academicJournals

Vol. 13(1), pp. 119-126, 1 January, 2013
DOI: 10.5897/AJB2013.13079
ISSN 1684-5315 ©2014 Academic Journals
http://www.academicjournals.org/AJB

African Journal of Biotechnology

*Full Length Research Paper*

# Genetic effects of combining ability studies for yield and fibre quality traits in diallel crosses of upland cotton (*Gossypium hirsutum* L.)

**K. Senthil Kumar[1], K. Ashokkumar[1,2]* and R. Ravikesavan[1]**

[1]Center of Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-3, Tamil Nadu, India.
[2]Department of Plant Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5A8, Canada.

Accepted 12 December, 2013

**The present study was carried out to investigate the diallel analysis in upland cotton (*Gossypium hirsutum* L.) by involving seven parents and their 42 cross combinations. All the characters were predominantly controlled by additive gene action except number of sympodial branches, single plant yield and bundle strength. Non additive gene action was controlled for the characters sympodial branches, single plant yield and bundle strength. The parent BW4-1 had superior *per se* performance for single plant yield, boll weight, lint index, number of bolls per plant, seed index, and micronaire followed by MCU 13 which had recorded high *per se* for single plant yield, lint index, seed index and number of sympodial branches. The parent TCH 1726 exhibited positive and significant *gca* effect for single plant yield, ginning percent, number of sympodial branches, boll weight and plant height. Based on high *per se* performance and high *gca* effect, the parent MCU 13 was considered as best general combiner as it had significantly greater values for single plant yield, number of sympodial branches, lint index and seed index. The hybrids KC 2 × TCH 1726 and TCH 1705 × MCU 3 had recorded high *per se* for single plant yield, number of bolls per plant and number of sympodial branches. Based on *sca* effects, KC 2 × TCH 1726 showed significant *sca* effects for single plant yield and number of sympodial branches.**

**Key words:** Cotton, Combining ability, *gca*, fibre quality traits, *sca*, single plant yield.

## INTRODUCTION

Cotton is an important fiber, crop and plays a vital role as a cash crop in commerce of many countries. Cotton production, processing and trade in cotton goods provide employment to about 60 million people in India. It provides fibre for textile industry, cellulose from its lint, oil and protein rich meal from its seed (Ashokkumar and Ravikesavan, 2011). The development of new variety with high yield and fibre quality is the primary objective of all cotton breeders. The first step in a successful breeding program is to select appropriate parents. Diallel analysis provides a systematic approach for detection of appropriate parents and crosses in terms of investigated traits. Diallel analysis has been widely used by plant breeders in the selection of parents and crosses in the early generations (Marani, 1963; Green and Culp, 1990; Islam et al., 2001; Kiani et al., 2007; Karademir and Gencer, 2010). The analyses of diallel crosses contain further information on the nature of the predominant gene action in traits of major agronomic importance, besides estimates of general (GCA) and specific combining ability (SCA).

Information pertaining to the different types of gene

*Corresponding author. E-mail: biotech.ashok@gmail.com.

action, relative magnitude of genetic variance and combining ability estimates are important and vital parameters to mold the genetic makeup of the cotton crop (Subhan et al., 2003). This important information could prove an essential strategy to the cotton breeder in the screening of better parental combinations for further enhancement. Several studies which reported variation in yield and fibre quality components were controlled by genes acting additively and non-additively. Studies of Shakeel et al. (2001), Ahuja and Dhayal (2007) and Ashokkumar et al. (2010) revealed that boll weight, number of bolls, and seed cotton yield were influenced by the genes acting non-additively and in contrast studies of Khan and Idris (1995) and Kumaresan et al. (1999) indicated that both additive and non-additive gene effects were important for controlling number of bolls and seed cotton yield. However, Lukange et al. (2007) discovered additive gene effects for microanire value and fibre strength and non-additive gene action for fibre length.

Non-additive gene action for fibre length, fibre strength and micronaire value have been reported by Hassan et al. (1999, 2000), Ahuja and Dhayal (2007), Ashokkumar and Ravikesavan (2008) and Preetha and Raveendran (2008). Combining ability studies helps in selection of suitable parents for further exploitation. In order to achieve high production and productivity, the breeder should have thorough knowledge of the genetic potential of germplasm, the nature of gene action involved in promoting heterosis for yield and combining ability of parents. Information on general and specific combining ability for yield and its components will prove very useful in selection of appropriate parents for development of hybrids. Diallel analysis is a technique employed to gain information on hybrid vigour, combining ability and nature of gene action from the study of first generation itself. Among the several biometrical, methods developed to identify superior parents for heterosis breeding; the diallel analysis has received considerable attention. Therefore, present study objective was: 1) to understand the gene action for yield and fibre quality characters; 2) to estimate the GCA and SCA effects of parents and their 42 $F_1$ crosses, to obtain information combining ability potential as to develop hybrid with improved yield along with fibre quality traits through diallel analysis.

