# HETEROSIS AND INBREEDING DEPRESSION STUDIES FOR FIBRE QUALITY TRAITS IN UPLAND COTTON (*Gossypium hirsutum* L.)


**ABSTRACT**

Cotton hybrids have its own advantage than varieties in yield and fibre properties. Heterosis breeding helps in identifying $F_1$ hybrids and in creating variability. The chief intention of any hybridization programme is to combine all the desirable genes present in two or more parents into a single genetic background. This investigation helped in identifying the extent of heterosis in crosses among four families in upland cotton (*Gossypium hirsutum* L.) which was conducted at college Farm during *kharif* 2021-23. The all 4 hybrids were derived by generation mean analysis study which were analysed for fibre quality traits in a Compact Family Block Design. Among four crosses, cross G Cot 16 x GISV 361 manifested significant and desirable heterobeltiosis for fibre quality traits like ginning percentage, micronaire value, uniformity index and lint index. This cross also registered non-significant but desiraleheterobeltiosis for fibre elongation. Thus, cross combination *i.e.* G Cot 16 x GISV 361 looks promising so it need to be evaluated thoroughly for testing its commercial suitability for farmers benefit in particular.This study reveals good scope for commercial exploitation of heterosis as well as isolation of potential progenies from the heterotic $F_1$ hybrids.




## 1.1 INTRODUCTION

Cotton is one of the most important natural fibres in the world, playing a critical role in the global textile industry. The quality of cotton fibre significantly influences its value and usability, with characteristics such as fibre length, strength, fineness and uniformity being key determinants. As cotton provides basic raw materials to textile industry and country's productivity is far below the world average, so it is essential to concentrate the breeding efforts towards the development of still better, high yielding and more remunerative hybrids and standard varieties to increase yield *per* unit area.

Heterosis refers to increase of $F_1$ in fitness and vigour over the parental values. In current usage heterosis and hybrid vigour are used as synonyms and interchangeable. The expression of heterosis is governed by nuclear genes. In some cases, heterosis results due to interaction between nuclear genes and cytoplasm. The magnitude of heterosis is associated with heterozygosity, because the dominance variance is associated with heterozygosity. The application of heterosis in cotton breeding is not without challenges. Cotton is a predominantly self-pollinating crop, which complicates the production of hybrids. However, advances in breeding techniques and a better understanding of the genetic basis of fiber quality traits have paved the way for more effective utilization of heterosis in cotton.

## 1.2 MATERIALS AND METHOD

The current experiment on upland cotton which involve six different generations *viz.*, $P_1$, $P_2$, $F_1$, $F_2$, $BC_1$ and $BC_2$ of four different crosses (Table 3.3) representing six diverse parental genotypes procured from Regional Cotton Research Station, Navsari Agricultural University, Bharuch andMain Cotton Research Station, Navsari Agricultural University, Surat,was carried out to study the various genetic parameters of different traits. The crossing programme was carried out during Late *Kharif* 2021-22 while evaluation programme was carried out in *Kharif* 2022-23. Both crossing programme as well as evaluation programmes were conducted at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari. Navsari Agricultural University.

1. Cross- I: GN Cot 22 x GBHV 200
2. Cross- II: GN Cot 26 x GBHV 253
3. Cross- III: G Cot 16 x GISV 361
4. Cross- IV: G Cot 10 x Surat Dwarf

Randomly selected tencompetitive plants from each $P_1$, $P_2$, $F_1$ generations, twenty plants from each of the $BC_1$ and $BC_2$ generations and fortyplants from each $F_2$ generation were utilized per replication for recording observations. A total of seven traits *viz.*, Ginning percentage, Micronaire value (µg/inch), uniformity index (%), Upper Half Mean Length (mm), Lint Index (%), Fibre Strength (g/tex) and Fibre Elongation (%) were recorded and the mean values were subjected to statistical analysis.

