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# Evaluate the impact of sowing periods on pink bollworm incidence in *Bt* Cotton

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**Abstract**
The present investigation was carried out at the research farm of Regional Research Station, Anand Agricultural University, Anand, during *kharif* 2020-21 and 2021-22 to evulate of impact of *Bt* cotton sown during different periods *viz.*, first week of May, third week of May, first week of June, third week of June, first week of July, third week of July, and first week of August on incidence of pink bollworm. The results of experiment were revealed that *Bt* cotton sown during first week of May was found with minimum incidence of the pink bollworm larva as well as damage on squares, flowers, green boll, open boll and locule. Similarly, the minimum square damage, rosette flower and green boll damage was noticed in *Bt* cotton sown during third week of May. However, the highest seed cotton yield was recorded when *Bt* cotton sown at first week of June and third week of Jun whereas, the minimum seed cotton yield was recorded during first week of August.

**Keywords:** *Pectinophora gossypiella*, *Bt* cotton, sowing periods, boll damage, locule damage

## Introduction

The pink bollworm (*Pectinophora gossypiella*) is a significant pest affecting cotton production worldwide, leading to substantial economic losses in both yield and fiber quality (Kranthi, 2015; Dhawan *et al.*, 2020) [8, 6]. *Bt* cotton, genetically engineered to express insecticidal proteins from *Bacillus thuringiensis* (*Bt*), has been a valuable tool for managing this devastating pest (Tabashnik *et al.*, 2013) [16]. However, the efficacy of *Bt* cotton in controlling pink bollworm populations is not uniform and can be influenced by various agronomic practices, particularly the timing of sowing (Cattaneo *et al.*, 2006) [5]. The timing of sowing is crucial as it helps synchronize crop growth stages with the pink bollworm lifecycle, thereby impacting the effectiveness of *Bt* cotton in pest management.

While cultural and chemical methods are employed to control pink bollworms, adjusting planting dates is a key component of cultural control that minimizes early-season larval survival (Naranjo & Ellsworth, 2009) [13]. This strategy works by depriving overwintering larvae of the food and shelter pink bollworm need to survive. Pink bollworms overwinter in a dormant larval stage and complete their lifecycle when temperatures warm, emerging as adults. The adults then lay eggs, which hatch into larvae that depend on cotton squares at one-third of their full size for food and shelter. The planting date influences when the cotton reaches susceptible square stage, significantly impacting the survival of early-season pink bollworm larvae (Kranthi *et al.*, 2004) [11].

Early planting is a crucial cultural practice for disrupting the pink bollworm lifecycle. Early planting, along with proper residue disposal, limits food sources for the pest, helping to reduce overwintering populations (Naranjo & Ellsworth, 2009) [13]. Planting early enough to allow the crop to mature before peak pest infestation, combined with the "closed season" practiced in some regions where cotton is not grown for a period, can create a period where pink bollworms lack adequate host plants. This deprivation disrupts the pest lifecycle and reduces the population (Kranthi, 2015) [8].

Though *Bt* cotton is genetically modified for pest resistance, studies show that varieties are still susceptible to pink bollworm, particularly when planted later in the season (Tabashnik *et al.*, 2013) [16]. Delayed planting generally increases pest infestation rates, as the longer the crop is exposed to pests, the higher the risk of infestation. For instance, Cattaneo *et al.* (2006) [5] observed that pink bollworm incidence was highest in cotton planted in late June. Conversely, early planting often results in lower aphid, jassid, and pink bollworm incidence compared to later plantings (Dhawan *et al.*, 2020) [6].

Planting date also significantly impacts natural enemy populations, which play a key role in controlling pink bollworm populations (Carrière *et al.*, 2001) [4]. Delayed planting leads to a lower population of natural enemies, which can result in increased pink bollworm infestations. Naranjo & Ellsworth (2009) [13] found that an early planting date resulted in the highest number of natural enemies, which reduced bollworm numbers and ultimately increased the quantity and quality of the cotton yield.