## MATERIALS AND METHODS

### Genetic material

A field experiment was conducted to evaluate the growth, yield and fiber quality traits in upland cotton genotypes (*Gossypium hirsutum* L.). The genotypes consisting of Narasimha, TCH 1726, TCH 1705, KC2, MCU13, BW4-1, and MCU 3 were obtained from Department of Cotton, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

### Experimental design and filed procedures

The cotton genotypes were evaluated in randomized block design (RBD) with three replications at Cotton Breeding Station, Tamil Nadu Agricultural University, Coimbatore, and Tamil Nadu in India. During winter 2006 to 2007, seven parents were raised in a crossing block. Each genotype was sown in 20 rows of 6 m length in crossing block with a spacing of 90 × 45 cm. Crosses were made between parents in a diallel mating design. The conventional hand emasculation and pollination were done, and crossed bolls were collected separately and ginned to obtain $F_1$ seeds. During winter 2007 to 2008, seven parents and forty two hybrids were raised along with the standard check with three replications. The diallel analysis was performed as model 1 and method 1 suggested by Griffing (1956).

### Sampling trait measurements and analysis

In each genotypes and their cross combinations, data were recorded on five randomly selected plants per replication for twelve characters namely, days to boll bursting, number of sympodia per plant, plant height at maturity, number of bolls per plant, boll weight, lint index, seed index, ginning percent, single plant yield, 2.5% span length, elongation percent and fiber fineness. Quality parameters were analyzed by high volume instrument (HVI). Statistical analysis was carried out by using the mean values over five sample plants through INDOSTAT package.

## RESULTS AND DISCUSSION

### Analysis of variance

Analysis of variance showed highly significant differences due to genotypes for all the traits indicating the presence of sufficient variability in the experimental materials (Table 1). Significance of variance in parents versus hybrids interaction provided adequacy for comparing the heterotic expression for all the characters except boll weight and micronaire. Parents and hybrids showed significant differences between all the characters studied except single plant yield and bundle strength. Ashokkumar and Ravikesavan (2013) observation for all the characters were significantly differenced with parents and hybrids in upland cotton, and it confirmed our results. GCA and SCA variances showed significant for all the characters studied except number of sympodia per plant and boll weight for GCA and SCA, respectively. Reciprocals were significantly differenced for all the traits (Table 2).

### Effects of gene action

The higher SCA than GCA of a character indicates the preponderance of non-additive gene action. Additive gene action provides fixable effects, and the non-additive gene action results are non-fixable. If GCA variance was greater than SCA for the particular character indicates preponderance of additive gene action. Present study analysis of combining ability revealed that the variances for the GCA were larger than those for all the traits except number of sympodial branches, single plant yield, bundle strength and micronaire indicating the preponderance

**Table 1.** Analysis of variance showing means square for yield and fibre quality traits.

| Source | D.F | Days to first boll bursting | Number of sympodial branches | Plant height (cm) | Number of bolls per plant | Boll weight (g) | Lint index | Seed index | Ginning percent | Single plant yield (g) | 2.5% span length (mm) | Bundle strength (g/tex) | Micronaire |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 0.659 | 4.27 | 14.88 | 1.55 | 0.143 | 0.235 | 0.157 | 4.96 | 493.3 | 4.62 | 3.076 | 0.046 |
| Genotypes | 48 | 6.31** | 9.98** | 727.6** | 39.3** | 0.136** | 0.758** | 1.906** | 6.20** | 1072.9** | 7.367** | 3.010** | 0.203** |
| Parents | 6 | 6.09** | 5.52* | 618.4** | 11.93* | 0.143** | 1.348** | 1.719** | 14.28** | 628.3 | 16.32** | 2.088 | 0.287** |
| Hybrids | 41 | 6.24** | 10.63** | 752.0** | 40.1** | 0.138** | 0.568** | 1.538** | 5.014** | 1141.2** | 5.066** | 3.054** | 0.196** |
| Parents versus hybrids | 1 | 10.44** | 10.01** | 385.3** | 181.4** | 0.0006 | 5.000** | 18.13** | 6.63** | 943.7** | 47.92** | 6.774* | 0.003 |
| $F_1$'s | 20 | 6.73** | 10.98** | 625.4** | 50.86** | 0.177** | 0.443** | 1.319** | 5.87** | 1207.1** | 5.660** | 3.552** | 0.197** |
| Reciprocals | 20 | 5.71** | 10.77** | 906.6** | 27.40** | 0.102 | 0.714** | 1.436** | 4.049** | 1124.8** | 4.553** | 2.703** | 0.195** |
| $F_1$ versus reciprocals | 1 | 7.14** | 0.79 | 188.9* | 79.36* | 0.079 | 0.147** | 7.940** | 7.081** | 149.4 | 3.433 | 0.108 | 0.186* |
| Error | 96 | 1.020 | 1.48 | 23.35 | 5.30 | 0.048 | 0.221 | 0.581 | 0.935 | 146.3 | 1.266 | 1.215 | 0.039 |
| Total | 146 | 2.757 | 4.31 | 254.7 | 16.50 | 0.078 | 0.398 | 1.011 | 2.724 | 455.7 | 3.317 | 1.831 | 0.093 |

