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Effect of sowing windows on larval population dynamics of *Helicoverpa armigera* in chickpea under protected and unprotected conditions

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Abstract

Larval population of *H. armigera* was significantly lower under protected conditions (P_1) (1.12 and 0.94 larvae m^{-1}) than under unprotected conditions (P_2) (2.98 and 3.25 larvae m^{-1}) during 2023 and 2024, respectively. The varieties exhibited only marginal differences in larval incidence, with Phule Vikram (V_1) recording slightly lower larval population than Vijay (V_2). Irrespective of treatments, larval population increased from the vegetative stage, reached a peak between 49 and 63 DAS, and declined thereafter towards crop maturity. Among the sowing windows, early sowing (41 MW) consistently recorded the lowest larval infestation, whereas sowing during 45 MW (S3) resulted in the highest larval population.

Keywords: *Helicoverpa armigera*, Population dynamics, larvae/m row length, chickpea, sowing windows

1. Introduction

Chickpea (*Cicer arietinum* L.) is an important pulse crop cultivated worldwide and serves as a major source of dietary protein, particularly in India. However, its productivity is severely constrained by insect pests, among which the gram pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae), is the most destructive. The pest is highly polyphagous, feeding on more than 180 host plant species, and causes severe damage by feeding on flowers and developing pods, resulting in yield losses ranging from 30–40%, which may exceed 80% under favourable conditions (Fitt, 1989; Sehgal and Ujagir, 1990; War *et al.*, 2024) ^[3, 7, 9]. The population buildup of *H. armigera* is largely influenced by crop phenology and prevailing weather conditions, making sowing time a crucial cultural practice for minimizing infestation (Shah and Shahzad, 2005; Meena and Bhatia, 2014) ^[8, 5]. Therefore, the present study was conducted to evaluate the influence of different sowing windows, varieties, and protection regimes on the seasonal dynamics of the larval population of *H. armigera* in chickpea under field conditions.

2. Materials and Methods

2.1 Experimental site

The field experiment was conducted during *Rabi* 2023 and 2024 at the Department of Agricultural Meteorology Farm, Centre of Advanced Faculty Training (CAFT) in Agricultural Meteorology, College of Agriculture, Pune, Maharashtra State (India).

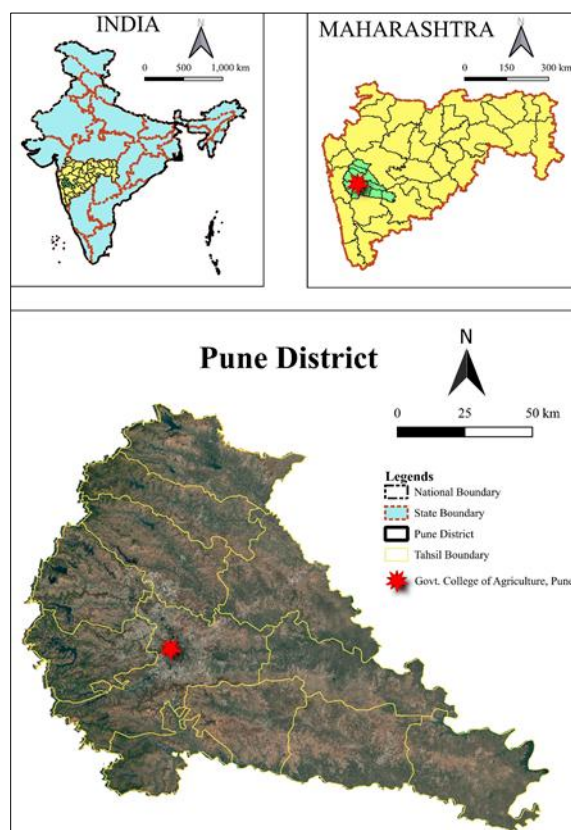


Fig 1: Study area

(Department of Agricultural Meteorology Farm, Govt. College of Agriculture, Pune)

2.2 Experimental details

The experiment was conducted in a split-split-plot design with three replications and sixteen treatment combinations considering different protection, varieties, and sowing windows.

2.3 Number of larvae per meter row length (mrl⁻¹)

The larval population of pod borer was recorded at a weekly interval on one meter row length at three spots selected randomly in each plot from the first appearance till harvesting of the crop in the early morning hours without disturbing the flora and fauna. (Protection - Flubendiamide 480 SC (39.35% w/w) @ 0.4 mL/L will be applied at the ETL level)

3. Results and Discussion

3.1 Number of larvae per meter row length (mrl⁻¹)

The data on larval population per meter row length (mrl⁻¹), as influenced by various treatments, are presented in Table 1 and graphically illustrated in Figure 2 for the cropping seasons of 2023 and 2024. A progressive rise in larval count (mrl⁻¹) was observed from 28 DAS (0.44 and 0.30) to a maximum at 63 DAS (2.05 and 2.09), followed by a subsequent decline towards harvest (0.21 and 0.25) during 2023 and 2024, respectively.

3.1.1 Effect of protection treatments

The results revealed that protection treatments exerted a significant influence on larval population during most of the crop growth stages in both 2023 and 2024 (Table 1). The mean number of larvae per meter row length (mrl⁻¹) increased with the advancement of chickpea age. Statistically, the highest mean number of larvae per meter row length (mrl⁻¹) registered under unprotected conditions was 2.98 and 3.25, whereas under protected conditions (Flubendiamide 480 SC @ 0.4mL/L) it was

1.12 and 0.94 at 63 DAS during the years 2023 and 2024, respectively. During the early stages (28 to 42 DAS), the mean number of larvae per meter row length (mrl⁻¹) remained statistically at par between protected (P₁) and unprotected (P₂) plots, indicating minimal infestation in the vegetative phase. A pronounced peak in larval population was recorded around 70 DAS, with the mean number of larvae reaching 2.35 mrl⁻¹ in unprotected plots as against only 0.52 mrl⁻¹ in protected plots. Thereafter, a sharp decline was observed towards harvest, with the lowest infestation recorded at 90 DAS (0.34 and 0.12 larvae mrl⁻¹ in unprotected and protected plots, respectively).

