ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating: 4.97
IJAFS 2025; 7(7): 592-598
www.agriculturaljournals.com
Received: 26-05-2025
Accepted: 28-06-2025

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Heterosis and inbreeding depression studies for Seedcotton yield and its components in upland cotton (*Gossypium hirsutum* L.)

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DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i7h.572

Abstract
Six generation (P_1, P_2, F_1, F_2, BC_1 and BC_2) of four crosses *viz*., cross I (MCB-16-1×GTHV 0/32), cross II (MCB-16-1×GTHV-17/70), cross III (GTHV-17/15×GTHV-0/35) and cross IV (MCB-9-2×GSHV-204) derived from eight genotypes and they were evaluated to study heterosis and inbreeding depression for seed cotton yield and its component traits. Out of that, for seed cotton yield and its component traits, cross IV (MCB-9-2 × GSHV-204) registered the highest estimate of relative heterosisalong with significant and desired inbreeding depression.The crosses MCB-16-1 × GTHV-17/70 and GTHV-17/15 × GTHV-0/35 demonstrated significant positive heterobeltiosis for key economic traits such as seed index, lint index and ginning outturn. Additionally, these hybrids exhibited notable inbreeding depression for traits like plant height, number of sympodia and fiber strength, indicating the involvement of non-additive gene action. The findings of the present study suggest promising opportunities for both the isolation of superior pure lines from heterotic F_2 populations and the commercial exploitation of heterosis in cotton breeding programs.

Keywords: Heterosis, heterobeltiosis, inbreeding depression

Introduction

Cotton is one of the most important and widely used natural fibers in the world. Cotton, often referred to as the "King of Fibre" and "white gold". It is an economically important crop grown for its lint used in textiles and seeds used for oil extraction and cattle feed. It belongs to the family Malvaceae and is an often-cross-pollinated crop. Cotton originates from regions like India, the USA, and Egypt. The plant shows monopodial (vegetative) and sympodial (fruiting) branching. Apart from fiber, cotton plays a crucial role in food and livestock industries, making it a valuable multipurpose crop.The genus Gossypium contains 50 different species of cotton among which four species are cultivated having spinnable lint and the remaining 46 species are in wild form. India has the distinction of growing all the four spinnable lint bearing species of *Gossypium viz*., *G. hirsutum*, *G. barbadense*, *G. arboreum and G. herbaceum*. The first two species are tetraploid (2n = 52) and commonly known as New World cottons, while the latter two are diploid (2n = 26) and originate from the Old World. Among the four cultivated cotton species, *Gossypium hirsutum* L. dominates global cotton production, accounting for over 90% of the total cultivated area. This species is widely valued for its broad variability in yield-related traits and fiber quality characteristics, making it the preferred choice in most cotton-growing regions.

Cotton is one of India's most vital fibre and commercial crops, playing a key role in both the agricultural and industrial sectors of the economy. It serves as the primary raw material for the cotton textile industry. The crop supports the livelihoods of approximately 6 million farmers directly, while an additional 40 to 50 million individuals are engaged in activities related to cotton marketing, processing, and trade. In India, cotton cultivation spans across ten major states, which are categorized into three primary zones: the northern, central, and southern zones. Apart from these, cotton is also grown on a smaller scale in a few non-traditional states, including Uttar Pradesh, Tripura and West Bengal.

In the context of agricultural advancements, the concept of heterosis holds a significant place. Its scientific application has contributed immensely to the progress of crop improvement efforts over the years. Heterosis, also known as hybrid vigor, is a widely recognized and extensively applied concept in the field of crop improvement. Plant breeders regard it as a significant breakthrough that has greatly enhanced the effectiveness of breeding techniques aimed at improving crop yield.

Inbreeding refers to the mating of genetically related individuals that share a common ancestry, thus belonging to the same gene pool. In naturally cross-pollinated species, inbreeding often leads to noticeable phenotypic effects such as reduced plant height and vigor, diminished seed production, lower yield potential and increased occurrence of physical abnormalities. On a genetic level, inbreeding results in higher homozygosity and may lead to the expression of harmful alleles, both lethal and sub-lethal in nature.

Cotton production in India has not shown a significant upward trend in recent years. One of the major strategies to overcome this stagnation is the development and adoption of high-yielding hybrids that demonstrate substantial economic heterosis. Increasing the area under hybrid cotton cultivation could lead to a considerable boost in national production. Hybrids are not only known for their higher productivity but also for their stability in yield performance across diverse environments. They are considered a critical tool in achieving breakthroughs in cotton yield and receiving greater focus and investment (Khadi *et al.*, 2010) [13].

The extent of heterosis observed in hybrids serves as an indicator of the underlying genetic diversity and plays an essential role in the selection of appropriate parental lines. Identifying the right combination of parents is key to producing superior F_1 hybrids that can fully express hybrid vigor. Moreover, such hybrids can contribute to the development of an improved gene pool for use in later generations (Kumar *et al*., 2013) [16].

