Combining Ability for Yield and its Components in Ethiopian Sorghum (*Sorghum bicolor* (L.) Moench) Landraces

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Abstract: Crossing sorghum [Sorghum bicolor (L.) Moench] obtained from different areas of Ethiopia were done in 2004/05 cropping season. In 2005/06 evaluation of 15 F_1s with their parents were done in a randomized complete block design with three replications at Bako. The study was conducted to estimate combining ability and determine type of gene actions involved in the inheritance of yield and yield components traits. Analysis of variance revealed that mean squares due to genotypes, parents and crosses were highly significant ($P<0.01$) for all the traits except for 100 kernel weight that were significant for crosses. Mean squares due to general combining ability (GCA) and specific combining ability (SCA) were highly significant for all characters studied, except non significant SCA for 100 kernel weight. For yield, three of the parents, 212646, 69543 and 69193 had the best general combiner and incorporating these parents for grain yield per panicle in sorghum breeding may be importatnt. Based on specific combining ability analysis for grain yield per panicle five hybrids 69543 x 223506, 212646 x 223506, 97MW5122 x 212646, 97MW5122 x 69543 and 212646 x 69193 were the best in the experiment. The estimate of variance components showed that the variance due to SCA was higher in magnitude than GCA in the case of days to maturity, panicle width, panicle weight, kernel number per panicle and grain yield. Therefore, these traits were predominantly under the control of non-additive type of gene actions. Whereas variance of GCA was higher than SCA in the case of days to flowering, plant height, leaf number per plant, leaf length, leaf width, leaf area, panicle length and 100 kernel weight indicating that additive type of gene action was playing a greater role in the inheritance of these traits.

Keywords: Combining Ability; Diallel; Gene Action; *Sorghum bicolor*

1. Introduction

Sorghum [Sorghum bicolor (L.) Moench] is the fifth leading cereal grain worldwide after wheat, rice, maize and barley with area coverage of about 42.7 million ha and total production of 56.96 million metric tons (FAO, 2004). Ethiopia is third largest sorghum producer in Africa next to Nigeria and Sudan (FAO, 2004). It is among the top four cereal crops next to tef, wheat and maize in Ethiopia (CSA, 2005). It ranks 3rd in area cultivated to cereals and 2nd in total production. The area under sorghum production was estimated to be 1.25 million ha with a total production and average yield of 1.72 million tons and 1.37 tons/ha, respectively (CSA, 2005).

Effective selection method for grain yield and other desirable traits requires information on the magnitude of useful genetic variances present in the parents, in terms of combining ability. Analysis of diallel data is usually conducted according to the methods of Griffing (1956) which partition the total variation of diallel data into general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses (Yan & Hunt, 2002).

Combining ability helps to identify the better combiners which may be hybridized to exploit heterosis and select better crosses for further breeding (Singh and Chaudhary, 1985). Therefore, the objective of this study was to estimate GCA and SCA and determine the type of gene actions for yield and yield related traits of sorghum landraces.

2. Materials and Methods

Six sorghum landraces were crossed in a half diallel fashion at Bako Agricultural Research Center in 2004 main season. Bako is located at an altitude of 1650 masl. It lies between 9° 6' N latitude and 37° 09' E longitude in the sub-humid agro-ecology of the country. It annually receives 1242.1 mm rainfall.

The parents were from the zones (Kafa, Wello, Hararghe, Bale and Wellega) having distant cluster analysis and one advanced line from Melkasa Agricultural Research Center. Background information of these sorghum landraces is given in Table 1.

The entries were arranged in a randomized complete block design with three replications. A plot size of 3 m length was used with 1 m and 0.15 m spacing between rows and plants within the row, respectively. Fertilizers were applied at the rate of 46/46 kg ha^{-1} N/P_2O_5. Nitrogen was applied in split (half at planting and the other half at knee height). All other agronomic practices were carried out as needed. Data on days to flowering, days to maturity, plant height (cm), number of leaf per plant, leaf length (cm), leaf width (cm), leaf area (cm²), panicle length (cm), panicle (head) width (cm), head weight (g), kernel number per panicle, hundred-kernel weight (g) and grain yield per panicle (g) were recorded. Five plants were randomly taken from the plot and tagged for which the data were collected except for days to flowering and maturity recorded on plot basis. The grain yield was adjusted to 12% moisture.

