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. For traits like Ginning percentage, uniformity index, Upper Half Mean Length, Lint index, and Fibre strength, most of the crosses showed positive and significant relative heterosis. While, heterobeltiosis was also found positive and significant for ginning percentage, uniformity index, Upper half mean length and fibre strength for most of the crosses under study. Most of the crosses under study also showed little inbreeding depression for traits like ginning percentage, uniformity index and fibre strength. Thus, by exploiting the benefits of heterosis while mitigating risks associated with inbreeding depression may lead to the development of superior hybrid varieties with consistently improved fibre quality.

Keywords: Relative heterosis, heterobeltiosis, inbreeding depression, hybrids etc.

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. Cotton belongs to family *Malvaceae* and genus *Gossypium. Gossypium* includes about 54 species, four of which are cultivated, 44 are wild diploids and two are wild tetraploids (Percival and Kohel, 1990). 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 is the enhanced performance of hybrid offspring compared to their parents. It can manifest in various forms, including increased yield, growth rate, stress tolerance, and overall vitality. Heterosis is crucial in hybrid production as it allows breeders to create offspring with superior traits, leading to higher agricultural productivity and better adaptability to environmental changes. Heterosis occurs due to the combination of different alleles from two genetically diverse parents. This genetic complementation can mask deleterious recessive alleles, leading to an enhanced phenotype (Shull, 1914).

Inbreeding depression occurs when genetically similar individuals are crossed, leading to a high likelihood of homozygosity at many loci (Liu and Reddy, 2001). This can result in the expression of deleterious recessive alleles, leading to reduced vigour, fertility, and yield. Thus, to maximize heterosis, breeders deliberately cross genetically diverse parent lines. By avoiding excessive inbreeding, they reduce the risk of inbreeding depression and ensure that hybrids produced retain hybrid vigour and productivity. Thus, heterosis study is essential for achieving the high productivity and resilience needed to meet agricultural demands. At the same time, minimizing inbreeding depression is critical to maintain genetic health and performance of crop populations.

By strategically combining genetically diverse parents and avoiding excessive inbreeding, we can exploit the benefits of heterosis while mitigating risks associated with inbreeding depression, leading to the development of superior hybrid varieties with consistently high yields. Thus, the present investigation was carried out to study heterosis and inbreeding depression for improving fibre quality traits in upland cotton.

2. MATERIALS AND METHOD

2.1 Field experiment

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 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. The F_1 seeds along with parents were sown during late *Kharif* 2021-22 at the College Farm, Navsari Agricultural University, Navsari.Manual hybridization was practiced for producing fresh seed of all four F_1s as well as backcrosses while some plants of parents and F_1 were selfed for getting pure seed of parents and F_2 respectively. The seed of all six generations of four crosses were sown during *Kharif* 2022-23 for evaluation.Details of parental genotypes with their specific traits are given in Table 1.

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.

2.2 Experimental Design

The experimental material for present investigation was consisted of six different generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of each of four single crosses which were sown during the *Kharif* 2022-23 in Compact Family Block Design (CFBD) with three replications. Each replication was divided into four compact blocks, each block was consisted of six generations of each cross. Within replication, each family was allotted to block randomly and within block, different generations were allotted to different plots randomly. Each block comprised of two rows of each parent and F_1; four rows of each back cross generation and eight rows of the F_2 generation with each row having 10 plants. Each row spaced 120 cm apart and plant to plant distance within row was 60 cm. All the cultural practices were adopted as per recommendation to raise the good crop. Plant protection measures were taken up at appropriate time and as per recommendation to control pests and diseases.

Table 1: Details of parental genotypes with their specific traits

S.No.	Parent	Specific character
1.	GN Cot 22	Jassid Resistance, Hairy leaf and other plant parts

2.	GBHV 200	High yielding, suited to rainfed condition
3.	GN Cot 26	High yielding released variety for rainfed condition
4.	GBHV 253	High yielding suited to rainfed condition
5.	G Cot 16	High yielding and female parent of famous cotton hybrid GCH-6
6.	GISV 361	Inter specific cross derivatives between *G. hirsutum* x *G. barbadense*, Tall plant
7.	G Cot 10	Pilose leaves, bracts and stems, Jassid Resistance, Good GCA, High yield
8.	Surat Dwarf	Smooth leaves, Jassid susceptible, dwarf height and early flowering

2.3 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

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

(Standard error for relative heterosis)

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

(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.

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

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

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_2mostly 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:

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

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

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

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

Where,

$\overline{F}_1$ = Mean value of the F_1 hybrid

$\overline{F}_2$ = 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.

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.

3.1 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).

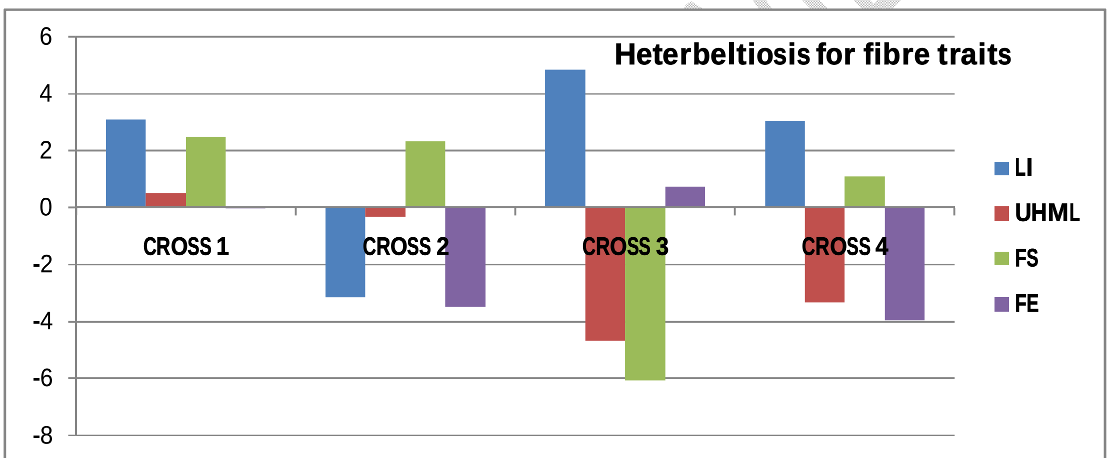
3.2Fibre fineness(micronaire value): negative heterosis is desirable.Negative and significant heterobeltiosis was observed in cross GN Cot 22 x GBHV 200 (-14.32%) and cross GN Cot 26 x GBHV 253 (-7.41%), which is desirable for further improvement in this trait. It was very surprising and promising that 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 2: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	Lint Index (%)	Fibre Strength (g/tex)	Fibre Elongation (%)

				(mm)			
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 (%).

3.3 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).

3.4Upper Half Mean Length: From Table 2, relative heterosis was found to be highly significant and positive (desirable)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).

3.5 Lint index: High positive values are desirable for Lint index. 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 varies 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).

3.6 Fibre Strength: 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 were 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%).

3.7 Fibre Elongation: Experimental data presented in Table 2 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 were 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.

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.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Details of the AI usage are given below:

1. Chat GPT

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