Heterosis was estimated as per cent increase or decrease in the mean value of $F_1$ hybrid over the mid-parent, *i.e.*, relative heterosis (Briggle, 1963) and over the better parent, *i.e.*, heterobeltiosis (Fonseca and Patterson, 1968) for each character.

$$\text{Relative heterosis (\%)} = \frac{\bar{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\bar{F}_1$ = Mean performance of the $F_1$ hybrid

$\overline{MP}$ = Mean value of the parents ($P_1$ and $P_2$) of a hybrid

$\overline{BP}$ = Mean value of better parent

**Standard errors**

$$\text{S.E.}\left(\bar{F}_1 - \overline{MP}\right) = \sqrt{\frac{3Me}{2r}}$$

(Standard error for relative heterosis)

$$\text{S.E.}\left(\bar{F}_1 - \overline{BP}\right) = \sqrt{\frac{2Me}{r}}$$

(Standard error for heterobeltiosis)

Where,

Me = Error mean square

r = Number of replications

**t-test**

The test of significance of the heterosis and heterobeltiosis was carried out by comparing the calculated values of 't' with the tabulated values 't' at 5 % (1.96) and 1 % (2.58) levels of significance, respectively.

$$t = \frac{\bar{F}_1 - \overline{MP}}{\text{S.E.}\left(\bar{F}_1 - \overline{MP}\right)} \quad \text{(For relative heterosis)}$$

$$t = \frac{\bar{F}_1 - \overline{BP}}{\text{S.E.}\left(\bar{F}_1 - \overline{BP}\right)} \quad \text{(For heterobeltiosis)}$$

Inbreeding depression refers to a decrease in fitness and vigour due to continuous inbreeding and decreased heterozygosity. It results due to fixation of unfavourable recessive genes in $F_2$mostly because of homozygous condition, while in case of heterosis; undesirable effect ofrecessive genes of one parent are suppressed by favourable dominant genes of another parent.

Inbreeding depression was computed by using the following formulae:

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

The standard error and 't' value for the test of significance for inbreeding depression were estimated as under:

$$S.E.(\bar{F}_1 - \bar{F}_2) = \sqrt{\frac{[V(F_1)(n_1 - 1)] + [V(F_2)(n_2 - 1)]}{n_1 + n_2 - 2}}$$

$$t = \frac{\bar{F}_1 - \bar{F}_2}{S.E.(\bar{F}_1 - \bar{F}_2)}$$

Where,

| | | |
|---|---|---|
| $\bar{F}_1$ | = | Mean value of the $F_1$ hybrid |
| $\bar{F}_2$ | = | Mean value of the $F_2$ generation |
| $V(F_1)$ | = | Variance of the $F_1$ generation |
| $V(F_2)$ | = | Variance of the $F_2$ generation |
| $n_1$ | = | Number of observations in the $F_1$ generation |
| $n_2$ | = | Number of observations in the $F_2$ generation |

The significance of the inbreeding depression was tested by comparing the calculated 't' value with the table 't' value at 5 % (1.96) and 1 % (2.58) levels of significance, respectively.

**1.3 RESULTS AND DISCUSSION**

The estimates of heterosis and inbreeding depression together provide information about the type of gene action involved in the expression of various quantitative traits. If high heterosis is followed by inbreeding depression, it indicates the presence of non-additive gene action (dominance and epistasis). If the performance is same in $F_1$ and $F_2$, it reveals presence of additive genes. If the heterosis is negative in $F_1$and there is increase in $F_2$, it again indicates presence of additive genes. In practical plant breeding, heterosis can be fully exploited in the form of hybrids, and partially in the form of synthetic and composite varieties.

**For Ginning percentage,** all the four crosses under evaluation obtained significant and positive values for relative heterosis. Significant and positive (desirable) relative heterosis ranged from 1.42% (GN Cot 26 x GBHV 253) to 4.31% (GN Cot 22 x GBHV 200). Heterosis over better parent was found positive (desirable) significant for all the four crosses *viz.*, cross GN Cot 26 x GBHV 253(4.19%), cross GN Cot 22 x GBHV 200 (3.46%), cross G Cot 10 x Surat dwarf (3.40%) and cross G Cot 16 x GISV 361 (2.29%).The magnitude of inbreeding depression varies from positive (undesirable) to negative (desirable). Non-significant but negative (desirable) non-significant inbreeding depression was observed in cross G Cot 16 x GISV 361 (-

0.61%) and cross GN Cot 22 x GBHV 200 (-0.32%). While, cross GN Cot 26 x GBHV 253 (3.19%) exhibited positive (undesirable) inbreeding depression. The positive and negative values of inbreeding depression for ginning percentage were also reported by Komal *et al.* (2014), Khan *et al.* (2017) and Tigga *et al.* (2017).