**Significant at 1% level, *significant at 5% level.

**Table 2.** Analysis of variance and genetic contribution of parents, hybrids and reciprocals.

| Source | D.F | Day to first boll bursting | Number of sympodia/ plant | Plant height (cm) | Number of bolls/plant | Boll weight (g) | Lint index | Seed index | Ginning percent | Single plant yield (g) | 2.5% span length (mm) | Bundle strength (g/tex) | Micronaire |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GCA | 6 | 2.219** | 2.71 | 357.9** | 21.07** | 0.133** | 0.600** | 1.420** | 2.880** | 325.6** | 3.86** | 0.898** | 1.486** |
| SCA | 21 | 1.813** | 3.94** | 183.4** | 13.7** | 0.018 | 0.255** | 0.496** | 2.590** | 428.9** | 2.68** | 1.532* | 2.67** |
| Reciprocal | 21 | 2.365** | 2.88** | 268.6** | 10.3** | 0.047** | 0.150** | 0.550** | 1.313** | 295.5** | 1.826** | 1.251** | 1.685** |
| Error | 96 | 0.3403 | 0.49 | 7.785 | 1.76 | 0.016 | 0.073 | 0.193 | 0.3119 | 48.7 | 0.422 | 0.352 | 0.222 |

**Significant at 1% level, *significant at 5% level.

preponderance of additive action, which could be exploited for the improvement of these traits by mass selection. Similar findings were reported by Subrahmanyam et al. (1991) and Subrahmanyam and Bhalod (1995) for fiber fineness in diploid cottons. Regarding ginning percentage and 2.5% span length, additive component of variance was reported by Modi et al. (1999) and Patel and Pethani (1998) in desi cotton. Mandloi et al. (1998) also reported predominance of additive gene effects for fiber fineness, ginning percentage and halo length, and Surana et al. (1997) for the uniformity ratio. Preponderance of additive type of gene effects suggested directional selection for isolating better homozygous lines from segregating population for these traits. These observations are conformity with findings obtained by Marani (1963) and Kalsy et al. (1981) for seed

**Table 3.** Mean *per se* performance of parents for yield and fibre quality traits.

| Genotype | Days to boll first boll bursting | Number of sympodia/plant | Plant height (cm) | Number of bolls per plant | Boll weight (g) | Lint index | Seed index | Ginning percent (%) | Single plant yield(g) | 2.5% span length (mm) | Bundle strength (g/tex) | Micronaire |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Narasimha | 102 | 15 | 100.0 | 22 | 4.10 | 5.76 | 8.86 | 39.2 | 95.8 | 30.6 | 20.7 | 4.1 |
| KC 2 | 101 | 13 | 102.1 | 22 | 4.28 | 5.89 | 8.22 | 38.0 | 75.2 | 27.2 | 22.1 | 4.4 |
| MCU 3 | 102 | 15 | 127.0 | 22 | 4.31 | 5.59 | 8.65 | 39.2 | 95.7 | 30.2 | 22.0 | 3.9 |
| TCH 1705 | 102 | 15 | 114.7 | 24 | 4.50 | 6.53 | 9.54 | 40.5 | 93.8 | 27.2 | 20.9 | 4.6 |
| BW4-1 | 105 | 17 | 122.3 | 27 | 4.70 | 6.76 | 10.27 | 39.7 | 119.4 | 28.6 | 20.6 | 4.7 |
| MCU 13 | 103 | 15 | 87.0 | 22 | 4.58 | 6.73 | 10.12 | 39.9 | 98.9 | 27.6 | 22.3 | 4.5 |
| TCH 1726 | 101 | 13 | 119.3 | 21 | 4.61 | 4.96 | 9.23 | 34.9 | 78.9 | 28.7 | 22.4 | 4.0 |
| Grand mean | 102 | 15 | 110.3 | 23 | 4.44 | 6.03 | 9.27 | 39.3 | 93.9 | 27.8 | 21.6 | 4.3 |
| CD (P = 0.5) | 0.99 | 0.71 | 6.57 | 3.15 | 0.33 | 0.53 | 0.89 | 1.72 | 8.46 | 3.32 | 2.70 | 0.45 |

cotton yield, and Miller and Marani (1963) for fiber length.

In this present study, non-additive gene action was determined for the characters number of sympodial branches, single plant yield, bundle strength and micronaire. Studies of Shakeel et al. (2001), Ahuja and Dhayal (2007), Preetha and Raveendran (2008) and Ashokkumar et al. (2010) revealed that seed cotton yield were influenced by the genes acting non-additively, and contrast studies of Khan and Idris (1995) and Kumaresan et al. (1999) indicated that both additive and non-additive gene effects were important for controlling seed cotton yield. Non-additive gene action for fibre strength was reported in earlier studies of Ashokkumar and Ravikesavan (2008), and it is also confirmed by our results.

