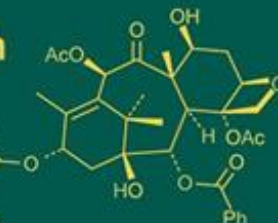
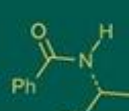
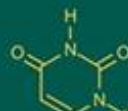
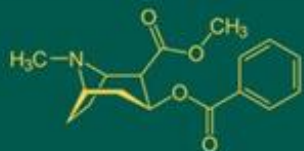


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Evaluation of eco-friendly management strategies against *Helicoverpa armigera* in tomato under the agro-ecological conditions of Jamtara district (Jharkhand)

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Abstract

Tomato (*Solanum lycopersicum* L.) is one of the most economically important vegetable crops of Jharkhand, but its productivity is heavily constrained by the fruit borer *Helicoverpa armigera*. The present investigation was conducted during 2023–24 and 2024–25 at farmers fields of the Jamtara district to evaluate the efficacy of bio-insecticides and their combinations against *H. armigera* under field conditions. Eight treatments comprising NSKE, Ha. NPV, *Bacillus thuringiensis* (Bt), their combinations, alternated sprays, and water control were evaluated in a Randomized Block Design with three replications. Four sprays were applied at 15-day intervals beginning 15 days after transplanting (DAT). Observations on larval population were recorded at 24 h before spray and 3, 7, 10, 15 days after spraying. Results revealed that Bt (T6) consistently recorded the lowest larval population across spray schedules, followed by alternate spraying of Ha. NPV and Bt (T7). NSKE in combination with Ha. NPV + Bt (T3) also exhibited superior suppression compared to NSKE alone. Control plots (T8) recorded the highest larval infestation. The study concludes that Bt alone or its alternate application with Ha. NPV provides effective eco-friendly management of *H. armigera* in tomato under Jamtara conditions.

Keywords: Tomato, *helicoverpa armigera*, nske, ha. npv, *bacillus thuringiensis*, biological control, eco-friendly pest management

1. Introduction

Tomato (*Solanum lycopersicum* L.) is a highly valued solanaceous vegetable in India and plays a significant role in the livelihood of small and marginal farmers in Jharkhand. However, its productivity is severely affected by insect pests, of which the tomato fruit borer, *Helicoverpa armigera* (Hubner), is the most destructive. The larvae feed voraciously on flowers and fruits, leading to yield losses up to 55% (Singh *et al*, 2017) [1]. Sometimes losses in yield may reach 60-70% also (Ghosal *et al.*, 2016) [2]

Indiscriminate use of synthetic insecticides has resulted in resistance development, resurgence, residue hazards, and negative impacts on beneficial insects (Kranthi *et al.*, 2002 & Rahman *et al.*, 2014) [3]. Therefore, biological control agents such as Neem Seed Kernel Extract (NSKE), *Helicoverpa armigera* Nucleopolyhedrosis Virus (Ha.NPV), and *Bacillus thuringiensis* (Bt) have emerged as environmentally safe and sustainable alternatives.

However, the efficacy of these agents varies with local climatic conditions, application schedule, and pest load. Hence, location-specific validation is essential. The present study was conducted to evaluate the effectiveness of bio-pesticides and their combinations under the agro-climatic conditions of Jamtara district.

2. Materials and Methods

Field experiments were conducted at farmers' fields in Jamtara district, Jharkhand, during 2023–24 and 2024–25 to evaluate the efficacy of various biopesticides and their combinations against *Helicoverpa armigera* on tomato. The tomato variety Swarn Baibhav was transplanted on 4 September 2023 and 1 September 2024. The experiment was laid out in a Randomized Block Design (RBD) consisting of eight treatments replicated three times, with a total of four insecticidal sprays applied at 15-day intervals, beginning 15 days after transplanting. Observations on larval population were recorded at 24 hours before spray and at 3, 7, 10, and 15 days after each spray. The treatments included: T₁-NSKE (5%) × four sprays + Ha.NPV × last two sprays; T₂-NSKE ×

four sprays + Bt × last two sprays; T₃- NSKE × four sprays + Ha.NPV (3rd spray) + Bt (4th spray); T₄-NSKE× four sprays; T₅- Ha.NPV × four sprays; T₆-Bt× four sprays; T₇ – alternate sprays of Ha.NPV and Bt; and T₈ – control (water spray). Data recorded over both years were pooled and subjected to $\sqrt{(x + \alpha)}$ (0.5) transformation whenever required, and the analysis of variance (ANOVA) was performed at the 5% level of significance, with critical difference (CD) values used to compare treatment

