ -PDKV-SAK-6 75% SC	41.00 (39.81)	38.31 (38.22)	35.71 (36.68)	37.84 (37.95)	28.46 (32.20)	26.23 (30.76)	34.59 (36.03)	56.57
T ₉ -PDKV-SAK-9 25% WP	37.87 (37.98)	36.22 (37.00)	37.77 (37.91)	35.76 (36.71)	27.08 (31.33)	26.14 (30.70)	33.47 (35.35)	57.98
T ₁₀ -PDKV-SAK-9 75% SC	34.62 (36.04)	34.62 (36.04)	31.25 (33.97)	30.86 (33.71)	25.68 (30.44)	24.86 (29.80)	30.31 (33.39)	61.94
T ₁₁ -PDKV-SGd-1 25% WP	28.71 (32.40)	26.52 (30.96)	25.20 (30.03)	24.20 (29.40)	22.16 (28.07)	20.20 (26.68)	24.50 (29.66)	69.24
T ₁₂ -PDKV-SGd-1 75% SC	32.11 (34.33)	30.76 (33.54)	28.06 (31.92)	26.71 (31.08)	24.81 (29.79)	22.07 (27.92)	27.42 (31.56)	65.57
T ₁₃ -PDKV-SGn-4 25% WP	48.79 (44.30)	44.27 (41.71)	42.89 (40.90)	45.96 (42.67)	35.49 (36.56)	33.97 (35.62)	41.89 (40.32)	47.40
T ₁₄ -PDKV-SGn-4 75%	41.14 (39.88)	41.14 (39.88)	42.48 (40.67)	43.09 (41.03)	31.33 (34.03)	29.87 (33.11)	38.17 (38.16)	52.07

SC								
T ₁₅ -PDKV-SGn-5 25% WP	50.37 (45.21)	47.44 (43.53)	49.55 (44.73)	46.51 (43.00)	40.63 (39.59)	38.33 (38.24)	45.47 (42.40)	42.91
T ₁₆ -PDKV-SGn-5 75% SC	48.53 (44.16)	46.57 (43.03)	45.61 (42.48)	47.55 (43.59)	38.80 (38.51)	36.52 (37.15)	43.93 (41.51)	44.84
T ₁₇ -PDKV-SBn-2 25% WP	40.74 (39.65)	42.15 (40.48)	42.73 (40.81)	44.19 (41.66)	33.37 (35.28)	34.22 (35.79)	39.57 (38.97)	50.32
T ₁₈ -PDKV-SBn-2 75% SC	51.49 (45.86)	49.11 (44.49)	48.69 (44.25)	48.28 (44.01)	40.84 (39.60)	39.24 (38.73)	46.27 (42.86)	41.90
T ₁₉ -PDKV-I-3 25% WP	39.75 (39.04)	37.20 (37.58)	39.25 (41.86)	41.55 (40.12)	27.73 (31.77)	26.43 (30.94)	36.20 (36.98)	54.55
T ₂₀ -PDKV-I-3 75% SC	33.93 (35.60)	35.98 (36.80)	38.15 (38.12)	32.98 (34.95)	26.74 (31.06)	26.00 (30.60)	32.30 (34.61)	59.45
T ₂₁ -PDKV-SY-4 25% WP	25.18 (29.91)	20.95 (27.20)	22.00 (27.90)	18.42 (25.36)	19.35 (26.08)	18.41 (25.33)	20.72 (27.04)	73.99
T ₂₂ -PDKV-SY-4 75% SC	29.87 (33.11)	28.85 (32.48)	27.15 (31.37)	24.72 (29.80)	21.88 (27.81)	21.93 (27.91)	25.73 (30.48)	67.69
T ₂₃ -Delfin	25.38 (30.13)	24.18 (29.29)	21.33 (27.38)	21.16 (27.24)	19.13 (25.63)	17.91 (24.94)	21.52 (27.48)	72.98
T ₂₄ -Chlorpyrifos 20% EC	24.18 (29.29)	25.38 (30.13)	18.60 (25.40)	19.69 (26.32)	18.07 (25.09)	17.30 (24.55)	20.54 (26.86)	74.21
T ₂₅ -Control	70.28 (57.43)	71.11 (57.92)	79.08 (62.94)	81.71 (65.29)	85.25 (67.42)	90.44 (72.05)	79.64 (63.21)	0.00
F test	SIG	SIG	SIG	SIG	SIG	SIG	SIG	
SE±(m)	2.98	2.66	2.52	2.47	2.22	2.11	1.52	
CD at 5%	8.71	7.75	7.37	7.22	6.49	6.16	4.42	
CV	11.06	10.04	9.60	9.51	9.48	9.16	5.97	

