World Journal of Environmental Biosciences
Available Online at: **www.environmentaljournals.org**

Volume 15, Issue 1: 1-7

https://doi.org/10.51847/pQzjOxyuYl

ISSN 2277- 8047

Management of *Helicoverpa armigera* in Chickpeas Using Planting Date and NPS Fertilizer in Ambo, Ethiopia

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ABSTRACT

One of the major leguminous crops grown in Ethiopia is the chickpea, scientifically known as Cicer arietinum L. To evaluate the effects of planting date and nitrogen rates on the management of Africa bollworm, Helicoverpa armigera in chickpeas, a field experiment was conducted in October 2022 at a farmer's field in the Ambo district. The experiment, structured in a randomized complete block design, and it was replicated three times in the field. The planting dates were categorized as early, normal, and late October 16, 2022, October 26, 2022, and November 06, 2022, respectively. The results revealed that, apart from days to emergence, maturity date, and total pods per plant, all parameters were significantly influenced by the main effects of planting date and NPS rate on managing the African bollworm in chickpeas. The crop planted on October 28th with a 100 kg/ha NPS fertilizer treatment was found to be the most effective in reducing the incidence of H. armigera and achieving a higher grain yield, based on the combination of planting dates and NPS rates.

Keywords: *Chickpea, Bollworm, Fertilizer rate, Planting date, Management*

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Received: 23 January 2026
Accepted: 09 March 2026

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the most important grain legumes cultivated worldwide and is believed to have originated in the Fertile Crescent region, particularly southeastern Turkey and northern Syria (Gowda, 2014; Varshney *et al*., 2021). It is widely grown in semi-arid and subtropical regions because of its ability to utilize residual soil moisture and tolerate relatively dry conditions, making it suitable for double-cropping systems in many parts of Ethiopia where it is planted toward the end of the rainy season (Gebretsadkan *et al*., 2019; Merga & Haji, 2019; Shiferaw *et al*., 2020). Chickpea plays a vital role in human nutrition, serving as an affordable source of plant protein, carbohydrates, vitamins, and minerals. The crop is particularly valued for its high-quality protein content and balanced amino-acid composition, which contributes significantly to improving dietary quality and reducing protein-energy malnutrition in developing countries (Jukanti *et al*., 2020; Semba *et al*., 2021).

Despite its nutritional and economic importance, chickpea productivity in Ethiopia remains below its potential due to several biotic and abiotic constraints. Among these, insect pests, diseases, soil fertility limitations, and inappropriate agronomic practices are major factors affecting yield (Shiferaw *et al*., 2020; Tesfaye *et al*., 2022). According to recent agricultural statistics, chickpea is the second most widely produced pulse crop in Ethiopia after faba bean and contributes significantly to the national pulse production and export market (CSA, 2023). The national average yield has improved in recent years but still remains considerably lower than the attainable yield under optimal management conditions, which can exceed 4–5 t ha^{-1} in favorable environments (Tebkew & Makasha, 2016; ICARDA, 2022).

Ethiopia is the largest producer of chickpea in Africa and one of the major producers globally, contributing a substantial share of the continent's total production (FAOSTAT, 2023). The crop is widely cultivated in the central highlands of Ethiopia, particularly in the Oromia region, where zones such as West Shewa, East Shewa, and North Shewa account for the majority of chickpea production. These areas provide suitable agro-ecological conditions for chickpea cultivation and contribute significantly to both domestic consumption and export markets (CSA, 2023).

Among the biotic constraints affecting chickpea production, the African bollworm or pod borer, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), is considered the most destructive insect pest. This pest is highly polyphagous and attacks a wide range of economically important crops, including chickpea, tomato, cotton, and maize (Fitt *et al*., 2021; Tay *et al*., 2022). The larvae cause severe damage by feeding initially on tender leaves and flowers before boring into developing pods, where they consume the seeds. A single larva can damage several pods during its development, resulting in significant yield losses that may exceed 50% under severe infestations (Verma *et al*., 2015; Sharma *et al*., 2020; Tay *et al*., 2022). Moreover, extensive and improper use of chemical insecticides has led to the development of resistance in *H. armigera*, making its management increasingly difficult (Bird *et al*., 2020).