Table 1: Impact of different bio-insecticides on larval mortality of *Helicoverpa armigera* observed after 1st spray during the experimental year 2023-24 & 2024-25 (Pooled Value)

	Treatment detail	Larval Population of <i>H. armigera</i> per plant after 1 st Spray		
		24 hrs before, 3 DAS, 7 DAS, 10 DAS	15 DAS	
T ₁	Four spray of NSKE @ 5%+ two spray of Ha.NPV (1x10 ⁹ PIB/ml)	0	0.64 (1.07)	
T ₂	Four spray of NSKE @ 5%+ two spray of Bt. (1x10 ¹¹ cfu/gram)	0	0.52 (1.01)	
T ₃	Four spray of NSKE @ 5% + 3 rd spray of Ha.NPV (1x10 ⁹ PIB/ml) + 4 th spray of Bt. (1x10 ¹¹ cfu/gram)	0	0.49 (1.00)	
T ₄	Four spray of NSKE @ 5%	0	0.53 (1.01)	
T ₅	Four spray of Ha.NPV (1x10 ⁹ PIB/ml)	0	0.43 (0.96)	
T ₆	Four spray Bt. (1x10 ¹¹ cfu/gram)	0	0.33 (0.91)	
T ₇	Four alternate spray of Ha.NPV (1x10 ⁹ PIB/ml) and Bt. (1x10 ¹¹ cfu/gram)	0	0.39 (0.95)	
T ₈	Control (Four spray of plain water)	0	0.63 (1.06)	
	C.D. (P= 0.05%)		0.070	

Legend: Figure in parentheses are square root transformed

Following the second spray (Table.2), Bt (T₆) again exhibited the highest level of suppression with a mean larval population of 0.31 larvae per plant and was statistically superior to all other treatments, while alternate sprays (T₇) remained the next best with 0.35 larvae per plant, and combinations such as NSKE + Bt (T₂) and NSKE+Ha . NPV+Bt (T₃)

recorded significantly lower larval counts than the untreated control, thereby confirming the continued superiority of Bt during the second spray cycle.

During the third spray (Table.3), which coincided with relatively higher pest pressure, Bt (T₆) maintained its effectiveness by recording 0.93 larvae per plant, followed by treatments T₇ and T₂, whereas NSKE alone (T₄) and the control (T₈) registered considerably higher infestations, highlighting the advantage of Bt-based treatments under increased pest density.

After the fourth spray (Table. 4), even at later crop stages, Bt (T₆) again recorded the lowest larval population (1.26 larvae per plant), followed by alternate sprays of Ha.NPV and Bt (T₇) and the NSKE + Bt combination (T₂), while the control treatment exhibited the highest larval incidence (mean 4.4 larvae per plant), reflecting natural pest buildup in the absence

3. Results and Discussion

The pooled results from both years revealed that after the first spray, Bt alone (T₆) recorded the lowest larval population of *H. armigera* (0.33 larvae per plant), followed by alternate sprays of Ha.NPV and Bt (T₇) and Ha.NPV alone (T₅), while NSKE-based combinations produced a moderate reduction and the control showed 0.63 larvae per plant, indicating that Bt was the most effective treatment at the initial stage (Table.1).

of treatment. Overall, a consistent trend was observed in which Bt alone (T₆) and the alternate use of Ha.NPV and Bt (T₇) outperformed all other treatments across all four spray schedules, demonstrating superior and sustained suppression of *H. armigera*.

These findings are supported by earlier studies, including Kumar *et al.* (2021) ^[4], who reported the high efficacy of *Bacillus thuringiensis* against *Helicoverpa armigera* and highlighted enhanced larval mortality when Bt was combined with neem-based biopesticides; Rabindra and Jayaraj (1988) ^[5], who emphasized the effectiveness of Ha.NPV as a biological control agent; Rahman *et al.* (2014) ^[6], who demonstrated that alternating applications of Ha.NPV and Bt effectively reduced fruit infestation and increased tomato yield, and Reddy and Chowdary (2021) ^[7], who highlighted that integrating botanical and microbial biopesticides in IPM helps improve pest suppression while minimizing the risk of resistance development. Neem (NSKE) showed moderate suppression but performed better when used in combination with Bt or Ha.NPV, and the alternate spraying of Ha.NPV and Bt (T₇) proved particularly beneficial for maintaining long-term suppression and preventing resurgence of the pest population.