*Figures in parentheses are corresponding arc sin transformation

Effect of PDKV *Bacillus thuringiensis* formulations on fruit damage caused by *Leucinodes orbonalis* on weight basis

The cumulative mean fruit damage on weight basis differed significantly among the treatments (Table 3), indicating considerable variation in the efficacy of the PDKV *Bacillus thuringiensis* formulations against *Leucinodes orbonalis*. The cumulative fruit damage ranged from 21.22 to 79.37 per cent, with the untreated control (T₂₅) recording the highest fruit damage (79.37%).

Among all the treatments, Chlorpyrifos 20 EC @ 1 L/ha (T₂₄) recorded the lowest cumulative fruit damage (21.22%), followed by PDKV-SY-4 25% WP @ 1 kg/ha (T₂₁) with 22.89 per cent fruit damage. These treatments were highly effective and remained statistically at par with commercial *Bt* formulation (Delfin) @ 1 kg/ha (T₂₃) (23.49%), PDKV-SA-20 25% WP @ 1 kg/ha (T₅) (26.80%), PDKV-SGd-1 25% WP @ 1 kg/ha (T₁₁) (27.18%) and PDKV-SY-4 75% SC @ 1 L/ha (T₂₂) (29.49%), PDKV-SA-6 25% WP @ 1 kg/ha (T₁) (35.68%).

PDKV-SAK-9 75% SC (T₁₀), PDKV-SA-6 75% SC (T₂), PDKV-I-3 75% SC (T₂₀), PDKV-SAK-9 25% WP (T₉), PDKV-SAK-6 75% SC (T₈), PDKV-I-3 25% WP (T₁₉), PDKV-SA-18 25% WP (T₃) and PDKV-SAK-6 25% WP (T₇) recorded cumulative fruit damage of 36.23, 38.34, 40.11, 42.13, 42.55, 43.63, 44.91 and 46.43 per cent, respectively. These treatments exhibited moderate suppression of fruit damage and were significantly superior to the untreated control.

Comparatively higher fruit damage was recorded in PDKV-SGn-4 75% SC (T₁₄) (48.45%), PDKV-SBn-2 25% WP (T₁₇) (48.93%), PDKV-SGn-4 25% WP (T₁₃) (49.10%), PDKV-SA-18

75% SC (T₄) (50.69%), PDKV-SGn-5 75% SC (T₁₆) (52.25%), PDKV-SGn-5 25% WP (T₁₅) (53.52%) and PDKV-SBn-2 75% SC (T₁₈) (53.85%). Although these treatments were comparatively less effective than the superior formulations, they also reduced fruit damage significantly over the untreated control. Among the indigenous PDKV *Bt* formulations, PDKV-SY-4 25% WP @ 1 kg/ha emerged as the most promising formulation for reducing fruit damage on weight basis. The commercial *Bt* formulation (Delfin) @ 1 kg/ha, PDKV-SA-20 25% WP, PDKV-SGd-1 25% WP, PDKV-SY-4 75% SC, PDKV-SA-20 75% SC and PDKV-SGd-1 75% SC were statistically at par with PDKV-SY-4 25% WP. Furthermore, PDKV-SY-4 25% WP, commercial *Bt* (Delfin), PDKV-SA-20 25% WP, PDKV-SGd-1 25% WP and PDKV-SY-4 75% SC were also statistically at par with the chemical check Chlorpyrifos 20 EC @ 1 L/ha. The untreated control recorded the highest cumulative fruit damage (79.37%), confirming the effectiveness of the evaluated PDKV *Bt* formulations in minimizing fruit damage on weight basis under field condition.

