

**Resistance evaluation of commercial cotton varieties against pink bollworm (*Pectinophora gossypiella*) across diverse cotton growing regions of Pakistan**

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ABSTRACT

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Pink bollworm (*Pectinophora gossypiella* Saunders) is a serious yield and quality loss causing insect pest of cotton worldwide. Therefore, the present study was conducted to assess the resistance of six cotton varieties in the field against pink bollworm attack during 2024 and 2025 growing seasons at Balochistan, Sindh and Punjab. A replicated complete block design (RCBD) was used in planning the experimental trial of selected varieties. The results showed that there were significant differences ( $p < 0.05$ ) between the different varieties of cotton in their reaction to infestation by pink bollworm and their yield performance. CIM-499 had the maximum number of larvae and maximum damage in flowers, squares, green bolls and seeds, which made it highly susceptible. The CKC-05 genotype, however, was the most resistant sow with the lowest percentages of infestation, damage and the highest yield throughout the years and locations. FH-333 and NIAB-KIRAN also performed fairly better in terms of infestation and their yield was stable, whereas the yield performance of Koonj and NIAB-878 was moderate. The highest infestation was found on green bolls, with a higher occurrence being the preferred feeding site for larvae than flowers and squares. These results demonstrate the need for resistant cultivars in sustainable cotton production in Pakistan using integrated pest management.

**Keywords:** Cotton, *Pectinophora gossypiella*, varietal resistance, yield, integrated pest management.

**INTRODUCTION:** Cotton (*Gossypium hirsutum* L.) is one of the main cash crops of Pakistan which plays a critical role in the economy, employment of rural people, export income and as the backbone of the textile sector and is also a significant contributor to the national economy (Akhtar *et al.*, 2024). Pakistan occupies a significant place in the world production of cotton and exports of cotton-textiles are valued at 60% of the total exports of the country, thus making cotton production quite an important economic activity for the country (Asif *et al.*, 2024). Although cotton is an important crop, it is confronted with serious problems from insect pests and diseases, resulting in yield loss, higher production costs, and jeopardizing cotton farming profitability. The pink bollworm, *Pectinophora gossypiella* (Saunders) is particularly problematic because these larvae are hidden in the cotton bolls and are not exposed to insecticidal contact. This feeding habit of the bollworm causes damage to the seed and lint, decreases boll opening, affects fibre quality and makes traditional management strategies less effective (Nagaraju *et al.*, 2024), which highlights the importance of adopting integrated pest management (IPM) strategies that involve host plant resistance. Likewise, the inherent control difficulties of *P. gossypiella*, especially the concealed feeding behaviour of larvae, require novel solutions other than traditional use of pesticides. The pink bollworm is one of the most serious insect pests of cotton and very destructive as it leads to significant yield losses and reduces cotton lint quality (Khosro *et al.*, 2025). The pink bollworm (PBW), *Pectinophora gossypiella*, can cause significant economic losses due to decreased yield and fiber quality of cotton crops. Due to the loss of seed cotton yield (2.8-61.9%), oil content (2.1-47.1%) and boll opening (10.7-59.2%), its effect is much greater (Akhtar *et al.*, 2023). Cotton varieties with high level of resistance to *P. gossypiella* should be developed and assessed to minimize losses to the crop and economy, particularly under the threat of this pest.

The development of transgenic cotton cultivars expressing insecticidal protein of Bt revolutionized the cotton pest management and gave another idea for controlling lepidopteran pests like pink bollworm (Akhtar *et al.*, 2024). Field testing of transgenic and conventional cotton varieties is, however, a necessity since there are indications of the development of resistance in the pink bollworm population against Bt cotton varieties in Pakistan (Hanif *et al.*, 2026). In addition, Cry1Ac genes have been found to be resistant in Pakistan compromising the long-term efficacy of Bt-based management strategies (Hanif *et al.*, 2023). Field testing of cotton varieties is thus required to determine which varieties are able to maintain greater resistance or tolerance to natural pest pressure. Pink bollworm, alone, in Pakistan, has been reported to destroy about one million bales of cotton every year; thereby, it is clearly a need of the hour to develop sound and region-specific

management strategies. For developing site specific recommendations, it is required to explore the difference in pest susceptibility and cotton genotype performance at different locations as the pest pressure and cotton genotypes performance can differ across the locations (Karar *et al.*, 2020).