Heterosis and inbreedingdepression are complementary to each other and the twophenomenon's are usually observed in the same study. Thus, a character which show high heterosis due to dominant allelic factors proportionally show high inbreeding depression because of fixation of allelic gene with increased homozygosity. Considerable success in developing superior cotton hybrids has been achieved by releasing cotton hybrids *viz*., Hybrid - 4, G. Cot. Hy. - 6, G. Cot Hy. -8, 10, 12 (Singh *et al.*, 2014) [24]. Both positive and negative heterosis values were observed, highlighting the potential of these hybrid combinations to improve various traits in breeding programs (Geddam *et al*., 2011 [5]; Panni *et al*., 2012) [20]. The objective of the present study was to evaluate the magnitude of heterosis and inbreeding depression among various cotton hybrids.

Materials and methods

The experimental material comprised of four crosses each representing six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2). Four crosses were developed from seven parents *viz.*, MCB-16-1, GTHV 0/32, GTHV 17/70, GTHV 17/15, GTHV 0/35, MCB-9-2 and GSHV 204. The selected genotypes were chosen based on their geographical origin and diverse morphological traits. Hybridization was carried out using the conventional hand emasculation and pollination technique as described by Dock (1934) [4]. To develop the F_2 population, selfing was performed on the F_1 plants. The experiment was conducted during *Kharif* 2022 at the Cotton Research Station, Sardarkrushinagar Dantiwada Agricultural University, Talod, following a compact family block design with three replications. Observations for all studied traits were recorded for each generation. Specifically, data were collected from five randomly selected plants in each of the parental lines (P_1 and P_2) and the F_1 generation, ten plants each from the backcross generations (BC_1 and BC_2) and twenty plants from the F_2 generation. For accuracy, observations were taken only from vigorous, competitive plants, while border plants were excluded to minimize edge effects.

The selected plants were tagged and numbered for recording different observations. Individual observation of each generation of each cross was considered for statistical analysis. Heterosis expressed over mid parental value (H_1) or relative heterosis (RH) was work out as per Turner (1953). Heterosis expressed over better parent or heterobeltiosis (H_2) or better parent heterosis (HB) was worked out as per Fonseca and Patterson (1968). Inbreeding depression was computed by using the following formulae:

$$\text{Inbreeding depression}(\%) = \frac{\overline{F}_1 - \overline{F}_2}{\overline{F}_2} \times 100$$

Results and discussion

The combined estimation of heterosis and inbreeding depression offers valuable insights into the nature of gene action governing the expression of quantitative traits. A scenario where high heterosis is accompanied by significant inbreeding depression typically suggests the involvement of non-additive gene effects, such as dominance and epistasis. In contrast, when the performance of traits remains consistent between the F_1 and F_2 generations, it indicates the predominance of additive gene action. Similarly, if the F_1 exhibits negative heterosis but the F_2 shows improvement, it further supports the presence of additive effects.From a plant breeding perspective, heterosis can be most effectively harnessed through the development of hybrid varieties. However, in crops where hybrid seed production is less feasible or economically viable, it can still be partially utilized through the creation of synthetic and composite varieties.

For earliness (days to flower), negative estimates of relative heterosis (RH) and heterobeltiosis (HB) are desirable. The estimate of relative heterosis in four crosses varied from -15.22 per cent (cross IV) to –2.31 per cent (cross I). Significant relative heterosis was observed in all the crosses. The highest significant relative heterosis in desired direction was observed in cross I (-15.22%) followed by cross II (-5.61%), cross III (-4.46%) and cross IV (-2.31%). Heterobeltiosis ranged from -12.08 per cent (cross IV) to -1.52 per cent (cross I). But, negative significant better parent heterosis was observed in cross I (-12.08%) followed by cross III (-4.32%) and cross II (-3.14%). The estimates of inbreeding depression varied from -15.00 per cent (cross II) to -2.24 per cent (cross III). The estimates of inbreeding depression were significant and negative in cross II which indicated F_2 population was having late flowering than their F_1 generations. Whereas, no significant and positive inbreeding depression was observed which indicate F_2 population having delayed flowering than their F_1 generation. (Table 1) For days to flower, Srinivas and Bhadru (2015) [27], Monicashree*et al.* (2017) [18], Lingaraja *et al.* (2017) [17], Khan *et al.* (2017) [14], Gohil *et al.* (2017) [7] and Chhavikant*et al.* (2017) [3] reported heterosis in desired direction for various character in cotton.

