Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

**E-ISSN:** 2278-4136
**P-ISSN:** 2349-8234
JPP 2018; 7(1): 1963-1967
Received: 21-11-2017
Accepted: 22-12-2017

**Bilwal BB**
Main Cotton Research Station, Navsari Agricultural University, Navsari, Gujarat, India

**Vadodariya KV**
Main Cotton Research Station, Navsari Agricultural University, Navsari, Gujarat, India

**Lahane GR**
Main Cotton Research Station, Navsari Agricultural University, Navsari, Gujarat, India

**Rajkumar BK**
Main Cotton Research Station, Navsari Agricultural University, Navsari, Gujarat, India

**Correspondence**
**Bilwal BB**
Main Cotton Research Station, Navsari Agricultural University, Navsari, Gujarat, India

# Heterosis study for seed cotton yield and its yield attributing traits in upland cotton (*Gossypium hirsutum* L.)

**Bilwal BB, Vadodariya KV, Lahane GR and Rajkumar BK**

## Abstract
A study was made in upland cotton with 9 x 9 diallel to assess the extent of heterosis over standard check (G.Cot. Hy.14) for seed cotton yield and its related attributes traits at main cotton research station, Navsari Agricultural University Navsari, Gujarat. The highest heterotic effect were recorded in the hybrids GJHV-337 x GN.Cot-22, GJHV-337 x EC-10786 and GN.Cot-22 xKH-119 were promising hybrids in this study over the standard check for seed cotton yield per plant and its most of the yield attributing traits. Those hybrids exhibiting high heterosis for seed cotton yield per plant also had high heterosis for yield attributing characters. The study reveals good scope for commercial exploitation of heterosis as well as isolation of pure lines among the progenies of other heterotic $F_1$ hybrids

**Keywords:** cotton; standard heterosis; seed cotton yield; attributing traits; diallel

## Introduction
Cotton (*Gossypium hirsutum* L.) is an important fibre crop and plays a vital role as a cash crop in commerce of many countries such as USA, China, India, Pakistan, Uzbekistan, Australia and Africa. Cotton plays an important role in Indian economy and it is most important natural fibre for India's textile industry. Sufficient cotton production is required to meet the ever increasing fibre demand of growing World's population. In India, cotton is cultivated on about 115.53 lakh hectare with a production of 375 lakh bales. It occupies second position amongst all cotton producing countries in the world i.e. next to China. Average productivity of India is 552 Kg/ha which is much below compared to world average of 754 kg/ha (Anonymous, 2016a) [2]. Cotton contributes 30% of the GDP of Indian agriculture and 3% of total GDP. Gujarat ranks first in cotton production and productivity in India, and it is contributing nearly 35% production from 24% area in the country. Gujarat is the second largest cotton growing state with acreage of about 25 lakh hectares; and largest cotton producing state of India with production of nearly 100 lakh bales. The average productivity of cotton in the state (688.51 kg/ha) is higher than the national average (Anonymous 2016b) [3]. Development of new variety with higher yield and fibre quality are the primary objectives of cotton breeding programmes. The first step in successful breeding program is to select appropriate parents. Diallel analysis provides a systemic approach for the identification of suitable parents and cross combination for the investigated traits Griffings, (1956) [10]. Cotton being highly amenable for heterosis breeding of commercial exploitation of heterosis in cotton has achieved spectacular success in India, as is evident from the widespread use of *inter*specific and *intra* specific hybrids. All the hybrids being cultivated are single cross hybrids only. Breeding was done to develop suitable shot duration. The present study was undertaken to estimate the useful heterosis over the G.Cot. Hy.14 for seed cotton yield per plant and its attributing traits in cotton (*Gossypium hirsutum* L.).

