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COMBINING ABILITY ANALYSIS IN INTRASPECIFIC F_1 DIALLEL CROSS OF UPLAND COTTON

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Abstract

The research work comprised of combining ability and genetic variability in a 6 × 6 F_1 diallel cross which was carried out during crop seasons 2008 and 2009 at Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan. The parental genotypes (CIM-446, CIM-496, CIM-499, CIM-506, CIM-554 and CIM-707) were crossed in a complete diallel fashion during 2008. The 30 F_1 hybrids and their parents were grown in a randomized complete block (RCB) design with three replications during 2009. Genotypes manifested significant ($p \leq 0.01$) differences for days to first flowering, locules boll^{-1}, seeds locule^{-1}, lint % and seed cotton yield plant^{-1}. The F_1 hybrids showed significant increase over parents in mean values for all the traits. The correlation of seed cotton yield was significantly positive with majority of yield traits and negative with days to first flowering and lint %. Mean squares due to general (GCA) and specific combining ability (SCA) were highly significant for all the traits, except locules for GCA. Mean squares due to GCA were higher in magnitude than SCA for majority of the traits and their inheritance was mainly governed by additive type of gene action and partially by non-additive. Selection in such promising hybrids could be used in segregating generations, and also some specific cross combinations can be used for hybrid cotton production to increase the seed cotton yield. The best general combiners (CIM-446 and CIM-554) followed by CIM-496 and their utilization as one of the parents produced best specific F_1 hybrids (CIM-446 × CIM-499, CIM-446 × CIM-554, CIM-496 × CIM-707 and CIM-506 × CIM-554) having valuable SCA determination and remarkable mean performance for most of the traits. Reciprocal crosses having prominent maternal effects also involved one of the general combiners for majority of the traits. The promising hybrids also exhibited earliness through which the crop can escape from pests attack and soil can be vacated earlier for following crop like wheat. However, it was also concluded that we could not rely on F_1s only, however, the combined performance of F_1 and F_2 hybrids could be a good selection criteria to identify the most promising populations to be utilized either as F_2 hybrids or as a source population for further selection in advanced generations.

Introduction

Plant breeders are looking for desirable genes and gene complexes, and identification of promising individuals is very important in any breeding program. Diallel mating design is one of the tools which help the breeder to identify the potential genotypes and the promising recombinants produced by combining the parental individuals through GCA and SCA. In diallel mating, the parents are crossed in all possible combinations to identify parents as best/poor general combiners through GCA and the specific cross combinations through SCA. It involves both direct as well as reciprocal crosses through which maternal effects can also be ascertained.

In combining ability, the entire genetic variability of each trait can be partitioned into GCA and SCA as defined by Sprague & Tatum (1942) and reciprocal effects as sketched by Griffing's (1956). They stated that GCA effects administer the additive type of gene action whereas SCA effects are shown due to genes which are non-additive (dominant or epistatic) in nature. Sayal *et al*., (1997), Hassan *et al*., (1999) and Batool (2011) reported the importance of non-additive type of gene action for different cotton traits. However, Khan *et al*., (1991), Baloch *et al*., (2000), Bhutto *et al*., (2001) and Khan (2010) stressed upon the appreciable degree of variance due to GCA for morpho-yield traits. Khan (2003), Khan *et al*., (2005 & 2009a) and Makhdoom (2011) observed that mean squares due to GCA and SCA were highly significant; however, the genetic variances due to SCA were greater than GCA for the yield related traits, showing the predominance of non-additive gene action. High × low and low × high GCA parents performed well in SCA determination (Makhdoom, 2011).

Many commercial cotton cultivars despite their high/low agronomic performance combine in a better way/poorly when used as a parental cultivars in cross combinations (Batool *et al*., 2010; Makhdoom *et al*., 2010). Therefore, the said research work was conducted to analyze some important upland cotton genotypes and their 6 × 6 F_1 diallel hybrids to ascertain their relative performance regarding their genetic potential and variability, combining ability effects, and correlation coefficient of seed cotton yield with yield related traits.