This study aims to provide a comprehensive analysis of the effect of sowing dates on pink bollworm infestations in *Bt* cotton, contributing to the development of more effective and sustainable pest management strategies.

## Methodology

The impact of different sowing periods on pink bollworm, *P. gossypiella* incidence in *Bt* cotton, an experiment was laid out during *Kharif*, 2020-21 and 2021-22. The cotton variety Ajeet 155 (BG II) was grown at Regional Research Station, AAU, Anand by following all agronomical practice except insecticidal spray. The experiment was conducted with three replications, utilizing a spacing of 120 x 60 cm between plants. The gross plot size measured 6.0 x 4.8 meters, while the net plot size was 4.8 x 2.4 meters. The study included seven treatments based on the period of sowing *viz.*, W1 (first week of May), W2 (third week of May), W3 (first week of June), W4 (third week of June), W5 (first week of July), W6 (third week of July), and W7 (first week of August).

In order to record the pink bollworm infestation, five plants were randomly selected from the net plot area of each treatment and replication. From each selected plant, total square(s) as well as damaged square(s), total flower(s) as well as rosette flower were recorded at weekly interval from square formation to till harvest of crop.

To record the pink bollworm larva(e) and green boll damage, 20 green bolls were plucked randomly at 60, 90, 120 and 150 days after sowing (DAS) from each plot and green bolls brought to the laboratory for further observations. Each green boll was cut opened along with ridges of the locule(s) with the help of sharp knife carefully and number of live pink bollworm larvae from each boll were recorded. Then total number of pink bollworm larvae and green boll damage per 20 bolls were counted.

During picking of seed cotton, data on number of damaged opened bolls due to pink bollworms were recorded from 50 randomly selected bolls collected from net plot area and presented in percentage. Number of locule damage was recorded from the same bolls and data thus obtained were analyzed following standard statistical procedure. Picking wise seed cotton was recorded from each net plot of respective sowing periods. Based on these data yield of seed cotton per hectare was calculated for each sowing periods. The data obtained were analyzed following standard statistical procedure to draw valid conclusion after adopting square root transformation for data on number of larvae and green boll damage and arcsine transformation for data on square damage, rosette flowers, open boll damage and locule damage.

## Results

**Square Damage:** The data of pooled over periods and years are presented on Table 1, the impact of different sowing periods of *Bt* cotton on square damage due to pink bollworm in *Bt* cotton. The lowest square damage was observed cotton sown during first week of May (W1, 15.12 %). This was statistically similar to the third week of May (W2), which had 16.37 per cent damage. Both these periods were significantly better than the later sowing periods in terms of minimizing square damage. As the sowing period is delayed, the square damage increases. The highest square damage was recorded in the first week of August (W7) at 38.04 per cent. This trend suggests that earlier sowing helps in reducing square damage by pink bollworms.

### Rosette Flowers

Similar to square damage, the first week of May (W1) also recorded the lowest rosette flower damage at 17.20 per cent. The third week of May (W2) showed a statistically similar result with 18.34 per cent damage. Both these periods were significantly better than the later sowing periods for minimizing rosette flower damage. The damage percentage increases with the delay in sowing time. The highest rosette flower damage was observed in the first week of August (W7, 35.49 %). This pattern reinforces the finding that early sowing is beneficial in mitigating rosette flower damage caused by pink bollworms.

### Green Bolls Damage

While the first week of May (W1) exhibited the lowest green boll damage (18.43%), it statistically at par with the third week of May (W2) and the first week of June (W3) which had 21.52 per cent and 21.24 per cent damage, respectively. However, all three periods were significantly better than the later sowing periods. A consistent increase in green boll damage was observed with a delay in sowing time, with the highest damage observed in the first week of August (W7, 40.02 %). The data indicates that early sowing, particularly in May, leads to significantly lower green boll damage from pink bollworms

### Pink Bollworm Larval Population

Table 2 presents data on the number of pink bollworm larvae per 20 bolls of *Bt* cotton, examining the influence of different sowing periods across two years (2020-21 and 2021-22).