## Materials and Methods
The present investigation was part of the study undertaken during Ph.D. programme. A crossing programme was undertaken at the MCRS (Main Cotton Research Stations) Farm, Surat during *Kharif* 2014-15, by crossing 9 x 9 of *Gossypium hirsutum* L. in a diallel mating design. Resulted thirty six hybrids and nine parents were evaluated in a randomized block design, replicated thrice at Surat during kharif 2015-16. Soil of Surat is typical black cotton saline soil. Each plot was consisting of single row of 4.5 m length. Row to row and plant to plant spacing was 120 cm and 45 cm respectively. One guard row was planted on both sides of the experiments. Recommended agronomical practices and plant protection measures were

followed as and when required to raise a good crop of cotton. The data were recorded on sixteen yield related attributes traits and physiological characters and subjected to statistical analysis. Heterosis was calculated based on mean value which is percent increase or decrease of hybrid performance over standard check Fehr, (1987) [6].

$$\text{Standard Heterosis (\%)} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\overline{F_1}$ = Mean performance of F1 hybrid

$\underline{SC}$ = Mean performance of standard check

SC = Mean performance of standard check

## Results and Discussion

Through diallel analysis large number of parents and crosses could be evaluated and analysis. This analysis also provided very reliable information about the genetic architecture of inheritance pattern from its combining ability estimates. The results of analysis of variance of parents and their hybrids for various traits are given in the (Table: 1). and analysis of variance mean square due to genotypic differences were found significant for all the traits under studied. This study indicated that substantial genetic diversity present for different traits under study. Further, partitioning of sum of squares due to genotypes indicated that the differences among parents were significant for all the characters. In case of hybrids, significant differences were obtained all the characters except seed cotton yield per plant, sympodia per plant and seed index. However, mean square due to parents *vs*. hybrids were significant for all the characters which indicated the presence of substantial amount of genetic variability crosses. This suggested that parents significantly differed from the hybrids which indicated the presence of heterosis for the characters under investigation.

**Table 1:** Analysis of variance for seed cotton yield and its component traits in cotton *(G.hirsutum* L.).

| Source of variance | d.f. | Seed cotton yield /plant (g) | Sympodia /plant | Bolls/ plant | Boll weight (g) | Seed index (g) | Ginning outturn (%) | Lint yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 149.22 ** | 106.74 ** | 107.30 ** | 87.07** | 127.90** | 46.16** | 134.02 ** |
| Genotype | 44 | 152.34 ** | 149.12** | 188.38 ** | 98.38** | 198.43** | 47.49** | 152.52 ** |
| Parent | 8 | 3225.13 ** | 160.16 ** | 1202.43** | 596.37** | 1332.99** | 125.01** | 538.74 ** |
| Hybrids | 35 | 52.83 | 5.85 | 24.32 ** | 16.53** | 24.06 | 5.01** | 17.64 ** |
| Parent vs. Hybrids | 1 | 81.36 ** | 6.39 ** | 27.97 ** | 21.85** | 30.15** | 6.45** | 18.99 ** |
| Error | 88 | 35.53 | 3.71 | 11.53 | 10.44 | 15.24 | 1.97 | 6.17 |

* and ** = Significant at 5% and 1% levels of probability, respectively

Amount of heterosis in $F_1$ is indication of genetic diversity among the parents involved in crosses Moll *et al*. (2005). Commercial exploitation of heterosis in crop plants was a major breakthrough in the field of plant breeding. Heterosis breeding has led to considerable yield improvements in a variety of cross as well as self-pollinated crops. Heterosis studies guide the breeder in identifying crosses that are likely to throw transgressive segregants Singh *et al*. (1979) [18]. The scope of exploitation of hybrid vigour depends on directions and magnitude of heterosis and type of gene action involved. The measures of heterosis over better parent (heterobeltiosis) and over standard check (standard heterosis) are better rational parameters for assessing its practical utility. In the present investigation, heterosis over standard check (standard heterosis) was studied. Negative heterosis has been considered as desirable for days to 50% flowering, number of monopodia per plant and fibre fineness, while for other characters significant positive heterosis was considered as desirable. The degree of standard heterosis varied from cross to cross for all the characters. None of the hybrid had high standard heterosis for all the traits. Sizeable amount of standard heterosis in certain crosses and low in other crosses revealed that nature of gene action varied with the genetic architecture of parents. For seed cotton yield per plant, out of thirty six hybrids nine hybrids registered significant positive heterosis over standard check, which varied from -12.63 per cent (GSHV-97/13 x DELTA-15) to 30.90 per cent (GJHV-337 x GN.Cot-22). Whereas, none of hybrids registered significant negative standard heterosis for seed cotton yield per plant. The hybrids GJHV-337 x GN.Cot-22 (30.90%) expressed significant and maximum positive standard heterosis closely followed by GJHV-337 x EC-10786 (29.24%) and GN.Cot-22 x KH-119 (25.73%). Several workers *viz*., Nirania *et al*. (2005) [20], Tuteja *et al*. (2005) [28] Khosla *et al*. (2007) [15] and Shaikh *et al.* (2009) reported significant heterosis in positive direction for seed cotton yield per plant.