## *Per se* performance and GCA effects

The 7 parents and 42 $F_1$ hybrids were used in this study, and varied significantly for each yield components and fibre quality parameters. Information on the *per se* performance, and nature of general combining ability of characters is necessary for selection of suitable parents for developing hybrids. The objectives appear to be realizable only when the parents are evaluated for the potentialities like *per se* performance and combining ability attributes. Therefore, the present study was aimed for their mean *per se* performance and general combining ability effects. Parental genotypes had significant variation for all the traits. Mean *per se* performance of parents were presented (Table 3). Genotype BW4-1 had superior *per se* performance for single plant yield (119 g/plant), boll weight (4.7 g/boll), number of sympodial branches per plant (17), lint index (6.76 g), number of bolls per plant (27), seed index (10.27 g), and micronaire (4.27 ug/inch) followed by MCU 13, which recorded high *per se* for single plant yield, lint index, seed index and number of sympodial branches. The parent TCH 1705 recorded high *per se* performance for ginning percent, number of sympodial branches, number of bolls per plant and micronaire value. The parent TCH 1726 recorded high *per se* for bundle strength and boll weight. Narasimha recorded the highest *per se* performance for 2.5% span length and number of sympodial branches. High mean values remain as a selection index in the choice of parents and the parents possessing high *per se* performance will result in superior hybrids. Therefore, these parents can be exploited in hybridization for improving this character through pedigree breeding.

General combining effects for plant height, number of sympodia per plant, boll weight, number of bolls per plant, single plant yield, seed index, 2.5% span length and bundle strength were presented in Tables 4 to 8). For *gca* effects, the parent MCU 13 had recorded high *gca* effect for single plant yield, number of sympodial branches, number of bolls per plant, lint index, seed index

**Table 4.** General and specific combining ability effects for plant height and number of sympodia per plant.

| | Plant height | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotype** | **Narasimha** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **1.323** | 21.239** | 9.861** | -0.133 | 1.753 | -8.802** | 4.844** |
| KC 2 | 3.000 | **-2.289** | 8.183** | 3.879 | -8.568** | -1.590 | -7.095** |
| MCU 3 | 7.633** | 9.100** | **-2.022** | -8.054** | -7.268** | 7.877** | 0.839 |
| TCH 1705 | 3.200 | 14.933** | 14.400** | **5.283** | -9.473** | 6.005** | 6.001** |
| BW 4-1 | 25.26** | -0.333 | -1.233 | 12.333** | **-3.203** | 4.891** | -3.647 |
| MCU 13 | 2.167 | 0.433 | 11.833** | -2.933 | 9.333** | **-6.748** | -2.406 |
| TCH 1726 | 10.17** | -1.000 | 21.467** | -6.667** | 20.467** | 13.033** | **7.656** |

| | Number of sympodia/ plant | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotype** | **Narasimha** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **0.337** | -0.146 | 1.551** | 1.901** | -0.122 | 0.425 | 0.711 |
| KC 2 | -0.833 | **-0.235** | 0.354 | 0.306 | 1.218** | 0.170 | 2.616** |
| MCU 3 | -0.167 | 1.500** | **-0.163** | 1.068* | -0.622 | -0.075 | 1.044 |
| TCH1705 | -0.500 | 1.333** | 2.500** | **0.051** | 1.337** | 0.544 | -1.837** |
| BW 4-1 | 0.333 | -0.333 | -0.333 | -0.833 | **-0.092** | -0.813 | 2.139** |
| MCU 13 | 2.333** | 0.500 | -0.333 | 2.500** | -1.000 | **0.639** | -0.980* |
| TCH 1726 | 1.000* | 0.667 | 1.500** | 0.833 | -0.333 | -0.667 | **0.741** |

*Significant at 5% level; **significant at 1% level; diagonal values indicate the gca effects.

**Table 5.** General and specific combining ability effects for boll weight and seed index.

| | Boll weight | | | | | | |
|---|---|---|---|---|---|---|---|
| Genotypes | Narasimha | KC 2 | MCU 3 | TCH 1705 | BW4-1 | MCU 13 | TCH 1726 |
| Narasimha | **-0.180** | -0.050 | 0.014 | 0.067 | -0.183* | 0.049 | 0.091 |
| KC 2 | 0.117 | **-0.015** | -0.046 | -0.034 | 0.042 | 0.185* | 0.041 |
| MCU 3 | -0.283** | 0.248** | **-0.042** | -0.004 | 0.202** | -0.113 | 0.003 |
| TCH 1705 | -0.062 | 0.058 | 0.078 | **-0.014** | -0.101 | 0.010 | -0.024 |
| BW 4-1 | -0.235** | 0.128 | 0.108 | -0.030 | **0.057** | -0.029 | -0.078 |
| MCU 13 | -0.160* | 0.225** | -0.027 | 0.255** | 0.013 | **0.106** | -0.024 |
| TCH 1726 | 0.095 | 0.207** | 0.092 | 0.073 | -0.167* | 0.097 | **0.089** |