Table 2: Impact of different bio-insecticides on larval mortality of *Helicoverpa armigera* observed after 2nd spray during the experimental year 2023-24 & 2024-25 (Pooled Value)

	Treatment detail	No. of Larva 24 hrs before	Larval Population of <i>H. armigera</i> per plant after 2 nd Spray				
			3 DAS	7 DAS	10 DAS	15 DAS	Mean
T ₁	Four spray of NSKE @ 5%+ two spray of Ha.NPV (1x10 ⁹ PIB/ml)	0.52 (1.01)	0.36 (0.93)	0.52 (1.01)	0.75 (1.12)	1.16 (1.29)	0.70 (1.09)
T ₂	Four spray of NSKE @ 5%+ two spray of Bt. (1x10 ¹¹ cfu/gram)	0.52 (1.01)	0.42 (0.96)	0.46 (0.98)	0.69 (1.09)	1.09 (1.26)	0.67 (1.07)
T ₃	Four spray of NSKE @ 5% + 3 rd spray of Ha.NPV (1x10 ⁹ PIB/ml) + 4 th spray of Bt. (1x10 ¹¹ cfu/gram)	0.44 (0.97)	0.36 (0.93)	0.52 (1.01)	0.71 (1.10)	1.01 (1.23)	0.65 (1.07)
T ₄	Four spray of NSKE @ 5%	0.56 (1.03)	0.36 (0.93)	0.48 (0.99)	0.62 (1.06)	0.96 (1.21)	0.61 (1.05)
T ₅	Four spray of Ha.NPV (1x10 ⁹ PIB/ml)	0.42 (0.96)	0.36 (0.93)	0.46 (0.98)	0.58 (1.04)	0.85 (1.16)	0.56 (1.03)
T ₆	Four spray Bt. (1x10 ¹¹ cfu/gram)	0.33 (0.91)	0.16 (0.81)	0.16 (0.81)	0.29 (0.89)	0.64 (1.07)	0.31 (0.89)
T ₇	Four alternate spray of Ha.NPV (1x10 ⁹ PIB/ml) and Bt. (1x10 ¹¹ cfu/gram)	0.40 (0.95)	0.19 (0.83)	0.16 (0.81)	0.35 (0.92)	0.71 (1.10)	0.35 (0.92)
T ₈	Control (Four spray of plain water)	0.56 (1.03)	0.75 (1.12)	0.85 (1.16)	1.04 (1.24)	1.43 (1.39)	1.02 (1.23)
	C.D. (P= 0.05%)	0.048	0.059	0.092	0.067	0.059	

Legend: Figure in parentheses are square root transformed

Table 3: Impact of diferent bio-insecticides on larval mortality of *Helicoverpa armigera* observed after 3rd spray during the experimental year 2023-24 & 2024-25 (Pooled Value)

	Treatment detail	No. of Larva	Larval Population of <i>H. armigera</i> per plant after 3 rd Spray				
			24 hrs before	3 DAS	7 DAS	10 DAS	15 DAS
T ₁	Four spray of NSKE @ 5%+ two spray of Ha.NPV (1x10 ⁹ PIB/ml)	1.16 (1.29)	0.82 (1.15)	0.87 (1.17)	1.43 (1.39)	1.78 (1.51)	1.23 (1.31)
T ₂	Four spray of NSKE @ 5%+ two spray of Bt. (1x10 ¹¹ cfu/gram)	1.09 (1.26)	0.73 (1.11)	0.62 (1.06)	0.96 (1.21)	1.49 (1.41)	0.95 (1.20)
T ₃	Four spray of NSKE @ 5% + 3 rd spray of Ha.NPV (1x10 ⁹ PIB/ml) + 4 th spray of Bt. (1x10 ¹¹ cfu/gram)	1.04 (1.24)	0.75 (1.12)	0.82 (1.15)	1.35 (1.36)	1.66 (1.47)	1.15 (1.27)
T ₄	Four spray of NSKE @ 5%	0.96 (1.21)	0.82 (1.15)	1.11 (1.27)	1.66 (1.47)	2.06 (1.60)	1.41 (1.37)
T ₅	Four spray of Ha.NPV (1x10 ⁹ PIB/ml)	0.82 (1.15)	0.87 (1.17)	0.92 (1.19)	1.35 (1.36)	1.78 (1.51)	1.23 (1.31)
T ₆	Four spray Bt. (1x10 ¹¹ cfu/gram)	0.64 (1.07)	0.80 (1.14)	0.50 (1.00)	0.92 (1.19)	1.49 (1.41)	0.93 (1.18)
T ₇	Four alternate spray of Ha.NPV (1x10 ⁹ PIB/ml) and Bt. (1x10 ¹¹ cfu/gram)	0.71 (1.10)	0.87 (1.17)	0.75 (1.12)	1.01 (1.23)	1.54 (1.43)	1.04 (1.24)
T ₈	Control (Four spray of plain water)	1.40 (1.38)	1.75 (1.50)	2.12 (1.62)	2.67 (1.78)	3.11 (1.90)	2.41 (1.70)
	C.D. (P= 0.05%)	0.091	0.053	0.16	0.199	0.093	