The lower larval incidence under protected conditions (Flubendiamide 480 SC @ 0.4mL/L) can be attributed to its mode of action as a selective phthalic acid diamide insecticide, which targets ryanodine receptors in insect muscles, causing uncontrolled calcium (Ca²⁺) release leading to paralysis and death of larvae. These findings are in agreement with the observations of Dinesh *et al.* (2017) [12], who reported that Flubendiamide-treated plots recorded minimal *H. armigera* infestation and superior pod protection in chickpea compared to untreated controls.

3.1.2 Effect of varieties

The mean number of larvae per meter row length (mrl⁻¹) influenced by varieties was significant at flowering and pod initiation stages of crop growth during the years 2023 and 2024 (Table 54). There was no major fluctuation in the number of larvae per meter row length (mrl⁻¹) among both the varieties. Across all growth stages, variety Phule Vikram (V₁) recorded the lowest number of larvae per meter row length (mrl⁻¹) (0.19 and 0.25) as compared to variety Vijay (V₂) (0.23 and 0.25) at harvest during both years. Thus, the period of increase in the number of larval populations was observed between 28 and 63 DAS, after which a gradual decline occurred towards harvest. (Choudhary *et al.* 2024) [11].

This trend may be due to inherent genetic potential rather than the effect of external weather parameters, which prevailed more or less in a similar range along the growing period of varieties.

3.1.3 Effect of sowing windows

The data presented in Table 1 revealed that the larval population of *H. armigera* was influenced by different sowing windows across the years 2023 and 2024. During the initial stages (28 to 42 DAS), the mean larval population remained low and statistically at par across all sowing windows, indicating minimal pest incidence in the early vegetative phase. This observation is consistent with previous studies, where early larval appearance was recorded only after several weeks of post-sowing (Meena and Bhatia, 2014; Choudhary *et al.*, 2024) [5, 1]. With crop advancement, a gradual increase in larval population was observed between 49 and 63 DAS. Among the sowing windows, S₃ (45 MW) recorded the highest mean larval population (2.25, 2.77 and 2.66 larvae/m row in 2023 at 49, 56 and 63 DAS, respectively), whereas S₁ (41 MW) consistently showed the lowest infestation during these stages. This pattern indicates that mid to late sowing windows (S₃) coincide with more favourable climatic conditions for pest multiplication, such as rising temperatures and relative humidity during the flowering to pod formation stages, in agreement with the findings of Pavani *et al.* (2019) [6] and Shah and Shahzad (2005) [8].

During the later stages of crop growth (70 to 90 DAS), a declining trend in larval population was recorded across all sowing windows, reflecting the natural decline of pest incidence towards crop maturity. The early sown crop (S₁) exhibited the lowest

larval population at 90 DAS (0.12 larvae/m row), whereas the highest infestation was noted in S₃ (0.37 larvae/m row), indicating that late sowings may escape peak pest incidence to some extent but are prone to higher larval buildup during critical reproductive stages. These findings align with observations from *rabi* seasons 2022–23 and 2023–24, where peak *Helicoverpa* populations were recorded during February (7 - 8 MW), following initial appearance in December (49 – 50 MW) (Choudhary *et al.* 2024) [1].

The variation in pest incidence among sowing windows may be attributed to the synchronization of larval activity with crop phenology and prevailing weather conditions, including temperature, relative humidity and rainfall (Kumawat *et al.* 2025) [4]. Early sowings (S₁ and S₂) coincided with relatively lower temperatures during vegetative growth, which suppressed early pest multiplication, whereas mid to late sowings (S₃ and S₄) experienced warmer temperatures and longer sunshine hours, favouring increased pest activity and population buildup.

Table 1: Number of larvae/m row length of chickpea as influenced by different treatments

Treatment	28 DAS			35 DAS			42 DAS		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A) Protection (P)									
P ₁ : Protected	0.44 ^a (0.97)	0.31 ^a (0.90)	0.37 ^a (0.93)	0.86 ^a (1.16)	0.79 ^a (1.14)	0.83 ^a (1.15)	0.93 ^b (1.27)	0.90 ^b (1.21)	0.92 ^b (1.24)
P ₂ : Unprotected	0.44 ^a (0.97)	0.30 ^a (0.91)	0.37 ^a (0.94)	0.87 ^a (1.17)	0.79 ^a (1.15)	0.83 ^a (1.15)	1.52 ^a (1.44)	1.50 ^a (1.35)	1.51 ^a (1.40)
S.E.m. ±	0.00	0.01	0.01	0.01	0.04	0.04	0.01	0.04	0.03
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.06	0.23	0.13
B) Varieties (V)									
V ₁ : Phule Vikram	0.33 ^a (0.91)	0.31 ^a (0.91)	0.32 ^a (0.91)	0.82 ^a (1.15)	0.80 ^a (1.14)	0.81 ^a (1.15)	1.24 ^a (1.30)	1.21 ^a (1.28)	1.23 ^a (1.30)
V ₂ : Vijay	0.34 ^a (1.02)	0.30 ^a (0.89)	0.33 ^a (0.96)	0.91 ^a (1.19)	0.76 ^a (1.13)	0.85 ^a (1.16)	1.21 ^a (1.41)	1.19 ^a (1.27)	1.20 ^a (1.35)
S.E.m. ±	0.01	0.01	0.01	0.04	0.05	0.05	0.04	0.03	0.04
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.15	NS	NS
C) Sowing windows (S)									
S ₁ : 41 MW	0.39 ^a (0.94)	0.25 ^a (0.88)	0.32 ^a (0.91)	0.83 ^a (1.15)	0.78 ^a (1.13)	0.80 ^a (1.14)	0.96 ^c (1.27)	0.92 ^b (1.19)	0.94 ^c (1.23)
S ₂ : 43 MW	0.49 ^a (0.99)	0.34 ^a (0.92)	0.41 ^a (0.95)	0.83 ^a (1.15)	0.77 ^a (1.13)	0.80 ^a (1.14)	1.19 ^b (1.49)	1.41 ^a (1.47)	1.30 ^{ab} (1.48)
S ₃ : 45 MW	0.50 ^a (1.00)	0.30 ^a (0.89)	0.40 ^a (0.95)	0.97 ^a (1.21)	0.84 ^a (1.16)	0.90 ^a (1.18)	1.55 ^a (1.31)	1.23 ^a (1.17)	1.39 ^a (1.24)
S ₄ : 47 MW	0.39 ^a (0.94)	0.33 ^a (0.91)	0.36 ^a (0.93)	0.83 ^a (1.15)	0.79 ^a (1.13)	0.80 ^a (1.14)	1.19 ^b (1.35)	1.25 ^a (1.27)	1.22 ^b (1.31)
S.E.m. ±	0.06	0.03	0.05	0.05	0.05	0.06	0.06	0.05	0.06
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.16	0.13	0.18
Interactions									
P×V									
S.E.m. ±	0.02	0.02	0.03	0.06	0.07	0.07	0.03	0.02	0.03
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	0.09	NS
P×S									
S.E.m. ±	0.08	0.04	0.08	0.07	0.07	0.08	0.07	0.08	0.09
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.21	0.24	0.27
V×S									
S.E.m. ±	0.08	0.04	0.08	0.07	0.07	0.08	0.07	0.08	0.09
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.21	NS	NS
P×V×S									
S.E.m. ±	0.11	0.06	0.11	0.10	0.09	0.11	0.10	0.12	0.13
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.29	0.34	NS
General Mean	0.44 (0.97)	0.30 (0.90)	0.37 (0.93)	0.87 (1.17)	0.79 (1.14)	0.83 (1.15)	1.22 (1.36)	1.20 (1.28)	1.21 (1.32)

