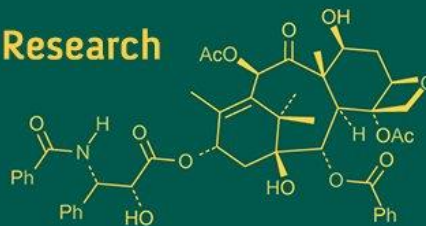
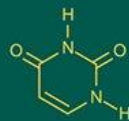


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Bio-efficacy of *Bacillus thuringiensis* formulations against lepidopteran pests of cabbage

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Abstract

A field experiment was conducted during Rabi 2025-26 at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, to evaluate the bio-efficacy of different *Bacillus thuringiensis* (*Bt*) formulations against lepidopteran pests of cabbage, viz., diamondback moth (*Plutella xylostella*) and *Spodoptera litura*. The experiment was conducted in a Randomized Block Design comprising 25 treatments with two replications. The treatments included different PDKV *Bt* strains formulated as wettable powder (WP) and suspension concentrate (SC), a commercial *Bt* formulation (Delfin), quinalphos 25% EC as a chemical standard and an untreated control. Three sprays were applied at 15-day intervals when the pest population reached the economic threshold level, and observations on larval populations were recorded at 7 and 14 days after spraying.

Quinalphos 25% EC @ 1 L ha⁻¹ recorded the lowest larval population of *P. xylostella* and was the most effective treatment. Among the *Bt* formulations, PDKV-SY-4 25% WP @ 1 kg ha⁻¹ showed the most promising performance and was statistically comparable with the chemical standard. Against *S. litura*, quinalphos 25% EC recorded the lowest larval population and was statistically at par with PDKV-SA-20 25% WP @ 1 kg ha⁻¹ and PDKV-SY-4 25% WP @ 1 kg ha⁻¹. The effective *Bt* treatments also resulted in reduced cabbage head damage and increased yield compared with the untreated control. Overall, PDKV-SY-4 25% WP showed promising bio-efficacy against both *P. xylostella* and *S. litura*, indicating its potential as an effective *Bt*-based option for management of major lepidopteran pests of cabbage.

Keywords: *Bacillus thuringiensis*, cabbage, *Plutella xylostella*, *Spodoptera litura*, lepidopteran pests

Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.) is an important vegetable crop of the family Brassicaceae and is widely cultivated for its nutritional and economic value. In India, cabbage was cultivated over 442.33 thousand hectares with a production of 10,431.70 thousand metric tonnes during 2023-24. In Maharashtra, the crop occupied 7.75 thousand hectares with a production of 101.37 thousand metric tonnes during the same period (Anonymous, 2024) [1]. Cabbage is attacked by several insect pests, of which lepidopteran pests are among the most important constraints to production. The diamondback moth (*Plutella xylostella* L.) is considered one of the most destructive pests of cabbage and other cruciferous crops, while the tobacco caterpillar (*Spodoptera litura* Fabricius) is an important defoliating pest that can cause substantial damage to cabbage foliage. Larval feeding results in loss of leaf area and can consequently reduce crop growth, marketable yield and economic returns.

Management of these pests has largely depended on synthetic insecticides. However, their repeated and indiscriminate use has resulted in problems such as development of insecticide resistance, pest resurgence, pesticide residues and environmental contamination. The development of resistance in *P. xylostella* to several groups of insecticides has further complicated its management. These limitations emphasize the need for effective and sustainable alternatives for the management of lepidopteran pests in cabbage.

Bacillus thuringiensis (*Bt*) is an important microbial insecticide used for the management of lepidopteran larvae. It produces insecticidal crystal (Cry) proteins that become active after ingestion by susceptible larvae and disrupt the midgut epithelium, ultimately causing larval mortality (Nester *et al.*, 2002) [6]. Its target-specific insecticidal activity has made *Bt* an important component of sustainable insect pest management programmes.

At Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola, indigenous Bt strains have been developed and evaluated under laboratory conditions against insect pests. However, their field bio-efficacy against major lepidopteran pests of cabbage has not been adequately evaluated. Further, the performance of Bt under field conditions may vary with the formulation used. Wettable powder (WP) and suspension concentrate (SC) are important formulation types that can influence product stability, application and field performance.

Therefore, the present investigation was undertaken to evaluate the field bio-efficacy of PDKV *Bacillus thuringiensis* formulations against the two important lepidopteran pests of cabbage, namely diamondback moth (*Plutella xylostella* L.) and tobacco caterpillar (*Spodoptera litura* Fabricius), and to assess the comparative performance of different Bt formulations under field conditions.