For earliness to boll opening, negative estimates of relative heterosis (RH) and heterobeltiosis (HB) are desirable. The estimate of relative heterosis in four crosses varied from -2.14 per cent (cross IV) to 1.60 per cent (cross I). Non-significant relative heterosis was observed in all the crosses. In case of days to boll opening, heterobeltiosis ranged from -1.98 per cent (cross III) to 2.47 per cent (cross I). Non-significant relative heterobeltiosis was observed in all the crosses. While, the estimates of inbreeding depression varied from -4.95 per cent (cross II) to -0.00 per cent (cross I). The estimates of inbreeding depression were significant and negative in cross II, III and IV which indicated F_2 population was having late boll opening than their F_1 generations. (Table 1) Similar result of desirable (negative) relative heterosis and negative inbreeding depression was earlier observed by Komal *et al.* (2014) [15] and Haq *et al.* (2019) [8] and Patel *et al.* (2024) [21].

Negative values of relative heterosis (RH) and heterobeltiosis (HB) are considered desirable for plant height, as reduced stature contributes to lodging resistance (Patel *et al.*, 2024) [21]. In the present study, relative heterosis across four crosses ranged from –10.72% in cross I to 15.23% in cross III. Cross II exhibited non-significant heterosis, while the most desirable and significant negative heterosis was recorded in cross I. In contrast, positive heterosis was observed in crosses II, III and IV. Heterobeltiosis values ranged between–9.45% (cross I) and 22.31% (cross III). Significant heterobeltiosis was found in crosses I, III and IV, while cross II showed a non-significant effect. Importantly, only cross I exhibited a significant negative heterobeltiosis (–9.45%), which is favourable for reducing plant height.

Inbreeding depression estimates varied from –5.49% (cross I) to 14.43% (cross IV). Crosses II, III and IV showed significant and positive inbreeding depression, suggesting that their F_2 populations had shorter plant height compared to their F_1 generations. In contrast, cross I exhibited non-significant and negative inbreeding depression, indicating that the F_2 plants were taller than those in the F_1 generation. (Table 1) Similar, result for relative heterosis and inbreeding depression was observed by Chhavikant *et al.* (2017) [3], Tigga *et al.* (2017) [28], Komal *et al.* (2014) [15] and Haq *et al.* (2019) [8], Geng *et al.* (2021) [6] and patel *et al.* (2024) [21].

Number of monopodial branches per plant is a trait of prime significance in cotton because development of sympodia is mainly associated with this trait (Sahito *et al.*, 2015) [23]. For monopodia per plant, the data presented in table indicated both negative (desirable) and positive (undesirable) values. The estimate of relative heterosis in four crosses varied from -21.57 per cent (cross I) to 21.31 per cent (cross IV). Non-Significant and positive relative heterosis was observed in cross II and III, while non-significant and negative relative hetetrosis was observed in cross I, whereas, significant and positive relative heterosis was observed in cross IV. Heterobeltiosis ranged from -13.04 per cent (cross I) to 68.18 per cent (cross IV). Whereas, highest significant better parent heterosis in undesired direction was observed in cross IV (68.18%). The estimates of inbreeding depression varied from -107.50 per cent (cross I) to 18.92 per cent (cross IV). The estimates of inbreeding depression were significant and positive in cross IV indicated that less number of monopodial branches in F_2 generation than F_1 generation, whereas highest significant and negative expression in desired direction in cross I (-107.50) followed by cross II (-38.89) which indicated F_2 population has more monopodial branches than their F_1 generation. Cross III showed non-significant and positive inbreeding depression. (Table 1) The present findings are in harmony with the results of Chhavikant *et al.* (2017) [3], Tigga *et al.* (2017) [28] and Haq *et al.* (2019) [8], AL-Hibbiny *et al.* (2020) [1] for this character.

The fruiting bodies (number of sympodia per plant) in cotton plant are produced on sympodial branches. It is one of the most important parameters contributing yield of cotton. Once sympodial branches formed on main stem, no monopodial branches are formed. For sympodia per plant, the data presented in table 1 indicated non-significant and both negative (undesirable) and positive (desirable) values except cross III, which have significant negative (undesirable) value. The estimate of relative heterosis in four crosses varied from -7.43 per cent (cross III) to 6.86 per cent (cross IV). Non-Significant and positive (desirable) relative heterosis was observed in cross IV, while non-significant and negative relative hetetrosis was observed in cross I and II, Whereas, significant negative (undesirable) relative heterosis was observed in cross III. Heterobeltiosis ranged from -2.99 per cent (cross III) to 7.28 per cent (cross IV). Looking to heterobeltiosis (HB), the highest non-significant better parent heterosis in desired direction was observed in cross IV (-7.28%) followed by cross I (2.24). Whereas non-significant better parent heterosis in undesired direction was observed in cross III (-2.99%) and cross II (-4.92). The inbreeding depression varied from -16.10 per cent (cross III) to 5.32 per cent (cross I). The inbreeding depression was highest non-significant and positive expression in desired direction in cross I indicated that high sympodial branches in F_1 generation, whereas highest significant and negative expression in undesired direction in crosses III (-16.10) and II (-11.49) followed by non-significant and negative cross IV (-3.72), which indicated F_2 population has more sympodial branches than their F_1 generation.(Table 1) Similar finding was recorded earlier by Kencharaddi *et al.* (2013) [12], Patel *et al.* (2014) [22], Solanki *et al.* (2014) [25], Tuteja (2014) [29], Chhavikant *et al.* (2017) [3], Tigga *et al.* (2017) [28] and Patel *et al.* (2024) [21] for this character.