For **fibre fineness** (micronaire value), negative heterosis is desirable.Negative and significant heterobeltiosis was observed in cross GN Cot 22 x GBHV 200 (-14.32%) and cross GN Cot 26 x GBHV 253 (-7.41%), which is desirable for further improvement in this trait. It was very surprising and promising that all the four crosses recorded significant and desirable (negative) inbreeding depression. High value of negative (undesirable) significant inbreeding depression was observed in G Cot 10 x Surat dwarf (-30.25%) followed by in G Cot 16 x GISV 361 (-19.00%) and in GN Cot 22 x GBHV 200 (-18.61 %).This suggested the presence of superior recombinants in $F_2$ population of all the crosses.

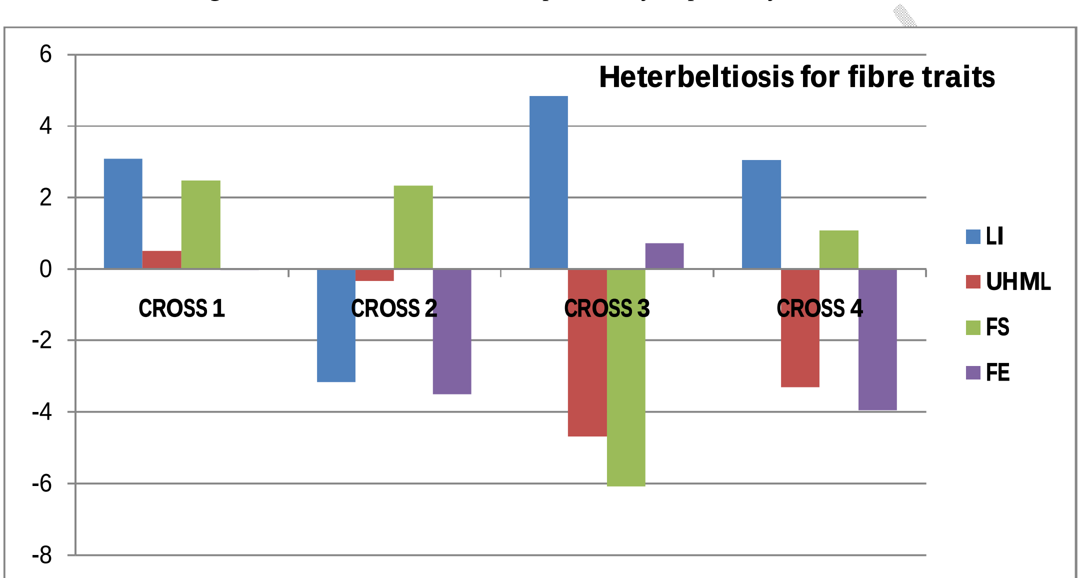


**Table 1:**Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for Ginning percentage, Micronaire value (μg/inch), Uniformity Index (%), Upper Half Mean Length (mm), lint index (%), fibre strength (g/tex) and fibre elongation (%) in four crosses of cotton