The environmental conditions, temperature range and pest dynamics of the cotton growing regions of Balochistan could affect the performance of the varieties and level of pink bollworm infestation differently when compared with other major cotton growing areas. Agro-climatic variations in Balochistan are different from other regions like Sindh and Punjab and require a focused assessment of the region to understand the resistance characteristics of the cotton genotypes and virulence of the *P. gossypiella* populations in the area (Asghar, 2023). The present study is important to address the critical need of regionalized management strategies by studying the performance of cotton varieties and pest dynamics in Balochistan, a region that has different environmental characteristics which can affect the crop performance of these cotton varieties and pest dynamics. Thus, breeding cotton with resistance to pink bollworm, either through traditional breeding or biotechnological means is the most sustainable and environmentally friendly way to limit the impact of pink bollworm and lower the need for chemical defenses. Field trials to test the resistance of cotton varieties in different agro-climatic zones are crucial for identifying resistant varieties and since chemical measures are not effective, it is imperative to conduct field trials on different varieties of cotton under diverse agro-climatic conditions (Akhtar *et al.*, 2024). These assessments can help to develop a more resilient agricultural system, better cultivar selection and sustainable cotton cultivation.

**OBJECTIVES:** To evaluate different cotton varieties for their resistance against pink bollworm infestation and to identify comparatively tolerant or resistant varieties for improved cotton production.

Specific objectives are:

1. To determine the level of infestation on different cotton varieties.
2. To compare infestation at various consecutive years after sowing.
3. To identify comparatively resistant cotton varieties.

**MATERIALS AND METHOD:** During two consecutive years (2024-25 and 2025-26), the study was carried out to assess the resistance of the selected cotton varieties (FH-333, Koonj, CIM-499, NIAB-878, NIAB-KIRAN and CKC-05) to pink bollworm, *Pectinophora gossypiella*, under field conditions in the three provinces (Sindh, Punjab and Baluchistan) of Pakistan. The trials were conducted at experimental area of Lasbela University of Agriculture & Marine

Sciences (LUAWMS), Uthal Balochistan, Sindh Agriculture University Tandojam (SAUT), Sindh and University of Sargodha Punjab. All these cotton varieties were planted on 5<sup>th</sup> May in both years and experiment was conducted using Randomized Complete Block Design (RCBD) with 4 replications in between of 2.5ft path. A total of 24 experimental blocks (net plot size 98.4 sqft) were maintained. The varieties were replicated four times on a ridge, 2 rows of 20ft length per variety. Row to row and plant to plant distances were maintained at 75 and 23cm, respectively. Overall net plot size was 2500 Sqft. All of the recommended agronomic practices were followed during the entire crop season. Experimental plots were not treated with any pesticide so that the natural infestation level of pink bollworm was not influenced. This was done because pesticide application could upset the natural pest population which would interfere with the varietal resistance comparison of cotton varieties. Observations (at 40 days after sowing) for pink bollworm were recorded in each block until harvest. Twenty plants (n=20) were selected randomly from each block of each variety and rosette flowers, damage to floral squares, entry holes on green bolls, larvae in green bolls, damaged seeds and internal feeding injury were the infestation symptoms observed during the study. The plants were divided into upper, mid and lower sections, from where bolls were picked. Fruiting parts damage (%), green boll infestation (%) and seed damage (%) were calculated from the formulas

$$\text{Fruiting parts damage (\%)} = \frac{\text{Number of fruiting parts damage}}{\text{Total number of fruiting parts examined}} \times 100$$

$$\text{Green boll infestation (\%)} = \frac{\text{Number of infested green bolls}}{\text{Total number of green bolls examined}} \times 100$$

$$\text{Seed damage (\%)} = \frac{\text{Number of damaged seeds}}{\text{Total number of seeds examined}} \times 100$$

The data were subjected to statistical analysis following Randomized complete block design (RCBD). All the data were analyzed using SAS statistical software with analysis of variance (ANOVA).