Therefore, developing effective and sustainable management strategies, including appropriate agronomic practices such as optimal sowing date and balanced nutrient management, is essential to reduce pest damage and enhance chickpea productivity. Understanding how sowing time and fertilizer application influence pest incidence and crop performance can provide valuable insights for integrated pest management and improved chickpea production systems. Hence, this study was conducted to evaluate the effects of sowing date and NPS fertilizer rate on the management of *Helicoverpa armigera* and the productivity of chickpea.

MATERIALS AND METHODS

Description of the study area

During the primary cropping seasons (October through the second, third, and fourth weeks) in 2022–2023, the field experiment was carried out on a farmer's field. 105 kilometers to the west of Addis Ababa is the district. With an average elevation of 1380–3030 m.a.s.l., the location is at 370 32' 0'' to 380 3'0'' E longitude and 8 0 47'0'' to 9 0 21'0''N latitude. *H. armigera* is a common pest of chickpea crops, and the district was one of the main areas for growing them.

Treatments and experimental design

Three replicates of the experiment were carried out in the field, and the entire setup was set up using a randomized complete block design (RCBD). To get the soil to a fine tilth, the field was manually harrowed and ploughed with oxen. Each plot was 1.5 m in width and 2 m in length (3 m^2 area), with 0.5 m between blocks and 0.5 m between plots. On prepared beds, chickpea seed "Kabul variety" was planted 6 cm deep in rows of each plot, with a spacing of 30 cm between rows and 10 cm between plants. NPS fertilizer was applied at a rate of 0, 100, 150, and 200 kg ha^{-1}, with several planting dates: early (October 16/2022, normal (October 26/2022), and late (November 06/2022). All required agronomic procedures were implemented consistently.

Data collection and measurement

Growth and phonological criteria, such as 90% of days until physiological maturity, 50% of days until flowering, and 50% of days till emergence, were noted. Height of the plant, by visually inspecting the chickpea plant or plot, the number of primary branches per plant, the number of pods per plant, the hundred seed weight in grams, and the number of bollworm larvae were tallied. The date of the *H. armigera* damage symptoms was also noted. number of damaged pods, pod borer larvae per plant, from five randomly chosen tagged plants in each plot, the following data were gathered: total number of undamaged pods, infestation %, number of pod borer larvae per plant, number of damaged pods, and total pods per plant. The formula was used to determine the infestation percentage.

Total number of damaged pods per plant divided by the total number of pods per plant times 100 is the infestation percentage (%). Ultimately, the average yield was expressed in kilograms per hectare after the seed yield per plot was converted to per hectare. The harvested net plot area, excluding the borders, was where the yields were obtained. Using Dizanion 60% EC at the economic threshold level of larvae, the treatments were administered three times at intervals of seven days. On the day that the first signs of damage and larvae infestation were observed, the first treatment was administered.

To get the most protection possible against pesticides, each plot was treated with three sprays (Hossain, 2010). When the larval population reached the economic threshold level (one larva per meter row) during the crop's pod formation stage, the first application was made. For optimal pest control, the second and third sprays were sprayed ten days apart. Evaluations of Yield Loss Insecticides (Diazinon 60% EC) were sprayed on treated chickpea plants at a rate of 1000 milliliters per hectare every seven days.

Calculating yield loss and pod damage

Five chickpea plants or plots were tagged by *H. armigera* larvae, and the total number of pods damaged and undamaged was determined using the following formula to determine the percentage of pod damage.

$$Yield\ loss\ (\%) = \frac{Potential\ yield - Actual\ yield}{Potential\ yield} \times 100 \qquad (1)$$

Analysis of statistical data

To guarantee the quality of the data gathered, the data were meticulously created. The findings were compiled and displayed in tabular form. SAS software was used to evaluate all of the data that was gathered (SAS, 2013). For the mean comparison, the least significant difference (LSD) was applied at both the 1% and 5% probability levels.

RESULTS AND DISCUSSION

Days to emergence and germination percentage affected by planting date and nps rate

The analysis of variance revealed a non-significant difference at ($P \geq 0.05$) in all treatments (0 kg NPS/ha, 100 NPS kg/ha, 150 kg NPS/ha, and 200 kg NPS/ha of fertilizer rate, with pesticide application and untreated check) on October 16/2022, while the analysis of variance revealed a significant difference at ($P \leq 0.05$) in all treatments (0 kg NPS/ha, 100 NPS kg/ha, 150 kg NPS/ha, and 200 kg NPS/ha of fertilizer rate, with pesticide application and untreated check) on October 26 and November 06/2022 **(Table 1)**. The greatest and smallest seedling emergencies were noted on October 26/2022, at 100 NPS kg/ha fertilizer rate (13.56) and 150 NPS kg/ha fertilizer rate (10.07) days, respectively (Prada *et al*., 2024).