Present studies proved that cumulative effect of PDKV *Bt* SY-4 25% WP @ 1kg/ha and commercial *Bt* @ 1kg/ha recorded lowest fruit infestation with 71.17 and 70.41 reduction over control these finding are in corroboration with findings of Mollah *et al.* (2023) [8] stated that combining biopesticides with *Bacillus thuringiensis* var. *kurstaki* significantly improved control of brinjal shoot and fruit borer, reducing shoot and fruit infestation and increasing yield compared to biopesticides used alone, due to synergistic action, these combinations confirmed, 72.40 % and 72.18 % fruit infestation control in weight basis, respectively.

Table 3: Effect of PDKV *Bacillus thuringiensis* formulation on brinjal fruit damage by *L. orbonalis* on weight basis

Treatments	Brinjal fruit damage (%) due to <i>L. orbonalis</i> on weight basis after						Cumulative mean fruit damage (%)	Per cent reduction over control
	1 st Spray		2 nd Spray		3 rd Spray			
	1 st Picking	2 nd Picking	3 rd Picking	4 th Picking	5 th Picking	6 th Picking		
T ₁ - PDKV-SA-6 25% WP	31.21 (33.95)	43.08 (40.98)	37.67 (37.86)	32.86 (34.95)	34.40 (35.70)	34.82 (36.16)	35.68 (36.67)	55.05
T ₂ - PDKV-SA-6 75% SC	32.47 (34.73)	40.06 (39.23)	42.75 (40.81)	36.55 (37.15)	42.75 (40.81)	35.44 (36.54)	38.34 (38.23)	51.7
T ₃ - PDKV-SA-18 25% WP	40.69 (39.62)	48.67 (44.22)	47.24 (43.42)	41.46 (40.06)	47.05 (43.31)	44.34 (41.75)	44.91 (42.07)	43.42
T ₄ - PDKV-SA-18	50.28 (45.16)	53.61 (47.11)	50.89 (45.52)	47.09 (43.33)	51.66 (45.96)	50.59 (45.35)	50.69 (45.40)	36.14