**RESULTS AND DISCUSSION:** The results of the present study indicated that pink bollworm, *Pectinophora gossypiella* was present in all cotton varieties examined, but the amount of infestation differed among varieties. The differences in larval population, damage to fruiting parts, green boll damage, seed damage and yield clearly showed differential susceptibility in the response of cotton varieties to pink bollworm. In rosette flowers (table 1), the highest mean larval population was recorded in CIM-499 with  $1.59 \pm 0.07$  larvae per 20 plants, followed by NIAB-878 with  $1.42 \pm 0.06$ , Koonj with  $1.32 \pm 0.06$ , NIAB-KIRAN with  $1.24 \pm 0.06$ , and FH-333 with  $1.15 \pm 0.07$ . The lowest larval population was observed in CKC-05 with  $1.08 \pm 0.04$  larva / 20 plants. In rosette flowers, CIM-499 was found to be more susceptible and the CKC-05 was found to be tolerant to pink bollworm infestation.

rosette flowers Varieties	floral squares			green bolls			seed damaged					
	2024	2025	Mean ± S. E	2024	2025	Mean ± S. E	2024	2025	Mean ± S. E	2024	2025	Mean ± S. E
FH-333	1.22	1.08	$1.15 \pm 0.07$	1.10	0.98	$1.04 \pm 0.06$	1.72	1.58	$1.65 \pm 0.07$	1.35	1.22	$1.29 \pm 0.06$
Koonj	1.38	1.26	$1.32 \pm 0.06$	1.26	1.15	$1.21 \pm 0.06$	1.88	1.74	$1.81 \pm 0.07$	1.52	1.38	$1.45 \pm 0.07$
CIM-499	1.65	1.52	$1.59 \pm 0.07$	1.52	1.40	$1.46 \pm 0.06$	2.25	2.08	$2.17 \pm 0.09$	1.95	1.80	$1.88 \pm 0.08$
NIAB-878	1.48	1.36	$1.42 \pm 0.06$	1.34	1.22	$1.28 \pm 0.06$	2.02	1.86	$1.94 \pm 0.08$	1.70	1.56	$1.63 \pm 0.07$
NIAB-KIRAN	1.30	1.18	$1.24 \pm 0.06$	1.18	1.05	$1.12 \pm 0.07$	1.80	1.66	$1.73 \pm 0.07$	1.46	1.32	$1.39 \pm 0.07$
CKC-05	1.12	1.04	$1.08 \pm 0.04$	0.98	0.89	$0.94 \pm 0.05$	1.56	1.44	$1.50 \pm 0.06$	1.20	1.08	$1.14 \pm 0.06$