Materials and Methods

A field experiment was conducted during the Rabi season of 2025-26 at the experimental field of the Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, to evaluate the bio-efficacy of *Bacillus thuringiensis* (Bt) formulations against major lepidopteran pests of cabbage. The experiment was laid out in a Randomized Block Design (RBD) with 25 treatments and two replications. Cabbage variety Royal Ball BC-79 was used for the experiment. The gross plot size was 2.7×1.5 m and the net plot size was 1.8×1.2 m. The crop was planted at a spacing of 60 cm between rows and 45 cm between plants. Transplanting was carried out on 17 December 2025. The experiment comprised different PDKV Bt strains formulated as 25% wettable powder (WP) and 75% suspension concentrate (SC). The WP and SC formulations were applied at 1 kg ha^{-1} and 1 L ha^{-1} , respectively. Delfin @ 1 kg ha^{-1} was included as a standard Bt formulation, while Quinalphos 25% EC @ 1 L ha^{-1} was used as a chemical insecticide treatment. An untreated control was also maintained. The complete treatment structure consisted of 25 treatments.

Preparation of Bt formulations

Local *Bacillus thuringiensis* isolates, previously isolated and screened for insecticidal activity at the Department of Entomology, Dr. PDKV, Akola, were subcultured and maintained on Luria broth medium. The PDKV Bt strains were subsequently developed into wettable powder (WP) and suspension concentrate (SC) formulations at the Department of Entomology. The WP formulation was prepared following the method described by Marzaban *et al.* (2021) [5], whereas the SC formulation was prepared according to the method of Vimla Devi *et al.* (2014) [8]. The prepared formulations were used for field evaluation against *Plutella xylostella* and *Spodoptera litura* on cabbage.

Three applications of the respective treatments were made at 15-day intervals. The first spray was applied when the pest population reached the economic threshold level (ETL), followed by two subsequent applications at 15-day intervals. The bio-efficacy of the treatments was evaluated against diamondback moth (*Plutella xylostella*) and *Spodoptera litura*. Pre-treatment observations were recorded before each spray, while post-treatment observations were recorded at 7 and 14 days after treatment (DAT).

For both *Plutella xylostella* and *Spodoptera litura*, five plants were selected randomly from each treatment plot for recording larval population. Pre-treatment observations were recorded before each spray, while post-treatment observations were recorded at 7 and 14 days after treatment (DAT). The number of larvae present on the selected plants was recorded, and the mean larval population per plant was calculated for statistical analysis.

Results and Discussion

Bio-efficacy of Bt formulations against diamondback moth, *Plutella xylostella* L

The field evaluation revealed significant differences among the treatments in their ability to suppress the larval population of *Plutella xylostella*. After three sprays, the cumulative mean larval population varied considerably among the treatments. The untreated control recorded the highest larval population of 5.30 larvae plant⁻¹, whereas the lowest population was recorded in the chemical standard T₂₄ (Quinalphos 25% EC) with 1.58 larvae plant⁻¹. Among the Bt formulations, T₂₁ (PDKV-SY-4 25% WP) was the most effective, recording 1.78 larvae plant⁻¹ and 66.42% reduction over the untreated control. It was followed by T₁₂ (PDKV-SGd-1 75% SC) with 1.95 larvae plant⁻¹ (63.21% reduction), T₂₃ (commercial Bt formulation, Delfin) with 2.08 larvae plant⁻¹ (60.75% reduction) and T₂₂ (PDKV-SY-4 75% SC) with 2.27 larvae plant⁻¹ (57.17% reduction). The remaining Bt formulations produced progressively lower levels of suppression.

The superior performance of T₂₁ indicates that PDKV-SY-4 25% WP had the highest larvicidal efficacy among the Bt formulations tested against *P. xylostella*. The difference in performance among formulations may be associated with variation in the biological activity and formulation characteristics of the Bt preparations, which can influence deposition, persistence and ingestion by the larvae. The effectiveness observed in the present study is consistent with earlier findings that Bt formulations can substantially suppress *P. xylostella* populations on cabbage. Voltukhov (1975) [10] reported effective suppression of DBM by a Bt-based formulation, while Krishnaiah *et al.* (1981) [3] demonstrated that Dipel provided effective control comparable with conventional insecticides. Similarly, Raut and Simon (2010) [7] reported significant reduction of DBM infestation with *B. thuringiensis* var. *kurstaki* under field conditions.