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Table 1: Continued..

Treatment	49 DAS			56 DAS			63 DAS		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A) Protection (P)									
P ₁ : Protected	0.52 ^b (1.04)	0.66 ^b (1.07)	0.59 ^b (1.06)	0.84 ^b (1.14)	0.87 ^b (1.12)	0.86 ^b (1.13)	1.12 ^b (1.31)	0.94 ^b (1.17)	1.03 ^b (1.24)
P ₂ : Unprotected	2.61 ^a (1.88)	2.26 ^a (1.66)	2.43 ^a (1.77)	3.26 ^a (2.01)	3.02 ^a (1.88)	3.14 ^a (1.95)	2.98 ^a (1.84)	3.25 ^a (1.94)	3.11 ^a (1.89)
S.E.m. ±	0.02	0.03	0.03	0.02	0.05	0.05	0.02	0.04	0.04
C.D. at 5%	0.11	0.16	0.11	0.12	0.31	0.19	0.10	0.27	0.16
B) Varieties (V)									
V ₁ :	1.40 ^b	1.38 ^a	1.39 ^a	1.93 ^b	1.90 ^a	1.91 ^a	2.14 ^a	1.98 ^b	2.06 ^a

<i>Phule Vikram</i>	(1.50)	(1.40)	(1.45)	(1.61)	(1.53)	(1.57)	(1.63)	(1.57)	(1.60)
V2: <i>Vijay</i>	1.73 ^a (1.54)	1.54 ^a (1.39)	1.64 ^a (1.47)	2.18 ^a (1.66)	2.00 ^a (1.56)	2.09 ^a (1.61)	1.97 ^b (1.56)	2.21 ^a (1.63)	2.09 ^a (1.60)
S.Em. $\pm$	0.03	0.04	0.04	0.05	0.03	0.06	0.06	0.03	0.05
C.D. at 5%	0.11	NS	NS	0.18	NS	NS	0.22	0.10	NS
C) Sowing windows (S)									
S ₁ : 41 MW	1.05 ^c (1.43)	1.08 ^d (1.29)	1.07 ^c (1.36)	1.64 ^c (1.54)	1.39 ^c (1.37)	1.51 ^d (1.46)	1.91 ^b (1.64)	1.69 ^b (1.50)	1.80 ^b (1.57)
S ₂ : 43 MW	1.52 ^b (1.54)	1.55 ^b (1.49)	1.54 ^b (1.51)	2.02 ^b (1.68)	2.16 ^b (1.69)	2.09 ^b (1.69)	2.28 ^a (1.67)	2.53 ^a (1.82)	2.40 ^a (1.75)
S ₃ : 45 MW	2.25 ^a (1.62)	1.83 ^a (1.45)	2.04 ^a (1.54)	2.55 ^a (1.66)	2.77 ^a (1.69)	2.66 ^a (1.67)	2.33 ^a (1.57)	2.64 ^a (1.64)	2.48 ^a (1.61)
S ₄ : 47 MW	1.44 ^b (1.51)	1.37 ^c (1.33)	1.40 ^b (1.42)	2.00 ^b (1.66)	1.47 ^c (1.40)	1.73 ^c (1.54)	1.69 ^c (1.50)	1.53 ^b (1.42)	1.61 ^c (1.46)
S.Em. $\pm$	0.05	0.04	0.06	0.06	0.04	0.06	0.07	0.05	0.07
C.D. at 5%	0.15	0.12	0.17	0.16	0.13	0.18	0.19	0.15	0.21
Interactions									
P×V									
S.Em. $\pm$	0.04	0.03	0.05	0.07	0.04	0.07	0.02	0.04	0.04
C.D. at 5%	0.16	NS	0.15	NS	0.16	NS	0.09	NS	NS
P×S									
S.Em. $\pm$	0.09	0.06	0.10	0.07	0.07	0.09	0.08	0.06	0.08
C.D. at 5%	0.26	0.18	0.27	0.21	0.20	0.25	NS	0.18	0.24
V×S									
S.Em. $\pm$	0.09	0.06	0.10	0.07	0.07	0.09	0.08	0.06	0.08
C.D. at 5%	0.26	0.18	NS	0.21	0.20	0.25	0.22	NS	NS
P×V×S									
S.Em. $\pm$	0.13	0.09	0.13	0.10	0.10	0.12	0.11	0.09	0.12
C.D. at 5%	0.37	0.26	0.38	0.30	0.29	NS	0.32	0.25	NS
General Mean	1.57 (1.52)	1.46 (1.39)	1.51 (1.46)	2.05 (1.63)	1.95 (1.55)	2.00 (1.59)	2.05 (1.60)	2.09 (1.60)	2.07 (1.60)

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Table 1: Continued..