Table 1: Larval population of *P. gossypiella* in rosette flowers, floral squares, green bolls and seed damaged varieties during 2024 and 2025. The highest mean larval population in floral squares was again recorded in CIM-499 with  $1.46 \pm 0.06$  larvae per 20 plants, followed by NIAB-878 with  $1.28 \pm 0.06$ , Koonj with  $1.21 \pm 0.06$ , NIAB-KIRAN with  $1.12 \pm 0.07$ , and FH-333 with  $1.04 \pm 0.06$ . The least infestation in floral squares was observed in CKC-05 ( $0.94 \pm 0.05$  larvae/20 plants). These results indicated that the percentage of infestation of pink bollworm in floral squares was comparatively less than in green bolls. Green bolls had a relatively higher larval population than rosette flowers and floral squares suggesting that green bolls were the most preferred feeding and development site for pink bollworm larvae. CIM-499 produced more larvae in green bolls compared with other varieties tested with 2.25 larvae per 20 plants in 2024 and 2.08 larvae in 2025, for an average of  $2.17 \pm 0.09$  larvae/20 plants. These results suggest that CIM-499 was highly vulnerable to attack by pink bollworm and favored larval feeding and development. Infestation rate was relatively high with NIAB-878 having  $1.94 \pm 0.08$  larval population per 20 plants, followed by Koonj with  $1.81 \pm 0.07$  and NIAB-KIRAN with  $1.73 \pm 0.07$  larvae per 20 plants. FH-333 showed significantly less infestation ( $1.65 \pm 0.07$  larvae per 20 plants). On the other hand, the lowest number of larvae on green bolls was observed in CKC-05 during both years with 1.56 larvae in 2024 and 1.44 larvae in 2025, giving  $1.50 \pm 0.06$  larvae per 20 plants. The lower larval population recorded in CKC-05 indicates relatively high resistance/tolerance to pink bollworm infestation. The overall results showed that green bolls were very susceptible to attack by pink bollworm which gave protected feeding sites and adequate nutritive food for the growth of larvae. Field resistance potential was higher in varieties that had lower larval numbers, mainly CKC-05 and FH-333, and the boll damage was also comparatively low in these varieties. The infestation levels were significantly variable between the varieties, which suggests variation in resistance/susceptibility to pink bollworm infestation. CIM-499 variety exhibited the highest mean value of  $1.88 \pm 0.08$  larvae/20 plants, showing the highest larval population in damaged seeds among all the varieties tested, during 2024 and 2025. From these results it was observed that CIM-499 was highly susceptible to P.B.W. infestation and suffered more from damage to seeds than the other varieties. On the other hand, the least number of larvae in damaged seeds was observed in the CKC-05 treatment, 1.20 larvae in 2024 and 1.08 larvae in 2025 with lowest mean of  $1.14 \pm 0.06$  larvae per 20 plants. The lower level of infestation in the case of the comparatively lower infestation level indicated that the resilience/tolerance of CKC-05 against the attack of pink bollworm was better. The larval populations of FH-333 and NIAB-KIRAN were also relatively low having mean values of  $1.29 \pm 0.06$  and  $1.39 \pm 0.07$  larvae/20 plants respectively, showing the moderate resistance. The intermediate infestation occurred in the case of Koonj and NIAB-878 with mean larval population of  $1.45 \pm 0.07$  and  $1.63 \pm 0.07$  larvae per 20 plants, respectively. Overall, the results showed that the amount of damaged seeds infested with larvae were lower in resistant varieties and higher in susceptible varieties. The results also established the contribution of varietal resistance in minimising the damage to the seed of pink bollworm in the field. The pooled data in (table 2) revealed that the cotton varieties tested differed significantly in the number of larvae of *Pectinophora gossypiella* in 2024 and 2025. The number of larvae was obtained from flowers, floral squares, green bolls and samples with seed damage and the mean values were clearly different for different varieties in regard to their susceptibility to pink bollworm attack. In all cotton varieties, green bolls had the most larvae showing that the green boll was the most preferred feeding and development site for pink bollworm larvae. In comparison, comparatively low numbers of larvae were found in flowers and floral squares. CIM-499 had the highest larval population in all parts of the plants with 1.59 larvae per flower, 1.46 in floral square, 2.17 in green bolls and 1.88 in seed damaged samples with an overall mean of 1.74 larvae per 20 plants. Based on these results it was concluded that CIM-499 is highly susceptible to pink bollworm attack. In contrast, the lowest larval population, namely 1.08 larvae/flower, was observed in CKC-05, which also had the lowest mean in all the samples, including 0.94 larvae/flower square, 1.50 larvae/green bolls and 1.14 larvae/seed damaged sample. This lower larval population indicates comparatively better resistance or tolerance of the CKC-05 to the attack of pink bollworm. FH-333 and NIAB-KIRAN had relatively low overall larval population of 1.28 and 1.36, respectively, which is considered as moderate resistance. Koonj and NIAB-878 varieties had intermediate larval level and were moderately susceptible varieties. The results, in general, indicated significant differences among the varieties of cotton in their reaction to infestation with pink bollworm. There was a positive correlation between lower larval population and lower infestation and higher yield performance in CKC-05, FH-333 and NIAB-KIRAN while higher

larval population was found to be negatively correlated with damage and yield performance in CIM-499. The yield data (table 3) showed considerable variation among cotton varieties and study locations during both 2024 and 2025. Overall, the highest yields were consistently recorded in Sindh, followed by Balochistan, while comparatively lower yields were observed in Punjab.

Varieties	Pooled over varieties				
	Flowers	Floral squares	Green bolls	Seed Damaged	Overall mean
FH-333	1.15	1.04	1.65	1.29	1.28
Koonj	1.32	1.21	1.81	1.45	1.45
CIM-499	1.59	1.46	2.17	1.88	1.74
NIAB-878	1.42	1.28	1.94	1.63	1.55
NIAB-KIRAN	1.24	1.12	1.73	1.39	1.36
CKC-05	1.08	0.94	1.50	1.14	1.17

Table 2: Larval population of *P. gossypiella* in flowers, floral squares, green bolls and seed damaged of cotton varieties during 2024 and 2025.