### Sympodia /plant

The range of standard heterosis for number of sympodia per plant was -6.29 to 88.86 per cent. Out of thirty six hybrids six hybrids manifested positive and significant heterosis over standard check, the maximum value was observed for the crossGJHV-337 x GN.Cot-22 (88.86%)followed by GJHV-337 x EC-10786 (77.99%) and EC-10786 x KH-119 (74.22%). High heterosis for sympodia per plant was also reported by Niraniaet *al*. (2005) [20] and Tuteja *et al*. (2013) [31].

### Number of bolls per plant

Estimate of heterosis for number of bolls per plant over standard check varied between 9.80 and 75.68 per cent. Out of thirty six hybrids seventeen hybrids registered positive and significant standard heterosis. The highest value was observed for the cross GJHV-337 x EC-10786 (75.68%) followed by GJHV-337 x GN.Cot-22 (73.78%) and GN.Cot-22 x EC-10786 (68.22%) This indicated that increase in boll number also contributes for increase in seed cotton yield. Improvement in above yield attributes/characters by exploitation of heterosis in cotton showed considerable scope for increasing yield. The result assemble with the worker Tuteja *et al*. (2011) [32], Tuteja *et al*. (2013) [31] and Tuteja (2014) [30].

### Average boll weight

Seed cotton yield is also directly proportional to boll weight hence these trait important for contribution. The range of standard heterosis for boll weight was -15.95 to 71.16 per cent. The heterosis for boll weight was found in positive direction in 8 out of 36 cross-combinations. The maximum estimate of significant and positive standard heterosis for boll weight was exhibited by hybrid GJHV-337 x GN.Cot-22 (71.16%) followed by GSHV-97/13 x GJHV-337 (59.87%) and EC-10786 x KH-119 (58.78%) Jain (1996) [11] and Kumar *et al.* (2003) [16] have reported similar findings for this traits in *G. hirsutum* L.

**Seed index**

The cross combinations GJHV-337 x EC-10786 (28.01%), GJHV-337 x GN.Cot-22 (27.70%) and GJHV-337 x GN.Cot-22 (38.63%) exhibited highest, significant and positive heterosis over standard check for seed index. The extent of heterosis for seed index ranged from -3.29 to 28.01% over standard check. Among hybrids, six hybrids showed significant and positive heterosis over standard heterosis. Pole *et al*. (2008) [24] and Jyotiba *et al*. (2010) [12] also reported high heterosis for seed index.

**Ginning outturn (%)**

The heterotic expression for ginning outturn ranged from -4.12 to 38.63% over standard check. Out of thirty six hybrids seventeen hybrids registered positive and significant standard heterosis. Among hybrids, GJHV-337 x GN.Cot-22 (38.63%) GJHV-337 x EC-10786 (35.12%) and GN.Cot-22 x EC-10786 (15.05%) showed highest, significant and positive standard heterosis for ginning outturn. Nirania *et al*. (2005) [20], Rauf *et al*. (2005) [26], Preetha and Raveendaran (2008) [25], Patel *et al*. (2009) [22] and Geddam *et al*. (2011) [8] also reported varying magnitude of heterosis for this character.

**Lint yield per plant (g)**

The extent of heterosis for lint yield per plant ranged from -2.08 to 56.18% over standard check. Among hybrids, fourteen hybrids showed significant and positive heterosis over standard heterosis. The cross combinations GJHV-337 x GN.Cot-22 (56.18%), GN.Cot-22 x EC-10786 (55.68%) andGN.Cot-22 x KH-119 (52.57%) showed significant and positive heterobeltiosis and standard heterosis for lint yield per plant. The results reported in the present investigation are in agreement with earlier workers by Desalegn and Ratanadilok (2004) [5], Tuteja *et al*. (2006) [29] and Basal *et al*. (2011) [4] for lint yield per plant.