| Particulars | Ginning percentage | Micronaire value (μg/inch) | Uniformity index (%) | Upper Half Mean Length (mm) | Lint Index (%) | Fibre Strength (g/tex) | Fibre Elongation (%) |
|---|---|---|---|---|---|---|---|
| **Cross I (GN Cot 22 × GBHV 200)** | | | | | | | |
| **RH %** | 4.31* | -2.46* | 7.38** | 3.27** | 7.21** | 4.74** | 0.46 |
| **HB %** | 3.46** | -14.32** | 1.12** | 0.51 | 3.08 | 2.47* | -0.03 |
| **ID %** | -0.32 | -18.61** | 0.67* | 4.07** | 9.58** | 0.16 | 0.06 |
| **Cross II (GN Cot 26 × GBHV 253)** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **RH %** | 1.42* | -2.23* | 1.21* | 2.39** | 2.06 | 4.36** | 1.30 |
| **HB %** | 4.19* | -7.41** | 1.41* | -0.33 | -3.16 | 2.34* | -3.49 |
| **ID %** | 3.19** | -16.55** | 0.22 | 2.75** | -5.72** | -0.87 | -3.47* |
| **Cross III (G Cot 16 × GISV 361)** | | | | | | | |
| **RH %** | 4.02** | 4.81* | 6.14** | -0.75 | 13.09** | 1.28 | 2.85** |
| **HB %** | 2.29** | 29.50** | 1.98** | -4.67** | 4.83* | -6.06** | 0.72 |
| **ID %** | -0.61 | -19.00** | 0.08 | 0.14 | 5.35* | -1.71* | 2.70** |
| **Cross IV (G Cot 10 × Surat dwarf)** | | | | | | | |
| **RH %** | 1.55** | -4.96* | -0.07 | 1.42* | 4.06 | 5.48** | -1.91 |
| **HB %** | 3.40** | 7.69* | -2.97* | -3.31** | 3.05 | 1.08* | -3.95* |
| **ID %** | 0.13 | -30.25** | 0.61 | 2.05** | 1.38 | 5.61** | 0.90 |

* and ** indicates significant at 5% and 1% levels of probability respectively




**Graph 1:** Estimates of Heterobeltiosis (HB%) for different fibre quality traits in four crosses under study. LI: Lint index (%), UHML: Upper Half Mean Length (mm), FS: Fibre Strength (g/tex) and Fibre Elongation (%).

**For uniformity index,** results indicated significant and positive (desirable) relative heterosis for three crosses under evaluation *viz.*, GN Cot 22 x GBHV 200 (7.38%), GN Cot 26 x GBHV 253 (1.21%) and G Cot 16 x GISV 361 (6.14%), while negative (undesirable) and non-significant heterosis was observed in cross G Cot 10 x Surat dwarf (-0.07%). The magnitude of heterobeltiosis was significant in all the four crosses but it was significant and positive (desirable) in crosses GN Cot 22 x GBHV 200 (1.12%), GN Cot 26 x GBHV 253 (1.41%) and G Cot 16 x GISV 361 (1.98%) whereas, it was significant and negative in cross G Cot 10 x Surat dwarf (-2.97%). The values for inbreeding depression in all four crosses under evaluation was positive but non-significant in cross G Cot 10 x Surat dwarf (0.61%) followed by GN Cot 26 x GBHV 253 (0.22%) and G Cot 16 x GISV 361 (0.08%). similar findings have also reported earlier by El-Adly and Arafa (2009), Carvalho *et al.* (2018), Yehia and EL-Hashash (2022) and AL-Hibbiny*et al.*(2020).

The data embodied for **Upper Half Mean Length (mm)**in Table 1 of relative heterosis showed high significant positive (desirable)values of heterosis in cross GN Cot 22 x GBHV 200 (3.27%) followed by cross GN Cot 26 x GBHV 253 (2.39%), cross G Cot 10 x Surat dwarf (1.42%). The perusal of heterobeltiosis showed significant negative (undesirable) values of heterosis in cross G Cot 16 x GISV 361 (-4.67%) and cross G Cot 10 x Surat dwarf (-3.31%). While, significant positive value was observed in cross GN Cot 22 x GBHV 200 (0.51%).These results generally correspond with the findings of Carvalho *et al.* (2018), AL-Hibbiny *et al.*(2020) and Yehia and El-Hashash (2022).