Legend: Figure in parentheses are square root transformed

Table 4: Impact of diferent bio-insecticides on larval mortality of *Helicoverpa armigera* observed after 4th spray during the experimental year 2023-24 & 2024-25 (Pooled Value)

Treatment detail		No. of Larva	Larval Population of <i>H. armigera</i> per plant after 4th Spray				
			24 hrs before	3 DAS	7 DAS	10 DAS	15 DAS
T1	Four spray of NSKE @ 5%+ two spray of Ha.NPV (1x109 PIB/ml)	1.81 (1.52)	1.49 (1.41)	1.19 (1.30)	1.90 (1.55)	2.56 (1.75)	1.78 (1.50)
T2	Four spray of NSKE @ 5%+ two spray of Bt. (1x1011 cfu/gram)	1.49 (1.41)	1.24 (1.32)	0.78 (1.13)	1.01 (1.23)	2.12 (1.62)	1.29 (1.30)
T3	Four spray of NSKE @ 5% + 3rd spray of Ha.NPV (1x109 PIB/ml) + 4th spray of Bt. (1x1011 cfu/gram)	1.66 (1.47)	1.30 (1.34)	0.85 (1.16)	1.57 (1.44)	2.46 (1.72)	1.54 (1.41)
T4	Four spray of NSKE @ 5%	2.06 (1.60)	1.52 (1.42)	1.87 (1.54)	2.22 (1.65)	2.81 (1.82)	2.10 (1.61)
T5	Four spray of Ha.NPV (1x109 PIB/ml)	1.78 (1.51)	1.60 (1.45)	1.46 (1.40)	1.93 (1.56)	2.70 (1.79)	1.92 (1.55)
T6	Four spray Bt. (1x1011 cfu/gram)	1.46 (1.40)	1.01 (1.23)	0.69 (1.09)	1.35 (1.36)	2.00 (1.58)	1.26 (1.31)
T7	Four alternate spray of Ha.NPV (1x109 PIB/ml) and Bt. (1x1011 cfu/gram)	1.52 (1.42)	1.27 (1.33)	0.71 (1.10)	1.49 (1.41)	2.16 (1.63)	1.41 (1.37)
T8	Control (Four spray of plain water)	3.07 (1.89)	3.58 (2.02)	4.17 (2.16)	4.70 (2.28)	5.15 (2.38)	4.40 (2.21)
	C.D. (P= 0.05%)	0.100	0.131	0.292	0.350	0.160	

Legend: Figure in parentheses are square root transformed

4. Conclusion

The results from two consecutive years clearly indicate that:

- Bt (T₆) at 2 g/litre applied at 15-day intervals was the most effective and consistent treatment for suppressing *H. armigera* larval populations.
- Alternate sprays of Ha.NPV and Bt (T₇) also provided significantly effective and ecofriendly control.
- NSKE-based combinations offered moderate protection but were inferior to Bt.
- Control plots showed heavy infestation, proving the necessity of interventions.

Therefore, Bt alone or in alternation with Ha.NPV is recommended as an eco-friendly and effective strategy for tomato fruit borer management under the agro-climatic conditions of Jamtara, Jharkhand.

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