Treatment	70 DAS			77 DAS			84 DAS		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A) Protection (P)									
P ₁ : Protected	0.43 ^b (0.98)	0.62 ^b (1.04)	0.52 ^b (1.01)	1.03 ^a (1.26)	0.90 ^b (1.14)	0.96 ^b (1.20)	0.33 ^b (0.91)	0.35 ^b (0.85)	0.34 ^b (0.88)
P ₂ : Unprotected	1.98 ^a (1.58)	2.72 ^a (1.80)	2.35 ^a (1.69)	1.23 ^a (1.27)	1.69 ^a (1.49)	1.46 ^a (1.39)	0.73 ^a (1.10)	0.75 ^a (1.12)	0.74 ^a (1.11)
S.Em. $\pm$	0.05	0.04	0.05	0.02	0.01	0.02	0.04	0.04	0.04
C.D. at 5%	0.31	0.22	0.21	NS	0.09	0.09	0.22	0.23	0.18
B) Varieties (V)									
V ₁ : <i>Phule Vikram</i>	1.14 ^a (1.32)	1.64 ^a (1.46)	1.39 ^a (1.39)	1.14 ^a (1.32)	1.33 ^a (1.34)	1.23 ^a (1.33)	0.54 ^a (1.02)	0.53 ^a (1.00)	0.53 ^a (1.01)
V ₂ : <i>Vijay</i>	1.27 ^a (1.31)	1.71 ^a (1.48)	1.49 ^a (1.40)	1.12 ^a (1.21)	1.26 ^a (1.31)	1.19 ^a (1.26)	0.52 ^a (0.98)	0.57 ^a (0.99)	0.54 ^a (0.99)
S.Em. $\pm$	0.04	0.03	0.04	0.04	0.03	0.05	0.02	0.03	0.03
C.D. at 5%	NS	NS	NS	0.17	NS	0.15	NS	NS	NS
C) Sowing windows (S)									
S ₁ : 41 MW	1.05 ^b (1.35)	1.08 ^d (1.28)	1.07 ^d (1.32)	1.00 ^b (1.34)	1.08 ^c (1.26)	1.04 ^c (1.30)	0.44 ^b (1.01)	0.42 ^{bc} (0.96)	0.43 ^{bc} (0.98)
S ₂ : 43 MW	1.22 ^b (1.32)	1.86 ^b (1.62)	1.54 ^b (1.48)	1.11 ^b (1.31)	1.55 ^b (1.48)	1.33 ^b (1.40)	0.49 ^b (1.02)	0.55 ^b (1.09)	0.52 ^b (1.06)
S ₃ : 45 MW	1.39 ^a (1.26)	2.44 ^a (1.60)	1.91 ^a (1.44)	1.58 ^a (1.26)	1.72 ^a (1.39)	1.65 ^a (1.32)	0.75 ^a (1.01)	0.83 ^a (1.00)	0.79 ^a (1.00)
S ₄ : 47 MW	1.16 ^b (1.33)	1.30 ^c (1.34)	1.23 ^c (1.34)	0.83 ^c (1.15)	0.83 ^d (1.14)	0.83 ^d (1.15)	0.44 ^b (0.97)	0.39 ^c (0.93)	0.41 ^c (0.95)
S.Em. $\pm$	0.05	0.05	0.06	0.06	0.05	0.06	0.04	0.04	0.05
C.D. at 5%	0.14	0.15	0.17	0.17	0.13	0.18	NS	0.13	0.14
Interactions									
P×V									
S.Em. $\pm$	0.04	0.05	0.05	0.05	0.06	0.06	0.03	0.05	0.05
C.D. at 5%	0.15	0.20	NS	0.18	NS	NS	NS	NS	NS
P×S									
S.Em. $\pm$	0.06	0.07	0.08	0.06	0.08	0.09	0.05	0.07	0.08
C.D. at 5%	0.19	0.21	0.24	0.16	0.24	0.24	0.15	NS	NS

V×S									
S.Em. ±	0.06	0.07	0.08	0.06	0.08	0.09	0.05	0.07	0.08
C.D. at 5%	0.19	0.21	NS	0.16	NS	NS	NS	NS	NS
P×V×S									
S.Em. ±	0.09	0.10	0.12	0.08	0.12	0.12	0.07	0.10	0.11
C.D. at 5%	0.27	NS	NS	0.23	NS	NS	NS	NS	NS
General Mean	1.20 (1.32)	1.67 (1.47)	1.44 (1.39)	1.13 (1.27)	1.30 (1.32)	1.21 (1.30)	0.53 (1.00)	0.55 (0.99)	0.54 (1.00)

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Table 1: Continued..

Treatment	90 DAS		
	2023	2024	Pooled
A) Protection (P)			
P ₁ : Protected	0.11 ^b (0.74)	0.12 ^b (0.73)	0.12 ^b (0.74)
P ₂ : Unprotected	0.32 ^a (0.89)	0.37 ^a (0.94)	0.34 ^a (0.92)
S.Em. ±	0.02	0.04	0.04
C.D. at 5%	0.10	0.24	0.14
B) Varieties (V)			
V ₁ : Phule Vikram	0.19 ^a (0.84)	0.25 ^a (0.85)	0.22 ^a (0.84)
V ₂ : Vijay	0.23 ^a (0.81)	0.25 ^a (0.84)	0.24 ^a (0.82)
S.Em. ±	0.02	0.03	0.03
C.D. at 5%	NS	NS	NS
C) Sowing windows (S)			
S ₁ : 41 MW	0.14 ^a (0.85)	0.11 ^c (0.80)	0.12 ^c (0.82)
S ₂ : 43 MW	0.22 ^a (0.85)	0.28 ^b (0.95)	0.25 ^b (0.91)
S ₃ : 45 MW	0.30 ^a (0.80)	0.44 ^a (0.83)	0.37 ^a (0.82)
S ₄ : 47 MW	0.19 ^a (0.80)	0.17 ^{bc} (0.78)	0.18 ^{bc} (0.79)
S.Em. ±	0.05	0.03	0.04
C.D. at 5%	NS	0.08	0.12
Interactions			
P×V			
S.Em. ±	0.03	0.04	0.04
C.D. at 5%	NS	NS	NS
P×S			
S.Em. ±	0.06	0.06	0.08
C.D. at 5%	NS	NS	NS
V×S			
S.Em. ±	0.06	0.06	0.08
C.D. at 5%	NS	NS	NS
P×V×S			
S.Em. ±	0.09	0.09	0.11
C.D. at 5%	NS	NS	NS
General Mean	0.21 (0.82)	0.25 (0.84)	0.23 (0.84)

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test. NS: Non-significant.