The present findings are also supported by field and laboratory studies demonstrating the effectiveness of Bt against DBM. Commercial Bt formulations have been reported to effectively reduce *P. xylostella* larval populations and increase cabbage yield, while different Bt formulations have shown differences in their relative efficacy. Thus, the present results demonstrate that PDKV-SY-4 25% WP has promising potential for the management of Diamondback moth (*P. xylostella*) under field conditions.

Bio-efficacy of Bt formulations against *Spodoptera litura* Fabricius

Significant differences were also observed among the treatments in suppressing the larval population of *Spodoptera litura*. The cumulative mean larval population in the untreated control was 2.90 larvae plant⁻¹. The chemical standard T₂₄ (Quinalphos 25% EC) recorded the lowest population of 0.77 larvae plant⁻¹ (73.45% reduction over control). Among the Bt formulations, T₅ (PDKV-SA-20 25%

WP) and T21 (PDKV-SY-4 25% WP) were equally effective, each recording 0.97 larvae plant⁻¹ and 66.55% reduction over the untreated control. They were followed by T11 (PDKV-SGd-1 25% WP) with 0.98 larvae plant⁻¹ (66.21% reduction), T12 (PDKV-SGd-1 75% SC) with 1.00 larvae plant⁻¹ (65.52% reduction), T6 (PDKV-SA-20 75% SC) with 1.02 larvae plant⁻¹ (64.83% reduction), T23 (Delfin) with 1.05 larvae plant⁻¹, and T22 (PDKV-SY-4 75% SC) with 1.08 larvae plant⁻¹.

The comparable performance of T₅ and T₂₁ indicates that both formulations had strong activity against *S. litura*. The results further show that the response of *S. litura* was not identical to that of *P. xylostella*, indicating that Bt formulations may differ in efficacy according to the target pest. This variation is biologically relevant because susceptibility to Bt formulations can differ among lepidopteran species and larval stages. Earlier studies included in the present review also support the activity of Bt against *S. litura*. Venkadasubramanian and David (1999) also reported effective suppression of *S. litura* by commercial Bt products, while Martinez *et al.* (2004) [4] found differences in the relative performance of Bt formulations against *S. litura*.

The present field results therefore confirm that Bt formulations, particularly PDKV-SA-20 25% WP and PDKV-SY-4 25% WP, can substantially suppress *S. litura* populations on cabbage. Their performance against this pest demonstrates the potential of native Bt formulations as biological tools for management of lepidopteran pests.

Effect of Bt formulations on cabbage yield

Significant differences were observed among treatments with respect to cabbage head yield. The untreated control produced the lowest yield of 158.02 q ha⁻¹. The highest yield was recorded in T₂₄ (Quinalphos 25% EC) with 294.63 q ha⁻¹, followed by T₂₁ (PDKV-SY-4 25% WP) with 292.35 q ha⁻¹, representing an 85.01% increase over the untreated control. Other treatments producing comparatively high yields included T₁₁ (PDKV-SGd-1 25% WP) with 284.44 q ha⁻¹, T₁₂ (PDKV-SGd-1 75% SC) with 284.20 q ha⁻¹, T₂₂ (PDKV-SY-4 75% SC) with 269.63 q ha⁻¹, T₂₃ (Delfin) with 259.75

q ha⁻¹, T₅ (PDKV-SA-20 25% WP) with 259.63 q ha⁻¹ and T₆ (PDKV-SA-20 75% SC) with 256.05 q ha⁻¹. The treatment effect on yield was statistically significant

The higher yield obtained from Bt-treated plots can be attributed primarily to reduced larval feeding and consequently lower crop damage during head formation and development. The performance of T₂₁ was particularly noteworthy because it combined effective suppression of both major lepidopteran pests with low head damage and high cabbage yield. Although the chemical standard produced the numerically highest yield, the yield obtained with T₂₁ was statistically comparable with several of the better-performing treatments according to the experimental comparison.

The present results are in agreement with earlier reports that Bt application can reduce lepidopteran infestation and improve cabbage yield. Voltukhov (1975) [10] reported a 17-18% increase in cabbage yield following application of a Bt-based formulation against *P. xylostella*, while Justin *et al.* (1990) [2] observed improved crop yield with Bt treatment. Field evaluation of Bt formulations against DBM has also demonstrated increased cabbage yield following effective pest suppression.