**2020-21:** The first week of May (W1) sowing yielded the lowest larval count (1.36). This was statistically different from all other treatments except for the third week of May (W2). The third week of May (W2), first week of June (W3), and third week of June (W4) demonstrated statistically similar larval counts (2.11, 2.17, and 2.36, respectively). The larval count increased significantly with the first week of July (W5) sowing (2.85) compared to the previous three treatments. The highest larval counts were observed in the third week of July (W6) and the first week of August (W7) sowings (3.39 and 4.17, respectively), significantly different from all other treatments.

**2021-22:** Mirroring the 2020-21 trend, the first week of May (W1) sowing again exhibited the lowest larval count (1.18), statistically different from all other sowing periods. The third week of May (W2), first week of June (W3), and third week of June (W4) sowings displayed statistically similar larval numbers (1.84, 1.87, and 1.98, respectively). The first week of July (W5) sowing resulted in a higher larval count (2.52) than the preceding three treatments but lower than the third week of July (W6) and the first week of August (W7), with 2.85 and 3.72 larvae per 20 bolls, respectively.

### Pooled Analysis (2020-21 & 2021-22)

The first week of May (W1) sowing consistently produced the lowest larval count (1.27) across both years. 1 This was statistically significant compared to all treatments except the third week of May.

**Table 1:** Effect of sowing periods on squares, flowers and green bolls due to pink bollworm in *Bt* cotton (pooled over periods and years)

| Tr. No. | Sowing Weeks | Square damage (%) | Rosette flowers (%) | Green boll damage (%) |
|---|---|---|---|---|
| $W_1$ | First week of May | 15.12a | 17.20a | 18.43a |
| | | (6.81) | (8.75) | (9.99) |
| $W_2$ | Third week of May | 16.37a | 18.34a | 21.52ab |
| | | (7.95) | (9.90) | (13.46) |
| $W_3$ | First week of June | 22.09b | 22.48b | 21.24ab |
| | | (14.14) | (14.62) | (13.12) |
| $W_4$ | Third week of June | 25.34c | 25.82c | 25.25b |
| | | (18.32) | (18.97) | (18.19) |
| $W_5$ | First week of July | 28.16d | 27.29d | 30.50c |
| | | (22.28) | (21.02) | (25.76) |
| $W_6$ | Third week of July | 35.00e | 33.50e | 37.08d |
| | | (32.91) | (30.46) | (36.35) |
| $W_7$ | First week of August | 38.04f | 35.49f | 40.02d |
| | | (37.96) | (33.71) | (41.36) |
| S. Em. ± | Treatment (T) | 0.47 | 0.69 | 1.44 |
| | Period (P) | 1.41 | 1.42 | 0.56 |
| | Year (Y) | 0.25 | 0.24 | 0.46 |
| | T x P | 2.06 | 2.06 | 1.49 |
| | P x Y | 1.10 | 1.10 | 0.80 |
| | Y x T | 0.69 | 0.69 | 1.22 |
| | Y x P x T | 2.92 | 2.19 | 2.12 |
| F test | | Sig. | Sig. | Sig. |
| C.V. (%) | | 19.81 | 19.63 | 13.25 |

**Note:** 1. Figures in parentheses are retransformed values and arcsine transformed values
2. Treatment mean(s) with the letter(s) in common are not differed significantly by Duncan's New Multiple Range test (DNMRT) at 5 % level of significance,
3. Sig.: Significant
4. Significant parameters and their interactions: i. square damage: P, Y, T x P, P x Y
ii. Rosette flower: P, Y, Y x P, P x T
iii. Green boll damage: P, T, Y x T, P x T