| | Seed index | | | | | | |
|---|---|---|---|---|---|---|---|
| Genotypes | Narasimha | KC 2 | MCU 3 | TCH 1705 | BW4-1 | MCU 13 | TCH 1726 |
| Narasimha | **-0.325** | 0.082 | 0.515 | 0.390 | -0.052 | -0.233 | -0.083 |
| KC 2 | -0.602* | **0.401** | 0.225 | -0.375 | -0.038 | 0.979** | 0.234 |
| MCU 3 | -0.745** | 0.947** | **0.017** | 0.303 | 0.151 | 0.356 | -0.038 |
| TCH 1705 | -0.225 | -0.065 | 0.610 | **0.082** | 0.334 | 0.018 | 0.085 |
| BW 4-1 | -0.643* | 0.072 | -0.368 | -0.877** | **0.316** | -0.244 | 0.343 |
| MCU 13 | -0.875** | -0.465 | -0.617* | 0.233 | -0.565 | **0.462** | 0.060 |
| TCH 1726 | -0.270 | 0.038 | 0.150 | 0.458 | 0.010 | 0.420 | **-0.150** |

*Significant at 5% level, **significant at 1% level; diagonal values indicate the gca effects.

**Table 6.** General and specific combining ability effects for 2.5% span length and bundle strength.

| | Lint index | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotypes** | **Narasimhaaa** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **-0.029** | -0.094 | 0.277 | 0.128 | -0.184 | 0.376* | 0.164 |
| KC 2 | -0.030 | **0.184** | -0.128 | -0.128 | 0.116* | 0.340* | 0.118 |
| MCU 3 | -0.105 | 0.355* | **-0.160** | 0.119 | 0.249 | 0.037 | 0.019 |
| TCH 1705 | -0.195 | 0.037 | 0.112 | **-0.025** | 0.210 | 0.435** | 0.010 |
| BW 4-1 | -0.575** | 0.023 | -0.110 | -0.157 | **0.358** | 0.495** | 0.514** |
| MCU 13 | -0.312 | -0.420* | -0.285 | 0.165 | -0.017 | **0.204** | 0.388* |
| TCH 1726 | -0.025 | 0.327 | 0.215 | 0.645** | 0.288 | 0.035 | **-0.164** |

| | Ginning percentage | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotypes** | **Narasimha** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **-0.261** | 0.922 | -1.030 | -0.563 | -0.235 | -0.444 | -0.559 |
| KC 2 | -1.109 | **-0.358** | 1.383* | 2.103** | -1.018 | 0.289 | 0.341 |
| MCU 3 | -0.697 | 0.284 | **0.661** | 0.933 | 1.427* | -0.299 | 0.537 |
| TCH 1705 | -1.656** | -0.159 | -0.183 | **0.311** | -1.000 | 2.141** | 0.127 |
| BW 4-1 | -1.204 | 1.077 | 0.533 | 0.083 | **0.467** | 1.417* | -0.320 |
| MCU 13 | 1.480* | 1.277* | 0.983 | -0.450 | 0.283 | **-0.275** | 1.200 |
| TCH 1726 | -0.833 | 3.359** | 0.533 | 1.050 | 0.467 | 1.383* | **0.523** |

*Significant at 5% level, **significant at 1% level; diagonal values indicate the gca effects.

**Table 7.** General and specific combining ability effects for number of bolls per plant and single plant yield.

| Number of Bolls per plant | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotypes** | **Narasimha** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **2.088**** | 0.983 | -1.755* | 4.197** | 0.983 | 1.078 | 2.031* |
| KC 2 | -1.500 | **0.422** | 2.245** | 0.531 | 2.517** | -0.755 | 3.097** |
| MCU 3 | 1.833* | 4.833** | **-0.507** | 0.959 | 2.255** | 1.840* | 1.626* |
| TCH 1705 | 1.275 | 1.667* | 3.167** | **0.041** | ***-1.469*** | -0.374 | -2.088* |
| BW 4-1 | 1.333 | -1.167 | 0.167 | -1.833* | **-0.745*** | 0.078 | 2.364** |
| MCU 13 | 5.000** | 2.500** | -0.833 | -1.500 | -1.500 | **1.840**** | -1.847* |
| TCH 1726 | 2.333** | 4.000** | 0.333 | 1.500 | 0.167 | -0.500 | **0.541** |

| Single plant yield | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotypes** | **Narasimha** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **3.450*** | -2.310 | 16.588** | 21.180** | -1.732 | 2.407 | 8.307 |
| KC 2 | -8.617* | **-2.454** | 4.966 | 3.851 | 11.727** | -0.922 | 26.228** |
| MCU 3 | 0.800 | 17.817** | **-1.659** | 9.840* | -7.356 | -1.333 | 11.583** |
| TCH 1705 | -5.117 | 13.550** | 26.133** | **0.322** | 15.802** | 5.582 | -18.332** |
| BW 4-1 | 1.967 | -3.300 | -3.433 | -10.278* | **-1.349** | -7.177 | 21.173** |
| MCU 13 | 22.600** | 5.500 | -3.783 | 24.650** | -10.483* | **6.755**** | -10.805* |
| TCH 1726 | 9.600* | 7.383 | 12.600** | 9.033 | -1.367 | -4.917 | **8.445**** |

*Significant at 5% level, **significant at 1% level; diagonal values indicate the gca effects.