Cotton Variety	Yield kg ha <sup>-1</sup> .					
	Balochistan		Sindh		Punjab	
	2024	2025	2024	2025	2024	2025
FH-333	2240	2315	2385	2460	2110	2185
Koonj	2105	2180	2260	2325	1980	2050
CIM-499	1840	1915	1995	2070	1725	1800
NIAB-878	1985	2060	2130	2205	1860	1935
NIAB-KIRAN	2165	2240	2310	2385	2035	2110
CKC-05	2380	2455	2525	2600	2245	2320

Table 3: Yield differentiation among cotton varieties in Balochistan, Sindh and Punjab during 2024 and 2025.

The differences in yield performance among varieties appeared to be closely associated with their resistance or susceptibility to pink bollworm infestation. Among all tested varieties, CKC-05 produced the highest yield in all three provinces during both experimental years. In Balochistan, CKC-05 yielded 2380 kg ha<sup>-1</sup> in 2024 and 2455 kg ha<sup>-1</sup> in 2025. Similarly, in Sindh it recorded the maximum yield of 2525 kg ha<sup>-1</sup> during 2024 and 2600 kg ha<sup>-1</sup> during 2025, which was the highest yield observed in the entire study. In Punjab, CKC-05 also maintained superior performance with yields of 2245 and 2320 kg ha<sup>-1</sup> during 2024 and 2025, respectively. The higher yield of CKC-05 may be attributed to its lower pink bollworm infestation and better resistance potential. FH-333 and NIAB-KIRAN also demonstrated comparatively high yield performance across all regions. FH-333 produced yields ranging from 2110 to 2460 kg ha<sup>-1</sup>, while NIAB-KIRAN yielded between 2035 and 2385 kg ha<sup>-1</sup> during the study period. Their relatively lower infestation levels may have contributed to better boll retention and seed development. In contrast, CIM-499 recorded the lowest yield in all provinces during both years. The minimum yield of 1725 kg ha<sup>-1</sup> was observed in Punjab during 2024, while slightly higher yields were recorded in 2025. The poor performance of CIM-499 was likely associated with its higher susceptibility to pink bollworm infestation, resulting in greater boll and seed damage. Koonj and NIAB-878 showed intermediate yield performance, indicating moderate tolerance against pink bollworm. Overall, the results demonstrated that cotton varieties with lower infestation levels generally produced higher yields, confirming the negative impact of pink bollworm infestation on cotton productivity.

The data presented (in table 4) revealed clear differences among cotton varieties in their susceptibility to pink bollworm infestation during the 2024 and 2025 cropping seasons. The results showed that fruiting parts damage, green boll damage, and seed damage varied significantly among the tested varieties, indicating differences in resistance or tolerance against *P. gossypiella*. Among all varieties, CIM-499 recorded the highest level of infestation during both years. In 2024, CIM-499 showed 19.85% fruiting parts damage, 27.75% green boll damage, and 7.80% seed damage. Similarly, during 2025, it recorded 18.95% fruiting parts damage, 26.80% green boll damage, and 7.35% seed damage. These results confirmed that CIM-499 was the most susceptible variety to pink bollworm infestation under field conditions. In contrast, CKC-05 consistently exhibited the lowest damage percentages during both years. In 2024, CKC-05 recorded only 11.75% fruiting parts damage,

16.20% green boll damage, and 3.65% seed damage, while in 2025 the values further decreased to 10.90%, 15.40%, and 3.30%, respectively. The lower infestation levels and reduced damage indicated that CKC-05 possessed comparatively better resistance or tolerance against pink bollworm attack. FH-333 and NIAB-KIRAN also demonstrated relatively lower damage percentages compared with CIM-499 and NIAB-878. FH-333 recorded fruiting parts damage ranging from 12.60% to 13.42%, whereas NIAB-KIRAN showed damage between 13.55% and 14.35%. Their comparatively lower infestation suggests moderate resistance against pink bollworm. Koonj and NIAB-878 exhibited intermediate levels of infestation and were categorized as moderately susceptible varieties. Overall, green boll damage was higher than fruiting parts and seed damage in all varieties, indicating that green bolls were the most preferred feeding sites for pink bollworm larvae. The findings further demonstrated that varieties with lower infestation levels generally maintained better yield performance and greater field tolerance against pink bollworm infestation.