75% SC								
T ₅ - PDKV-SA-20 25% WP	21.91 (27.91)	29.99 (33.20)	28.92 (32.53)	26.32 (30.85)	26.27 (30.83)	27.39 (31.50)	26.80 (31.17)	66.24
T ₆ - PDKV-SA-20 75% SC	24.90 (29.89)	36.01 (36.86)	33.96 (35.60)	30.47 (33.44)	31.16 (33.93)	33.22 (35.17)	31.62 (34.19)	60.16
T ₇ - PDKV-SAK-6 25% WP	44.19 (41.66)	49.41 (44.66)	48.29 (44.02)	42.43 (40.64)	48.31 (44.03)	45.98 (42.69)	46.43 (42.95)	41.5
T ₈ - PDKV-SAK-6 75% SC	35.57 (36.56)	45.05 (42.16)	46.06 (42.73)	39.83 (39.12)	46.11 (42.66)	42.69 (40.69)	42.55 (40.72)	46.39
T ₉ - PDKV-SAK-9 25% WP	34.90 (36.15)	46.84 (43.17)	44.83 (42.03)	38.64 (38.39)	45.95 (42.68)	41.64 (40.18)	42.13 (40.47)	46.92
T ₁₀ - PDKV-SAK-9 75% SC	29.85 (33.11)	41.06 (39.84)	40.37 (39.44)	33.40 (35.30)	39.29 (38.79)	33.40 (35.30)	36.23 (37.00)	54.36
T ₁₁ - PDKV-SGd-1 25% WP	22.36 (28.17)	30.98 (33.81)	29.34 (32.68)	27.10 (31.36)	27.06 (31.29)	26.27 (30.83)	27.18 (31.41)	65.75
T ₁₂ - PDKV-SGd-1 75% SC	26.28 (30.76)	39.54 (38.94)	36.12 (36.82)	32.75 (34.88)	36.57 (37.20)	34.40 (35.70)	34.28 (35.81)	56.81
T ₁₃ - PDKV-SGn-4 25% WP	46.42 (42.92)	52.26 (46.33)	50.01 (45.00)	45.52 (42.38)	50.69 (45.41)	49.73 (44.84)	49.10 (44.48)	38.13
T ₁₄ - PDKV-SGn-4 75% SC	49.06 (44.45)	50.18 (45.10)	49.11 (44.48)	43.88 (41.48)	49.64 (44.79)	48.82 (44.32)	48.45 (44.11)	38.96
T ₁₅ - PDKV-SGn-5 25% WP	53.87 (47.26)	57.31 (49.33)	53.87 (47.26)	49.52 (44.72)	53.87 (47.26)	52.68 (46.57)	53.52 (47.05)	32.57
T ₁₆ - PDKV-SGn-5 75% SC	51.90 (46.10)	55.70 (48.29)	51.90 (46.10)	48.86 (44.34)	53.23 (46.86)	51.90 (46.10)	52.25 (46.30)	34.17
T ₁₇ - PDKV-SBn-2 25% WP	47.30 (43.43)	51.43 (45.83)	50.11 (45.06)	44.56 (41.86)	50.70 (45.40)	49.47 (44.69)	48.93 (44.38)	38.36
T ₁₈ - PDKV-SBn-2 75% SC	54.28 (47.51)	56.62 (48.89)	54.15 (47.44)	50.35 (45.20)	54.15 (47.39)	53.56 (47.05)	53.85 (47.24)	32.15
T ₁₉ - PDKV-I-3 25% WP	37.75 (37.86)	47.34 (43.47)	46.44 (42.91)	40.08 (39.21)	46.00 (42.70)	44.16 (41.63)	43.63 (41.31)	45.03
T ₂₀ - PDKV-I-3 75% SC	33.67 (35.47)	44.67 (41.93)	43.26 (41.12)	36.62 (37.22)	43.26 (41.12)	39.20 (38.75)	40.11 (39.29)	49.46
T ₂₁ - PDKV-SY-4 25% WP	21.80 (27.82)	20.55 (26.95)	24.23 (29.46)	23.59 (29.01)	24.47 (29.61)	22.69 (28.42)	22.89 (28.56)	71.17
T ₂₂ - PDKV-SY-4 75% SC	23.27 (28.84)	34.85 (36.14)	31.97 (34.35)	28.96 (32.53)	28.96 (32.53)	28.96 (32.53)	29.49 (32.86)	62.84
T ₂₃ - Delfin	21.64 (27.63)	23.64 (29.03)	23.48 (28.93)	24.33 (29.50)	23.67 (29.00)	24.16 (29.43)	23.49 (28.93)	70.41
T ₂₄ - Chlorpyrifos 20% EC	17.80 (24.92)	26.05 (30.67)	20.10 (26.64)	20.27 (26.76)	22.42 (28.25)	20.71 (27.03)	21.22 (27.43)	73.26
T ₂₅ - Control	68.85 (56.08)	71.77 (58.00)	78.02 (62.24)	82.02 (66.19)	84.92 (67.18)	90.65 (72.29)	79.37 (62.99)	0.00
F test	SIG	SIG	SIG	SIG	SIG	SIG	SIG	
SE±(m)	3.24	3.58	3.50	3.22	3.39	3.26	2.25	
CD at 5%	9.46	10.44	10.21	9.40	9.90	9.52	9.52	
CV	12.36	12.23	12.19	11.86	11.81	11.58	8.03	