DAS: Days after sowing; P: Protection (P₁: Protected, P₂: Unprotected); V: Variety (V₁: Phule Vikram, V₂: Vijay); S: Sowing windows; MW: Meteorological week; S.Em. ±: Standard error of mean; CD: Critical difference.

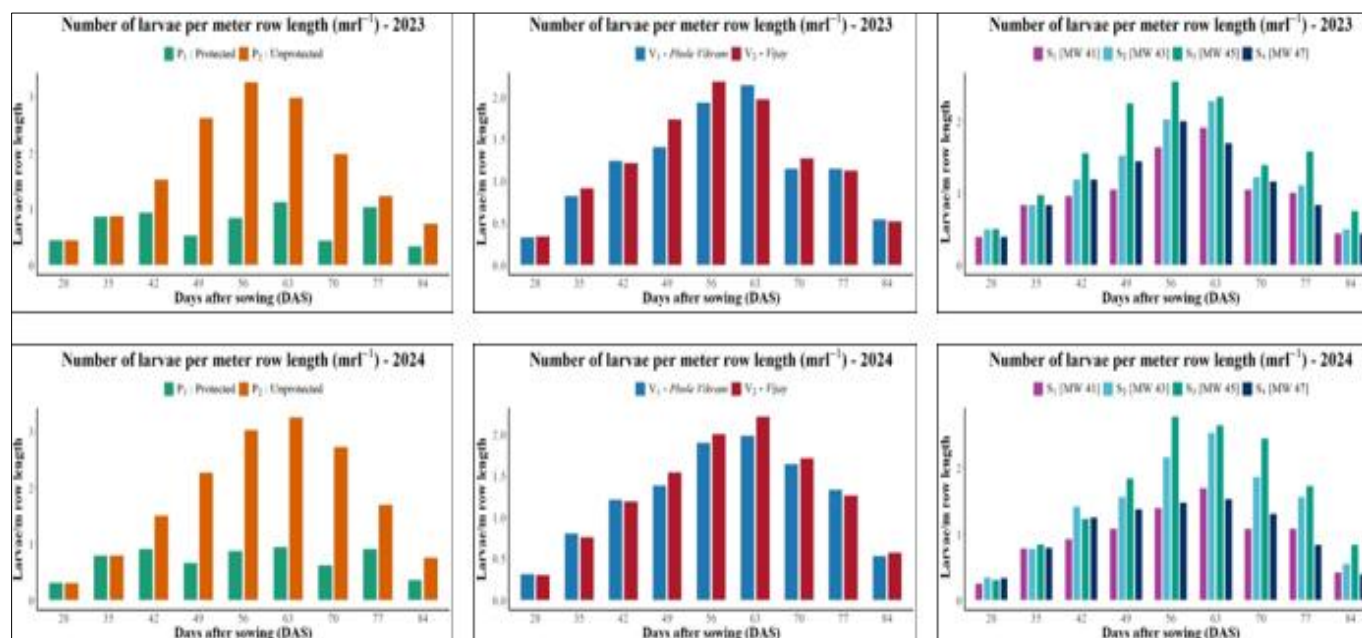


Fig 2: Number of larvae/m row length of chickpea as influenced by different treatments during 2023 and 2024

Table 2: Number of larvae/m row length of chickpea as influenced by the interaction between protection and varieties at 42, 49, 56, 63, 70 and 77 DAS (2023, 2024 and pooled)

Treatments	42 DAS		49 DAS				56 DAS		63 DAS		70 DAS				77 DAS	
Protection	2023		2024		Pooled		2024		2023		2023		2024		2023	
Variety	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂
V ₁ : Phule Vikram	1.01 ^b (1.23)	1.41 ^a (1.38)	0.61 ^c (1.05)	2.19 ^b (1.64)	0.61 ^c (1.05)	2.16 ^b (1.63)	0.89 ^c (1.18)	2.91 ^b (1.85)	1.25 ^b (1.32)	3.03 ^a (1.88)	0.3 ^c (0.9)	1.97 ^a (1.57)	0.66 ^c (1.08)	2.61 ^b (1.76)	1.14 ^b (1.28)	1.14 ^b (1.28)
V ₂ : Vijay	0.80 ^b (1.14)	1.58 ^a (1.44)	0.44 ^c (0.97)	3.03 ^a (1.88)	0.57 ^c (1.03)	2.71 ^a (1.79)	0.86 ^c (1.17)	3.14 ^a (1.91)	1.00 ^c (1.22)	2.94 ^a (1.85)	0.55 ^b (1.03)	2.00 ^a (1.58)	0.58 ^c (1.04)	2.83 ^a (1.82)	0.92 ^c (1.19)	1.33 ^a (1.35)
S. Em. ±	0.02		0.04		0.05		0.04		0.02		0.04		0.05		0.05	
C.D. at 5%	0.09		0.16		0.15		0.16		0.09		0.15		0.20		0.18	

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test.

DAS: Days after sowing; P: Protection (P₁: Protected, P₂: Unprotected); V: Variety (V₁: Phule Vikram, V₂: Vijay); S.Em. ±: Standard error of mean; CD: Critical difference.

Table 3: Number of larvae/m row length of chickpea as influenced by interaction between protection and sowing windows at 42, 49, 56, 63, 70, 77 and 84 DAS (2023, 2024 and pooled)