The maximum and lowest seedling emergencies were noted on November 06/2022, at 150 NPS kg/ha fertilizer rate (12.00) and untreated check (10.33) days, respectively. In the case of germination percentage, the following table showed that there was a non-significant difference at ($P \geq 0.05$) on October 16/2022, and November 06/2022, while there was a significant difference at ($p \leq 0.05$) on October 26/2022. The highest germination percentage (82.47%) was recorded on October 26/2022, planting date at a fertilizer rate of 200 NPS kg/ha, and the lowest germination percentage (58%) was recorded on October 26/2022, untreated check. The outcome could be the result of fertilizer rate and ambient conditions (temperature, soil, and moisture) (Varoneckaitė *et al*., 2024).

Table 1. Effect of planting date and NPS rate on Days to Emergence, and Germination Percentage

Treatments	Planting date					
	Seedling Emergence			Germination Percentage (%)		
	Oct. 16/2022	Oct. 26/2022	Nov. 06/2022	Oct 16/2022	Oct 26/2022	Nov. 06/2022
NPS(0kg/ha)	11.00[a]	10.67[b]	10.67b[a]	60.00[a]	61.00[ba]	65.5[a]
NPS (100kg/ha)	10.33[a]	13.56[a]	11.80[ba]	75.33[a]	77.20[ba]	74.80[a]
NPS (150kg/ha)	10.33[a]	10.07[b]	12.00[a]	79.13[a]	80.80[a]	79.27[a]
NPS (200kg/ha)	11.00[a]	10.62[b]	10.49[ba]	80.47[a]	82.47[a]	79.67[a]
Diazinon 60% EC	11.00[a]	10.67[b]	10.67[ba]	75.07[a]	77.27[ba]	76.47[a]
Untreated control	10.67[a]	11.21[ba]	10.33[b]	61.00[a]	58.00[b]	57.67[a]
MSE ±	1.48	1.43	1.20	13.96	12.31	13.64
LSD at 0.05%	2.64	2.54	1.56	24.83	21.90	24.27
CV (%)	13.83	12.83	11.29	19.43	16.92	18.89

Note: Means with the same letter(s) in the columns are not significantly different from each other
All treatment effects were significant at P≤ 0.05 least significance difference (LSD)

The impact of NPS rate and planting date on the number of pods per plant and maturity dates

The results of the analysis of variance showed that the number of main pods per plant and the number of maturity days for all treatments and planting dates differed significantly (P≤0.05) **(Table 2)**. The reason could be that all treatments prevent bollworms from eating the chickpea plant's leaves, and a healthy plant can yield strong plant performance, a good main pod per plant, and a consistent maturation date. This shows that the implementation of general fertilizer recommendations is not hampered by weather conditions (temperature, moisture, and rainfall), cropping structure, crop planting area, soil fertility, and/or management. Chickpea maturity was unaffected by the date of planting or the NPS rate. The untreated check had the highest maturity, 132.2 days, whereas the Diazinon 60% EC-controlled check had the lowest, 107 days **(Table 2)**.

Effect of planting date and NPS Fertilizer rate on larvae and damaged pod per plant

The outcome demonstrated that there was a significant difference (P≤0.05) in the number of larvae per plant compared to the untreated control. The greatest number of larvae (5.51) was seen during the untreated check on October 16, 2022. However, the treatment of Diazinon 60% EC resulted in the lowest number of larvae/plant (1.33).

The greatest number of larvae (3.91) was seen at the untreated check on October 28, 2022. However, the application of Diazinon 60% EC resulted in the lowest number of larvae/plant (2.53). The greatest number of larvae (5.46) was seen at NPS 200Kg on November 06, 2022. However, the application of Diazinon 60% EC resulted in the lowest number of larvae/plant (2.33). In the case of damaged pods, the analysis of variance showed that the damaged pods at all treatments and planting dates (October 16, 2022, October 26/2022, and November 06/2022) differed significantly (P≤0.05) **(Table 3)**. The greatest number of damaged pods (7.8) was noted at the untreated check on October 16, 2022. However, the application of Diazinon 60% EC resulted in the lowest number of larvae/plant (1.33). The greatest number of damage pods (7.06) was noted at the untreated check on October 26, 2022. However, the application of Diazinon 60% EC resulted in the lowest number of larvae/plant (0.66). The most damage pods (7.30) were found at the untreated check on November 06, 2022. However, the application of Diazinon 60% EC resulted in the lowest number of larvae/plant (0.33).