*Figures in parentheses are corresponding arc sin transformation

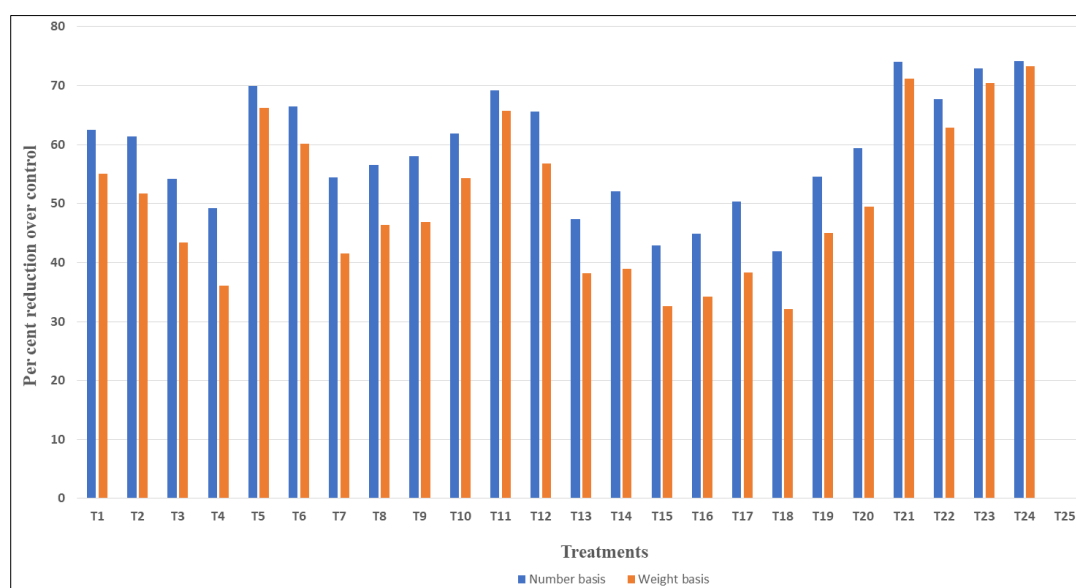


Fig 1: Percent reduction in the number and weight of baits under different treatments (T₁-T₂₅) compared with the control

Effect of PDKV *Bacillus thuringiensis* formulations on yield of brinjal fruits

The fruit yield of brinjal differed significantly among the treatments (Table 4), indicating the effectiveness of different PDKV *Bt* formulations in reducing fruit damage caused by *Leucinodes orbonalis*. Among all the treatments, Chlorpyrifos 20 EC @ 1 L/ha (T₂₄) recorded the highest fruit yield (432.84 q/ha) and was statistically at par with PDKV-SY-4 25% WP @ 1 kg/ha (T₂₁) (429.56 q/ha), commercial *Bt* formulation (Delfin) @ 1 kg/ha (T₂₃) (427.93 q/ha), PDKV-SA-20 25% WP @ 1 kg/ha (T₅) (418.35 q/ha), PDKV-SGd-1 25% WP @ 1 kg/ha (T₁₁) (415.38 q/ha), PDKV-SY-4 75% SC @ 1 L/ha (T₂₂) (408.83 q/ha), PDKV-SA-20 75% SC @ 1 L/ha (T₆) (407.74 q/ha) and PDKV-SGd-1 75% SC @ 1 L/ha (T₁₂) (405.60 q/ha). These treatments produced significantly higher fruit yield than the remaining treatments and were the most effective in minimizing fruit borer damage.

The next group of treatments comprising PDKV-SA-6 25% WP (T₁) (400.30 q/ha), PDKV-SAK-9 75% SC (T₁₀) (395.48 q/ha), PDKV-SA-6 75% SC (T₂) (391.47 q/ha), PDKV-I-3 75% SC (T₂₀) (387.65 q/ha), PDKV-SAK-9 25% WP (T₉) (382.24 q/ha), PDKV-SAK-6 75% SC (T₈) (378.32 q/ha), PDKV-I-3 25% WP (T₁₉) (373.51 q/ha), PDKV-SA-18 25% WP (T₃) (368.10 q/ha) and PDKV-SAK-6 25% WP (T₇) (359.47 q/ha) recorded moderate fruit yield and were significantly superior to the untreated control.

Comparatively lower fruit yield was recorded in PDKV-SGn-4 75% SC (T₁₄) (353.37 q/ha), PDKV-SBn-2 25% WP (T₁₇) (346.28 q/ha), PDKV-SGn-4 25% WP (T₁₃) (340.43 q/ha), PDKV-SA-18 75% SC (T₄) (324.50 q/ha), PDKV-SGn-5 75% SC (T₁₆) (310.22 q/ha), PDKV-SGn-5 25% WP (T₁₅) (298.51 q/ha) and PDKV-SBn-2 75% SC (T₁₈) (291.02 q/ha). Although these treatments produced comparatively lower yields than the superior formulations, they still recorded significantly higher fruit yield than the untreated control.