Materials and Methods

Plant material and field procedure: The research work pertaining to study the genetic potential of genotypes and combining ability in F_1 hybrids of cotton (*Gossypium hirsutum* L.) was carried out at Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan. Six diverse genotypes **(**CIM-446, CIM-496, CIM-499, CIM-506, CIM-554 and CIM-707) of upland cotton were hand sown during May 2008 and were crossed in a complete diallel fashion. During 2009, the 30 F_1s and their parents were also hand sown in a RCB design. Parents and F_1s were planted in a single row measuring six meter with four replications. The row and plant spacings were 75 and 30 cm, respectively. Thinning was performed after 15 to 20 days when the plant height reached up to 15-20 cm to ensure single plant per hill. Recommended cultural practices were carried out and the crop was grown under uniform field conditions to minimize environmental variations to the maximum possible extent. Picking was made during the month of November on individual plant basis and ginning was performed with eight saw-gins.

Traits measurement and statistical analyses: Data were recorded for days to first flowering, locules boll^{-1}, seeds locule^{-1}, lint % and seed cotton yield plant^{-1}. Data were subjected to analysis of variance technique as outlined by Steel & Torrie (1980) to test the null hypothesis of no differences between various F_1 populations and their parental line means. Least Significant Difference test was also used for means separation and comparison after significance. The data of all the parameters on 30 F_1s and six parental genotypes were further subjected to the combining ability analysis according to Griffing's (1956) Method-I based on Eisenhart's Model-II as also stated by Singh & Chaudhary (1985).

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Results and Discussion

Mean performance: According to analysis of variance, the F_1 hybrids and their parental lines showed highly significant differences for all the traits (Table 1). According to genetic potential and mean performance (Table 2), the parental cultivars CIM-554, CIM-499 and CIM-707 found with best performance for all the traits. However, their use in F_1 hybrids also showed extraordinary performance and were found as best general combiners. The involvement of the cultivar CIM-554 as paternal/maternal parent with other cultivars in F_1 hybrids (CIM-554 × CIM-496, CIM-554 × CIM-707 and CIM-506 × CIM-554) exhibited best mean values and excelled other genotypes for the traits i.e., minimum days to first flowering (52.00 days), and increased lint % (38.78%) and seed cotton yield plant^{-1} (190.88 g). The other two F_1 hybrids of above said cultivar (CIM-554) i.e., CIM-554 × CIM-499 and CIM-554 × CIM-506 also manifested 2nd maximum mean values for lint % (37.80%) and less days to first flowering (52.33 days).

The cultivars CIM-499 and CIM-707 were second promising cultivars and there involvement in F_1 hybrids with other cultivars (CIM-499 × CIM-707, CIM-499 × CIM-446 and CIM-554 × CIM-707) also showed best performance for three traits viz., locules boll^{-1} (4.94), seeds locule^{-1} (8.11) and lint % (38.78%), respectively. Genetic potential studies of different cultivars in form of their expression for different morpho-yield traits are earnestly needed for selection of parental lines for breeding programme (Badr, 2003; Khan, 2003, Khan *et al.* 2010). The F_1 hybrids of CIM-554 were also found earlier in flowering through which the crop can escaped from pests attack and land can be vacated earlier for following crop like wheat. Different *G. hirsutum* cultivars were evaluated for yield and other economic characters and observed significant variations for morphological and yield related traits (Khan *et al*., 2007b).

Combining ability: The significance through ANOVA for all the traits in a 6 × 6 F_1 diallel hybrids and their parental lines (Table 1), allowed arbitrating the genetic components of variance due to GCA, SCA and reciprocal effects. Means squares due to GCA (Table 1) were significant ($p \leq 0.01$) for days to first flowering (10.67), lint % (5.12), seed cotton yield plant^{-1} (5566.19), merely significant ($p \leq 0.05$) for seeds locule^{-1} (0.12) and non-significant for locules boll^{-1}. As far as SCA is concerned, highly significant differences were observed for all the traits viz., days to first flowering (10.42), locules boll^{-1} (0.02), seeds locule^{-1} (0.27), lint % (2.22) and seed cotton yield plant^{-1} (1390.01). Mean squares due to reciprocals were also found highly significant for three traits i.e., days to first flowering (10.43), seeds locule^{-1} (0.36) and lint % (3.79). The traits locules boll and seed cotton yield plant^{-1} showed non-significant maternal effects. Significant mean squares for GCA and SCA for seed cotton yield and other yield contributing traits have also been observed by earlier researchers (Baloch *et al.*, 1999; Ali *et al.*, 2000; Hassan *et al.*, 2000; Tuteja *et al.*, 2003; Hague *et al.*, 2008).