Table 1. Sorghum landraces and advanced lines used as parents for half diallel crossing.

No.	Code	Collection Zone	Altitude	Grain color
1.	97MW5122	Advanced line from MRC[1]	-	Brown
2.	69543	Kafa	1860	White
3.	212646	Wello	1690	Dark red
4.	223506	Wellega	1830	Bright yellow
5.	69046	Bale	1630	Dark red
6.	69193	Hararghe	1710	Light yellow

[1]MRC = Melkasa Research Center; from Sr. No. 2-6 is code given by Institute of Biodiversity Conservation (IBC)

Analysis of variance was performed using SPAR-1, MSTAT-C (Fried, 1990) combining ability effect was done in AgroBase software programs (Agrobase, 2000), respectively. The data was analyzed according to Griffing's Model I, method 2 (Griffing, 1956).

The mathematical model for the combining ability (Griffing, 1956) is:

$$X_{ij} = \mu + g_i + g_j + s_{ij} + \frac{1}{bc}\left(\sum_k \sum_l e_{ijkl}\right)$$

where $S_{ij} = S_{ji}$; i, j, = 1, …, p;   k = 1, … ,b;   l = 1, …, c; X_{ij} is the mean of i x j^{th} genotype over k and l; μ = Population mean; g_i = general combining ability of effect of ith parent; g_j = general combining ability effect of jth parent; s_{ij} = is the interaction, i.e., specific combining ability effect

$$\frac{1}{bc}\sum_k \sum_l e_{ijkl} \quad \text{Mean error}$$

where P, b and c = number of parents, block and sampled plants, respectively.

3. Results and Discussion
3.1. Analysis of Variance
The analysis of variance revealed highly significant (P < 0.01) difference among genotypes, parents and crosses for all traits (Table 2). Mean squares due to parents vs crosses were also highly significant for most of the traits considered including plant height, leaf length, leaf width, leaf area, panicle length, panicle width, panicle weight, kernel number per panicle, grain yield. The results showed that (Table 3) both GCA and SCA were significant, indicating the role of both additive and non-additive gene action in the inheritance of these traits. However, mean squares due to SCA showed non significant for 100 kernel weight, indicating the major role of only additive gene actions in the inheritance of the character.

3.2 Estimates of GCA Effects
The estimated values of GCA effects are presented in (Table 4). The results showed negative and significant GCA effects for days to flowering in four parents including 69046, 97MW5122, 212646 and 69193 suggesting the contribution of these parents for earliness in crosses they were involved. Positive and significant

GCA effects were observed in 223506 and 69543 for the same trait. These parents greatly induced lateness in their crosses. The former parents were low general combiners (i.e. significant and negative GCA effects). The parent, 223506 greatly induced lateness in its crosses. The highest significant negative GCA effect (-15.03) was exhibited by 69046, whereas the highest positive GCA (18.31) was observed in 223506.

Four of the six parents had negative GCA effects, though only two of these (212646 and 69046) were found to be highly significant for days to maturity. Thus, the parents might have contributed for earliness of their crosses. The remaining two parents were found to have positive GCA effects, of which one was highly significant for the same trait. It appeared that these parents contributed for lateness of their crosses.

Five of the six parents were observed to have significant GCA effects for plant height, of which 3 had negative and two had positive effects. These parents with significant positive GCA effects were good combiners in increasing tallness, while those with significant negative GCA effects were good combiners in decreasing plant height. The parent, 212646 were average combiners for this trait (i.e. nonsignificant GCA effect). It was observed that there was a direct relationship between GCA effects of parents and mean plant height of parents and crosses. The tallest crosses involved at least one parent with high GCA effect and the relatively dwarf crosses involved at least one parent with low GCA effect.