**Table 2:** Effect of sowing periods on larval population due to pink bollworm in *Bt* cotton

| Tr. No. | Sowing Weeks | No. of larva(e) per 20 bolls | | |
|---|---|---|---|---|
| | | 2020-21 | 2021-22 | Pooled over periods and years |
| $W_1$ | First week of May | 1.36a | 1.18a | 1.27a |
| | | (1.34) | (0.90) | (1.11) |
| $W_2$ | Third week of May | 2.11b | 1.84b | 1.97b |
| | | (3.92) | (2.91) | (3.40) |
| $W_3$ | First week of June | 2.17b | 1.87b | 2.02b |
| | | (4.17) | (3.03) | (3.57) |
| $W_4$ | Third week of June | 2.36b | 1.98b | 2.17b |
| | | (4.96) | (3.53) | (4.21) |
| $W_5$ | First week of July | 2.85c | 2.52c | 2.68c |
| | | (7.54) | (5.93) | (6.70) |
| $W_6$ | Third week of July | 3.39b | 2.85c | 3.12d |
| | | (10.95) | (7.65) | (9.24) |
| $W_7$ | First week of August | 4.17e | 3.72d | 3.94e |
| | | (16.63) | (13.59) | (15.05) |
| S. Em. ± | Treatment (T) | 0.11 | 0.11 | 0.08 |
| | Period (P) | 0.08 | 0.08 | 0.06 |
| | Year (Y) | - | - | 0.04 |
| | T x P | 0.23 | 0.19 | 0.14 |
| | P x Y | - | - | 0.17 |
| | Y x T | - | - | 0.11 |
| | Y x P x T | - | - | 0.13 |
| F test | | Sig. | Sig. | Sig. |
| C.V. (%) | | 13.86 | 16.57 | 15.13 |

**Note**: 1. Figures in parentheses are retransformed values and those outsides are $\sqrt{x+0.5}$ transformed values
2. Treatment mean(s) with the letter(s) in common are not differed significantly by Duncan's New Multiple Range test (DNMRT) at 5 % level of significance,
3. DAS: Day after sowing, Sig.: Significant
4. Significant parameters and their interactions: P, Y, T x P

($W_2$). The data reveals a consistent pattern of increasing larval population with later sowing dates, culminating in the highest infestation rate observed in the first week of August ($W_7$) (3.94). The findings from Table 2 strongly suggest that early May sowing, particularly during the first week ($W_1$), is the most effective strategy for minimizing pink bollworm infestation in Bt cotton. Delaying sowing beyond the first week of May leads to a progressive increase in larval numbers, ultimately resulting in significantly higher pest pressure. This highlights the crucial role of sowing time in integrated pest management for *Bt* cotton.

**Locule Damage**

Cotton sown during first week of May ($W_1$) had the lowest locule damage at 20.67%. The third week of May ($W_2$) and the first week of June ($W_3$) had statistically higher locule damage than $W_1$, at 28.67 per cent and 31.33 per cent, respectively. However, $W_2$ and $W_3$ were not statistically different from each other. Later cotton sowing periods showed progressively higher damage *viz.*, third week of June ($W_4$, 32.00 %), first week of July ($W_5$, 35.33 %), third week of July ($W_6$, 39.33 %), and first week of August ($W_7$, 42.00 %).

**Open Bolls Damage**

The first week of May cotton sown ($W_1$) exhibited the lowest open boll damage (18.00 %). The third week of May ($W_2$) and the first week of June ($W_3$) showed higher damage than $W_1$ at 26.00% and 30.67%, respectively. However, there was no statistically significant difference between the damage in $W_2$ and $W_3$. Open boll damage increased with later sowing periods *i.e.*, third week of June ($W_4$, 37.33 %), First week of July ($W_5$, 38.67 %), third week of July ($W_6$, 48.00 %), and First week of August ($W_7$, 49.33 %).

