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Combining ability studies in grain sorghum using diallel analysis

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Abstract: Combining ability studies involving seven parents crossed in half diallel fashion revealed the presence of significant differences due to parents, hybrids and parents vs hybrids, indicating the presence of variability. The estimates of general combining ability (GCA) and specific combining ability (SCA) variances indicated the presence of higher magnitude of non additive gene action for most of the characters. Considering the general combining ability effects of parents for days to flowering, maturity and grain yield, IS 31651 was good general combiner. The crosses BJV-44 x IS 26025, BJV-44 x IS 31651, 104B x IS 31651, M35-1 x IS 26025 were identified promising for improving grain yield while crosses M35-1 x IS 28614 and 104B x IS 26025 have been selected for breeding for earliness.

Key words: Combining ability, Diallel, Panicle, Sorghum

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important cereal crop grown in Africa, Asia, USA, Australia, and Latin America. India has the largest share of world sorghum area (16.3%) and ranks fourth in the production after Mexico, Nigeria and USA. World's sorghum production of 64.16 million tonnes comes from an area of 41.00 million hectare with productivity of 1564 kg per hectare (Anon., 2016a). In India, sorghum is grown over an area 6.25 million hectare with the production of 6.0 million tonnes and productivity of 1010 kg per hectare. In Karnataka, the crop has a total acreage of 1.41 million hectare with a total production of 1.30 million tonnes having productivity 1105 kg per hectare (Anon., 2016).

Due to excellent grain and fodder quality, post-rainy sorghums are used as food and fodder for livestock. They usually produce high biomass (grain and stover) and have high lustrous grain with semi-corneous endosperm. Although several hybrids have been developed and released for *rabi* season cultivation, the area covered under hybrids is almost negligible. This is because of lack of appropriate hybrids with acceptable grain quality adapted to *rabi* season. Constraints in the development of hybrids in *rabi* sorghum were low heterosis due to low temperature sensitivity, biotic and abiotic stresses and fertility restoration (Prabhakar *et al.,* 2014).

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 and 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.

Material and methods

The present experiment on sorghum was conducted at botanical garden, Department of genetics and plant breeding, UAS, Dharwad in *rabi* 2016-17. All the recommended agronomic practices were followed to raise a good crop. Seven parents *viz.,* IS 26025, IS 31651, IS 24462, IS 22616, 104B, M35-1 and BJV-44 were crossed in half diallel fashion to produce 21 crosses. The resulting 21 F_1's along with their 7 parents were evaluated for various yield contributing traits of sorghum. The experiment was laid out in randomized block design with three replications with a row length of 4 m and a spacing of 45 x 15cm. The observations were recorded on randomly selected five plants for characters days to 50% flowering, days to maturity, plant height (cm), panicle length (cm), panicle width (cm), 100 seed weight (g), panicle weight (g), primaries panicle^{-1} and grain yield plant^{-1} (g). The data were subjected to statistical analysis to understand the magnitude of GCA and SCA of above mentioned parents and their F_1's.

Results and discussion

The analysis of variance revealed highly significant difference among genotypes, parents and crosses for all the traits studied (Table 1). Mean squares due to parents vs crosses were also highly significant for most of the traits considered including plant height, panicle length, panicle width, panicle weight, primaries panicle^{-1}, grain yield^{-1}. The results showed that (Table 2) 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 seed weight, indicating the major role of only additive gene actions in the inheritance of the character.

Estimates of GCA effects

The estimates of GCA effects are presented in (Table 3). The results showed negative and significant GCA effects for days to 50% flowering in IS 31651 (-5.94) suggesting the contribution of this parent for earliness in crosses involved.