Taken together, the results demonstrate that the tested Bt formulations differed considerably in their field performance against the two major lepidopteran pests of cabbage. PDKV-SY-4 25% WP (T₂₁) emerged as the most consistently effective Bt formulation, producing the lowest cumulative DBM population among the Bt treatments, a high level of suppression of *S. litura*, the lowest Bt-associated head damage and a high cabbage yield of 292.35 q ha⁻¹. For *S. litura*, PDKV-SA-20 25% WP (T₅) and PDKV-SY-4 25% WP (T₂₁) were equally effective based on cumulative larval population.

The overall pattern indicates that effective suppression of *P. xylostella* and *S. litura* by Bt formulations resulted in reduced head damage and consequently greater cabbage yield. Therefore, the present investigation demonstrates the potential of selected PDKV Bt formulations, particularly PDKV-SY-4 25% WP, for managing important lepidopteran pests of cabbage under field conditions.

Table 1: Effect of PDKV *Bacillus thuringiensis* formulations on larval population of *Plutella xylostella* on cabbage

Treatment	larval population of <i>Plutella xylostella</i> (No/plant) after							cumulative mean larval population (no/plant)	Per cent over control
	pre treatment	1 st spray		2 nd spray		3 rd spray			
		7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS		
T1-PDKV-SA-6 25% WP	5.3 (2.4)*	3.4 (1.97)	3 (1.86)	4.3 (2.19)	3.6 (2.02)	1.5 (1.41)	1.2 (1.3)	2.83 (1.79)	46.6
T2- PDKV-SA-6 75% SC	5 (2.34)	3.6 (2.02)	3.7 (2.05)	4.9 (2.32)	4.3 (2.19)	1.7 (1.48)	1.3 (1.34)	3.25 (1.9)	38.68
T3- PDKV-SA-18 25% WP	5.3 (2.4)	3.9 (2.1)	4.1 (2.14)	5.2 (2.39)	4.7 (2.28)	2 (1.58)	1.4 (1.37)	3.55 (1.98)	33.02
T4- PDKV-SA-18 75% SC	5.3 (2.41)	4.1 (2.13)	4.3 (2.19)	5.4 (2.41)	4.7 (2.28)	2 (1.58)	1.6 (1.45)	3.68 (2)	30.57
T5-PDKV-SA-20 25% WP	5.8 (2.5)	3.2 (1.92)	2.7 (1.79)	4.1 (2.14)	3.1 (1.89)	1.2 (1.3)	1 (1.21)	2.55 (1.71)	51.89
T6-PDKV-SA-20 75% SC	5.3 (2.4)	3.4 (1.97)	2.8 (1.81)	4.3 (2.19)	3.4 (1.97)	1.4 (1.38)	1.1 (1.25)	2.73 (1.76)	48.49
T7-PDKV-SAk-6 25% WP	6 (2.55)	4.3 (2.18)	4.4 (2.21)	5.5 (2.44)	4.8 (2.3)	2 (1.58)	1.6 (1.45)	3.73 (2.02)	29.62
T8-PDKV-SAk-6 75% SC	5.3 (2.41)	3.8 (2.07)	3.9 (2.1)	5 (2.32)	4.5 (2.19)	1.9 (1.55)	1.3 (1.34)	3.4 (1.93)	35.85
T9-PDKV-SAk-9 25% WP	5.5 (2.45)	3.6 (2.02)	3.4 (1.97)	4.7 (2.28)	4.1 (2.14)	1.6 (1.45)	1.2 (1.3)	3.1 (1.86)	41.51
T10-PDKV-SAk-9 75% SC	5 (2.34)	3.4 (1.97)	3.3 (1.94)	4.5 (2.23)	3.8 (2.04)	1.5 (1.41)	1.2 (1.29)	2.95 (1.81)	44.34