Table 2. Effect of planting date and NPS Fertilizer rate on larvae and damage pod per plant

Treatments	*Planting date*					
	Oct. 16/2022	Oct. 26/2022	Nov. 06/2022	Oct 16/2022	Oct 26/2022	Nov. 06/2022
	Larvae/plant			Damaged pods/plant		
NPS(0kg/ha)	5.01[a]	3.80[a]	4.34[ba]	5.26[b]	4.06[a]	6.45[a]
NPS (100kg/ha)	4.07[a]	3.04[a]	3.48[ba]	4.23[b]	3.93[a]	5.58[a]
NPS (150kg/ha)	4.67[a]	3.59[a]	5.21[a]	5.33[b]	3.93[a]	5.74[a]
NPS (200kg/ha)	5.39[a]	3.80[a]	5.46[a]	5.40[b]	4.60[a]	5.90[a]
Diazinon 60%EC	1.33[b]	2.53[ba]	2.33[b]	1.33[c]	0.66[b]	0.33[b]
Untreated control	5.51[a]	3.91[a]	5.23[a]	7.80[a]	4.90[a]	7.30[a]
MSE ±	1.30	0.90	1.19	13.00	7.06	18.35
LSD at 0.05	2.32	1.60	2.12	1.45	1.57	2.08

CV (%)	22.18	18.22	21.38	16.75	23.8	22.47

Note: Means with the same letter(s) in the columns are not significantly different from each other
All treatment effects were significant at p<0.05 least significance difference (LSD)

Effect of planting date and NPS rate on Infestation percentage and plant height

The analysis variance result indicated that there was a significant difference (P≤0.05) between the percentage of infestations and plant height compared to the untreated control. The greatest infection percentage (15.86) was observed at NPS 200 Kg on October 16, 2022. On the other hand, Diazinon 60% EC application had the lowest infection percentage (3.19). The greatest infection percentage (19.03) was noted at the untreated inspection on October 26, 2022. On the other hand, Diazinon 60% EC application had the lowest infection percentage (3.86). The greatest infection percentage (18.63) was noted at the untreated check on November 06, 2022. On the other hand, the Diazinon 60% EC application had the lowest infection percentage (2.8).

The tallest plant (39.30) was measured at 150 kg NPS on October 16, 2022. On the other hand, the untreated check had the lowest plant height (23.00). The maximum plant height (46.00) was measured at 100Kg NPS on October 26, 2022. On the other hand, the untreated check had the lowest plant height (26.00). The maximum plant height (38.33) was measured at 100 kg NPS on November 06, 2022. On the other hand, the untreated check and 100 kg/ha NPS fertilizer rate had the lowest plant height (28.67). On the other hand, on October 16, 2022, the untreated control plant had the lowest height (23.00 m). On October 26, 2022, the medium plant height of 42.47 meters was measured, and the NPS fertilizer rate was 150 kg/ha **(Table 3)**.

Table 3. Effect of planting date and NPS rate on Infestation percentage and plant height

Treatments	**Planting Date**					
	Oct. 16/2022	**Oct. 26/2022**	**Nov. 06/2022**	**Oct 16/2022**	**Oct 26/2022**	**Nov. 06/2022**
	Infestation percentage			**Plant height**		
NPS(0kg/ha)	14.86[a]	9.97[b]	16.40[a]	32.27[a]	38.03[a]	35.62[a]
NPS (100kg/ha)	10.03[bc]	7.86[b]	18.46[a]	38.90[a]	46.00[a]	38.33[a]
NPS (150kg/ha)	12.43[b]	7.73[b]	11.03[b]	39.30[ba]	42.47[a]	32.73[a]
NPS (200kg/ha)	15.86[d]	11.30[ab]	13.93[ab]	37.60[a]	34.53[ba]	36.00[a]
Diazinon 60%EC	3.19[a]	3.86[b]	2.8[c]	34.67[a]	38.85[ba]	35.83[a]
Untreated control	14.53[c]	19.03[c]	18.63[d]	23.00[b]	26.00[b]	28.67[a]
MSE ±	18.35	78.3	15.14	5.89	8.53	7.62
LSD at 0.05	15.06	8.4	6.92	10.49	15.18	13.56
CV (%)	26.85	37.5	28.73	17.19	22.67	22.08