Seed cotton yield in cotton is one of the most important economic characters and is the final product of the multiplicative interaction of contributing traits. It is imperative to know the causes of heterosis for seed cotton yield. Whitehouse *et al*. (1958) [34] and Grafius (1959) [9] suggested that there may not be any gene system for yield *per se* as yield is an end product of the multiplicative interaction between the yield components. This would indicate that the heterosis for yield should be through heterosis for the individual yield components or alternatively due to the multiplicative effects of partial dominance of component characters. William and Gilbert (1960) [35] reported that even simple dominance in respect of yield components may lead to expression of heterosis for yield. Hagberg (1952) observed similar effects and termed it “Combinational heterosis”. In order to see whether similar situation exists in cotton or not, a comparison of ten most heterotic crosses for seed cotton yield was made with other yield related traits along with seed cotton yield per plant.

It was revealed that high significant and positive heterosis for seed cotton yield per plant in nine crosses were not accompanied by single unique trait (Table 2). High significant and positive heterosis for seed cotton yield per plant in crosses GJHV-337 x GN.Cot-22, GJHV-337 x EC-10786 and GN.Cot-22 x KH-119 were accompanied by significant and positive heterosis for number of bolls per plant, ginning outturn, lint yield per plant. Besides, the cross combination EC-10786 x KH-119 had also significant and positive heterosis for number of sympodia per plant, average boll weight, ginning outturn and lint yield per plant.

This indicated that in different crosses, the pathway for realizing heterotic effect varied from cross to cross. This results revealed that number of sympodia per plant, number of bolls per plant, boll weight and lint yield per plant were the main contributors toward increased in heterotic effects for seed cotton yield per plant. While ginning percentage, seed index and lint yield per plant were secondary contributors toward increased heterotic effects for seed cotton yield per plant in specific cross combinations only. Similar findings have been reported by Tuteja (2001) [27], Nirania *et al*. (2005) [20], Muthu *et al*. (2005) [19], Tuteja *et al*. (2005) [28], Verma *et al*. (2006) [33], Ganapathy and Nadarajan (2008) [7], Abro *et al*. (2009) [1], Khan *et al*. (2009) [14], Jyotiba *et al*. (2010) [12], Kaushik and Shastry (2011) [13] and Patil *et al*. (2011) [23].

Based on data of standard heterosis, it can be concluded that, three cross combinations namely GJHV-337 x GN.Cot-22, GJHV-337 x EC-10786 and GN.Cot-22 x KH-119 appeared to be the most heterotic crosses for seed cotton yield per plant to exploit heterosis in cotton. The present study revealed of considerable amount of heterosis for seed cotton yield per plant in cotton. It indicates larger scope for heterosis breeding for commercial exploitation of heterosis. The crosses showing desirable heterosis over standard check can be advanced for isolation of improved lines for different yield contributing traits.

**Table 2:** Estimates of heterosis over standard heterosis (G. Cot. Hy.14) for seed cotton yield per plant and its yield attributing traits in cotton (*G. hirsutum* L.).

