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COMBINING ABILITY STUDIES FOR YIELD, EARLINESS AND DROUGHT PARAMETERS OF *RABI* SORGHUM (*SORGHUM BIOCOLOR* (L.) *MONECH*) PARENTAL LINES AND HYBRIDS

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ABSTRACT
The experiment was confined to fifteen rabi sorghum hybrids (*Sorghum bicolor* (L.) Moench), developed by crossing three females lines (M-35-1, Phule Anuradha, Parbhani Moti) and five testers (10538, 4189, 10515, 10704, 10593). These hybrids along with check (SPV 1595) and parents were evaluated to study combining ability for 12 yield attributing characters during *rabi* 2013-14 at Sorghum Research Station, VNMKV, Parbhani. The results revealed, presence of significant differences due to parents, crosses, parents vs crosses and line x tester for almost all the traits. The ratio of $á^2$gca: $á^2$sca variance for general and specific combining ability was less than unity for all the characters. The female line Phule Anuradha and tester, 10593 and 10515 were best general combiners for grain yield and fodder yield. For early maturity and drought parameters, line M-35-1 and Phule Anuradha showed significant gca effects in desirable direction. Significant sca effects were observed in crosses Phule Anuradha X 10515 and Parbhani Moti X 10704 (7.85 and 6.66) for grain yield/plant and Phule Anuradha x 10704 (20.06) for fodder yield/plant. Two crosses, M-35-1 X 10515 and Parbhani Moti X4189, exhibited significant SCA effects in desirable direction for days to 50% flowering. Hence it can be conclude that the parental lines Phule Anuradha, M-35-1 and testers; 10515 and 10593 has scope for breeding high yielding genotypes with early maturity duration adaptable to dry land farming.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Monech) is a third important cereal crop after rice and wheat in India and grown during both rainy and post rainy season for food fodder and feed. Sorghum covers 9.4 million ha. area with production and productivity of 5.53 and 0.77 tone/ha. post-rainy sorghum is predominantly grown in states of Maharashtra, Karnataka, Andhrapradesh and Tamilnadu (Seetharama *et al.*, 2003) with an average productivity of 719 kg per ha. The yield levels of rabi sorghum are lower as compared to kharif. Hybrid vigor and its commercial exploitation have paid rich dividends in *kharif* sorghum leading to quantum jump in sorghum production (Rana *et al.*, 1997), where the progress in *rabi* sorghum is limited. The lower yields are mainly due to various biotic and abiotic stresses. Also the phenomenon of heterosis has not been exploited to the full extent in *rabi* sorghum. There is need for critical studies on combining ability and heterosis involving diverse sources of germplasm and landraces. Combining ability analysis provides guideline to plant breeder in choosing parents for hybridization to isolate desirable recombination from segregating population and to identify the potential crosses for exploitation of heterosis. It would also help to define the pattern of gene effects in the expression of quantitative traits (Goyal and Kumar, 1991). Selection of parents on the basis of their phenotypic performance alone is not a sound procedure since phenotypicaly superior lines may yield poor recombination. It is therefore, essential that parents should be chosen on the basis of their genetic value (Krupkar *et al.*, 2013).The studies on selection of parents on the basis of their combining ability have been successfully made in sorghum (Maheshwari *et al.*, (1993), Prabhakar *et al.*, (2013), Ghorade *et al.*, (2014) Jain and Patel (2014) and Kalpande e*tal* 2015). As rabi sorghum is an important component of dry-land farming in these states, there is need to develop new varieties with high yield potentials along with stress tolerance and early maturity. Therefore present investigation has been made to identify the parents and recombination with good combining ability to mitigate the stress conditions.

MATERIALS AND METHODS

Fifteen F1 *rabi* sorghum hybrids were produced during rabi 2013 by mating three widely adopted varieties viz., M-35-1, Phule Anuradha and Parbhani moti as female lines with five high yield potential testers viz.,10515, 10593, 10538, 10704 and 4189 in Line x tester mating design. These Fifteen *rabi* sorghum F_1 along with parents and check SPV- 1595 were evaluated in randomized block design with two replications during *rabi* 2014 for grain, fodder yield and their drought parameters at Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.).row to row and plant to plant distance of 45 cm x 15 cm was maintained. Recommended dose of fertilizer; 60:40:0 kg NPK/ ha was applied. Observations were recorded on five randomly selected plants in each entry from each replication for the following twelve characters viz., days to 50 % flowering, panicle length (cm), panicle breadth (cm), number of primaries, number of grains per primaries, grain yield per plant (gm), fodder yield per plant (gm) harvest index, leaf area (cm2), number of leaves, total chlorophyll content and relative water content (%). The data for al the traits was subjected to combining ability analysis suggested by Kempthorne (1957). Test of significance was applied as per Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The analysis of variance for line x tester design indicated significant differences due to the parents and crosses for most of the characters under study. The significant variances due to parents vs crosses indicated occurrence of substantial heterotic response for almost all the traits except panicle breadth, number of leaves per plant and plant vigor. Kenga (2004) also reported significant mean square value due to parents vs. hybrids for grain yield, days to anthesis, plant height and inflorescence length showing high heterotic responses for these traits.