For number of bolls per plant, parent with more number of bolls per plant was adjudged as better parent and positive estimates of relative heterosis and heterobeltiosis are desirable. The estimate of relative heterosis in four crosses varied from -17.25 per cent (cross II) to -1.30 per cent (cross III). Non-Significant and negative relative heterosis was observed in all the crosses except cross II. No crosses exhibited the significant relative heterosis in desired direction. Heterobeltiosis ranged from -15.73 per cent (cross II) to 9.15 per cent (cross III). Looking to heterobeltiosis (HB), the highest non-significant better parent heterosis in desired direction was observed in cross III followed by cross IV. Significant and negative better parent heterosis was observed in cross II.The estimates of inbreeding depression varied from -25.38 per cent (cross IV) to 16.61 per cent (cross I). The estimates of inbreeding depression were significant and positive in cross I and non-significant and positive in cross III, which indicate F_2 population was having less number of bolls per plant than their F_1 generations. Hence, these crosses would not likely yield beneficial transgressive segregants. Whereas significant and negative estimates of inbreeding depression were in cross II and IV which indicates F_2 population was having more number of bolls per plant than their F_1 generations. Hence, these crosses would likely yield beneficial transgressive segregants. (Table 2) The present findings are in concurrence with the results of Komal *et al.* (2014) [15], Patel *et al.* (2014) [22], Solanki *et al.* (2014) [25], Tuteja (2014) [29], Sahito *et al.* (2015) [23], Munir *et al.* (2016) [19], Chhavikant *et al.* (2017) [3], Geng *et al.* (2021) [6] who recorded heterosis and heterobeltiosis. Whereas, Katageri *et al.* (1992) [10], Soomro *et al.* (2000) [26], Ashwathama *et al.* (2003) [2], Tigga *et al.* (2017) [28], AL-Hibbiny *et al.* (2020) [1].

Seed cotton yield is one of the most critical economic traits in cotton and serves as a key indicator of productivity (Wang *et al*., 2019). Being a dependent variable, it is influenced by multiple morphological and physiological traits, making it essential to understand the relationships between yield and its contributing factors. Such understanding is particularly important for interpreting the expression of heterosis for seed cotton yield. In this context, the parent with the higher seed cotton yield was considered the better parent and positive estimates of both relative heterosis and heterobeltiosis were deemed desirable. In the present study, relative heterosis across four crosses ranged from 10.70% (cross II) to 34.06% (cross IV), with all crosses exhibiting significant and positive values, indicating enhanced performance of F_1hybrids over the mid-parent. (Figure 1) Heterobeltiosis values varied between 18.47% (cross I) and 37.39% (cross IV). All crosses showed significant better parent heterosis in the desired positive direction, confirming the potential for yield improvement through hybrid breeding. (Table 2)

Inbreeding depression estimates ranged from –11.15% (cross III) to 21.69% (cross I). Crosses I, II and IV displayed significant and positive inbreeding depression, suggesting that the F_2 populations had reduced seed cotton yield per plant compared to their respective F_1 generations. Conversely, cross III exhibited significant negative inbreeding depression, indicating that the F_2 generation outperformed the F_1 in terms of seed cotton yield. This result points to the possibility of obtaining favourable transgressive segregants in cross III, making it a promising cross for further selection and yield enhancement. (Table 2) The present findings are in accordance with the results of Patel *et al.* (2014) [22], Tuteja (2014) [29], Munir *et al.* (2016) [19], Chhavikant *et al.* (2017) [3], Gohil *et al.* (2017) [7], Khan *et al.* (2017) [14], Lingaraja *et al.* (2017) [17], Patel *et al.* (2024) [21] who reported significant and positive heterosis and heterobeltiosis for this trait. Whereas, Katageri *et al.* (1992) [10], Soomro *et al.* (2000) [26], Kaushik and Kapoor (2013) [11], Islam *et al.* (2015) [9] observed significant positive inbreeding depression for seed cotton yield per plant.