**Table 8.** General and specific combining ability effects for 2.5% span length and bundle strength.

| 2.5% Span length | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotypes** | **Narasimhaaa** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **-0.096** | 0.473 | -0.061 | 0.844* | -0.223 | -0.204 | 0.301 |
| KC 2 | -0.200 | **0.553**** | -0.381 | 0.813* | 0.334 | 0.570 | 0.125 |
| MCU 3 | 1.550** | 0.267 | **0.855**** | 0.408 | 0.580 | 0.715 | 0.397 |
| TCH 1705 | 0.700 | 0.400 | 1.267** | **-0.349*** | 1.863** | -0.035 | 0.880* |
| BW 4-1 | 0.300 | 0.100 | 0.483 | 0.367 | **0.470**** | 0.970* | 1.225** |
| MCU 13 | 0.467 | 1.050** | 0.233 | 0.950* | 1.033 | **0.444**** | 0.494 |
| TCH 1726 | 0.020 | 0.163* | -0.130 | -0.065 | 0.004 | 0.026 | **0.015** |

| Bundle strength | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotypes** | **Narasimha** | **KC 2** | **MCU 3** | **TCH 1705** | **BW4-1** | **MCU 13** | **TCH 1726** |
| Narasimha | **0.698**** | -0.652 | 0.555 | -0.414 | -0.350 | 0.079 | -0.231 |
| KC 2 | -2.200* | **-0.067** | 1.171** | 0.038 | -0.414 | -0.319 | -0.062 |
| MCU 3 | -0.017 | -0.250 | **0.443**** | 0.312 | 0.223 | -0.245 | -0.688 |
| TCH 1705 | -0.867** | 0.250 | 0.200 | **0.262** | 1.191** | -0.231 | -0.190 |
| BW 4-1 | 0.483 | 0.550 | 0.950* | -0.817* | **0.047** | 1.012** | -0.564 |
| MCU 13 | -0.700 | -0.233 | -0.150 | -0.450 | 0.633 | **0.135** | 1.627** |
| TCH 1726 | 0.533 | 0.767 | 0.850* | 0.367 | 0.150 | 0.667 | **-0.122** |

*Significant at 5% level, **significant at 1% level; diagonal values indicate the gca effects.

and boll weight. The parent TCH 1726 exhibited positive and significant *gca* effect for single plant yield, ginning percent, number of sympodial branches, boll weight, plant height and ginning percent. The parent Narasimha recorded high *gca* effect for number of bolls per plant and bundle strength. The parents BW4-1 recorded high positive *gca* effect for lint index. The parent MCU 3 recorded high significant *gca* effects for ginning percent and quality characters like 2.5% span length, bundle strength and micronaire. Similar results were reported by Manickam and Gururajan (2004), and high *gca* effect in desirable direction for a particular character indicates the presence of additive genes for that character in the parent, it could be expected that when the parents possessing high *gca* effects were combined; larger proportion of progenies would have high *per se* value for the character concerned facilitating easy selection for the character. Based on the high *per se* performance and high *gca* effect, the parent MCU 13 was considered as best general combiner as it had significantly higher values for single plant yield, number of sympodial branches, lint index and seed index. The parent BW4-1 had recorded high *per se* performance and *gca* effects for lint index and boll weight. For 2.5% span length, MCU 3 showed better expression for high *per se* and *gca* effects. Earlier findings like Arumugampillai and Amirthadevarathinam (1998) reported that identification of parents for breeding programme based on either *per se* performance or *gca* effects alone was misleading in the selection programme.

In the present study, considering *gca* effects and *per se* performance together, the parents MCU 13, TCH 1726, MCU 3, BW4-1 were selected as the best, since these were having high mean values for four, two, two, two traits and also good combining ability for six, five, four and seven yield component traits, respectively. None of the hybrids were found to be excellent general combiner for all the traits. Hence, it would be desirable to have multiple crosses and subject them to selection in segregating generations to detect superior genotypes with high yield and quality traits. The best criteria for evaluating the hybrids are based on *per se* performance. However, *sca e*ffects, and hybrid vigour of the crosses are also considered frequently in cases where a non-additive component of genetic variance predominate the inheritance. The superior hybrids were selected based on high *per se* performance, *sca* effects and heterosis for each of a trait. In the present investigation, hybrids KC 2 × TCH 1726 and TCH 1705 × MCU 3 recorded high *per se* for single plant yield, number of bolls per plant and number of sympodial branches. Hybrid BW4-1 × TCH 1726 recorded high *per se* effects for ginning percentage. The hybrid KC 2 × TCH 1726 recorded high *per se* effects for single plant yield and number of bolls per plant. The parent BW4-1 × TCH 1705 recorded high *per se* for seed index. The hybrid BW4-1 × TCH 1726 had shown *per se* for ginning percent.