Overall, the GCA mean squares were greater in magnitude than SCA and reciprocals for three traits viz., days to first flowering (10.67), lint % (5.12) and seed cotton yield plant (5566.19) seems that these traits were controlled by additive genes. The trait locules boll^{-1} was having maximum SCA mean squares (0.02) as compared to GCA and reciprocals. However, for seed cotton yield plant^{-1}, the SCA mean squares (1390.01) followed the GCA values but greater than reciprocal mean squares. The trait seeds locule^{-1} was having maximum mean square (0.36) due to reciprocal as compared to GCA and SCA. Additive type of gene action for most of the traits was noticed in upland cotton (Chinchane *et al.*, 2002; Yuan *et al.*, 2002; Khan *et al.*, 2005; Aguiar *et al.*, 2007). Additive genetic effects were also observed for most of the yield related traits with enough genetic variability and effective selection (Lukonge *et al.*, 2008). However, non-additive type of gene action for different yield traits was observed by Hassan *et al*., (1999), Muthu *et al*., (2005) and Ahuja & Dhayal (2007). Such contradictions may be due to different genetic backgrounds of breeding material used under various environmental conditions.

In case of genetic components of variance (Table 3), the magnitude of SCA variances were found greater than GCA and reciprocals for three parameters i.e., days to first flowering (4.56), locules boll^{-1} (0.007) and seed cotton yield plant^{-1} (560.18). In reciprocal variances, the traits seeds locule^{-1} (0.15) and lint % (1.85) revealed maximum genetic variances as compared to GCA and SCA. In seed cotton yield, the GCA variance (350.60) followed the SCA (560.18) and was found greater than reciprocals. However, none of the trait showed promising variances due to GCA. Significant genetic variances due to GCA and SCA were also noted by Baloch *et al*., (1997 & 1999), Ali *et al*., (2000) and Hassan *et al.* (2000) for different morpho-yield traits in upland cotton.

The parental cultivar CIM-446 superseded all other cultivars for GCA and showed highest GCA effects for seeds locule^{-1} (0.14) and seed cotton yield plant^{-1} (26.69), and was also found 2nd ranking genotype for locules boll^{-1} (0.01) (Table 4). Cultivar CIM-554 was having maximum GCA effects for locules boll^{-1} (0.02) and was also the 2nd best cultivar for lint % (0.43) and seed cotton yield (19.85). Cultivar CIM-496 was found 3rd ranking cultivar by having maximum GCA effects for lint % (0.71), desirable negative GCA effects for days to first flowering (-1.01) and 2nd ranking genotype top values for locules boll^{-1} (0.01) and seeds locule^{-1} (0.05). The performance of cvs. CIM-499, CIM-506 and CIM-707 was poor and showed maximum negative GCA effects for majority of the traits. Results also confirmed that parent cultivars CIM-446 and CIM-554 were found as best general combiners, followed by CIM-496.