Positive and significant GCA effects were exhibited by parents, 223506, 69543 and 97MW5122, for leaf length indicating good combiners for the trait, while the remaining parents showed negatively significant effects. The highest leaf length, 111.3 cm was exhibited by (97MW5122 x 223506) cross and it was also among the top exhibiting for the same trait. This situation appears to bring out the importance of additive gene actions. In the case of leaf width only two parents 223506 and 69543 exhibited positively significant GCA effects. The other three parents, 69046, 69193 and 97MW5122 were low general combiners having negatively significant for the trait. The parent, 212646 were average combiners for the same trait (i.e. nonsignificant GCA effect).

Table 2. Mean squares due to genotypes, parents, crosses, P vs C and error for yield and other traits in 6 x 6 half diallel crosses of sorghum evaluated at Bako in 2005 cropping season.

Character	Mean squares					
	Replication (df = 2)	Genotypes (df = 20)	Parents (P) (df = 5)	Crosses (C) (df = 14)	P vs C (df = 1)	Error (df = 40)
DF	104.83	1022.99**	1370.59**	970.80**	15.56	20.49
DM	42.49	787.96**	977.43**	775.97**	8.46	46.26
PH	6025.96	14838.29**	14246.83**	14438.61**	23391.09**	633.38
LNP	8.84	13.49 **	16.49**	13.30**	1.14	0.62
LL	27.80	255.49**	282.89**	231.22**	458.24**	10.29
LW	0.55	5.58**	5.93**	5.49**	5.14**	0.36
LA	7146.83	70555.78**	70841.21**	68412.39**	99136.24**	2884.20
PL	4.86	183.11**	293.86**	144.10**	175.49**	6.09
PW	0.33	14.29**	10.72**	14.26**	32.41**	1.15
PWT	1820.35	10463.10**	6772.13**	10195.88**	32669.28**	567.87
KNPP	1098830.43	14858145.20**	6055971.89**	17321072.58**	24387141.51**	1199296.50
HKW	0.35	0.93**	2.78**	0.33*	0.02	0.15
GY	3483.55	7393.67**	2778.60**	7755.52**	25404.44**	583.83

*df = Degree of freedom; * = 5% significant level; ** = 1% significant level; DF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); LNP = Number of leaves per plant; LL = Leaf length (cm); LW = Leaf width (cm); LA = Leaf area (cm²); PL = Panicle length (cm); PW = Panicle width (cm); PWT = Panicle weight (g); KNPP = Kernel number per panicle; HKW = 100 kernel weight (g); GY = Grain yield/panicle (g)*

Table 3. Mean squares due to general combining ability (GCA), specific combining ability (SCA) and error for yield and other traits in diallel crosses of sorghum.

Character	Mean squares		
	GCA (df = 5)	SCA (df = 15)	Error (df = 40)
Days to flowering	1058.48**	101.84**	6.83
Days to maturity	698.55**	117.36**	15.42
Plant height (cm)	15751.80**	1344.20**	211.13
Leaf number per plant	13.34**	1.55**	0.21
Leaf length (cm)	247.50**	31.05**	3.43
Leaf width (cm)	5.57**	0.63**	0.12
Leaf area (cm²)	70518.18**	7852.07**	961.40
Panicle length (cm)	207.20**	12.32**	2.03
Panicle width (cm)	10.91**	2.72**	0.38
Panicle weight (g)	6593.70**	2452.37**	189.29
Kernel number per panicle	12298037.70**	2470940.90**	399765.49
100 kernel weight (g)	1.04**	0.04	0.05
Grain yield per panicle (g)	4102.10**	1918.71**	194.61

* = 5% significant level; ** = 1% significant level; df = degrees of freedom; GCA = General combining ability; SCA = Specific combining ability

Parents 223506 and 69543 had positive and significant GCA effects for leaf area, indicating they are good combiners for this trait. While two parents 69046 and 69193 showed negatively significant GCA for the trait. The remaining two parents were average combiners for this trait.