**Seed Cotton Yield**

During 2020-21, third week of June sowing (W4) harvested the maximum of seed cotton at 2290 kg/ha. The first week of June sowing (W3) was not statistically different, producing 2155 kg/ha of seed cotton. *Bt* cotton sown during third week of May sowing (W2) obtained significantly less seed cotton at 1859 kg/ha. The first week of May sowing (W1) produced even less seed cotton at 1599 kg/ha. The remaining sowing periods (W5, W6, and W7) produced progressively less seed cotton, with the first week of August sowing (W7) harvested the least seed cotton at 1249 kg/ha.

During 2021-22, *Bt* cotton sown during third week of June (W4) harvested the highest seed cotton at (2369 kg/ha). Similar to 2020-21, the first week of June sown (W3) was not statistically different, yielded 2046 kg/ha of seed cotton. *Bt* cotton sown during third week of May (W2) produced significantly less seed cotton at 1618 kg/ha, while the first week of May sowing (W1) yielded even less at 1403 kg/ha. The remaining sowing weeks (W5, W6, and W7) showed progressively decreasing seed cotton yield, with the first week of August (W7) sowing cotton obtained in the lowest seed cotton yield (930 kg/ha).

The data of pooled over years, *Bt* cotton sown during third week of June (W4) harvested maximum seed cotton at 2329 kg/ha which was at par with first week of June (W3) harvested 2100 kg/ha of seed cotton. The third week of May (W2) sown cotton produced significantly less seed cotton (1738 kg/ha), followed by the first week of May sowing (W1) at 1501 kg/ha. The later sowing periods (W5, W6, and W7) harvested progressively lower seed cotton yield, with the first week of August sown (W7) cotton produced the lowest seed cotton yield of 1089 kg/ha.

**Table 3:** Effect of sowing periods on open boll and locule due to pink bollworm in *Bt* cotton (pooled over years)

| Tr. No. | Sowing Weeks | Open boll damage (%) | Locule damage (%) |
|---|---|---|---|
| $W_1$ | First week of May | 18.00a | 20.67a |
| $W_2$ | Third week of May | 26.00b | 28.67b |
| $W_3$ | First week of June | 30.67b | 31.33b |
| $W_4$ | Third week of June | 37.33c | 32.00b |
| $W_5$ | First week of July | 38.67c | 35.33bc |
| $W_6$ | Third week of July | 48.00d | 39.33c |
| $W_7$ | First week of August | 49.33d | 42.00c |
| S. Em. ± | Treatment (T) | 2.96 | 1.84 |
| | Year (Y) | 1.77 | 0.98 |
| | Y x T | 5.80 | 3.20 |
| F test | | Sig. | Sig. |
| C.V. (%) | | 11.05 | 15.39 |

**Note**: 1. Figures in parentheses are retransformed values and arcsine transformed values
2. Treatment mean(s) with the letter(s) in common are not differed significantly by Duncan's New Multiple Range test (DNMRT) at 5 % level of significance,
3. Sig.: Significant
4. Significant parameters and their interactions: i. P, Y, T x P, P x Y

**Table 4:** Impact of sowing periods on seed cotton yield

| Tr. No. | Sowing Weeks | Seed cotton yield (Kg/ha) | | |
|---|---|---|---|---|
| | | 2020-21 | 2021-22 | Pooled over years |
| $W_1$ | First week of May | 1599cd | 1403c | 1501cd |
| $W_2$ | Third week of May | 1859bc | 1618bc | 1738b |
| $W_3$ | First week of June | 2155ab | 2046b | 2100a |
| $W_4$ | Third week of June | 2290a | 2369a | 2329a |
| $W_5$ | First week of July | 1721c | 1507bc | 1614cd |
| $W_6$ | Third week of July | 1477cd | 1273cd | 1375d |
| $W_7$ | First week of August | 1249d | 930d | 1089e |
| S. Em. ± | Treatment(T) | 115 | 120 | 80 |
| | Year (Y) | - | - | 231 |

| | | | | |
|---|---|---|---|---|
| | T x Y | - | - | NS |
| F test | | Sig. | Sig. | Sig. |
| C.V. (%) | | 11.26 | 13.26 | 12.20 |