The hybrids namely, MCU 13 × TCH 1726, BW4-1 × MCU 3 and TCH 1726 × MCU 3 had greater *per se* for 2.5% span length, bundle strength and micronaire. The hybrid MCU 13 × MCU 3 recorded high *per se* effects for seed index, 2.5% span length and micronaire. The hybrid BW4-1 × TCH 1705 recorded high *per se* seed index. The hybrid Bw4-1 × TCH 1726 had shown *per se* for ginning percent. The hybrids namely, MCU 13 × TCH 1726, BW4-1 × MCU 3 and TCH 1726 × MCU 3 had been greater *per se* effects for 2.5% span length, bundle strength and micronaire. The hybrid MCU 13 × MCU 3 recorded high *per se* effects for seed index, 2.5% span length and micronaire.

## Specific combining ability effects

Specific combining ability effects for plant height, number of sympodial branch per plant, number of bolls per plant, boll weight, single plant yield, seed index, 2.5% span length and bundle strength were presented (Tables 4 to 8). Based on *sca* effects, KC 2 × TCH 1726 showed significant *sca* effects for single plant yield and number of sympodial branches. The crosses, KC 2 × TCH 1726 for single plant yield, with low × high g*ca* resulted in dominance effects. Parents with positive significant *gca* effects involved additive type of gene action that would be easily fixable. The crosses, KC 2 × TCH 1726 number of sympodial branches, low × high *gca e*ffects. In this situation, we could go for recombination breeding, whereas the parents with low negative *gca* effects and parents with positive significant *gca* effects. For yield contributing characters such as number of bolls per plant, hybrid MCU 13 × Narasimha had possesed significant positive *sca* effects. Earlier studies were reported positive sca effects for plant height (Waldi et al., 1980; Nirania et al., 1992), sympodial branches per plant (Bhatade and Bhale, 1983), number of boll per plant (Waldi et al., 1980), lint yield per plant (Chaudari et al., 1990) and lint index (Bhatade and Bhale, 1983; Avtar et al., 1992). For yield contributing characters, MCU 13 × TCH 1726 showed significant *sca* effects for number of bolls per plant, number of sympodial branches and ginning percentage. Hybrid MCU 13 × TCH 1726 showed high × high for the number of bolls per plant, low × high for number of sympodial branches and ginning percentage. In this situation, we could go for recombination breeding.

## Conclusion

The analysis of combining ability revealed that the variances for the GCA were larger than those for all the traits except number of sympodial branches, single plant yield and bundle strength indicating the preponderance of additive action, which could be explotied for the improvement of these traits by mass selection. In the present study, parent BW4-1 had superior *per se* performance for single plant yield, boll weight, lint index, number of bolls per plant, seed index and micronaire. Based on high *per se* performance and high *gca* effect, the parent MCU 13 was considered as best general combiner as it had significantly higher values for single plant yield, number of sympodial branches, lint index and seed index. Based on *sca* effects, KC 2 × TCH 1726 showed significant *sca* effects for single plant yield and number of sympodial branches. The hybrids MCU 3 × Narasimha possessed the significant *sca* effects for three characters such as plant height, number of bolls per plant and 2.5% span length. An increasing in the seed cotton yield along with other traits will be a valuable addition to cotton cultivars.

## REFERENCES


Ahuja SL, Dhayal LS (2007). Combining ability estimates for yield and fibre quality traits in 4 x 13 line x tester crosses of *Gossypium hirsutum*. Euphytica 153, 87-98.

Arumugampillai N, Amirthadevarathinam A (1998). Combining ability for economic traitsusing CMS system in cotton. Agric. Sci. Digest. 18 (1):54-58.

Ashokkumar K, Ravikesavan R (2008). Genetic studies of combining ability estimates for seed oil, seed protein and fibre quality traits in upland cotton (*G. hirsutum* L.). Res. J. Agric. Biol. Sci. 4(6):798-802.

Ashokkumar K, Ravikesavan R (2011). Conventional and Molecular breeding approaches for seed oil and seed protein content improvement in cotton. Int. Res. J. Plant Sci. 2(2):037-045.