Parents 69543 and 97MW5122 were good combiners for panicle length having significant positive GCA effects, while the remaining four parents were poor combiners having negatively significant GCA effects. The cross (97MW5122 x 69543) with the highest mean performance for panicle length involved high x high indicating the importance of additive gene action. Parents 223506 and 69543 had positive and significant GCA effects for

panicle width while there were negative and significant GCA effects for 69046 and 97MW5122. Similarly, the cross (69543 x 223506) having the highest panicle width involved parents high x high for the trait.

Only one parent, 69046, showed significant and negative GCA for panicle weight. From the remaining parents, 69193, 212646 and 69543 showed positively significant GCA. The parents, 223506 and 97MW5122 were average combiners.

Parents, 69543, 212646 and 97MW5122 had positive and significant GCA effects for kernel number per panicle and they were good combiners, while 69046 and 69193 were poor combiner since it had negative and significant GCA effects.

For hundred kernel weight two parents, 69193 and 69046, showed positive and significant GCA effects. Three other parents, 69543, 212646 and 97MW5122 showed negatively significant GCA effects for the same trait. The parent 223506 was average combiner.

Table 4. Estimates of general combining ability (GCA) effects for grain yield and other agronomic traits of six parents of sorghum used in diallel cross.

Trait	Parent						SE	
	97MW5122	69543	212646	223506	69046	69193	(gi)	(gi-gj)
DF	-4.90**	7.64**	-3.28**	18.31**	-15.03**	-2.74**	0.84	1.31
DM	-1.74	2.76*	-5.94**	16.68**	-10.53**	-1.24	1.27	1.96
PH	-30.67**	74.45**	-2.51	27.9**	-44.22**	-24.95**	4.69	7.27
LNP	-0.47**	0.71**	-0.61**	2.31**	-1.06**	-0.88**	0.15	0.23
LL	3.54**	4.27**	-3.51**	6.38**	-7.98**	-2.70**	0.60	0.93
LW	-0.31**	0.51**	0.14	1.23**	-1.21**	-0.37**	0.11	0.17
LA	3.46	64.48**	-19.83	136.03**	-137.09**	-47.04**	10.01	15.50
PL	4.49**	8.02**	-2.44**	-1.62**	-4.83**	-3.62**	0.46	0.71
PW	-0.72**	0.95**	-0.02	1.62**	-1.65**	-0.18	0.20	0.31
PWT	5.91	11.15*	15.16**	5.21	-57.47**	20.04**	4.44	6.88
KNPP	429.74*	1443.50**	842.5*	-138.94	-2134.4**	-442.44*	204.06	316.14
HKW	-0.18*	-0.38**	-0.29**	0.01	0.25**	0.57**	0.07	0.11
GY	7.63	12.39**	14.68**	-1.21	-44.80**	11.31*	4.50	6.98

* = 5% significant level; ** = 1% significant level; DF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); LNP = Number of leaves per plant; LL = Leaf length (cm); LW = Leaf width (cm); LA = Leaf area (cm²); PL = Panicle length (cm); PW = Panicle width (cm); PWT = Panicle weight (g); KNPP = Kernel number per panicle; HKW = 100 kernel weight (g); GY = Grain yield/panicle (g)

For yield, the important trait, three of the parents, 212646, 69543 and 69193 exhibited positive and significant GCA effects. The parent, 69543 was observed to be high general combiner for the panicle characters. While the parent 97MW5122 showed positive and nonsignificant effects, indicating average combiner for the trait. The remaining two parents, 69046 and 223506 exhibited highly significant and nonsignificant negative effects, respectively, for the same trait. The highest mean performance for this trait was observed by the cross 69543 x 223506 with (high x low) indicating the importance of non-additive type of gene action. However, the lowest mean value was observed by the cross 223506 x 69046 involving the parents having low x low general combiners. Parent, 212646 was the best general combiner while 69046 was poorest one for grain yield per panicle. Therefore, in the future, the incorporation of parents 212646, 69543 and 69193 for grain yield per panicle in sorghum breeding programme may be worthwhile.