The single boll weight (g) is one of the most important contributing trait of cotton lint yield. Predicting the single boll weight in a large area is important for variety selection and yield improvement. So, for this character, parent with higher boll weight was adjudged as better parent and positive estimates of relative heterosis and heterobeltiosis are desirable. The estimate of relative heterosis in four crosses varied from -17.61 per cent (cross I) to 6.15 per cent (cross II). Significant and negative (undesired) relative heterosis was observed in crosses I and III. Heterobeltiosis ranged from -15.98 per cent (cross I) to 11.05 per cent (cross II). Looking to heterobeltiosis (HB), the significant better parent heterosis in desired direction was observed in cross II and non-significant better parent heterosis in desired direction was observed in cross IV. Significant and negative better parent heterosis was observed in cross I. The estimates of inbreeding depression varied from -21.59 per cent (cross I) to -5.44 per cent (cross II). The estimates of inbreeding depression show no significant and positive (undesired) values in all the crosses which indicates F_2 population was having higher boll weight than their F_1 generations. Significant and negative inbreeding depression was observed in crosses I (-21.59%) and III (-12.24). Hence, these crosses would likely yield useful transgressive segregants. (Table 2) The present findings are in harmony with the results of Komal *et al.* (2014) [15], Solanki *et al.* (2014) [25], Tuteja (2014) [29], Chhavikant *et al.* (2017) [3], Gohil *et al.* (2017) [7], Tigga *et al.* (2017) [28], Geng *et al.* (2021) [6], Patel *et al.* (2024) [21] who also reported significant and positive heterosis over mid parent and better parent for this character. Whereas, Katageri *et al.* (1992) [10] observed significant positive inbreeding depression for boll weight as observed in the present investigation.

For seed index, negative value of heterosis and heterobeltiosis is desirable as low seed index value corresponds to high lint yield. Here, for all crosses evaluated, the magnitude of relative heterosis recorded has positive values. The estimate of relative heterosis in four crosses varied from 8.53 per cent (cross II) to 17.53 per cent (cross I). Significant and negative (desired) relative heterosis was not observed in all crosses. Significant and positive (undesired) relative heterosis was observed in all the crosses. Heterobeltiosis ranged from 11.19 per cent (cross II) to 32.80 per cent (cross III). Looking to heterobeltiosis (HB), the significant better parent heterosis in desired direction was not observed in the crosses attempted. The estimates of inbreeding depression were positive and significant/non-significant for all crosses except for cross II, ranging from -4.72 per cent (cross II) to 11.14 per cent (cross III). The significant negative inbreeding depression was observed in cross II (- 4.72%) which indicates F_2 population was having high seed index than their F_1 generations. Hence, this cross would likely yield beneficial transgressive segregants. (Table 2) The present findings are in concurrence with the results of Komal *et al.* (2014) [15], Gohil *et al.* (2017) [7], Lingaraja *et al.* (2017) [17], Tigga *et al.* (2017) [28], and AL-Hibbiny *et al.* (2020) [1] who also reported similar results for this character. Kaushik and Kapoor (2013) [11] observed significant positive inbreeding depression for seed index.

For Lint index, high positive values are desirable. So, for this character, parent with higher lint index was adjudged as better parent and positive estimates of relative heterosis and heterobeltiosis are desirable. The estimate of relative heterosis in four crosses varied from -9.60 per cent (cross I) to 17.03 per cent (cross II). Significant and positive (desired) relative heterosis was observed in all crosses except cross I (-9.60%). Significant and positive (desired) relative heterosis was observed in cross II (17.03%) followed by cross IV (12.44%) and cross III (8.57%). Heterobeltiosis ranged from 4.57 per cent (cross I) to 22.60 per cent (cross III). Looking to heterobeltiosis (HB), the significant better parent heterosis in desired direction was observed in the cross I (22.60%) followed by cross II (19.81%) and cross IV (15.51%). Non-significant and positive (desired) value was in cross I (4.57). The magnitude of inbreeding depression for crosses under evaluation varies from negative (desirable) to positive (undesirable). The estimate of inbreeding depression was varied from -25.89 per cent (cross I) to 13.52 per cent (cross II). The estimates of inbreeding depression were significant and negative (desirable) in cross I followed by cross IV (- 8.64%). Cross III (-1.07%) reveal non-significant and negative (desired) inbreeding depression. (Table 2) The present findings are in concurrence with the results of Munir *et al.* (2016) [19], Chhavikant *et al.* (2017) [3], Gohil *et al.* (2017) [7], Lingaraja *et al.* (2017) [17] who also reported significant and positive heterosis over mid parent and better parent for this character. Kaushik and Kapoor (2013) [11] observed significant negative inbreeding depression for lint index.