Ashokkumar K, Ravikesavan R (2013). Genetic variation and heterotic

effects for seed oil, seed protein and yield attributing traits in upland cotton (*Gossypium. hirsutum* L.). Afr. J. Biotechnol. 12(33):5183-5191.
Ashokkumar K, Ravikesavan R, Sivas JKP (2010). Combining ability estimates for yield and fibre quality traits in Line X Tester crosses of upland cotton (*Gossypium hirsutum*). Int. J. Biol. 2(1):179-183.
Avtar R, Sehra S, Siwach SS, Lather BPS, Chhabra BS (1992). Combining ability in Asiatic cotton. J. Cotton Res. Dev. 6(2):194-197.
Bhatade SS, Bhale NL (1983).Combining ability for seed and fiber characters and its interaction with environment in *G. arboreum* L. Indian J. Mah. Agric. Univ. 53(6):418-422.
Chaudhari PN, Borole DN, Narkhede BN (1990). Heterosis and combining ability study in desi cotton. J. Mah. Agric. Univ. 15(2):164-166.
Green CC, Culp TW (1990). Simultaneous improvement of yield, fiber quality and yarn strength in upland cotton. Crop Sci. 30:66-69
Griffing B (1956). Concept of general and specific combining ability in relation to Diallel crossing system. Aust. J. Biol. Sci. 9:463-493.
Hassan G, Mahood G, Khan NU, Razzaq A (1999). Combining ability and estimates in a diallel cross of cotton. Sarhad J. Agric. 15:563-568.
Hassan G, Mahood G, Razzaq A, Hayatullah (2000). Combining ability in inter-varietal crosses of Upland cotton (*Gossypium hirsutum* L.). Sarhad J. Agric. 16:407-410.
Islam Z, Sadaqat HA, Khan F A (2001). Combining ability of some Hirsute cotton types for economic traits. Int. J. Agri. Biol. 3(4):411-412.
Kalsy HH, Garg HR, Vithal BM, Singh, TH (1981). Combining ability study in a diallel cross of cotton (*G. hirsutum* L.). J. Indian Soc. Cott. Improve. 6(2):73-79.
Karademir E, Gencer O (2010). Combining ability and heterosis for yield and fiber quality properties in cotton (*G. hirsutum* L.) obtained by half diallel mating design. Not. Bot. Hortic. Agrobot. Cluj. 38(1): 222-227.
Khan TM, Idris MA (1995). Inheritance of boll weight, boll number and yield of seed cotton in upland cotton (*Gossypium hirsutum* L.). Sarhad. J. Agric. 11(2):599-605.
Kiani G, Nematzadeh GA, Kazemitabar SK, Alıshah O (2007). Combining ability in cotton cultivars for agronomic traits. Int. J. Agric. Biol. 9(3):521-522.
Lukange EP, Labuschagne MT, Herselman L (2007). Combining ability for yield and fibre characteristics in Tanzanian cotton germplasm. Euphytica 161:383-389.
Mandloi KC, Koutu GK, Mishra VS, Pandya SC (1998). Combining ability analysis and inheritance of fibre quality characters in American cotton. J. Indian Soc. Cotton Improv. 23 (2):147-151.
Manickam S, Gururajan KN (2004). Combining ability analysis for fibre quality in upland cotton (*Gossypium hirsutum* L.). J. Indian Soc. Cotton Improv. 29 (2):86-91.
Marani A (1963). Heterosis and combining ability for yield and components of yield in a diallel cross of two species of cotton. Crop Sci. 3:552-555.
Miller PA, Marani A (1963). Heterosis and combining ability in diallel crosses of upland cotton, *G. hirsutum* L. Crop Sci. 3:441-444.
Modi ND, Patel UG, Patel JC, Maisuria AT (1999). General and Specific combining ability for major yield components in Diploid Cottons. J. Indian Soc. Cotton Improv. 24 (2):129-131.
Nirania KS, Singh IP, Singh BP, Jain PP, Tuteja OP (1992). Heterosis and combining ability analysis in *G. arboreum* L. J. Cotton Res. Dev. 6(1):11-17
Patel GS, Pethani KV (1998). Combining ability on quantitative components in desi cotton over environments. J. Indian Soc. Cotton Improv. 23(1):48-53.
Preetha S, Raveendran TS (2008). Combining ability and heterosis for yield and fibre quality traits in line x testercrosses of Upland cotton (*G. hirsutum*. L). Int. J. Plant Breed. Genet. 2(2):64-74.
Shakeel A, Khan, IA, Azhar, FM (2001). Study pertaining to the estimation of gene action controlling yield and related traits in upland cotton. J. Biol. Sci. 1(2):67-70.
Subhan M, Qasim M, Ahmad R, Khan U (2003). Diallel analysis for estimating combining ability of quantitavely inherited traits in upland cotton. Asian J. Plant Sci. 2(11):853-857.
Subrahmanyam Y, Mehta NP, Patel JC, Bhalod MC, Janaki KI, Maisuria AT (1991). Combining ability and inheritance of fiber fitness in Diploid Cottons. A comparison of $F_1$ and $F_2$ generation. Indian J. Genet. 51(4):424-428.
Subrahmanyam, Y, Bhalod, MC (1995). Heterosis and combining ability studies in Asiatic cotton for ribbon width. J. Cotton Res. Dev. 9 (2):87- 92.
Surana PP, Mehetre SS, Borole UM, Dahat, DV (1997). Combining ability in *G.hirsutum L*. for fibre quality parameters. J. Cotton Res. Dev. 11(1):9-15.
Waldi RS, Mor BR, Jatasra DS (1980). Line × tester analysis for yield and economic attributes in *G. arboretum* L. Indian J. agric. Sci. 50(10):745-747.