T11-PDKV-SGd-1 25% WP	4.5 (2.23)	3.1 (1.9)	2.5 (1.73)	4 (2.12)	2.9 (1.83)	1 (1.22)	1 (1.22)	2.42 (1.67)	54.34
T12-PDKV-SGd-1 75% SC	5 (2.34)	2.3 (1.67)	1.9 (1.55)	3.4 (1.97)	2.4 (1.7)	0.9 (1.18)	0.8 (1.14)	1.95 (1.54)	63.21
T13-PDKV-SGn-4 25% WP	5.5 (2.45)	4.7 (2.28)	4.9 (2.32)	5 (2.34)	6 (2.54)	1.8 (1.52)	1.4 (1.38)	3.97 (2.06)	25.09
T14-PDKV-SGn-4 75% SC	5 (2.34)	4.5 (2.23)	4.3 (2.19)	5.5 (2.44)	4.9 (2.32)	2 (1.58)	1.6 (1.45)	3.8 (2.03)	28.3
T15-PDKV-SGn-5 25% WP	5.2 (2.39)	4.9 (2.32)	4.9 (2.32)	5.2 (2.38)	6 (2.54)	1.8 (1.52)	1.4 (1.38)	4.03 (2.08)	23.96
T16-PDKV-SGn-5 75% SC	4.8 (2.3)	5.2 (2.38)	4.8 (2.3)	5.2 (2.38)	6.4 (2.62)	1.4 (1.38)	1.4 (1.38)	4.07 (2.07)	23.21
T17-PDKV-SBn-2 25% WP	5.5 (2.44)	4.9 (2.32)	4.9 (2.32)	5 (2.34)	6 (2.54)	1.8 (1.52)	1.4 (1.38)	4 (2.07)	24.53
T18-PDKV-SBn-2 75% SC	5 (2.34)	4.9 (2.32)	4.9 (2.32)	5.2 (2.38)	6.4 (2.62)	1.8 (1.52)	1.4 (1.38)	4.1 (2.09)	22.64
T19-PDKV-I-3 25% WP	4.9 (2.31)	4.6 (2.26)	4.8 (2.3)	4.9 (2.32)	5.9 (2.52)	1.8 (1.52)	1.4 (1.38)	3.9 (2.05)	26.42
T20-PDKV-I-3 75% SC	4.5 (2.23)	4.5 (2.23)	4.6 (2.26)	5.7 (2.48)	4.9 (2.32)	2 (1.58)	1.6 (1.45)	3.87 (2.05)	26.98
T21-PDKV-SY-4 25% WP	4.9 (2.32)	2.1 (1.61)	1.8 (1.52)	3.1 (1.89)	2.1 (1.61)	0.8 (1.14)	0.8 (1.14)	1.78 (1.48)	66.42
T22-PDKV-SY-4 75% SC	4.5 (2.24)	2.7 (1.78)	2.2 (1.62)	3.8 (2.07)	2.9 (1.83)	1 (1.22)	1 (1.22)	2.27 (1.62)	57.17
T23 (Delfin)	4.9 (2.32)	2.3 (1.67)	2.1 (1.61)	3.6 (2.02)	2.7 (1.79)	0.9 (1.18)	0.9 (1.18)	2.08 (1.57)	60.75
T24-Quinolpos 25% EC	5.5 (2.44)	2 (1.58)	1.7 (1.47)	2.8 (1.82)	1.9 (1.55)	0.6 (1.04)	0.5 (1)	1.58 (1.41)	70.19
T25- Untreated Control	5.2 (2.37)	5.8 (2.51)	6.2 (2.59)	6.8 (2.7)	7.2 (2.77)	3.5 (2)	2.3 (1.67)	5.3 (2.37)	-
'F' Test	NS	SIG	SIG	SIG	SIG	SIG	SIG	SIG	
SE (m) +	0.14	0.12	0.10	0.12	0.19	0.08	0.08	0.05	
C.D. (5%)	0.41	0.35	0.29	0.36	0.54	0.24	0.23	0.14	
C. V.	8.37	8.16	6.93	7.75	12.07	8.27	8.29	3.45	

* Figures in parenthesis are corresponding square root transformation value. DAS-Day after spraying

Table 2: Effect of PDKV *Bacillus thuringiensis* formulations on larval population of *Spodoptera litura* (Fab.) on cabbage