Table 1: Estimates of relative heterosis (RH%), heterobeltiosis (HB%) and inbreeding depression (ID%) for days to flower, days to boll opening, plant height, number of monopodia per plant and number of sympodia per plant in four crosses of cotton in irrigated conditions

Particulars	Days to Flower	Days to boll opening	Plant height	Number of monopodia per plant	Number of sympodia per plant
Cross I (MCB-16-1× GTHV-0/32)					
RH (%)	-15.22** (1.77)	1.60 (1.18)	-10.72** (4.63)	-21.57 (0.23)	-2.04 (1.22)
HB (%)	-12.08** (2.04)	2.47 (1.34)	-9.45** (5.73)	-13.04 (0.14)	2.24 (1.74)
ID (%)	-10.38** (2.05)	0.00 (1.27)	-5.49 (4.83)	-107.50** (0.15)	5.32 (1.99)
Cross II (MCB-16-1× GTHV-17/70)					
RH (%)	-5.61** (0.90)	-1.05 (0.77)	3.78 (4.20)	1.89 (0.22)	-5.01 (1.40)
HB (%)	-3.14** (0.73)	-0.48 (0.93)	4.95 (6.81)	3.85 (0.27)	-4.92 (1.44)
ID (%)	-15.00** (0.88)	-4.95** (0.93)	12.32** (3.06)	-38.89** (0.18)	-11.49** (1.35)
Cross III (GTHV-17/15 × GTHV-0/35)					
RH (%)	-4.46** (0.62)	-2.08 (1.02)	15.23** (4.41)	9.09 (0.21)	-7.43* (1.07)
HB (%)	-4.32** (0.83)	-1.98 (1.20)	22.31** (4.46)	16.13 (0.21)	-2.99 (1.48)
ID (%)	-2.24* (0.65)	-2.31* (1.07)	4.30** (3.16)	6.25 (0.21)	-16.10** (1.01)
Cross IV (MCB-9-2 × GSHV-204)					
RH (%)	-2.31* (0.66)	-2.14 (1.15)	9.26** (3.70)	21.31* (0.20)	6.86 (1.46)
HB (%)	-1.52 (0.90)	-1.55 (1.30)	11.91** (5.14)	68.18** (0.22)	7.28 (1.75)
ID (%)	-6.21** (0.91)	-3.28** (1.26)	14.43** (3.59)	18.92* (0.20)	-3.72 (1.29)

*, ** indicates significant at 5% and 1% levels of significance, *respectively* and figures in parentheses are S.Em. value

Table 2: Estimates of relative heterosis (RH%), heterobeltiosis (HB%) and inbreeding depression (ID%) for number of bolls per plant, seed cotton yield per plant, boll weight, seed indexand lint index in four crosses of cotton in irrigated conditions

Particulars	Number of bolls per plant	Seed Cotton yield per plant	Boll weight	Seed index	Lint index
Cross I (MCB-16-1× GTHV-0/32)					
RH (%)	-3.49 (1.46)	16.61** (7.69)	-17.61** (0.08)	17.53** (0.27)	-9.60** (0.19)
HB (%)	-2.20 (2.50)	18.47** (8.25)	- 15.98** (0.09)	22.14** (0.26)	4.57 (0.19)
ID (%)	16.61** (1.18)	21.69** (7.66)	-21.59** (0.07)	0.29 (0.27)	- 25.89** (0.20)
Cross II (MCB-16-1× GTHV-17/70)					
RH (%)	-17.25** (1.42)	10.70** (8.26)	6.15 (0.13)	8.53** (0.22)	17.03** (0.13)
HB (%)	-15.73** (1.62)	28.88** (10.26)	11.05** (0.14)	11.19** (0.27)	19.81** (0.14)
ID (%)	-7.31* (1.31)	7.79* (7.85)	-5.44 (0.14)	- 4.72* (0.18)	13.52** (0.12)
Cross III (GTHV-17/15 × GTHV-0/35)					
RH (%)	-1.30 (2.36)	25.87** (9.48)	- 12.78** (0.08)	14.88** (0.23)	8.57* (0.18)
HB (%)	9.15 (2.73)	27.77** (9.73)	- 3.41 (0.10)	32.80** (0.28)	22.60** (0.19)
ID (%)	7.01 (2.21)	-11.15* (9.58)	-12.24** (0.10)	11.14** (0.27)	-1.07 (0.17)
Cross IV (MCB-9-2 × GSHV-204)					
RH (%)	-1.69 (1.70)	34.06** (9.88)	- 2.26 (0.18)	17.42** (0.24)	12.44** (1.46)
HB (%)	3.13 (2.02)	37.39** (12.19)	0.50 (0.18)	23.02** (0.27)	15.51** (1.75)
ID (%)	-25.38** (1.69)	9.80** (9.70)	- 6.46 (0.17)	0.16 (0.24)	- 8.64** (1.29)

*, ** indicates significant at 5% and 1% levels of significance, *respectively* and figures in parentheses are S.Em. value