Treatments	42 DAS						49 DAS						56 DAS					
Protection	2023		2024		Pooled		2023		2024		Pooled		2023		2024		Pooled	
Sowing windows	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂
S ₁ : 41 MW	0.96 ^c (1.21)	0.96 ^c (1.21)	0.94 ^c (1.20)	0.89 ^c (1.18)	0.95 ^c (1.20)	0.92 ^c (1.19)	0.72 ^d (1.10)	1.39 ^c (1.37)	0.67 ^{ef} (1.08)	1.50 ^d (1.41)	0.69 ^e (1.09)	1.44 ^d (1.39)	0.55 ^f (1.03)	2.72 ^c (1.79)	0.61 ^e (1.05)	2.17 ^c (1.63)	0.58 ^g (1.04)	2.44 ^d (1.72)
S ₂ : 43 MW	1.17 ^{bc} (1.29)	1.22 ^b (1.31)	1.39 ^b (1.37)	1.44 ^b (1.39)	1.28 ^b (1.33)	1.33 ^b (1.35)	0.39 ^e (0.94)	2.66 ^b (1.78)	0.50 ^f (1.00)	2.61 ^b (1.76)	0.44 ^f (0.97)	2.63 ^b (1.77)	0.77 ^{ef} (1.13)	3.28 ^b (1.94)	0.72 ^e (1.10)	3.61 ^b (2.03)	0.75 ^{fg} (1.12)	3.44 ^b (1.98)
S ₃ : 45 MW	0.44 ^d (0.97)	2.66 ^a (1.78)	0.40 ^d (0.95)	2.05 ^a (1.60)	0.42 ^d (0.96)	2.36 ^a (1.69)	0.61 ^{de} (1.05)	3.89 ^a (2.09)	0.67 ^{ef} (1.08)	3.00 ^a (1.87)	0.64 ^{ef} (1.07)	3.44 ^a (1.99)	1.16 ^d (1.29)	3.94 ^a (2.11)	1.44 ^d (1.39)	4.11 ^a (2.15)	1.30 ^e (1.34)	4.03 ^a (2.13)
S ₄ : 47 MW	1.17 ^{bc} (1.29)	1.22 ^b (1.31)	0.89 ^c (1.18)	1.61 ^b (1.45)	1.03 ^c (1.23)	1.41 ^b (1.38)	0.39 ^e (0.94)	2.50 ^b (1.73)	0.79 ^e (1.14)	1.94 ^c (1.56)	0.59 ^{ef} (1.04)	2.22 ^c (1.65)	0.88 ^e (1.18)	3.11 ^b (1.90)	0.72 ^e (1.10)	2.22 ^c (1.65)	0.80 ^f (1.14)	2.67 ^c (1.78)
S. Em. ±	0.07		0.08		0.09		0.09		0.06		0.10		0.07		0.07		0.09	
C.D. at 5%	0.21		0.24		0.27		0.26		0.18		0.27		0.21		0.20		0.25	

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test.

DAS: Days after sowing; P: Protection (P₁: Protected, P₂: Unprotected); S: Sowing windows; S.Em. ±: Standard error of mean; CD: Critical difference.

Table 3: Continued..

Treatments	63 DAS				70 DAS						77 DAS						84 DAS	
Protection Sowing windows	2023		Pooled		2023		2024		Pooled		2023		2024		Pooled		2024	
	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂
S ₁ : 41 MW	1.00 ^{de} (1.22)	2.39 ^c (1.70)	1.06 ^e (1.25)	2.55 ^c (1.75)	0.33 ^e (0.91)	1.77 ^c (1.51)	0.33 ^f (0.91)	1.83 ^c (1.53)	0.33 ^e (0.91)	1.80 ^c (1.52)	1.00 ^c (1.22)	1.00 ^c (1.22)	1.06 ^d (1.25)	1.11 ^{cd} (1.27)	1.03 ^c (1.24)	1.06 ^c (1.25)	0.33 ^d (0.91)	0.55 ^{bc} (1.02)
S ₂ : 43 MW	1.17 ^d (1.29)	3.89 ^b (2.09)	1.22 ^d (1.31)	3.58 ^b (2.02)	0.33 ^e (0.91)	2.11 ^b (1.62)	0.50 ^{ef} (1.00)	3.22 ^b (1.93)	0.41 ^e (0.96)	2.66 ^b (1.78)	1.11 ^{bc} (1.27)	1.11 ^{bc} (1.27)	1.11 ^{cd} (1.27)	2.00 ^b (1.58)	1.11 ^c (1.27)	1.55 ^b (1.43)	0.33 ^d (0.91)	0.65 ^b (1.07)
S ₃ : 45 MW	0.83 ^e (1.15)	4.44 ^a (2.22)	1.11 ^{de} (1.27)	3.86 ^a (2.09)	0.33 ^e (0.91)	2.44 ^a (1.71)	1.05 ^d (1.25)	3.83 ^a (2.08)	0.69 ^d (1.09)	3.13 ^a (1.91)	1.28 ^b (1.33)	1.89 ^a (1.54)	1.11 ^{cd} (1.27)	2.33 ^a (1.68)	1.19 ^c (1.30)	2.11 ^a (1.61)	0.44 ^{cd} (0.97)	1.06 ^a (1.25)
S ₄ : 47 MW	0.78 ^e (1.13)	2.28 ^c (1.67)	0.75 ^f (1.12)	2.47 ^c (1.72)	0.72 ^d (1.10)	1.61 ^c (1.45)	0.61 ^e (1.05)	2.00 ^c (1.58)	0.67 ^d (1.08)	1.80 ^c (1.52)	0.72 ^d (1.10)	0.94 ^c (1.20)	0.34 ^e (0.91)	1.33 ^c (1.35)	0.53 ^d (1.01)	1.14 ^c (1.28)	0.22 ^{de} (0.85)	0.66 ^b (1.08)
S. Em. ±	0.06		0.08		0.06		0.07		0.08		0.06		0.08		0.09		0.05	
C.D. at 5%	0.18		0.24		0.19		0.21		0.24		0.16		0.24		0.24		0.15	

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test.

DAS: Days after sowing; P: Protection (P₁: Protected, P₂: Unprotected); S: Sowing windows; S.Em. ±: Standard error of mean; CD: Critical difference.

Table 4: Number of larvae/m row length of chickpea as influenced by the interaction between varieties and sowing windows at 42, 49, 56, 63, 70 and 77 DAS (2023, 2024 and pooled)