Lines showed significant variances for days to 50% flowering and plant height, while testers for number of grains per primaries and third leaf area. The component of line x tester was significant for most of traits except for fodder yield. High magnitude of variance due to lines against line x tester interaction for these traits indicated the presence of considerable variability among female lines. In most of the other traits viz., panicle length, number of grains per primary, harvest index, third leaf area, number of leaves per plant, chlorophyll content and plant vigour presence of considerable variability was due to line x tester interaction. These results are in agreement with those published earlier for days to 50 per cent flowering, plant height, panicle length and grain yield per plant, (Maheshwari *et al.*, 1993) days to 50 per cent flowering and grain yield per plant (Veerabadhiran *et al.*, 1994) and days to 50 per cent flowering, plant height, grain yield per plant and test weight (Khapre *et al.*, 2000a).

The estimates of components of variance for sca were larger for all the characters indicating predominance of non additive gene action. The ratio of variance due to general and specific combining ability ranged from -0.01 for third leaf area to 0.69 for relative water content (Table 2).

Predominance of non-additive gene action for days to 50 % flowering and 100 grain weight was reported by Badhe and Patil (1997) and Ramkrishnan (2000), for leaf area index by Sanghi and Monpara (1981), for panicle length (Pillai *et al.*1995), for number of leaves per plant and number of grains per plant (Manickam and Das, 1995a) and for grain yield per plant (Subbarao and Aruna, 1997). Khandelwal *et al.* (2004) and Kenga *et al.* (2004) observed non additive gene action for grain yield, days to anthesis, plant height, inflorescence length, threshing percentage, test weight and fodder yield and predicted possibility of improving these traits through heterosis

Table 1: ANOVA for line x tester analysis

Sr. no.	Genotypes	d.f.	Days to 50% flowering	Panicle length (cm)	Panicle breadth (cm)	No. of primaries	No. of grains / primary	Grain yield/ plant (gm)	Fodder yield/ plant (gm)	Harvest index (%)	Leaf area (m2)	No. of chlorophyl l leaves/ content (%)plant	Relative Water Content (%)
1	Replications	1	0.54	0.29	0.078	3.67	9.58	0.12	95.57	2.90	743.13	0.10 2.51	4.60
2	Genotypes	22	20.93**	7.44**	1.56**	155.89**	359.72**	126.87**	570.60**	88.34**	4216.16**	1.19* 106.71**	37.23**
3	Crosses	14	17.80**	9.53**	1.85**	174.15**	399.26**	143.18**	705.75**	92.42**	0.942**	1.62** 126.54**	45.83**
4	Parents	7	15.85**	1.93	1.14**	92.99**	90.49*	22.49*	335.27**	23.00	7071.99**	0.42 7.72*	20.88
5	Parents vs. Cross	1	100.27**	16.81**	0.33	340.51**	1690.76**	629.19**	325.74*	488.59**	2327.31**	0.41 522.06**	31.28
6	Lines	2	77.20*	8.10	0.75	441.70	251.43	90.51	1016.84	18.21	1750.83	0.00 93.61	145.60*
7	Testers	4	4.46	4.60	3.87	131.88	911.66*	278.18	933.10	92.01	2535.90**	0.45 228.22	26.91
8	Line x tester	8	9.61**	12.35**	1.12**	128.40**	180.01**	88.84**	514.30	111.18**	3409.90**	2.62** 83.93**	30.35*
9	Error	22	2.08	1.67	0.18	13.35	25.58	7.82	61.24	10.42	679.96	0.29 10.92	10.52

GCA 0.43 -0.14 0.038 2.42 11.62 2.88 10.15 -0.99 -25.81 -0.052 2.25 0.572; SCA 3.76 5.34 0.468 57.52 77.21 40.51 22.65 -3.19 1336.7 1.08 36.50 -0.821 * Significant 5 per cent level; ** Significant 1 per cent level