Treatment	larval population of <i>Spodoptera litura</i> (No/plant)							cumulative mean larval Population (no/plant)	Per cent reduction over control
	pre treatment	1 st spray		2 nd spray		3 rd spray			
		7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS		
T1-PDKV-SA-6 25% WP	1.5 (1.41)*	1.1 (1.26)	1.9 (1.55)	1 (1.22)	1.5 (1.4)	0.8 (1.14)	0.7 (1.09)	1.17 (1.28)	59.66
T2- PDKV-SA-6 75% SC	1.8 (1.51)	1.4 (1.38)	2.5 (1.73)	1.8 (1.52)	2 (1.58)	1.7 (1.48)	1.7 (1.47)	1.85 (1.53)	36.21
T3- PDKV-SA- 18 25% WP	1.9 (1.55)	1.6 (1.45)	2.1 (1.61)	1.2 (1.3)	1.2 (1.3)	0.7 (1.09)	0.7 (1.09)	1.25 (1.31)	56.90
T4- PDKV-SA- 18 75% SC	1.9 (1.55)	1.7 (1.48)	1.6 (1.45)	1.2 (1.3)	0.9 (1.18)	0.7 (1.09)	0.7 (1.09)	1.13 (1.27)	61.03
T5-PDKV-SA-20 25% WP	1.5 (1.41)	1 (1.22)	1.2 (1.29)	1.1 (1.26)	1 (1.22)	0.8 (1.14)	0.7 (1.09)	0.97 (1.2)	66.55
T6-PDKV-SA-20 75% SC	1.9 (1.55)	1.2 (1.29)	1.3 (1.34)	1.2 (1.3)	1 (1.22)	0.7 (1.09)	0.7 (1.09)	1.02 (1.22)	64.83
T7-PDKV-SAk-6 25% WP	1.6 (1.45)	1.4 (1.38)	1.9 (1.55)	1.6 (1.45)	1.4 (1.37)	1 (1.22)	0.8 (1.14)	1.35 (1.35)	53.45
T8-PDKV-SAk-6 75% SC	1.6 (1.43)	1.4 (1.38)	1.9 (1.55)	1.6 (1.44)	1.4 (1.38)	1 (1.22)	0.8 (1.14)	1.35 (1.35)	53.45
T9-PDKV-SAk-9 25% WP	2.1 (1.6)	1.7 (1.48)	1.6 (1.45)	1.8 (1.52)	1.2 (1.3)	1 (1.22)	0.6 (1.05)	1.32 (1.34)	54.48
T10-PDKV-SAk- 9 75% SC	1.5 (1.41)	1.3 (1.34)	2.1 (1.6)	1.3 (1.34)	1.8 (1.52)	0.9 (1.18)	0.8 (1.14)	1.37 (1.35)	52.76
T11-PDKV-SGd- 1 25% WP	1.8 (1.52)	1.4 (1.37)	1.4 (1.38)	1 (1.22)	0.7 (1.09)	0.7 (1.09)	0.7 (1.09)	0.98 (1.21)	66.21
T12-PDKV-SGd- 1 75% SC	1.7 (1.48)	1 (1.22)	1.5 (1.41)	0.9 (1.18)	0.9 (1.18)	0.9 (1.18)	0.8 (1.14)	1 (1.22)	65.52
T13-PDKV-SGn- 4 25% WP	1.8 (1.52)	1.6 (1.45)	1.5 (1.4)	1.2 (1.3)	1.1 (1.26)	0.8 (1.14)	0.7 (1.09)	1.15 (1.27)	60.34
T14-PDKV-SGn- 4 75% SC	2.1 (1.6)	1.8 (1.52)	2.3 (1.67)	1.4 (1.38)	1.7 (1.48)	0.9 (1.18)	0.8 (1.14)	1.48 (1.4)	48.97

T15-PDKV-SGn-5 25% WP	1.9 (1.55)	1.3 (1.34)	1.4 (1.38)	1.2 (1.29)	1 (1.22)	0.9 (1.18)	0.8 (1.14)	1.1 (1.26)	62.07
T16-PDKV-SGn-5 75% SC	1.8 (1.51)	1.6 (1.45)	1.5 (1.41)	1.2 (1.29)	1.1 (1.26)	0.8 (1.14)	0.6 (1.05)	1.13 (1.27)	61.03
T17-PDKV-SBn-2 25% WP	1.5 (1.41)	1.6 (1.45)	1.6 (1.45)	1.6 (1.45)	1 (1.22)	0.8 (1.14)	0.7 (1.09)	1.22 (1.3)	57.93
T18-PDKV-SBn-2 75% SC	1.5 (1.41)	1.6 (1.45)	1.6 (1.45)	1.6 (1.45)	1 (1.22)	0.8 (1.14)	0.7 (1.09)	1.22 (1.3)	57.93
T19-PDKV-I-3 25% WP	1.9 (1.54)	1.8 (1.52)	1.8 (1.52)	1.5 (1.41)	1.7 (1.48)	1.1 (1.26)	0.9 (1.18)	1.47 (1.4)	49.31
T20-PDKV-I-3 75% SC	1.8 (1.52)	1 (1.22)	1.9 (1.55)	1.6 (1.45)	1.7 (1.48)	0.8 (1.14)	0.7 (1.09)	1.28 (1.32)	55.86
T21-PDKV-SY-4 25% WP	2 (1.58)	1.2 (1.3)	1.4 (1.38)	0.9 (1.18)	0.9 (1.18)	0.7 (1.09)	0.7 (1.09)	0.97 (1.2)	66.55
T22-PDKV-SY-4 75% SC	1.6 (1.45)	1.5 (1.41)	1.4 (1.38)	1.4 (1.38)	0.8 (1.14)	0.7 (1.09)	0.7 (1.09)	1.08 (1.25)	62.76
T23-(Delfin)	1.8 (1.52)	1.5 (1.41)	1.5 (1.41)	1.3 (1.34)	0.8 (1.14)	0.6 (1.05)	0.6 (1.05)	1.05 (1.23)	63.79
T24-Quinolpos 25% EC	1.7 (1.47)	0.8 (1.14)	1 (1.22)	0.9 (1.18)	0.8 (1.14)	0.6 (1.05)	0.5 (1)	0.77 (1.12)	73.45
T25- Untreated Control	1.6 (1.45)	1.8 (1.52)	2.3 (1.67)	2.7 (1.79)	3.2 (1.92)	3.6 (2.02)	3.8 (2.07)	2.9 (1.83)	0.00
'F' Test	NS	SIG	SIG	SIG	SIG	SIG	SIG	SIG	
SE (m) $\pm$	0.11	0.07	0.08	0.07	0.08	0.07	0.07	0.02	
C.D. (5%)	0.31	0.21	0.23	0.21	0.23	0.19	0.20	0.06	
C. V.	9.99	7.48	7.52	7.54	8.58	7.73	8.49	2.27	