***Note*:** Means with the same letter(s) in the columns are not significantly different from each other
All treatment effects were significant at p<0.05 least significance difference (LSD)

Effect of planting date and NPS rate on harvesting index and grain yield

The results indicated that there was a significant difference between the harvesting index and grain yield (P≤0.05) compared to the untreated control. On October 16, 2022, 100 Kg NPS recorded the maximum grain yield (1.53 t/ha), while the untreated check recorded the lowest grain yield (0.82 t/ha). On October 28, 2022, 100 Kg NPS achieved the highest grain yield (1.72t/ha), while untreated produced the lowest (0.95t/ha). On November 06, 2022 the untreated check produced the lowest grain yield (0.86 t/ha), while the 150 Kg NPS rate recorded the best grain output (1.53 t/ha).

Harvesting Index is significantly impacted by the primary effects of NPS fertilizer rate and sowing date. Regarding the harvesting index for the October 16, 2022 planting date, the 100 kg NPS rate had the highest harvesting index (39.08), while the Untreated/Control had the lowest (12.36%). On October 28, 2022, the 100 kg NPS rate had the highest harvesting index (36.06%), while the untreated check had the lowest harvesting index (12.30%) **(Table 4)**.

Table 4. Effect of planting date and NPS rate on Grain yield and harvesting index

Treatment	**Planting date**					
	Oct. 16/2022	**Oct. 26/2022**	**Nov.06/2022**	**Oct. 16/2022**	**Oct. 26/2022**	**Nov. 06/2022**
	Grain yield/T/ha			**Harvesting index**		
NPS (0kg/ha)	1.33[a]	1.51[a]	1.35[ba]	32.08[a]	31.65[a]	34.27[ba]
NPS (100kg/ha)	1.57[a]	1.72[a]	1.50[ba]	31.91[a]	39.08[a]	36.06[a]
NPS (150kg/ha)	1.53[a]	1.67[a]	1.53[a]	38.38[a]	35.60[a]	34.46[ba]
NPS (200kg/ha	1.36[a]	1.60[a]	1.28[a]	38.58[a]	31.97[a]	23.24[bac]

Diazinon 60%EC	1.3^{a}	1.54^{a}	1.45^{a}	22.96^{ba}	19.21^{b}	19.28^{bc}
Untreated control	0.82^{b}	0.95^{b}	0.86^{b}	10.99^{b}	12.36^{b}	12.30^{c}
MSE ±	0.21	0.23	0.18	9.07	4.59	10.24
LSD at 0.05	0.46	0.38	0.26	16.15	9.95	18.22
CV (%)	19.60	14.3	11.1	30.90	20.28	31.80

Note: Means with the same letter(s) in the columns are not significantly different from each other
All treatment effects were significant at $p<0.05$ least significance difference (LSD)

The present study demonstrated that the African bollworm, *Helicoverpa armigera*, significantly affects chickpea growth and productivity by damaging plants during both vegetative and reproductive stages. The results indicated that appropriate planting time combined with the recommended rate of NPS fertilizer can effectively reduce bollworm infestation and improve chickpea performance in the Ambo district. Several recent studies have emphasized that agronomic practices such as planting date play a crucial role in minimizing pest pressure and improving yield stability in chickpea production systems (Roditakis *et al*., 2021; Urbaneja *et al*., 2021). Adjusting sowing time can help synchronize crop phenology with unfavorable conditions for pest development, thereby reducing pest population buildup (Dipalma *et al*., 2022; Spirito *et al*., 2022; Sugimori *et al*., 2022; Zhao *et al*., 2022; Samaranayake *et al*., 2024).

The findings also revealed that optimal fertilizer management contributed to enhanced plant vigor and reduced pest damage. Adequate nutrient supply improves crop tolerance and compensatory growth, allowing plants to better withstand insect attacks. Similar results were reported by Tesfahun *et al*. (2018) and Silva *et al*. (2022), who noted that balanced fertilization enhances plant growth and indirectly reduces pest damage by strengthening plant defense mechanisms. Moreover, proper fertilizer management has been reported to improve pod formation and yield attributes in chickpea under different agroecological conditions (FAOSTAT, 2023; CSA, 2023).