Varieties	Fruiting parts damage %		Green boll damage %		Seed damage %	
	2024	2025	2024	2025	2024	2025
FH-333	13.42	12.60	18.65	17.85	4.35	4.05
Koonj	15.28	14.45	21.40	20.55	5.12	4.80
CIM-499	19.85	18.95	27.75	26.80	7.80	7.35
NIAB-878	17.10	16.25	24.30	23.45	6.25	5.90
NIAB-KIRAN	14.35	13.55	20.15	19.35	4.88	4.50
CKC-05	11.75	10.90	16.20	15.40	3.65	3.30

Table 4: Seasonal mean percent fruiting parts damaged by pink bollworm in different cotton varieties during 2024 and 2025.

The analysis of variance showed that the effect of cotton varieties on pink bollworm infestation was highly significant (table 5). The ANOVA showed F = 28.26 with p = 0.0001, indicating that the tested cotton varieties differed significantly in their resistance or susceptibility against pink bollworm infestation. Therefore, the results confirmed that varietal response played an important role in determining pink bollworm infestation level.

Source of variation	D.F.	Sum of Squares	Mean Square	F-value	P-value
Varieties	5	2.684	0.537	28.26	0.0001
Error	18	0.342	0.019	—	—
Total	23	3.026	—	—	—

Table 5: ANOVA for effect of cotton varieties on pink bollworm infestation.

There were significant varietal differences between resistance and susceptibility to pink bollworm (table 6). CKC-05 was highly resistant with less than 10% infestation, along with the highest yield capacity and minimum boll and seed damage among all tested varieties of cotton. The superior performance indicates that there are favorable resistance traits in CKC-05, which can minimize the attack of pink bollworms and enhance overall productivity. The varieties were classified as resistant with infestation of 10% to 20% as in the case of FH-333 and Koonj varieties. Lower larval population and stable yield performance were observed in both varieties in natural infestation. These varieties should thus be recommended for use in integrated pest management programs designed to minimize the damage caused by pests and to achieve good cotton yields. Both the varieties NIAB-KIRAN and NIAB-878 were classified in moderately resistant category as they had 21% and 30% infestation respectively. Heating the seeds up first reportedly did not improve the yield of these varieties despite moderate pink bollworm damage. Relatively high yield stability was observed in NIAB-NIRDHG NIRD, NIAB-KIRAN and RAKNI-3 as compared to RAKNI-878 indicating some tolerance to pest infestation in these lines. CIM-499 was classified as susceptible as it had more than 30% infestation with the highest larval population, maximum boll and seed damage and lowest yield performance among all the varieties tested.

The lower level of susceptibility of CIM-499 suggests that it is not well suited for growing in areas where there are high levels of pink bollworm. Overall the results revealed that varietal resistance has a significant effect on the infestation of pink bollworm and yield of cotton. Resistant varieties, specifically CKC-05 and FH-333, can contribute to the control of pests and be used to achieve sustainable cotton production. It was confirmed had pink bollworm infest both Bt and non-Bt cotton cultivars, but the severity of infestation.

Varieties	Infestation Threshold (%)	Resistance Category	Yield Potential	Main Advantages
FH-333	10 – 20	Resistant	High	Lower larval population, reduced boll damage, stable yield performance
Koonj	10 – 20	Resistant	Moderate to High	Moderate tolerance, comparatively better adaptation under field conditions
CIM-499	> 30	Susceptible	Low	High boll formation but highly vulnerable to pink bollworm infestation
NIAB-878	21–30	Moderately Resistant	Moderate	Moderate infestation level with acceptable yield stability
NIAB-KIRAN	21–30	Moderately Resistant	High	Better yield performance with comparatively lower infestation
CKC-05	< 10	Highly Resistant	Very High	Lowest infestation, highest yield, superior resistance against pink bollworm

Table 6: Resistance scale of cotton varieties on pink bollworm infestation.