The positive SCA effects ranges for different traits were 0.04 to 0.13 for locules boll^{-1}, 0.02 to 0.68 for seeds locule^{-1}, 0.06 to 0.48 for lint %, 4.32 to 58.58 for seed cotton yield plant^{-1} and desirable negative SCA effects for days to first flowering (-0.27 to -3.21) (Table 5). The F_1 hybrid CIM-446 × CIM-499 had highest SCA effects for lint % (0.48) and desirable negative SCA (-2.06) for days to first flowering. The cross combination CIM-446 × CIM-554 was found best for seeds locule^{-1} (0.68), while for locule boll^{-1} and seed cotton yield plant^{-1} the crosses CIM-496 × CIM-707 and CIM-506 × CIM-554 had highest SCA effects of 0.13 and 58.58, respectively. Most of the crosses with high SCA have at least one highest GCA parent (CIM-446, CIM-554 and CIM-496). Therefore, high × low, low × high and in some cases high × high GCA parents performed well in SCA determination and revealed also best mean performance. Coyle and Smith (1997), Hassan *et al*., (2000) and Lukonge *et al*., (2008) also concluded that parents with maximum GCA values were found better responsive to produce high yielding hybrids. F_1 hybrids with high heterosis were also associated with higher inbreeding depression (Khan *et al*., 2000; Soomro & Kalhoro, 2000; Basal & Turgut (2003); Khan *et al*., 2007c). Therefore, after analyzing the F_1 hybrids through combining ability with reasonable SCA variance, the medium type of heterosis in such specific cross combinations may have some stability and such promising F_1 hybrids can also be used for hybrid cotton productions.

Table 1. Mean squares for ANOVA and combining ability in a 6 × 6 F_1 diallel cross of upland cotton.

Parameters	Mean squares						
	ANOVA			**Combining ability**			
	Reps.	**Genotypes**	**Error**	**GCA**	**SCA**	**Rec.**	**Error**
Days to first flowering	13.36	29.76**	7.57	10.67**	10.42**	10.43**	2.55
Locules boll^{-1}	0.07	0.02**	0.01	0.00$^{N.S}$	0.02**	0.00$^{N.S}$	0.00
Seeds locule^{-1}	0.06	0.87**	0.14	0.12*	0.27**	0.36**	0.05
Lint %	0.15	9.92**	0.24	5.12**	2.22**	3.79**	0.08
Seed cotton yield plant^{-1}	1883.37	4798.73**	1275.21	5566.19**	1390.01**	495.30$^{N.S}$	425.25

* , ** = Significant at $p \leq 0.05$ & $p \leq 0.01$, N.S. = Non-significant

Table 2. Mean performance for morpho-yield traits in a 6 × 6 F_1 diallel cross of upland cotton.

F_1 Hybrids and parents	Days to Flowering	Locules boll^{-1}	Seed locule^{-1}	Lint %	Seed cotton yield plant^{-1} (g)
CIM-446 × CIM-496	55.33	4.74	6.99	34.71	165.19
CIM-446 × CIM-499	57.00	4.76	7.22	33.44	84.54
CIM-446 × CIM-506	57.33	4.79	7.21	30.74	140.07
CIM-446 × CIM-554	57.33	4.73	7.91	34.69	176.87
CIM-446 × CIM-707	56.67	4.61	6.99	32.58	146.42
CIM-496 × CIM-446	57.00	4.61	7.43	32.30	172.00
CIM-496 × CIM-499	54.00	4.80	7.03	34.69	66.24
CIM-496 × CIM-506	55.33	4.70	7.31	33.04	85.42
CIM-496 × CIM-554	52.67	4.67	7.39	37.79	112.83
CIM-496 × CIM-707	52.67	4.83	6.69	35.51	77.75
CIM-499 × CIM-446	52.33	4.76	8.11	34.94	75.16
CIM-499 × CIM-496	55.00	4.77	6.36	37.32	118.20
CIM-499 × CIM-506	62.00	4.64	7.61	36.28	91.96
CIM-499 × CIM-554	57.67	4.75	6.87	33.53	101.68
CIM-499 × CIM-707	57.00	4.94	7.22	35.21	53.69
CIM-506 × CIM-446	59.67	4.72	7.40	31.95	178.50
CIM-506 × CIM-496	57.33	4.62	7.62	36.15	104.38
CIM-506 × CIM-499	58.33	4.72	7.19	35.00	121.88
CIM-506 × CIM-554	65.33	4.76	8.01	33.28	190.88
CIM-506 × CIM-707	54.00	4.62	7.42	30.84	75.61
CIM-554 × CIM-446	53.00	4.83	7.63	33.48	172.84
CIM-554 × CIM-496	52.00	4.80	6.16	33.57	89.97
CIM-554 × CIM-499	52.67	4.75	6.17	37.80	113.15
CIM-554 × CIM-506	52.33	4.77	6.02	34.45	151.29
CIM-554 × CIM-707	52.67	4.78	7.08	38.78	130.05
CIM-707 × CIM-446	53.67	4.70	6.88	34.26	121.35
CIM-707 × CIM-496	52.67	4.85	7.95	31.69	149.13
CIM-707 × CIM-499	58.00	4.78	7.36	34.16	78.90
CIM-707 × CIM-506	53.00	4.66	6.59	35.05	69.44
CIM-707 × CIM-554	59.00	4.62	7.04	33.25	130.26
CIM-446	62.67	4.60	7.35	33.28	125.86
CIM-496	59.67	4.57	6.49	37.42	85.69
CIM-499	57.33	4.43	6.45	32.73	46.77
CIM-506	58.33	4.63	6.62	35.68	109.56
CIM-554	57.67	4.60	6.56	34.49	101.36
CIM-707	57.67	4.63	6.93	35.66	81.51
L.S.D$_{(0.05)}$	4.48	0.18	0.62	0.79	64.05