Among the indigenous PDKV *Bt* formulations, PDKV-SY-4 25% WP @ 1 kg/ha proved to be the most promising formulation for enhancing fruit yield. The formulations commercial *Bt* (Delfin) @ 1 kg/ha, PDKV-SA-20 25% WP, PDKV-SGd-1 25% WP, PDKV-SY-4 75% SC, PDKV-SA-20 75% SC and PDKV-SGd-1 75% SC were statistically at par with PDKV-SY-4 25% WP. Furthermore, PDKV-SY-4 25% WP, commercial *Bt* (Delfin), PDKV-SA-20 25% WP, PDKV-SGd-1 25% WP and PDKV-SY-4 75% SC were also statistically at par with the chemical check, Chlorpyrifos 20 EC @ 1 L/ha. The highest yield recorded in T₂₄ Chlorpyrifos 20 EC is similar with the finding of Sahu *et al.*, (2017) ^[11] who reported that among the treatments the Chlorpyrifos 20 EC found superior over all the treatments. Minimum per cent infestation (10.05%) and highest yield of (350 q/ha.) were recorded in Chlorpyrifos against Brinjal shoot and fruit borer (*L. orbonalis*) on Brinjal.

Table 4: Effect of PDKV *Bacillus thuringiensis* formulations on yield of brinjal fruits

Treatments	Yield of brinjal fruits(q/ha)	Increase in yield over control (%)
T ₁ - PDKV-SA-6 25% WP	400.30	128.48
T ₂ - PDKV-SA-6 75% SC	391.47	123.44
T ₃ - PDKV-SA-18 25% WP	368.10	110.11
T ₄ - PDKV-SA-18 75% SC	324.50	85.22
T ₅ - PDKV-SA-20 25% WP	418.35	138.79
T ₆ - PDKV-SA-20 75% SC	407.74	132.73
T ₇ - PDKV-SAK-6 25% WP	359.47	105.18
T ₈ - PDKV-SAK-6 75% SC	378.32	115.94
T ₉ - PDKV-SAK-9 25% WP	382.24	118.18
T ₁₀ - PDKV-SAK-9 75% SC	395.48	125.74
T ₁₁ - PDKV-SGd-1 25% WP	415.38	137.09
T ₁₂ - PDKV-SGd-1 75% SC	405.60	131.51
T ₁₃ - PDKV-SGn-4 25% WP	340.43	94.31
T ₁₄ - PDKV-SGn-4 75% SC	353.37	101.70
T ₁₅ - PDKV-SGn-5 25% WP	298.51	70.39
T ₁₆ - PDKV-SGn-5 75% SC	310.22	77.07
T ₁₇ - PDKV-SBn-2 25% WP	346.28	97.65
T ₁₈ - PDKV-SBn-2 75% SC	291.02	66.11
T ₁₉ - PDKV-I-3 25% WP	373.51	113.19
T ₂₀ - PDKV-I-3 75% SC	387.65	121.26
T ₂₁ - PDKV-SY-4 25% WP	429.56	145.19
T ₂₂ - PDKV-SY-4 75% SC	408.83	133.35
T ₂₃ - Delfin	427.93	144.25
T ₂₄ - Chlorpyrifos 20% EC	432.84	147.06
T ₂₅ - Control	175.20	0.00
F test	SIG	-
SE±(m)	1.27	-
CD at 5%	3.70	-
CV (%)	22.87	-

Conclusion

The present investigation demonstrated that the indigenous *Bt* formulations developed at Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV) possess considerable potential for the eco-friendly management of the brinjal shoot and fruit borer,

Leucinodes orbonalis, under field conditions. All the *Bt* formulations significantly suppressed fruit infestation compared with the untreated control, thereby confirming their effectiveness as biological alternatives for managing this destructive pest. Among the formulations evaluated, PDKV-SY-4 25% WP @ 1

kg/ha emerged as the most effective indigenous *Bt* formulation, consistently recording the lowest fruit damage on both number and weight basis while producing a higher marketable fruit yield. Its performance was statistically comparable with the commercial *Bt* formulation (Delfin) as well as the recommended chemical insecticide, Chlorpyrifos 20 EC @ 1 L/ha.

In addition, the indigenous formulations PDKV-SGd-1 25% WP, PDKV-SY-4 75% SC, PDKV-SA-20 25% WP and PDKV-SA-20 75% SC also exhibited promising field performance by effectively reducing fruit borer infestation and significantly enhancing fruit yield over the untreated control. Although their efficacy was marginally lower than that of PDKV-SY-4 25% WP, these formulations consistently provided satisfactory control of *L. orbonalis*, highlighting their potential as effective indigenous biopesticides. Their adoption could contribute to reducing dependence on conventional chemical insecticides and promote environmentally safe, residue-free pest management strategies, particularly in Integrated Pest Management (IPM) and organic production systems.

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