3.3. Estimates of SCA Effects
Estimates of SCA effects for the twelve traits that showed significant mean squares given in Table 5. Seven crosses showed positive SCA effects for days to flowering, of which four crosses exhibited significant effect. These latter crosses involved at least one parent with late flowering. The remaining 8 crosses had negative SCA effects, of which five had significant effects, indicating that these crosses had flowered earlier than what would be expected based on their parental performance. It was noted that most of these crosses involved at least one parent with low general combining

ability effects. The highest positively significant SCA effect (22.88) was displayed by high x low combination (223506 x 690460). It seemed that 223506 having genes for lateness than 69046 as these two parents stand at opposite ends with respect to this trait.

Crosses such as 69543 x 223506, 69046 x 69193, 212646 x 223506, 212646 x 69046 and 97MW5122 x 69046 had a significant negative SCA effects for days to maturity followed by cross 212646 x 69193 having negative but non-significant SCA effects, indicating that these combinations of parents gave earliness in maturity. Other crosses including 223506 x 69046, 69543 x 69046 and 97MW5122 x 223506 had significant and positive SCA values. This showed combinations of these parents gave lateness in maturity. Two crosses 69046 x 69193 and 212646 x 69046 had significantly reduced plant height since they had significant negative SCA effects while the remaining crosses including 97MW5122 x 69193 and 212646 x 223506 had non significant SCA effects. However, four crosses 97MW5122 x 69543, 69543 x 49046, 223506 x 69046, 97MW5122 x 212646 and 212646 x 69193 gave significant positive SCA effects for plant height. It can be concluded that combinations of these parents resulted in tall plant height. Except the last cross, the other crosses with significant positive SCA effects involved at least one of good combiner parent for the trait. While those with negative SCA effects having the combination of either both or one parents with low general combining ability.

Three crosses with significantly negative SCA effects for leaf length were 69046 x 69193, 69543 x 223506 and 97MW5122 x 69046, while seven crosses showed significant positive SCA for this trait. Most of the crosses

involved at least one parent with high general combining ability. The only cross, 212646 x 69046 exhibited negative and significant SCA effects for leaf width gave the lowest mean performance for this trait. The parents involved for the above cross was with low GCA effects. The crosses, 223506 x 69046, 97MW5122 x 223506, 69543 x 212646, 212646 x 69193 and 97MW5122 x 69543 expressed significant and positive SCA effects for leaf width. Crosses that showed significantly positive SCA effects

involved at least one parent with good combiner for the trait. While hybrids 223506 x 69046, 97MW5122 x 223506, 97MW5122 x 69543 and 212646 x 69193 showed significantly positive SCA effects for leaf area. The crosses performance for leaf area depends on their leaf length or width all crosses showed significant for both traits (leaf length and width) also expressed significant SCA effect for leaf area.

Table 5. Estimates of specific combining ability (SCA) effects for grain yield and other agronomic traits of F_1 hybrids of sorghum used in diallel cross.