**For Lint index** (%), high positive values are desirable. Thus, two crosses *viz.*, cross GN Cot 22 x GBHV 200 (7.21%) and cross G Cot 16 x GISV 361 (13.09%) recorded significant positive values for relative heterosis, hence it is desirable.The magnitude of heterobeltiosis ranged from -3.16% (cross GN Cot 26 x GBHV 253) to 4.83% (cross G Cot 16 x GISV 361). The significant positive heterobeltiosis was observed only in cross G Cot 16 x GISV 361 (4.83%) which is desirable. Similar results for positive and negative relative heterosis and heterobeltiosis for lint index were also reported by Hafez *et al.* (2022) and Yehia and EL-Hashash (2022).The magnitude of inbreeding depression for crosses under evaluation vary from negative (desirable) to positive (undesirable). Negative (desirable) significant inbreeding depression was observed only in cross GN Cot 26 x GBHV 253 (-5.72%). Similar results were also reported earlier by Hussain *et al.* (2009), Karademir *et al.* (2011), Komal *et al.* (2014), and Tigga *et al.* (2017).

**For Fibre Strength (g/tex),** High values of positive (desirable) and significant relative heterosis was observed in cross G Cot 10 x Surat dwarf (5.48%), GN Cot 22 x GBHV 200 (4.74%) and GN Cot 26 x GBHV 253 (4.36%). While, cross G Cot 16 x GISV 361 (1.28%) recorded positive non- significant value of relative heterosis.The values for heterobeltiosis was found to be positive for three crosses under evaluation which is desirable. Significant positive (undesirable) inbreeding depression was found only in cross G Cot 10 x Surat dwarf (5.61%) whereas, negative (desirable) and non-significant value was observed in cross GN Cot 26 x GBHV 253 (-0.87%).

**For Fibre Elongation,** an experimental data presented in Table 1 for fibre elongation indicated the positive (desirable) as well as negative values for this trait. Range for relative heterosis was from -1.91 % (G Cot 10 x Surat dwarf) to 2.85 % (G cot 16 x GISV 361). Among four crosses developed and accessed, only G Cot 16 x GISV 361 (2.85 %) registered significant as well as positive (desirable) relative heterosis. Only G Cot 16 x GISV 361 (0.72%) registered positive heterobeltiosis but it was non-significant. Positive as well as negative values of heterobeltiosis for fibre elongation was also reported earlier observed by Isong*et al.* (2019).For inbreeding depression, only GN Cot 26 x GBHV 253 (-3.47 %) was devoid of inbreeding depression. Its value was negative (*i.e.* desirable) and significant also that indicates that there may be chance of presence of superior recombinants in its $F_2$ population. El-Adly and Arafa (2009) earlier obtained similar trend of positive as well as negative inbreeding depression.

## 1.4 SUMMARY AND CONCLUSION

Among four crosses, cross G Cot 16 x GISV 361 manifested significant and desirable heterobeltiosis for fibre quality traits like ginning percentage, micronaire value, uniformity index and lint index. This cross also registered non-significant but desiraleheterobeltiosis for fibre elongation. Thus, cross combination *i.e.* G Cot 16 x GISV 361 looks promising so it need to be evaluated thoroughly for testing its commercial suitability for farmers benefit in particular.

In GN Cot 26 x GBHV 253 inbreeding depression was completely absent for lint index and fibre elongation while in G Cot 16 x GISV 361, for fibre strength, inbreeding depression was negative (desirable) and significant revealing segregating ($F_2$) population has more fibre strength than its $F_1$ generation thus suggesting presence of superior recombinants in $F_2$.

It is desirable to have high, significant and positive heterobeltiosis for seed cotton yield per plant with absence or low magnitude of inbreeding depression for fibre quality traits except for micronaire value. In this investigation, G Cot 16 x GISV 361 recorded significant positive heterobeltiosis along with absence of inbreeding depression for fibre strength and to some extent in ginning percentage which is very much desirable for fibre quality improvement in cotton.

## FUTURE PROSPECTS

Modern genetic engineering techniques, such as CRISPR/Cas 9 and other gene-editing tools, offer new opportunities to overcome some of the genetic challenges associated with heterosis. These technologies can be used to introduce desirable traits into parent lines, improve compatibility, and enhance hybrid vigor. Also, the use of precision breeding techniques such as genomic selection, marker assisted selection can help identify superior parent combinations more effectively. By understanding the genetic markers associated with heterosis, breeders can accelerate the development of high- performing hybrids with improved fiber quality and yield.

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