differed significantly depending on the cultivar, varietal tolerance, expression of Bt toxin, boll characters, and field conditions (Hanif *et al.*, 2025). All six cotton varieties were attacked by pink bollworm and none were completely protected in the field during the present study. The substantial differences between the four genotypes of FH-333, Koonj, CIM-499, NIAB-878 and CKC-05 corroborate the previous genotype screening studies, where some of the cotton entries performed better in reducing green boll damage and open boll damage than the susceptible checks. In the same way, Hanif *et al.* (2025) reported high infestation in flowers and bolls of cotton cultivars at various location across Pakistan with comparatively better protection by some cultivars against the damage of pink bollworm. Thus, the superiority of CKC-05 in the present investigation supports the concept that resistance/tolerance of the host plant could inhibit the establishment of larvae in the field and result in reduced boll damage and yield loss under natural pest pressure (Hanif *et al.*, 2025). The relatively low infestation and stable yield performance of CKC-05, FH-333 and NIAB-KIRAN also corroborate previous reports indicating that varietal resistance is also a crucial factor in controlling the pink bollworm. The moderate resistance of FH-333 and NIAB-KIRAN may relate to differences in boll development, plant architecture, biochemical traits, or to antibiosis/antixenosis mechanisms found in the different cotton germplasm as reported in cotton resistance breeding (Patel *et al.*, 2024). Susceptible cotton genotypes, in contrast, had high larval density, high boll damage and low yield of CIM 499 which is consistent with previous observations of susceptible cotton being more likely to support high larval survival and high internal boll damage (Hanif *et al.*, 2025). The present statistical finding of significant differences among cotton cultivars in resistance potential is complemented by Kumar *et al.* (2025) who noted that green boll damage by pink bollworm was variable between Bt and non-Bt cultivars and various regions. Green bolls were preferred feeding area of pink bollworm larvae which is also in line with the biology of the pest. Pink bollworm larvae are notorious for infesting cotton bolls and living inside the boll consuming the seeds (Fabrick *et al.*, 2023), making the pest very difficult to control by application of insecticides to the surface. Pink bollworm injury is most severe to bolls where larvae bore into the lint and feed on seeds resulting in lint staining, lint quality and loss. Fabrick *et al.* (2023) also reported that larvae feed primarily in the bolls of cotton, favoring the seeds which is consistent with the present study as higher density of larvae was directly correlated with higher boll damage and lower yield. This is also in line with the present observation that yield of cotton and quality of the seeds decreased with increasing infestation due to internal feeding which causes damage of lint, seed weight, boll opening and market quality (Khakwani *et al.*, 2022). The findings are also relevant to the Pakistani context as pink bollworm has emerged as a serious problem in cotton production in Pakistan. Increased pressure of pink bollworm, survival in Bt cotton, and the possibility of field-evolved resistance to Cry toxins were reported in previous studies in Pakistan and in neighboring cotton growing areas (Fabrick *et al.*, 2023; Hanif *et al.*, 2025). Some of the cultivars of Bt cotton in Pakistan have suffered high infestation of pink bollworm flowers and bolls with loss of seed yield as reported by Hanif *et al.* (2025) indicating that the available Bt traits are not always successful in controlling the infestation of pink bollworm on Bt cotton. This confirms the result of the current study that resistant/tolerant cultivars are required in cotton sustainable production. Hence, the improved performance of CKC-05, FH-333 and NIAB-KIRAN has practical significance as these cultivars can

help in reducing reliance on insecticides and mitigating yield losses in the field under infestation (Patel *et al.*, 2024; Hanif *et al.*, 2025). In summary, the current study corroborates and builds upon previous studies showing that there is cultivar-specific susceptibility to pink bollworm injury and that resistant/tolerant cotton genotypes could be an important component of an IPM program. The resistance and yield stability of CKC-05 are superior followed by moderate in FH-333 and NIAB-KIRAN which suggests that varietal selection can help minimise boll damage and maximise cotton productivity in the presence of pink bollworm. CIM-499, on the other hand, is susceptible which means that the cultivation of vulnerable varieties in regions of high pink bollworm incidence could pose a threat. They corroborate the previously recommended management strategies for pink bollworm (Patel *et al.*, 2024; Hanif *et al.*, 2025), which include the use of resistant cultivars, timely monitoring, pheromone-based tools, biological control, and crop sanitation and minimizing repeated insecticide sprays. So, the present study contributes some field-based evidences from Pakistan that the use of resistant cultivars could minimize pink bollworm damage and preserve cotton yield and thereby promote sustainable production.

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**LIFE SCIENCE REPORTING:** In current research article no life science threat was reported

**ETHICAL RESPONSIBILITY:** This is original research, and it is not submitted in whole or in parts to another journal for publication purpose.

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