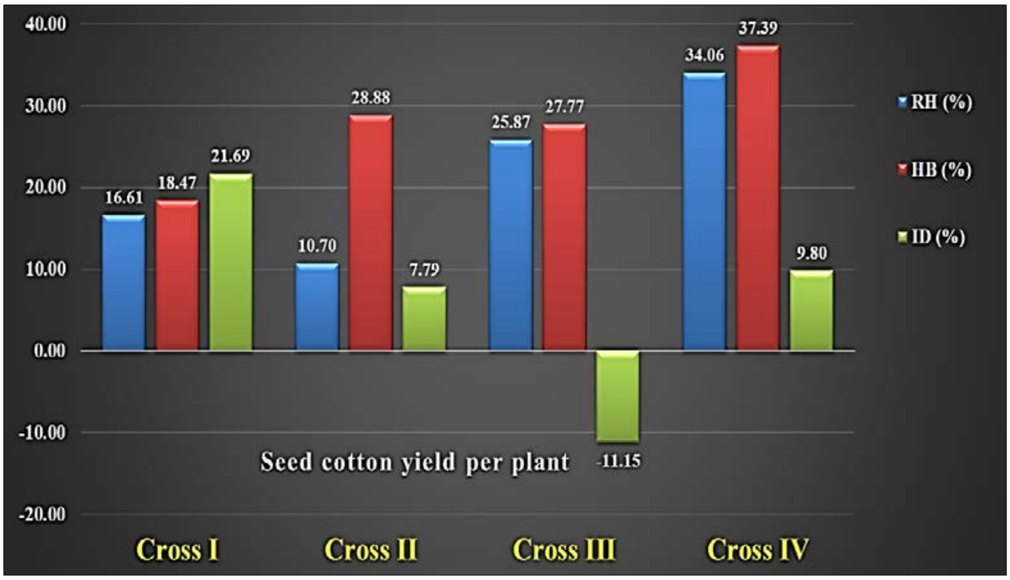

Fig 1: Graph depicting Relative heterosis (RH%), Heterobeltiosis (HB%) and Inbreeding depression (ID%) for seed cotton yield per plant.

Conclusion

Significant relative heterosis and heterobeltiosis in the favorable direction was observed for seed cotton yield and its associated traits across all four crosses: Cross I (MCB-16-1 × GTHV-0/32), Cross II (MCB-16-1 × GTHV-17/70), Cross III (GTHV-17/15 × GTHV-0/35) and Cross IV (MCB-9-2 × GSHV-204). Among these, cross IV exhibited the highest relative heterosis (34.06%) and heterobeltiosis (37.39%) for seed cotton yield per plant. It also showed desirable heterotic effects for key yield-contributing traits such as earliness (days to flowering and boll opening), number of sympodia and bolls per plant, boll weight and lint index. These results indicate that the evaluated hybrids, particularly cross IV, hold substantial promise for developing superior genotypes through the exploitation of heterosis and transgressive segregation in future cotton breeding programs.