Table 1. Analysis of variance for yield and its attributing traits in parents and single cross hybrids of sorghum

	DF	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g)	Primaries panicle^{-1}	Yield plant^{-1} (g)	100 seed weight (g)
Replicates	2	83.012	121.08	367.10	9.35	2.39	31.32	10.63	16.59	0.26
Genotypes	27	185.96 **	192.17 **	9193.49**	44.26**	3.782**	352.41**	503.94**	99.62**	0.44 *
Parents	6	140.63	113.74	11071.16**	34.584**	6.64**	139.60 *	993.91**	32.64	0.55
Hybrids	20	207.58 **	224.50 **	8440.57 ***	41.48**	3.10**	311.76**	244.78*	113.39**	0.40
Parent Vs. Hybrids	1	25.39	16.11	12986.04 **	157.85**	0.09	2442.16**	2747.38**	226.21**	0.48
Error	54	65.33	64.28	1219.42	9.14	1.13	45.07	114.34	24.72	0.24

* and ** significant at 5 and 1 per cent, respectively.

Table 2. Analysis of variance for combining ability in respect to yield and its attributing traits in parents and single cross hybrids of sorghum

	DF	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g)	Primaries panicle^{-1}	Yield plant^{-1} (g)	100 seed weight (g)
GCA	6	135.95 **	118.65 **	6946.26**	17.07 **	1.23 **	77.09 **	358.12 **	57.00 **	0.20 *
SCA	21	40.85 *	48.45 **	1955.42**	14.09 **	1.26 **	129.00**	113.65 **	26.41**	0.131
Error	54	21.77	21.42	406.47	3.04	0.37	15.02	38.11	8.24	0.08

* and ** significant at 5 and 1 per cent, respectively.

Table 3. Estimates of general combining ability effects of parents for yield and its attributing traits in sorghum

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g)	Primaries panicle^{-1}	Yield plant^{-1} (g)	100 seed weight (g)
104B	0.75	0.23	-30.00**	1.29 *	-0.23	3.82 **	6.75**	2.66	0.27 **
BJV-44	4.53 **	-0.43	5.37	0.25	-0.06	0.93	7.19**	2.41	-0.03
M35-1	-2.83	-3.06 *	-4.07	-0.79	0.27	-1.43	6.01**	1.72	-0.14
IS 31651	-5.94**	-4.83**	-7.77	1.25 *	-0.19	0.38	5.70**	3.66**	0.07
IS 28614	-2.54	-1.32	58.00**	-1.66 **	-0.37	-5.62**	-3.54	-1.32	-0.09
IS 24462	2.16	4.77 **	-14.59 *	-1.68 **	-0.10	0.67	-6.53**	-4.10**	0.07
IS 26025	3.86**	4.64 **	-6.92	1.34 *	0.70**	1.23	-4.16*	1.73	-0.14
S.E	1.44	1.42	6.22	0.53	0.18	1.19	1.90	0.88	0.08

* and ** significant at 5 and 1 per cent, respectively

Positive and significant GCA effects were observed in IS 26025 (3.86) and BJV-44 (4.53) for the same trait. However, the former parent was low general combiner (*i.e.,* significant and negative GCA effects).

Two of the seven parents M35-1 (-3.06) and IS 31651 (-4.83) had negative significant GCA effects for days to maturity. Thus, the parents might have contributed for earliness of their crosses. The parents IS 24462, IS 26025 were found to have positive GCA effects.

IS 28614 have significant GCA effects for plant height. These parents with significant positive GCA effects were good combiners in increasing the height of the plant, while 104B and IS 24462 with significant negative GCA effects were good combiners in decreasing plant height. 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, 104B and IS 26025 for panicle length indicating good combiners for the trait, while the IS 28614 and IS 24462 parents showed negatively significant effects.

Parents IS 26025 had positive and significant GCA effects for panicle width, indicating they are good combiners for this trait. While rest of parents showed negatively low GCA for the trait which were poor combiners for this trait.

Parents 104B was good combiner for panicle weight and primaries panicle^{-1} having significant positive GCA effects, while the IS 28614 parent was poor combiner for panicle weight having negatively significant GCA effects. The cross (104B x M35-1) with the high mean performance for primaries panicle^{-1} involved high x high indicating the importance of additive gene action. Parents IS 31651 and IS 24462 had negative and

Table 4. Estimates of variance components for yield and its attributing traits in sorghum

	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g)	Primaries panicle^{-1}	Yield plant^{-1} (g)	100 seed weight (g)
GCA Variance	12.69	10.80	726.64	1.56	0.10	6.90	35.56	5.42	0.01
SCA Variance	19.08	27.03	1548.95	11.04	0.89	113.98	75.54	18.17	0.05
Ratio	0.67	0.40	0.47	0.14	0.11	0.06	0.47	0.30	0.29

significant GCA effects for primaries panicle^{-1}. Similarly, the cross (104B x IS 31651) having the high panicle weight involved parents high x high for the trait.