Table 3. Genetic components of variance due to GCA, SCA and reciprocals in a 6 × 6 F_1 diallel cross of upland cotton.

Components of variation	Day to flowering	Locules bolls^{-1}	Seeds locule^{-1}	Lint %	Seed cotton yield plant^{-1}
G.C.A	0.04 (0.36)	-0.001 (-16.66)	-0.01 (-3.22)	0.24 (7.04)	350.60 (25.57)
S.C.A	4.56 (41.16)	0.007 (116.66)	0.12 (38.71)	1.24 (36.36)	560.18 (40.86)
Reciprocals	3.93 (35.47)	-0.0001 (0.00)	0.15 (48.39)	1.85 (54.25)	35.02 (2.55)
Error	2.55 (23.01)	0.00 (0.00)	0.05 (16.12)	0.08 (2.35)	425.25 (31.02)
Total	11.08 (100)	0.006 (100)	0.31 (100)	3.41 (100)	1371.05 (100)

Table 4. GCA effects for morpho-yield traits in a 6 × 6 F$_1$ diallel cross of upland cotton.

Cultivars	Days to flowering	Locules boll^{-1}	Seeds locule^{-1}	Lint %	Seed cotton yield plant^{-1}
CIM-446	0.77	0.01	0.14	-1.06	26.69
CIM-496	-1.01	0.01	0.05	0.71	-4.32
CIM-499	0.27	0.00	-0.09	0.41	-33.23
CIM-506	1.32	-0.03	0.04	-0.35	7.85
CIM-554	-0.45	0.02	-0.14	0.43	19.85
CIM-707	-0.90	-0.01	0.00	-0.15	-16.84

Table 5. SCA effects for morpho-yield traits in a 6 × 6 F$_1$ diallel cross of upland cotton.

F$_1$ Hybrids	Days to flowering	Locules boll^{-1}	Seeds locule^{-1}	Lint %	Seed cotton yield plant^{-1}
CIM-446 × CIM-496	0.12	0.04	-0.07	-0.51	46.42
CIM-446 × CIM-499	-2.66	0.04	-0.34	0.48	-30.09
CIM-446 × CIM-506	0.12	0.06	0.03	-1.61	8.27
CIM-446 × CIM-554	-1.44	0.04	0.68	0.35	11.84
CIM-446 × CIM-707	-0.99	-0.06	-0.29	0.26	7.56
CIM-496 × CIM-499	-1.05	0.06	0.52	0.19	13.30
CIM-496 × CIM-506	-0.27	-0.04	0.28	-0.14	-25.10
CIM-496 × CIM-554	-2.49	-0.02	-0.22	0.17	-30.60
CIM-496 × CIM-707	-1.71	0.13	0.18	-1.33	18.13
CIM-499 × CIM-506	-0.27	-0.04	0.28	-0.14	-25.10
CIM-499 × CIM-554	-0.94	0.11	-0.34	0.46	4.32
CIM-499 × CIM-707	1.84	0.06	0.29	0.06	-0.11
CIM-506 × CIM-554	1.68	0.06	0.02	-0.58	58.58
CIM-506 × CIM-707	-2.21	-0.04	-0.13	-0.92	-34.96
CIM-554 × CIM-707	0.90	-0.03	0.11	0.34	10.67

Table 6. Reciprocal effects for morpho-yield traits in a 6 × 6 F$_1$ diallel cross of upland cotton.