* Figures in parenthesis are corresponding square root transformation value. DAS Day after spraying

Table 3: Effect of PDKV *Bacillus thuringiensis* formulations on infestation of lepidopteran pests on cabbage on number basis

Treatment	Head damage (%) on number basis at harvest due to <i>P.xylostella</i> and <i>S.litura</i>	
	Mean	Per cent reduction over control
T1-PDKV-SA-6 25% WP	25 (29.89)*	54.55
T2- PDKV-SA-6 75% SC	35 (36.22)	36.36
T3- PDKV-SA-18 25% WP	30 (33.21)	45.45
T4- PDKV-SA-18 75% SC	25 (29.89)	54.55
T5-PDKV-SA-20 25% WP	20 (26.57)	63.64
T6-PDKV-SA-20 75% SC	20 (26.57)	63.64
T7-PDKV-SAk-6 25% WP	30 (33.21)	45.45
T8-PDKV-SAk-6 75% SC	30 (33.21)	45.45
T9-PDKV-SAk-9 25% WP	25 (29.89)	54.55
T10-PDKV-SAk-9 75% SC	25 (29.89)	54.55
T11-PDKV-SGd-1 25% WP	15 (22.5)	72.73
T12-PDKV-SGd-1 75% SC	15 (22.5)	72.73
T13-PDKV-SGn-4 25% WP	35 (36.22)	36.36
T14-PDKV-SGn-4 75% SC	40 (39.23)	27.27
T15-PDKV-SGn-5 25% WP	30 (33.21)	45.45
T16-PDKV-SGn-5 75% SC	35 (36.22)	36.36
T17-PDKV-SBn-2 25% WP	40 (39.23)	27.27
T18-PDKV-SBn-2 75% SC	45 (42.12)	18.18
T19-PDKV-I-3 25% WP	40 (39.23)	27.27
T20-PDKV-I-3 75% SC	45 (42.12)	18.18
T21-PDKV-SY-4 25% WP	10 (18.43)	81.82
T22-PDKV-SY-4 75% SC	20 (26.57)	63.64
T23-(Delfin)	20 (26.57)	63.64
T24-Quinolpos 25% EC	10 (18.43)	81.82
T25- Untreated Control	55 (47.88)	0.00
'F' Test	SIG	
SE (m) $\pm$	2.19	
C.D. (5%)	6.38	
C. V.	9.67	

*Figures in parentheses indicate corresponding arc sine transformed values

Table 4: Effect of PDKV *Bacillus thuringiensis* formulations on infestation of lepidopteran pests on cabbage on weight basis.