The parents 104B had positive and significant GCA effects for 100 seed weight and a good combiner, while IS 26025 was poor combiner since it had negative GCA effects.

The parents BJV-44, IS 26025 were average combiners for yield plant^{-1}. Parent IS 31651 had positive and significant GCA effects for grain yield plant^{-1} and a good combiner, while IS 28614, IS 24462 were poor combiners since it had negative GCA effects. Therefore, in the future, the incorporation of parents BJV-44, IS 26025, IS 31651 for grain yield panicle^{-1} in sorghum breeding programme may be worthwhile.

Estimates of SCA effects

Estimates of SCA effects for the nine traits that showed significant mean squares given in Table 5. M35-1 x IS 28614 showed negative and significant SCA effects and IS 24462 x IS 26025, IS 31651 x IS 26025, IS 31651 x IS 28614, 104B x IS 26025 had negative SCA effects for days to flowering indicating that these crosses had flowered earlier than what would have been 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.

Crosses such as 104B x IS 26025 and M35-1 x IS 28614 had a significant negative SCA effects for days to maturity followed by crosses 104B x BJV-44, BJV-44 x M35-1, IS 31651 x IS 28614 and IS 24462 x IS 26025 having negative but non-significant SCA effects, indicating that these combinations of parents were responsible for earliness in maturity. The high positive significant SCA effect was displayed by high x low combination (IS 28614 x IS 24462). It seemed that IS 24462 having genes for lateness than IS 28614 as these two parents stand at opposite ends with respect to this trait. Other crosses including IS 28614 x IS 24462, BJV-44 x IS 26025 and 104B x IS 24462 had significant and positive SCA values. This showed combination of these parents for lateness in maturity.

Three crosses IS 28614 x IS 24462, IS 31651 x IS 26025 and IS 24462 x IS 26025 had significantly reduced plant height since they had significant negative SCA effects while the remaining crosses including 104B x BJV-44, 104B x M35-1 and BJV-44 x M35-1 had non significant SCA effects. However, five crosses 104B x IS 24462, BJV-44 x IS 24462, BJV-44 x IS 26025, M35-1 x IS 31651 and IS 28614 x IS 26025 showed significant positive SCA effects for plant height. It can be concluded that combinations of these parents resulted in tall plant height. Umakanth *et al.* (2002) reported in sorghum that negative SCA effects of the combination is because of either both or one parents with low general combining ability.

Two crosses with significantly positive SCA effects for panicle length, panicle width and panicle weights were BJV-44 x IS 26025 and M35-1 x IS 24462. 104B x M35-1, BJV-44 x M35-1 and IS 24462 x IS 26025 showed significant negative SCA for panicle length, panicle width and panicle weight. Most of the crosses involved at least one parent with high general combining ability.

Table 5. Estimates of specific combining ability effects of parents for yield and its attributing traits in sorghum