Treatments	42 DAS		49 DAS				56 DAS						63 DAS	
Variety Sowing windows	2023		2023		2024		2023		2024		Pooled		2023	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₁	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
S ₁ : 41 MW	0.92 ^e (1.19)	1.00 ^{de} (1.22)	1.00 ^c (1.22)	1.11 ^c (1.27)	1.17 ^c (1.29)	1.00 ^c (1.22)	1.44 ^d (1.39)	1.83 ^c (1.53)	1.22 ^e (1.31)	1.55 ^d (1.43)	1.33 ^e (1.35)	1.69 ^d (1.48)	2.00 ^{bc} (1.58)	1.83 ^c (1.53)
S ₂ : 43 MW	1.11 ^{cde} (1.27)	1.28 ^{bc} (1.33)	1.22 ^c (1.31)	1.83 ^b (1.53)	1.50 ^b (1.41)	1.61 ^b (1.45)	2.00 ^c (1.58)	2.05 ^c (1.60)	2.05 ^c (1.60)	2.27 ^b (1.67)	2.02 ^c (1.59)	2.16 ^c (1.63)	2.33 ^a (1.68)	2.22 ^{ab} (1.65)
S ₃ : 45 MW	1.72 ^a (1.49)	1.39 ^b (1.37)	2.16 ^a (1.63)	2.33 ^a (1.68)	1.72 ^{ab} (1.49)	1.95 ^a (1.56)	2.33 ^b (1.68)	2.78 ^a (1.81)	2.66 ^a (1.78)	2.89 ^a (1.84)	2.50 ^b (1.73)	2.83 ^a (1.82)	2.28 ^a (1.67)	2.39 ^a (1.70)
S ₄ : 47 MW	1.22 ^{bcd} (1.31)	1.17 ^{bcd} (1.29)	1.22 ^c (1.31)	1.66 ^b (1.47)	1.13 ^c (1.27)	1.61 ^b (1.45)	1.94 ^c (1.56)	2.05 ^c (1.60)	1.67 ^d (1.47)	1.28 ^e (1.33)	1.80 ^d (1.52)	1.66 ^d (1.47)	1.94 ^c (1.56)	1.44 ^d (1.39)
S. Em. ±	0.07		0.09		0.06		0.07		0.07		0.09		0.08	
C.D. at 5%	0.21		0.26		0.18		0.21		0.2		0.25		0.22	

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test.

DAS: Days after sowing; V: Variety (V₁: Phule Vikram, V₂: Vijay); S: Sowing windows; S.Em. ±: Standard error of mean; CD: Critical difference.

Table 4: Continued..

Treatments	70 DAS				77 DAS	
Variety Sowing windows	2023		2024		2023	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
S ₁ : 41 MW	0.94 ^c (1.20)	1.16 ^{abc} (1.29)	1.05 ^e (1.25)	1.11 ^e (1.27)	1.00 ^c (1.22)	1.00 ^c (1.22)
S ₂ : 43 MW	1.22 ^{ab} (1.31)	1.22 ^{ab} (1.31)	1.72 ^d (1.49)	2.00 ^c (1.58)	1.11 ^c (1.27)	1.11 ^c (1.27)
S ₃ : 45 MW	1.39 ^a (1.37)	1.39 ^a (1.37)	2.27 ^b (1.67)	2.61 ^a (1.76)	1.39 ^b (1.37)	1.78 ^a (1.51)
S ₄ : 47 MW	1.00 ^{bc} (1.22)	1.33 ^a (1.35)	1.50 ^d (1.41)	1.11 ^e (1.27)	1.06 ^c (1.25)	0.61 ^d (1.05)
S. Em. ±	0.06		0.07		0.06	
C.D. at 5%	0.19		0.21		0.16	

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test.

DAS: Days after sowing; V: Variety (V₁: Phule Vikram, V₂: Vijay); S: Sowing windows; S.Em. ±: Standard error of mean; CD: Critical difference.

Table 5: Number of larvae/m row length of chickpea as influenced by the interaction between protection, varieties and sowing windows at 42, 49, 56, 63, 70 and 77 DAS (2023, 2024 and pooled)

Treatments P x V x S	42 DAS				49 DAS						56 DAS			
	2023		2024		2023		2024		Pooled		2023		2024	
	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂
V ₁ S ₁	0.92 ^{ef} (1.19)	0.92 ^{ef} (1.19)	0.89 ^{de} (1.18)	0.77 ^{def} (1.13)	1.00 ^f (1.22)	1.00 ^f (1.22)	1.00 ^f (1.22)	1.33 ^e (1.35)	1.00 ^{ef} (1.22)	1.17 ^e (1.29)	0.33 ⁱ (0.91)	2.55 ^e (1.75)	0.44 ^h (0.97)	2.00 ^e (1.58)
V ₁ S ₂	1.11 ^{cde} (1.27)	1.11 ^{cde} (1.27)	1.44 ^{bc} (1.39)	1.44 ^{bc} (1.39)	0.44 ^g (0.97)	0.44 ^g (0.97)	0.44 ^g (0.97)	2.55 ^{bc} (1.75)	0.44 ^{fg} (0.97)	2.27 ^{cd} (1.66)	0.88 ^{gh} (1.17)	3.11 ^{cd} (1.90)	0.55 ^{gh} (1.02)	3.55 ^c (2.01)
V ₁ S ₃	0.44 ^f (0.97)	3.00 ^a (1.87)	0.37 ^f (0.93)	2.00 ^{ab} (1.58)	0.66 ^{fg} (1.08)	0.66 ^{fg} (1.08)	0.55 ^g (1.02)	2.89 ^b (1.84)	0.61 ^{fg} (1.05)	3.27 ^{ab} (1.94)	0.88 ^{gh} (1.17)	3.77 ^b (2.07)	1.44 ^f (1.39)	3.89 ^b (2.09)
V ₁ S ₄	1.22 ^{cd} (1.31)	1.22 ^{cd} (1.31)	1.33 ^c (1.35)	1.44 ^{bc} (1.39)	0.33 ^h (0.91)	0.33 ^h (0.91)	0.48 ^g (0.99)	1.77 ^d (1.51)	0.40 ^{fg} (0.95)	1.94 ^d (1.56)	0.77 ^{ghi} (1.13)	3.11 ^{cd} (1.90)	1.11 ^{fg} (1.27)	2.22 ^{de} (1.65)
V ₂ S ₁	1.00 ^{de} (1.22)	1.00 ^{de} (1.22)	1.00 ^{cd} (1.22)	1.00 ^{cd} (1.22)	0.44 ^g (0.97)	0.44 ^g (0.97)	0.33 ^{gh} (0.91)	1.66 ^{de} (1.47)	0.39 ^g (0.94)	1.72 ^{de} (1.49)	0.77 ^{ghi} (1.13)	2.89 ^d (1.84)	0.77 ^g (1.13)	2.33 ^d (1.68)
V ₂ S ₂	1.22 ^{cd} (1.31)	1.33 ^c (1.35)	1.33 ^c (1.35)	1.44 ^{bc} (1.39)	0.33 ^h (0.91)	0.33 ^h (0.91)	0.55 ^g (1.02)	2.66 ^{bc} (1.78)	0.44 ^{fg} (0.97)	3.00 ^b (1.87)	0.66 ^{hi} (1.08)	3.44 ^c (1.98)	0.89 ^g (1.18)	3.66 ^{bc} (2.04)
V ₂ S ₃	0.44 ^f (0.97)	2.33 ^b (1.68)	0.44 ^{ef} (0.97)	2.11 ^a (1.62)	0.55 ^g (1.02)	0.55 ^g (1.02)	0.79 ^{fg} (1.13)	3.11 ^a (1.90)	0.67 ^{fg} (1.08)	3.61 ^a (2.03)	1.44 ^f (1.39)	4.11 ^a (2.15)	1.44 ^f (1.39)	4.33 ^a (2.20)
V ₂ S ₄	1.11 ^{cde} (1.27)	1.22 ^{cd} (1.31)	0.44 ^{ef} (0.97)	1.77 ^{abc} (1.51)	0.44 ^g (0.97)	0.44 ^g (0.97)	1.11 ^{ef} (1.27)	2.11 ^c (1.62)	0.78 ^f (1.13)	2.50 ^c (1.73)	1.00 ^g (1.22)	3.11 ^{cd} (1.90)	0.33 ^h (0.91)	2.22 ^{de} (1.65)
S. Em. ±	0.10		0.12		0.13		0.09		0.13		0.10		0.10	
C.D. at 5%	0.29		0.34		0.37		0.26		0.38		0.30		0.29	