Treatment	Head damage (%) on weight basis at harvest due to	Per cent reduction over control
	<i>Plutella xylostella</i> and <i>Spodoptera litura</i>	
T1-PDKV-SA-6 25% WP	14.75 (22.58)	60.70
T2- PDKV-SA-6 75% SC	23.45 (28.8)	37.52
T3- PDKV-SA-18 25% WP	16.65 (24.02)	55.64
T4- PDKV-SA-18 75% SC	15.24 (22.85)	59.39
T5-PDKV-SA-20 25% WP	12.37 (20.56)	67.04
T6-PDKV-SA-20 75% SC	13.57 (21.59)	63.84
T7-PDKV-SAk-6 25% WP	18.73 (25.61)	50.09
T8-PDKV-SAk-6 75% SC	18.26 (25.26)	51.35
T9-PDKV-SAk-9 25% WP	14.05 (22)	62.56
T10-PDKV-SAk-9 75% SC	15.49 (23.17)	58.73
T11-PDKV-SGd-1 25% WP	7.48 (15.69)	80.07
T12-PDKV-SGd-1 75% SC	7.56 (15.78)	79.86
T13-PDKV-SGn-4 25% WP	19.79 (26.33)	47.27
T14-PDKV-SGn-4 75% SC	28.36 (32.07)	24.43
T15-PDKV-SGn-5 25% WP	21.79 (27.83)	41.94
T16-PDKV-SGn-5 75% SC	21.22 (27.22)	43.46
T17-PDKV-SBn-2 25% WP	25.85 (30.54)	31.12
T18-PDKV-SBn-2 75% SC	30.48 (33.38)	18.78
T19-PDKV-I-3 25% WP	30.36 (33.32)	19.10
T20-PDKV-I-3 75% SC	29.73 (32.92)	20.78
T21-PDKV-SY-4 25% WP	6.39 (14.59)	82.97
T22-PDKV-SY-4 75% SC	10.88 (19.24)	71.01
T23-(Delfin)	11.97 (20.24)	68.11
T24-Quinolpos 25% EC	6.19 (14.36)	83.51
T25- Untreated Control	37.53 (37.72)	0.00
'F' Test	SIG	-
SE (m) +	1.80	-
C.D. (5%)	5.26	-
C. V.	10.32	-

*Figures in parentheses indicate corresponding arc sine transformed values

Table 5: Effect of *Bacillus thuringiensis* formulation on yield of cabbage.

Treatment	Yield of cabbage heads at harvest		Increase in yield over control (%)
	(kg /plot)	(q/ha)	
T1-PDKV-SA-6 25% WP	9.93	245.19	55.16
T2- PDKV-SA-6 75% SC	8.26	203.83	28.99
T3- PDKV-SA-18 25% WP	9.55	235.68	49.15
T4- PDKV-SA-18 75% SC	9.98	246.30	55.87
T5-PDKV-SA-20 25% WP	10.52	259.63	64.30
T6-PDKV-SA-20 75% SC	10.37	256.05	62.04
T7-PDKV-SAk-6 25% WP	9.25	228.27	44.46
T8-PDKV-SAk-6 75% SC	9.24	228.02	44.30
T9-PDKV-SAk-9 25% WP	10.40	256.79	62.50
T10-PDKV-SAk-9 75% SC	9.66	238.40	50.87
T11-PDKV-SGd-1 25% WP	11.52	284.44	80.00
T12-PDKV-SGd-1 75% SC	11.51	284.20	79.85
T13-PDKV-SGn-4 25% WP	9.25	228.27	44.46
T14-PDKV-SGn-4 75% SC	7.65	188.89	19.54
T15-PDKV-SGn-5 25% WP	9.00	222.10	40.55
T16-PDKV-SGn-5 75% SC	8.98	221.73	40.32
T17-PDKV-SBn-2 25% WP	7.85	193.83	22.66
T18-PDKV-SBn-2 75% SC	7.30	180.25	14.07
T19-PDKV-I-3 25% WP	7.38	182.10	15.24
T20-PDKV-I-3 75% SC	7.20	177.78	12.50
T21-PDKV-SY-4 25% WP	11.84	292.35	85.01
T22-PDKV-SY-4 75% SC	10.92	269.63	70.63
T23-(Delfin)	10.52	259.75	64.38
T24-Quinolpos 25% EC	11.93	294.63	86.45
T25- Untreated Control	6.4	158.02	0.00
'F' Test	SIG	SIG	
SE (m) ±	0.44	10.91	
C.D. (5%)	1.29	31.84	
C. V.	6.61	6.61	

Conclusion

The study demonstrated the efficacy of *Bacillus thuringiensis* (Bt) formulations against major lepidopteran pests of cabbage, *Plutella xylostella* and *Spodoptera litura*. Among the indigenous formulations, PDKV-SY-4 25% WP @ 1 kg ha⁻¹ was the most effective, recording lower pest infestation and higher head yield, comparable with Delfin and quinalphos 25% EC. Economically, it was the most promising indigenous Bt formulation. Thus, PDKV-SY-4 25% WP can be considered a potential Bt-based component of integrated management of lepidopteran pests in cabbage.

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