In the present experiment, the highest number of African bollworm larvae (5.51 larvae per plant) was observed in crops sown on October 16 with no NPS fertilizer application, whereas the lowest larval population (3.04 larvae per plant) was recorded in crops planted on October 26 with 100 kg NPS ha^{-1}. These results indicate that both sowing date and fertilizer application significantly influence the population dynamics of *H. armigera*. Similar observations have been reported by Bird *et al*. (2020), who highlighted that host plant phenology and crop nutritional status strongly affect the population development of *H. armigera*. In addition, Ullah *et al*. (2020) reported that chickpea provides a highly suitable host for larval development and survival compared with other legumes, which explains the relatively high infestation levels observed in chickpea fields.

Early and late sowing periods were associated with increased bollworm infestation in the present study, which may be related to synchronization between crop flowering stages and peak pest activity. Recent studies have confirmed that delayed sowing often exposes chickpea crops to higher pest pressure, resulting in increased pod damage and yield losses (Pannacci *et al*., 2020; An *et al*., 2022). Late-sown chickpea crops may also act as reservoirs for subsequent pest generations, facilitating population buildup and potentially contributing to the development of resistance to management strategies.

Although larvae were not always observed directly on the pods, significant pod damage was recorded, indicating the destructive feeding behavior of the pest. Previous studies have shown that even a single larva per plant can destroy a large number of chickpea pods, leading to substantial yield losses (Tariku *et al*., 2018; Hassan *et al*., 2022). Likewise, Akhtar *et al*. (2019) reported that late-sown chickpea crops generally experience higher levels of pod borer damage than early-planted crops due to increased pest pressure during reproductive stages.

Variations in sowing time and fertilizer rates also influenced the number of pods per plant in the current study. When planting dates deviated from the optimal period, pod numbers declined significantly. Similar findings have been reported by Chater *et al*. (2019), who indicated that inappropriate sowing dates can shorten the reproductive phase and reduce pod formation in chickpea. Environmental stresses such as low temperature and moisture fluctuations may further limit photosynthetic activity during the reproductive stage, ultimately affecting pod development and yield potential.

The highest harvest index (39.08%) was recorded from chickpea planted on October 26 with an NPS fertilizer rate of 100 kg ha^{-1}, whereas the lowest harvest index (12.36%) occurred in the untreated control under the same planting date. This suggests that proper nutrient management and optimal planting time improve biomass partitioning toward grain production. Similar findings have been reported in recent agronomic studies, which indicate that optimal nutrient management and appropriate planting schedules enhance harvest index and yield efficiency in chickpea production systems (FAOSTAT, 2023; Silva *et al*., 2023). However, delayed planting beyond the optimal window may reduce harvest index due to premature leaf senescence and reduced photosynthetic duration before maturity.

Overall, the results confirm that integrating appropriate sowing dates with recommended fertilizer application is a practical strategy for reducing *H. armigera* infestation and improving chickpea productivity. Such agronomic practices represent an important component of integrated pest management strategies aimed at reducing reliance on chemical control while sustaining chickpea yield under smallholder farming systems.

The present study demonstrated that the African bollworm, *Helicoverpa armigera*, significantly affects chickpea growth and productivity by damaging plants during both vegetative and reproductive stages. The results indicated that appropriate planting time combined with the recommended rate of NPS fertilizer can effectively reduce bollworm infestation and improve chickpea performance in the Ambo district. Several recent studies have emphasized that agronomic practices such as planting date play a crucial role in minimizing pest pressure and improving yield stability in chickpea production systems (Roditakis *et al*., 2021; Urbaneja *et al*., 2021). Adjusting sowing time can help synchronize crop phenology with unfavorable conditions for pest development, thereby reducing pest

population buildup.

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CONCLUSION

Overall, the results confirm that integrating appropriate sowing dates with recommended fertilizer application is a practical strategy for reducing *H. armigera* infestation and improving chickpea productivity. Such agronomic practices represent an important component of integrated pest management strategies aimed at reducing reliance on chemical control while sustaining chickpea yield under smallholder farming systems.

ACKNOWLEDGMENTS: None

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: None

ETHICS STATEMENT: None

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