Cross	Character					
	DF	DM	PH	NLP	LL	LW
97MW5122 x 69543	-0.91	1.23	46.35**	1.06*	6.37**	0.69*
x 212646	2.34	1.93	35.18**	0.59	4.52**	0.05
x 223506	9.42**	9.98**	13.97	1.59**	6.40**	1.13**
x 69046	-8.91**	-7.48*	0.62	-0.37	-3.44*	-0.40
x 69193	-1.87	5.56	-15.99	-0.55	-2.59	0.53
69543 x 212646	1.80	2.10	19.60	0.54	-2.51	0.87**
x 223506	-14.12**	-18.19**	24.46	-1.86**	-3.66*	-0.42
x 69046	13.88**	15.02**	45.44**	0.44	1.79	0.19
x 69193	0.92	0.39	12.60	0.07	6.85**	-0.25
212646 x 223506	-6.54**	-9.48*	-7.59	-1.47**	-3.08	-0.15
x 69046	-11.87**	-7.61*	-33.80*	-0.70	0.74	-1.08**
x 69193	-1.16	-5.90	26.59*	-0.54	6.39**	0.78*
223506 x 69046	22.88**	22.10**	37.83**	2.51**	8.02**	1.36**
x 69193	5.92*	5.14	5.05	1.07*	4.11*	-0.12
69046 x 69193	-7.08**	-11.32**	-27.50*	-1.10**	-4.34*	-0.47
S.E (S$_{ij}$) ±	2.32	3.48	12.88	0.40	1.64	0.31
S.E (S$_{ij}$-S$_{ik}$) ±	3.46	5.20	19.22	0.60	2.45	0.46
S.E (S$_{ij}$-S$_{kl}$) ±	3.20	4.81	17.80	0.56	2.27	0.42
Cross	Character					
	LA	PL	PW	PWT	KNP	GY
97MW5122 x 69543	103.42**	1.44	1.92**	44.28**	1696.4**	49.29**
x 212646	34.80	-0.38	1.91**	61.01**	1877.4**	50.93**
x 223506	145.77**	-0.66	-0.86	-19.48	-1014.7	-22.51
x 69046	-57.84*	3.43**	-0.18	8.69	-94.8	8.00
x 69193	13.21	6.03**	-0.16	23.54	172.0	18.80
69543 x 212646	41.45	3.50**	-0.43	17.91	445.8	12.85
x 223506	-54.85	5.08**	1.97**	64.69**	2834.5**	66.08**
x 69046	14.24	-1.84	1.32*	-5.93	-1225.8*	-15.38
x 69193	27.12	-4.38**	0.94	15.16	76.6	-0.75
212646 x 223506	-38.40	2.06	2.74**	72.15**	1798.8**	60.70**
x 69046	-64.75*	1.80	-0.20	-24.63*	-985.8	-18.18
x 69193	101.90**	-2.50	-0.77	24.40	1182.7*	28.31*
223506 x 69046	145.89**	0.16	0.31	8.25	136.6	-3.79
x 69193	18.91	-0.60	-0.69	-58.84**	-1252.0*	-40.96**
69046 x 69193	-54.57	2.70*	-1.01	-15.20	254.7	-2.88
S.E (S$_{ij}$) ±	27.48	1.26	0.55	12.20	560.45	12.37
S.E (S$_{ij}$-S$_{ik}$) ±	41.02	1.89	0.82	18.20	836.42	18.45
S.E (S$_{ij}$-S$_{kl}$) ±	37.98	1.75	0.76	16.85	774.37	17.09

*= 5% significant level; ** = 1% significant level; DF = Days to flowering; DM = Days to maturity; PH = Plant height (cm); LNP = Leaf number per plant; LL = Leaf length (cm); LW = Leaf width (cm); LA = Leaf area (cm²); PL = Panicle length (cm); PW = Panicle width (cm); PWT = Panicle weight (g); KNPP = Kernel number per panicle; GY = Grain yield/panicle (g); S.E (S$_{ij}$)± = Standard error of specific combining ability effect; S.E (S$_{ij}$-S$_{ik}$)± = Standard error of the difference of specific combining ability having one parent in common and S.E (S$_{ij}$-S$_{kl}$) ± = Standard error of the difference of specific combining ability effects of the crosses having no parents in common.*

For panicle length only one cross, 69543 x 69193 showed significant negative SCA effects, while crosses 97MW5122 x 69193, 69543 x 223506, 97MW5122 x 69046, 69543 x 212646 and 69046 x 69193 expressed significant positive SCA effects.

With respect to SCA effects for panicle weight only two cross, 223506 x 69193 and 212646 x 69046, exhibited negative and significant effect. Four crosses (212646 x 223506, 69543 x 223506, 97MW5122 x 212646 and 97MW5122 x 69543) showed positive and significant SCA effects for the trait. These crosses resulted from good combiner parents (i. e., high x high) indicating the importance of additive type of gene actions. These crosses displayed the higher mean performance for the trait.