| Sr. No. | Crosses/ Hybrid | Seed cotton yield /plant (g) | Sympodia/ plant | Bolls/ plant | Boll weight (g) | Seed index (g) | Ginning outturn (%) | Lint yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|
| 1 | GSHV-97/13 x GJHV-337 | 20.82 ** | 47.26* | 59.08** | **59.87**** | **22.85**** | 30.26** | 47.83** |
| 2 | GSHV-97/13 x AET-5 | 3.88 | 21.49 | 17.61 | 16.97 | 16.28* | 10.70 | 15.39 |
| 3 | GSHV-97/13 x GN.Cot-22 | 5.24 | -2.49 | 21.55 | 7.87 | 2.19 | 9.75 | 15.25 |
| 4 | GSHV-97/13 x GSHV-97/1016 | -5.42 | 0.80 | 9.80 | 30.70* | 4.85 | 10.80 | 5.33 |
| 5 | GSHV-97/13 x GISV-8/1029 | -2.30 | 3.72 | 19.29 | 6.92 | 7.67 | 10.42 | 8.31 |
| 6 | GSHV-97/13 x DELTA-15 | -12.63 | -6.69 | 14.88 | 17.66 | 3.44 | 11.37 | -2.08 |
| 7 | GSHV-97/13 x EC-10786 | 17.16 * | 5.13 | 31.70 | -7.14 | 9.23 | 9.50 | 28.48** |
| 8 | GSHV-97/13 x KH-119 | 19.41 ** | 27.31 | 19.85 | 4.22 | 12.83 | 26.04** | 47.70** |
| 9 | GJHV-337 x AET-5 | 12.30 | 45.04 | 31.71 | -0.84 | 9.70 | 19.95** | 36.54** |
| 10 | GJHV-337 x GN.Cot-22 | 30.90 ** | 88.86** | 73.78** | 71.16** | 27.70** | 38.63** | 56.18** |
| 11 | GJHV-337 x GSHV-97/1016 | -3.58 | 32.78 | 31.23 | -3.57 | 10.49 | 9.01 | 6.56 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12 | GJHV-337 x GISV-8/1029 | -1.22 | 24.45 | 38.32* | 10.34 | 10.33 | 12.28 | 11.25 |
| 13 | GJHV-337 x DELTA-15 | 0.60 | 19.44 | 29.80 | 3.28 | 9.23 | 12.00 | 13.07 |
| 14 | GJHV-337 x EC-10786 | 29.24 ** | 77.99** | 75.68** | 56.96** | 28.01** | 35.12** | 49.86** |
| 15 | GJHV-337 x KH-119 | -6.63 | 43.83 | 36.00* | -4.30 | 12.36 | 13.19* | 6.41 |
| 16 | AET-5 x GN.Cot-22 | 6.53 | 18.95 | 33.89* | 8.56 | 12.36 | 6.05 | 12.91 |
| 17 | AET-5 x GSHV-97/1016 | 1.23 | 19.42 | 29.88 | 9.61 | 6.89 | 8.16 | 9.02 |
| 18 | AET-5 x GISV-8/1029 | -5.55 | 9.13 | 40.40* | 11.58 | 3.29 | 4.47 | -0.87 |
| 19 | AET-5 x DELTA-15 | -7.92 | 7.30 | 25.57 | 14.35 | 7.20 | 7.67 | -0.96 |
| 20 | AET-5 x EC-10786 | 9.05 | 27.73 | 34.8* | 29.28 | 9.55 | 14.43* | 26.28** |
| 21 | AET-5 x KH-119 | 0.98 | 8.36 | 35.5* | 5.75 | 12.21 | 4.71 | 5.91 |
| 22 | GN.Cot-22 x GSHV-97/1016 | -3.02 | 42.65 | 46.6* | 26.73 | 1.72 | 7.92 | 5.72 |
| 23 | GN.Cot-22 x GISV-8/1029 | 3.34 | 49.14* | 36.8* | 18.57 | 15.18 | 15.52* | 20.01* |
| 24 | GN.Cot-22 x DELTA-15 | 1.03 | 15.70 | 22.87 | 6.48 | 8.76 | 10.42 | 11.78 |
| 25 | GN.Cot-22 x EC-10786 | 25.08 ** | 69.60** | 68.22** | 54.81** | 22.69** | 32.41** | 55.68** |
| 26 | GN.Cot-22 x KH-119 | 25.73 ** | 64.81** | 57.11 | 49.31** | 21.60** | 21.36** | 52.57** |
| 27 | GSHV-97/1016 x GISV-8/1029 | 6.45 | 4.67 | 37.66 | -7.10 | -3.29 | 9.22 | 16.52 |
| 28 | GSHV-97/1016 x DELTA-15 | 9.66 | 21.41 | 20.90 | 7.21 | 3.29 | 16.57* | 28.06** |
| 29 | GSHV-97/1016 x EC-10786 | 2.38 | 17.76 | 15.10 | -10.89 | 7.36 | 13.93* | 16.47 |
| 30 | GSHV-97/1016 x KH-119 | -0.02 | 44.50 | 30.71 | -5.90 | 4.54 | 13.48* | 13.51 |
| 31 | GISV-8/1029 x DELTA-15 | 0.34 | 30.09 | 34.05 | -15.95 | 7.98 | 16.85* | 17.33 |
| 32 | GISV-8/1029 x EC-10786 | 6.19 | 40.24 | 36.29 | 3.50 | 8.92 | 21.50** | 28.19** |
| 33 | GISV-8/1029 x KH-119 | -6.40 | 4.81 | 15.95 | 5.90 | 8.76 | 9.11 | 2.10 |
| 34 | DELTA-15 x EC-10786 | 24.04** | 39.46 | 16.72 | 55.57** | 14.24 | 27.02** | 48.80** |
| 35 | DELTA-15 x KH-119 | 4.65 | -5.54 | 42.23 | 3.35 | 13.93 | 4.12 | 8.86 |
| 36 | EC-10786 x KH-119 | 18.70 * | 74.22** | 19.97 | 58.78** | 15.02 | 26.43** | 46.14** |
| | S.E.± | 8.42 | 2.72 | 4.80 | 4.56 | 5.52 | 1.98 | 3.51 |
| | C.D. at 1% | 21.87 | 7.06 | 12.46 | 11.85 | 13.50 | 5.15 | 9.25 |