**Note:** 1. Treatment mean(s) with the letter(s) in common are not differed significantly by Duncan's New Multiple Range test (DNMRT) at 5 % level of significance
2. Sig.: Significant, NS: Non-significant

## Discussion

The results of this study underscore the significant impact of sowing time on the incidence of pink bollworm (*Pectinophora gossypiella*) and its subsequent effect on seed cotton yield. It was observed that cotton sown in the month of May exhibited a notably lower population of pink bollworm larvae and reduced damage to green bolls, open bolls, rosette flowers, and locules. This finding is strongly supported with earlier studies suggesting that early sowing can mitigate the vulnerability of cotton crops to pink bollworm infestations, likely due to the asynchrony between the pink bollworm life cycle and the availability of susceptible reproductive structures of the cotton plant (Naeem *et al.*, 2001; Ahmad *et al.*, 2013) [12, 1].

There are few reports which slightly deviated from present finding, Tomar *et al.* (2002) found that the cotton crop sown between fifth April to fifth June were less pink bollworm damage on green bolls and larval population. According to Kiran *et al.* (2022), the cotton sown during June first fortnight recorded less pink bollworm larval population. Ingole *et al.* (2019) noticed that the fifth June cotton sown had maximum pink bollworm infestation. Vennila *et al.* (2003) also reported that the minimum pink bollworm damage on bad bolls, open bolls and locules on cotton was recorded when crop during sixteen June than seventh July. All above reports are slightly deviation from present finding because all above reported experiment initiated with early June month.

Cotton crops sown during the later months, particularly in July and August, showed the highest incidence of pink bollworm infestation. This increased pest pressure during these months is likely attributable to the alignment of the bollworm's peak activity period with the availability of suitable reproductive plant parts, such as bolls, that provide optimal conditions for larval development (Ali *et al.*, 2015) [2]. Consequently, the damage was most severe during these periods, leading to a significant reduction in seed cotton yield. This observation aligns with the hypothesis that delayed sowing extends the crop's exposure to bollworm attacks, thus exacerbating the damage to critical reproductive structures (Kranthi *et al.*, 2009) [10].

Interestingly, the study also revealed that despite the observed damage to the reproductive parts of the cotton crop, this did not directly correlate with seed cotton yield in early sown crops. This could be due to the fact that early sowing provides a longer growing season, allowing the plants to compensate for any early damage through additional flowering and boll setting (Soomro *et al.*, 2012) [15]. Furthermore, early-sown cotton likely benefits from better weather conditions, such as optimal temperatures and rainfall patterns, which support healthy crop growth and development (Iqbal *et al.*, 2016) [7].

On the other hand, cotton sown in June, while showing a relatively higher yield compared to other sowing periods, still faced increased pink bollworm incidence compared to May month cotton sown. This suggests that while June month sown cotton might still offer a compromise between early season vigor and pest avoidance, it does not completely mitigate the risks posed by the pink bollworm. Therefore, careful consideration of sowing duration is crucial for managing pink bollworm infestations and harvested seed cotton yield (Babar et al., 2014) [3].

The marked decrease in seed cotton yield for crops sown in July and August, coinciding with the peak pink bollworm activity, reinforces the importance of early sowing as a cultural control strategy. These findings highlight the need for integrated pest management (IPM) approaches that consider sowing time as a critical factor in minimizing pest-related losses. By optimizing the sowing schedule, farmers can reduce the reliance on chemical controls, which are often associated with environmental and economic drawbacks (Kranthi & Russell, 2011) [9].

## Conclusion

*Bt* cotton sown during first week of May was found with minimum incidence of the pink bollworm larva as well as damage on squares, flowers, green boll, open boll and locule. Similarly, the minimum square damage, rosette flower and green boll damage was noticed in *Bt* cotton sown during third week of May. However, the highest seed cotton yield was recorded when *Bt* cotton sown at first week of June and third week of Jun whereas, the minimum seed cotton yield was recorded during first week of August.

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