Five of the 15 crosses showed negative SCA for kernel number per panicle, of which two crosses 223506 x 69193 and 69543 x 69046 exhibited negative and significant effects. These crosses involved either average or poor combiner for the trait. On the other hand, five other crosses (69543 x 225606, 97MW5122 x 212646, 212646 x 223506, 97MW5122 x 69543 and 212646 x 69193) showed positively significant SCA effects. The combination of these latter parents contributed for higher kernel number per panicle.

For grain yield per panicle five crosses (69543 x 223506, 212646 x 223506, 97MW5122 x 212646, 97MW5122 x 69543 and 212646 x 69193) exhibited positive and significant SCA, and these parental combinations enhanced grain yield per panicle. It was observed that significant and positive SCA effects were associated with crosses of high mean performance. Cross 223506 x 69193 showed negatively significant SCA effect for this trait. From positively significant SCA effects and mean performances of the crosses, there would be possibility of obtaining hybrids which would perform better than the high yielding parent.

3.4. Estimates of Variance Components

The estimates of variance components due to general combining ability and specific combining ability are presented in Table 6. The ratio of GCA to SCA variances was greater than unity for days to flowering, plant height, leaf number per plant, node number per plant, leaf length, leaf width, leaf area, panicle length and 100 kernel weight indicating that additive type of gene action was playing a greater role in the inheritance of these traits. Similar findings were reported by authors for days to flowering (Rafiq *et al.,* 2002). Moreover, Erenso (1998) reported similar result for plant height and 100 kernel weight; Amsalu (1987); Manickam and Vijendra Das (1994) for leaf number per plant. In contrast to the present study, higher magnitude of SCA variance were reported by several investigators (Manickam and Vijender Das, 1994; Umakanth *et al.,* 2002) for days to flowering and plant height. Yang (1991) for number of leaves per plant and Pathak and Sanghi (1992); Manickam and Vijendra Das (1994) for leaf area indicated the predominance of non-additive gene actions for the traits.

However, the ratio of GCA to SCA variances was less than unity for days to maturity, panicle width, panicle weight, kernel number per panicle and grain yield. Therefore, these traits appeared predominantly under the control of non-additive type of gene actions. In line with this study (Umakanth, *et al.,* 2000) for panicle weight; Erenso (1998) for kernel number per panicle; Hovny *et al.* (2000); Amsalu (1987); Umakanth *et al.* (2000) for grain yield. However, Toure *et al.* (1996) reported the importance of both additive as well as non-additive gene effects for grain yield.

Table 6. Estimates of variance components of general and specific combining ability of sorghum for yield and related traits.

Character	Variance components		
	GCA	SCA	GCA/SCA
Days to flowering	131.46	95.01	1.38
Days to maturity	85.391	101.937	0.84
Plant height (cm)	1942.58	1133.07	1.71
Leaf number per plant	1.64	1.34	1.22
Nod number per plant	1.98	1.86	1.06
Leaf length (cm)	30.51	27.62	1.10
Leaf width (cm)	0.68	0.51	1.33
Leaf area (cm^2)	8728.35	7160.67	1.22
Panicle length (cm)	25.646	10.288	2.49
Panicle width (cm)	1.316	2.335	0.56
Panicle weight (gm)	800.55	2263.08	0.35
kernel number per panicle	1499784.03	2071175.42	0.72
100 kernel weight	0.1243	0.016	7.77
Grain yield (g/panicle)	488.436	1724.098	0.28

GCA = variance component for general combining ability, SCA = variance component for specific combining ability

4. Conclusions

The significant mean squares due to GCA for all characters and SCA for most of the traits indicated that contribution of additive and non-additive genes, respectively, to total genetic factor controlling the traits. Estimates of specific combining ability effects revealed that some combinations had effects that were significantly higher or lower than what have been predicted based on their parental performances. The variation is usually attributed to genetic factor of non-additive components of gene action. Crosses with significant positive or negative SCA values for desirable traits indicated that hybridization is necessary to increase and decrease the traits.

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6. Reference

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