**References**


1. Abro S, Kandhro MM, Laghari S, Arain MA, Deho ZA. Combining ability and Heterosis for yield contributing traits in upland cotton (*Gossypium hirsutum* L.). Pak. J. Bot. 2009; 41(4):1769-1774.
2. Anonymous. Annual Report. Central Institute of cotton Research, 2016a. [Online]. *www.cicr.org.in.*
3. Anonymous. Cotton Advisory Board, 2016b. *[Online].www.cotcorp.gov.in.*
4. Basal H, Canavar O, Khan NU, Cerit CS. Combining ability and heterotic studies through line x tester in local and exotic upland cotton genotypes. Pak. J. Bot. 2011; 43(3):1699-1706.
5. Desalegn Z, Ratanadilok NC. Evaluation of $F_1$ and $F_2$ generations for yield and yield components and fiber quality parameters on cotton (*Gossypium hirsutum* L.) under Ethiopia condition. J National Sci. 2004; 38(1):176-182.
6. Fehr WR. Principles of Cultivar Development. Theory and Technique. Macmillan Pub. Co. Inc. New York, USA, 1987.
7. Ganapathy S, Nadarajan N. Heterosis studies for oil content, seed cotton yield and other economic traits in cotton (*Gossypium hirsutum* L.). Madras Agric. J 2008; 95(7-12):306-310.
8. Geddam SB, 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 J. Agric. Sci. 2011; 24(2):118-124.
9. Grafius JE. Heterosis in barley. Agron. J. 1959; 40(1):58-83.
10. Griffings B. Concept of general and specific combining ability in relation to diallel crossing system. Australian Journal of Biological Science. 1956; 9:463-493.
11. Jain S. Heterosis for yield contributing characters in intra and interspecific cross combination of cotton. J Cotton. Res. Dev. 1996; 10:147-149.
12. Jyotiba SS, Patil BR, Deshpande SK, Patil SS, Patil RS. Heterosis studies in GMS based diploid cotton (*Gossypium herbaceum* L.) Electronic J. Pl. Breed. 2010; 1(4):685-688.
13. Kaushik SK, Shastry EVD. Heterosis and inbreeding depression in (*Gossypium hirsutum* L.). SABRAOJ. Breeding & Genetics. 2011; 43(2):107-121.
14. Khan NU, Hassan G, Marwat KB, Khan MZ. Legacy study of cotton seed traits in upland cotton using Griffing's combining ability model. Pak. J. Bot. 2009; 41 (1):131-142.
15. Khosla G, Gill BS, Sohu RS. Heterosis and combining ability analysis for plant and seed characters in upland cotton. J. Cotton Res. Dev. 2007; 21(1):12-15.
16. Kumar M, Chhabra BS, Kumar R. Heterosis for seed cotton yield and fiber quality intra *Gossypium hirsutum* L. cross combination. J Cotton. Res. Dev. 2003; 17:27-29.
17. Moll RH, Sathuana WS, Robinson HF. Heterosis and genetic diversity in variety crosses of maize. *Crop Sci*., 1962; 2:197-198.
18. Singh S, Jain RP. Heterosis in mungbean. Indian Journal Genetics. 1979; 30:244-250.
19. Muthu R, Kandasamy G, Raveendran TS, Ravikesavan R, Jayaramachandran M. Combining ability and heterosis for yield traits in cotton (*Gossypium hirsutum*L.). Madras Agric. J. 2005; 92(1-3):17-22.
20. Nirania KS, Chhabra BS, Yagya D. Heterosis for yield and quality traits in genetic male sterility based upland cotton hybrids. J. Cotton. Res. Dev. 2005; 18(2):132-136.
21. Pandit SP, Lodam VA, Sakhare BA, Wandhare MR. Genetic architecture for seed cotton yield and fibre quality trait in upland cotton (*Gossypium hirsutum* L.). J. Cotton Res. Dev. 2014; 28(2):201-203.