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g)	Primaries panicle^{-1}	Yield plant^{-1} (g)	100 seed weight (g)
104B x BJV-44	-1.14	-4.78	-31.6	-1.65	-0.54	-8.627 *	-10.31	-0.67	-0.31
104B x M35-1	4.22	4.84	-35.50	-4.10 *	-1.22*	-3.257	-5.79	0.20	-0.09
104B x IS 31651	-2.33	5.28	24.86	1.84	0.91	9.59 *	-3.74	6.20 *	0.22
104B x IS 28614	3.25	4.43	12.41	2.26	0.76	0.27	6.09	-1.94	-0.46
104B x IS 24462	8.22	10.67 *	40.00 *	-1.38	0.65	7.30*	9.75	2.98	0.23
104B x IS 26025	-4.81	-11.53 *	35.67	3.09	-0.81	3.07	10.38	0.54	0.35
BJV-44 x M35-1	7.11	-5.16	-19.21	-3.40*	-1.22*	-8.70*	0.764	-6.03*	-0.48
BJV-44 x IS 31651	-4.44	-3.38	-3.84	-2.62	0.58	3.81	-1.85	10.64**	0.25
BJV-44 x IS 28614	2.14	0.43	5.38	2.30	0.93	2.83	0.98	-5.11	-0.32
BJV-44 x IS 24462	3.11	-1.32	69.63**	4.32*	0.49	6.52	7.31	-4.66	0.27
BJV-44 x IS 26025	3.74	9.80 *	63.63**	4.96**	1.85**	28.96**	8.61	8.40**	0.48
M35-1 x IS 31651	-0.07	-2.41	88.93**	2.76	1.40*	-2.47	-3.66	0.21	0.45
M35-1 x IS 28614	-11.48 *	-11.60 *	18.15	-2.64	-0.75	-2.13	8.84	-0.51	0.42
M35-1 x IS 24462	-1.85	6.96	-7.58	5.04 **	1.40 *	9.56*	3.83	1.97	0.17
M35-1 x IS 26025	-4.22	-0.90	14.75	0.68	0.07	12.33**	8.12	6.81*	0.33
IS 31651 x IS 28614	-5.37	-5.16	-9.80	0.63	-0.27	16.38**	11.22	4.20	0.04
IS 31651 x IS 24462	2.92	0.08	6.12	3.98*	0.28	6.07	20.21**	0.07	0.09
IS 31651 x IS 26025	-5.44	3.54	-41.54 *	3.63*	-1.18 *	0.52	10.17	-5.67*	-0.00
IS 28614 x IS 24462	11.18 *	9.89 *	-59.32**	2.24	0.03	-4.73	-6.54	3.82	0.05
IS 28614 x IS 26025	6.48	4.02	47.67 *	1.38	-1.84**	-5.79	4.68	2.33	-0.36
IS 24462 x IS 26025	-4.55	-8.40	-68.06 **	-6.75**	-1.11	-6.16	-9.76	-3.91	-0.43
S.E	4.18	4.15	18.09	1.56	0.55	3.47	5.54	2.57	0.25

* and ** significant at 5 and 1 per cent, respectively

For primaries panicle^{-1} only one cross, IS 31651 X IS 24462 showed significant positive SCA effects, while crosses 104B x BJV-44, 104B x M35-1 and IS 24462 x IS 26025 expressed negative SCA effects. 104B x IS 24462, 104B x IS 26025, IS 31651 x IS 28614 and IS 31651 x IS 26025 showed positive SCA effects.

With respect to SCA effects for grain yield plant^{-1} 104B x IS 31651, BJV-44 x IS 31651, BJV-44 x IS 26025 and M35-1 x IS 26025, exhibited positive and significant effects. Thakare *et al.* (2014) reported in sorghum that the crosses resulted from good combiner parents (*i.e.,* high x high) indicating the importance of non additive and additive type of gene actions. These crosses displayed the higher mean performance for the trait. Two crosses (BJV-44 x M35-1, IS 31651 x IS 26025) showed negative and significant SCA effects for the trait.

For 100 seed weight there were no significant crosses in either direction. Crosses BJV-44 x IS 26025, M35-1 x IS 31651 and M35-1 x IS 28614 exhibited positive SCA.

It was observed that significant and positive SCA effects were associated with crosses of high mean performance. Patil and Khute (2015) reported in sorghum that 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.

Estimates of variance components

The estimates of variance components due to general combining ability and specific combining ability are presented in Table 4. Majority of the characters showed higher proportion of *SCA* variance (more than two times) than *gca* variance indicating prominence of non additively for these characters. High specific combining ability was probably due to adequate genetic diversity in the material used. High *sca* variance for these characters were also reported by earlier workers Thakare *et al*. (2014) for grain yield per plant, Patil and Khute (2015) for panicle components, Ghorade *et al.* (2017) for plant height, Kalpande *et al.* (2016) for earliness.

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. 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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