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test.

DAS: Days after sowing; P: Protection (P₁: Protected, P₂: Unprotected); V: Variety (V₁: Phule Vikram, V₂: Vijay); S: Sowing windows; S.Em. ±: Standard error of mean; CD: Critical difference.

Table 5: Continued..

Treatments P x V x S	63 DAS				70 DAS		77 DAS	
	2023		2024		2023		2023	
	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂
V ₁ S ₁	1.11 ^{de} (1.27)	2.89 ^b (1.84)	1.00 ^g (1.22)	2.22 ^e (1.65)	0.22 ^e (0.85)	1.66 ^c (1.47)	1.00 ^{de} (1.22)	1.00 ^{de} (1.22)
V ₁ S ₂	1.33 ^d (1.35)	3.33 ^a (1.96)	1.11 ^{fg} (1.27)	3.77 ^c (2.07)	0.33 ^e (0.91)	2.11 ^b (1.62)	1.11 ^{cd} (1.27)	1.11 ^{cd} (1.27)
V ₁ S ₃	1.44 ^d (1.39)	3.11 ^{ab} (1.90)	0.77 ^{gh} (1.13)	4.22 ^b (2.17)	0.33 ^e (0.91)	2.44 ^a (1.71)	1.33 ^c (1.35)	1.44 ^b (1.39)
V ₁ S ₄	1.11 ^{de} (1.27)	2.77 ^{bc} (1.81)	0.44 ^h (0.97)	2.33 ^{de} (1.68)	0.33 ^e (0.91)	1.66 ^c (1.47)	1.11 ^{cd} (1.27)	1.00 ^{de} (1.22)
V ₂ S ₁	1.11 ^{de} (1.27)	2.55 ^c (1.75)	1.00 ^g (1.22)	2.55 ^d (1.75)	0.44 ^e (0.97)	1.89 ^c (1.54)	1.00 ^{de} (1.22)	1.00 ^{de} (1.22)
V ₂ S ₂	1.22 ^d (1.31)	3.22 ^a (1.93)	1.22 ^f (1.31)	4.00 ^{bc} (2.12)	0.33 ^e (0.91)	2.11 ^b (1.61)	1.11 ^{cd} (1.27)	1.11 ^{cd} (1.27)
V ₂ S ₃	1.33 ^d (1.35)	3.44 ^a (1.98)	0.89 ^{gh} (1.18)	4.66 ^a (2.27)	0.33 ^e (0.91)	2.44 ^a (1.71)	1.22 ^c (1.31)	2.33 ^a (1.68)
V ₂ S ₄	0.33 ^e (0.91)	2.55 ^c (1.75)	1.11 ^{fg} (1.27)	2.22 ^e (1.65)	1.11 ^d (1.27)	1.55 ^{cd} (1.43)	0.33 ^f (0.91)	0.89 ^e (1.18)
S. Em. ±	0.11		0.09		0.09		0.08	
C.D. at 5%	0.32		0.25		0.27		0.23	

Figures in parentheses are square-root transformed [$\sqrt{(x + 0.5)}$]

Means followed by the same lowercase letter(s) within a column are not significantly different at the 5% level of significance ($P = 0.05$) as per the Critical Difference (CD) test.

DAS: Days after sowing; P: Protection (P₁: Protected, P₂: Unprotected); V: Variety (V₁: Phule Vikram, V₂: Vijay); S: Sowing windows; S.Em. ±: Standard error of mean; CD: Critical difference.

3.1.4 Effect of interaction

Analysis of the number of larvae/m row length for both years revealed significant two-way interactions between protection and varieties (Table 2), protection and sowing windows (Table 3) and varieties and sowing windows (Table 4), as well as a significant three-way interaction among protection, varieties and sowing windows (Table 5). Among the treatment combinations, P₂V₁ and P₂V₂ consistently recorded higher larval count during 42 to 77 DAS in 2023, 2024 and the pooled mean. Similarly, P₂S₃, V₁S₃

and V₂S₃ in 2023, 2024 and the pooled mean consistently recorded higher larval count. Notably, the combined effect of protection, variety and sowing windows (P₂V₁S₃ and P₂V₂S₃) was superior to all other interactions across 42 to 77 DAS in both years and the pooled mean.

4. Conclusion

The seasonal population dynamics of *Helicoverpa armigera* indicated that larval incidence increased progressively from 28

DAS, reached its peak between 49 and 63 DAS, and declined thereafter towards crop maturity. Early sowing (41 MW) consistently recorded the lowest larval population, whereas delayed sowing (45 MW) favoured higher infestation. Protected plots treated with Flubendiamide 480 SC (0.4 ml L⁻¹) significantly suppressed larval population compared to unprotected plots, while the variety Phule Vikram exhibited slightly lower larval incidence than Vijay. The findings suggest that early sowing combined with timely crop protection can effectively reduce *H. armigera* infestation and should be considered as an important component of integrated pest management in chickpea.

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