22. Patel AD, Patel UG, Kumar V. Heterosis and combining ability for yield and oil content in a half diallel cotton (*Gossypium hirsutum* L.) over environments. J. Cotton. Res. Dev. 2009; 23(2):232236.
23. Patil SA, Naik MR, Patil AB, Chaugule GR. Heterosis for seed cotton yield and its contributing characters in cotton (*Gossypium hirsutum* L.). Plant Archives. 2011; 11(1):461-465.
24. Pole SP, Kamble SK, Madrap IA, Sarang DH. Diallel analysis for combining ability for seed cotton yield and its components in upland cotton (*Gossypium hirsutum* L.). J. Cotton. Res. Dev. 2008; 22(1):19-22.
25. Preetha S, Raveendran TS. Combining ability and heterosis for yield and fibre quality traits in line x tester crosses of upland cotton. International J. Pl. Breed. 2008; 2(2):64-74.
26. Rauf S, Khan TM, Nazir S. Combining Ability and Heterosis in *Gossypium hirsutum* L. Int. J. Agri. Biol. 2005; 7(1):109-113.
27. Tuteja OP. Heterosis for yield and yield components in upland cotton. J. Cotton. Res. Dev. 2001; 13(1):79-80.
28. Tuteja OP, Kumar S, Singh M, Manojkumar. Heterosis in single cross hybrids of *G. hirsutum* L. in cotton. J. Cotton. Res. Dev. 2005; 19:165-167.
29. Tuteja OP, Singh M, Verma SK, Khadi BM. Introgressed lines as sources for improvement of upland cotton (*G. hirsutum* L.) genotypes for yield and fibre quality traits. Indian J. Genet. 2006; 66(3):251-252.
30. Tuteja OP. Studies on heterosis for yield and fiber quality traits in GMS hybrids of upland cotton (*Gossypium hirsutum* L.). J. Cotton Res. Dev. 2014; 28(1):1-6.
31. Tuteja OP, Banga M, Hasan H. Heterosis for seed cotton yield component traits and fiber properties of American cotton (*Gossypium hirsutum* L). J. Cotton Res. Dev. 2013; 27(2):184-187.
32. Tuteja OP, Banga M, Nirania KS. Heterosis studies on GMS based hybrids in *Gossypium hirsutum*L. cotton. J Cotton Res. Dev. 2011; 25(2):162-164.
33. Verma SK, Tuteja OP, Kumar S, Ramprakash RN, Monga D. Heterosis for seed cotton yield and its qualitative characters in cotton (*G. hirsutum* L.). J. Cotton. Res. Dev. 2006; 20(1):14-17.
34. Whitehouse RNH, Thompson JB, Riberio DV. Studies on the breeding of self-pollinated cereals. 2. The use of diallelcross analysis in yield prediction. *Euphytica.* 1958; 7:147-169.
35. Williams W, Gilbert N. Heterosis and the inheritance of yield in the tomato. Heredity. 1960; 14:133-135.