F$_1$ Hybrids	Days to flowering	Locules boll^{-1}	Seeds locule^{-1}	Lint %	Seed cotton yield plant^{-1}
CIM-496 × CIM-446	-0.83	-0.04	-0.22	1.21	13.26
CIM-499 × CIM-446	2.33	0.00	0.42	-0.75	4.69
CIM-506 × CIM-446	-1.17	0.03	-0.09	-0.61	-19.22
CIM-554 × CIM-446	2.17	-0.05	0.14	0.61	2.01
CIM-707 × CIM-446	1.50	-0.04	0.05	-0.84	12.54
CIM-499 × CIM-496	-0.50	0.01	-0.54	-1.65	-25.98
CIM-506 × CIM-496	-1.00	0.04	-0.16	-1.55	-9.48
CIM-554 × CIM-496	0.33	-0.07	0.62	2.11	11.43
CIM-707 × CIM-496	0.00	-0.01	-0.63	1.91	-35.69
CIM-506 × CIM-499	1.83	-0.04	0.21	0.38	-14.96
CIM-554 × CIM-499	2.50	0.10	0.35	-2.13	-5.74
CIM-707 × CIM-499	-0.50	-0.02	-0.07	0.53	-12.61
CIM-554 × CIM-506	6.50	-0.01	1.00	-0.59	51.46
CIM-707 × CIM-506	0.50	-0.02	0.42	-2.11	3.09
CIM-707 × CIM-554	-3.17	0.08	0.02	1.43	-0.11

The F$_1$ reciprocal cross (CIM-554 × CIM-506) having one good general combiner, also manifested maximum reciprocal effects for two traits (Table 6) viz., seeds locule^{-1} (1.00) and seed cotton yield plant^{-1} (51.46). The remaining traits were also controlled by such reciprocal crosses which involve at least one general combiner as one of the parents and manifested maximum reciprocal effects for locules boll^{-1} (0.10; CIM-554 × CIM-499), lint % (2.11; CIM-554 × CIM-496) and highest desirable negative reciprocal effects (-3.17) were shown by cross CIM-707 × CIM-554 for days to first flowering. In combining ability the maternal effects which came through cytoplasmic effects cannot be ignored also and the F$_1$ hybrids having desirable reciprocal effects should also be kept under consideration during future breeding.

Parental cultivars with best GCA i.e., CIM-446, CIM-554 followed by CIM-496 and their utilization as one of the parents produced excellent F$_1$ hybrid combinations and performed well in GCA and SCA determination in addition to excellent mean performance for majority of the traits. Results also revealed that majority of traits governed by additive genes and partially by non-additive gene action and selection in such promising population could be effective in early segregating generations. The F$_1$ hybrids having extraordinary performance could also be used as such (seed source for F$_2$ crop) for hybrid cotton production to boost up the seed cotton yield as also mentioned by Basal & Turgut (2003), Muthu *et al*., (2005) and Khan *et al*., (2007c) that high SCA effects associated with standard heterosis.

Conclusion

Best general combiners i.e., CIM-446, CIM-554 followed by CIM-496 and their use as paternal/maternal parent in F$_1$ hybrids viz., CIM-446 × CIM-499, CIM-446 × CIM-554, CIM-

496 × CIM-707 and CIM-506 × CIM-554 performed well with highest SCA determination. However, it was also concluded that combined performance of F_1 and F_2 hybrids could be a good selection criteria for assortment of most promising populations to be utilized either as F_2 hybrids or as a resource population for further selection in advanced generations.

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