References

1. AL-Hibbiny YIM, Mabrouk AH, Ramadan BM. Generation means analysis for some quantitative characters in cotton. Journal of Plant Production. 2020b;5:129–141.
2. Ashwathama VH, Patil BC, Kareekatti SR, Adarsha TS. Studies on heterosis for biophysical traits and yield attributes in cotton. World Cotton Research Conference-3: Cape Town - South Africa. 2003.
3. Chhavikant VB, Nirania KS, Ankit K, Pundir SR. Heterosis studies for seed cotton yield and other traits in upland cotton (*Gossypium hirsutum* L.). Journal of Pharmacognosy and Phytochemistry. 2017;6(6):583-586.
4. Dock CC. A new technique in cotton hybridizing. suggested changing in exhisting method of emasculation and bagging cotton flowers. Journal heredity. 1934;25:187-194.
5. Geddam S, Khadi BM, Mogali S, Patil RS, Katageri IS, Nadaf HL, et al. Study of heterosis in genetic male sterility based diploid cotton hybrids for yield, yield component and fibre quality characters (*Gossypium hirsutum* L.). Karnataka Journal Agriculture Science. 2011;24(2):118-124.
6. Geng X, Qu Y, Jia Y, He S, Pan Z, Wang L, et al. Assessment of heterosis based on parental genetic distance estimated with SSR and SNP markers in upland cotton (*Gossypium hirsutum* L.). BMC Genomics. 2021;22:123.
7. Gohil SB, Parmar MB, Chaudhari DJ. Study of heterosis in interspecific hybrids of cotton (*Gossypium hirsutum* L. ×*Gossypium barbadense* L.). Journal of Pharmacognosy and Phytochemistry. 2017;6(4):804-810.
8. Haq AU, Khan NU, Raza H, Akbar S, Khan SU, Muhammad S, et al. Genetic attributes of F3 populations and their parental lines in upland cotton. Journal Animal and Plant Science. 2019;27(2):655-666.
9. Islam MK, Ahmed MS, Islam MM. Heterosis and inbreeding depression in F2 populations of upland cotton. Int. J. Sustain. Agril. Tech. 2015;11(12):07-11.
10. Katageri IS, Kadapa SN, Khadi BM, Eshnna MR, Naik RB. Hybrid vigor and inbreeding depression in the intra-racial crosses of G. *hirsutum* L. Karnataka Journal Agriculture Science. 1992;5:1-3.
11. Kaushik SK, Kapoor CJ. Hybrid vigour and inbreeding depression for fibre quality in upland cotton (G. *hirsutum* L.). Journal of Cotton Research and Development. 2013;27(1):7-10.
12. Kencharaddi HG, Patil RS, Mohan NB, Chowkimath A, Praveenkumar B, Adiger S, et al. Estimation of hybrid vigour and inbreeding depression in upland cotton (*Gossypium hirsutum* L.). Plant Archives. 2013;13(1):253-257.
13. Khadi BM, Santhy V, Yadav MS. Cotton: An Introduction. In: Cotton- Biotechnological advances, Zehr and Usha Basrwale (Eds). Springer. 2010. p. 1-14.
14. Khan BA, Khan NU, Ahmed M, Iqbal M, Ullah I, Saleem M, et al. Heterosis and inbreeding depression in F2 populations of upland cotton (*Gossypium hirsutum* L.). Agriculture Science. 2017;8:1283-1295.
15. Komal P, Madariya RB, Raiyani GD, Raval L. Assessment of heterosis and inbreeding depression in cotton (*Gossypium hirsutum* L.). Bioscan. 2014;9(4):1853-1856.
16. Kumar M, Nirania KS, Sangwan RS, Yadav NK, Somprakash. Heterosis for seed cotton yield and its contributing traits in upland cotton (*Gossypium hirsutum* L.). Journal of Cotton Research and Development. 2013;27(1):11-15.
17. Lingaraja L, Sangwan RS, Nimbal S, Sangwan O, Singh S. Heterosis studies for economic and fibre quality traits in line x tester crosses of upland cotton (*Gossypium hirsutum* L.). International Journal of Pure & Applied Bioscience. 2017;5(2):240-248.
18. Monicashree C, Balu PA, Gunasekaran M. Combining ability and heterosis studies on yield and fibre quality traits in upland cotton (*Gossypium hirsutum* L.). International Journal of Current Microbiology and Applied Sciences. 2017;6(8):912-927.
19. Munir S, Hussain SB, Manzoor H, Quereshi MK, Zubair M, Nouman W, et al. Heterosis and correlation in interspecific and intraspecific hybrids of cotton. Genetics and Molecular Research. 2016;15(2):1-13.
20. Panni MK, Khan NU, Sundas FB, Maryam B. Heterotic studies and inbreeding depression in F2 populations of upland cotton. Pakistan Journal of Botany. 2012;44(3):1013-1020.
21. Patel A, Chaudhari KN, Kapadia CV, Faldu GO, Patel S, Patel HR, et al. Heterosis and inbreeding depression studies for seed cotton yield and its components in upland cotton (*Gossypium hirsutum* L.). Plant Archives. 2024;24(2):2078-2084.
22. Patel DH, Patel DU, Kumar V. Heterosis and combining ability analysis in tetraploid cotton (G. *hirsutum*, L. and G. *barbadense*, L.). Electronics Journal Plant Breeding. 2014;5(3):408-414.
23. Sahito A, Baloch ZA, Mahar A, Otho SA, Kalhoro SA, Ali A, et al. Effect of water stress on the growth and yield of cotton crop (*Gossypium hirsutum* L.). American Journal of Plant Sciences. 2015;6:1027-1039.
24. Singh P, Kairon MS, Singh SB. CICR Technical Bulletin: 14, CICR, Nagpur. 2014.
25. Solanki HV, Mehta DR, Rathod VB, Valu MG. Heterosis for seed cotton yield and its contributing characters in cotton (*Gossypium hirsutum* L.). Electronics Journal Plant Breeding. 2014;5(1):124-130.
26. Soomro AR. Assessment of useful heterosis in glandless *Gossypium hirsutum* cotton strains through their performance in hybrid combination. Pakistan Journal of Botany. 2000;32(1):5–68.

27. Srinivas B, Bhadru D. Heterosis studies for yield and yield contributing traits of upland cotton in line x tester design. The Bioscan. 2015;10(4):1939-1946.
28. Tigga A, Patil SS, Edke V, Roy U, Kumar A. Heterosis and inbreeding depression for seed cotton yield and yield attributing traits in intra hirsutum (*G. hirsutum* L. X *G. hirsutum* L.) hybrids of cotton. International Journal of Current Microbiology and Applied Sciences. 2017;6(10):2883-2887.
29. Tuteja OP. Studies on heterosis for yield and fibre quality traits in GMS hybrids of upland cotton (*Gossypium hirsutum* L.). Journal of Cotton Research and Development. 2014;28(1):1-6.