Table 2: General combining ability effects (GCA) for yield and yield parameters

Sr. no.	Genotypes	Days to 50% flowering	Panicle length (cm)	Panicle breadth (cm)	No. of primaries	No. of grains / primary	Grain yield/ plant (gm)	Fodder yield/ plant (gm)	Harvest index (%)	Leaf area (m2)	No. of Leaves/ plant	Chlorophy llContent (%)	Relative Water Content (%)
	Lines												
1	M-35-1	-1.80**	0.95*	-0.13	5.90*	2.43	-2.71**	-6.11*	0.34	-8.88	0.00	3.53**	3.36*
2	Parbhani Moti	3.20**	-0.82	-0.18	1.30	-5.76**	-0.51	-5.52*	1.14	15.20	0.00	-1.77	-4.14**
3	Phule Anuradha	-1.40**	-0.13	0.31*	-7.20**	3.33	3.23**	11.39**	-1.48	-6.31	0.00	-1.75	0.77
	SE +	0.45	0.40	0.13	1.15	1.59	0.88	2.47	1.02	8.24	0.21	1.04	1.02
	Tester												
1	10538	0.43	1.26*	0.07	-4.90**	-4.66*	0.72	5.37	-1.13	-1.78	-0.13	5.38**	1.61
2	4189	-0.23	-2.27	-1.07**	-1.23	-12.33**	-6.92**	-19.39**	-0.77	-32.55**	0.36	-6.61**	-2.12
3	10515	1.10	0.47	1.01**	7.60**	16.66**	3.41**	6.60	1.19	23.53*	-0.30	6.16**	1.11
4	10704	-0.06	-0.54	-0.45*	-2.67	-8.66**	-6.39**	-4.83	-5.01**	2.64	0.20	-6.28**	2.47
5	10593	-1.23	-0.93	0.44*	0.67	9.00**	9.18**	12.25**	5.73**	8.16	-0.13	1.35	1.86
	SE +	0.59	0.52	0.17	1.49	2.06	1.14	3.19	1.31	10.64	0.27	1.34	1.32

Table 3: Specific combining ability effects (SCA) for yield and yield parameters

Sr. no.	Genotypes	Days to 50% flowering	Panicle length (cm)	Panicle breadth (cm)	No. of primaries	No. of grains / primary	Grain yield/ plant (gm)	Fodder yield/ plant (gm)	Harvest index (%)	Leaf area (m2)	No. of leaves/ plant	chlorophyll content (%)	Relative Water Content (%)
1	M-35-1 x10538	-1.53	-2.88**	-0.61	-9.90**	8.56*	3.64	7.02	0.01	-40.4*	1.33*	-5.48*	-0.31
2	M-35-1 x4189	3.13**	2.80**	-0.06	2.93	10.26**	1.66	-3.56	2.81	-14.1	-1.16*	-4.18	-4.56
3	M-35-1 x10515	-2.70*	0.25	0.70*	3.10	-0.76	-9.40**	8.92	-13.45**	-41.1*	-0.50	3.03	3.82
4	M-35-1 x10704	1.96	-2.22*	-0.13	5.76*	2.56	2.36	6.73	1.35	50.5*	0.50	-4.61	-0.58
5	M-35-1 x10593	-0.86	2.04*	0.11	-1.90	-0.10	1.73	-19.22**	9.27**	45.0*	-0.16	11.25**	1.63
6	P.Moti x10538	1.46	2.70*	0.01	5.20	-6.23	-6.44**	-20.06**	0.31	38.3	-0.16	5.88*	-3.58
7	P.Moti x4189	- 2.36*	-1.80	0.28	10.96**	-6.06	-1.05	6.32	-3.73	1.58	-0.83	0.92	2.37
8	P.Moti x10515	1.30	1.14	0.50	2.70	-7.56	1.55	-10.62	6.50*	14.8	0.00	-1.25	0.22
9	P.Moti x10704	-1.03	0.16	0.11	-3.63	3.76	6.66**	13.32*	2.26	-41.4*	-1.50**	1.73	3.50
10	P.Moti x10593	0.63	-2.20*	-0.88	6.70*	10.10*	-0.72	11.07	-5.34*	-13.2	0.83	-7.29**	-2.51
11	P.Anuradha x10538	0.06	0.18	0.63	4.70	-2.33	2.79	13.03*	-0.32	2.10	-1.16*	-0.39	3.90
12	P. Anuradha x4189	-0.76	-1.00	-0.21	8.03*	10.33*	-0.61	-2.75	0.92	12.5	0.33	3.25	2.19
13	P. Anuradha x10515	1.40	-1.40	-1.20**	-5.80	8.33*	7.85**	1.72	6.95**	26.2	0.50	-1.77	-4.05
14	P. Anuradha x10704	-0.93	2.06	0.01	-2.13	-6.33	-9.02**	20.06*	-3.61	-9.07	1.00	2.87	-2.91
15	P. Anuradha x10593	0.23	0.15	0.76*	-4.80	-10.10**	-1.01	8.05	-3.93	-31.7	-0.66	-3.96	0.87
	SE ±	1.02	0.57	0.30	2.58	3.57	1.97	5.53	2.28	18.43	0.47	2.33	2.29

breeding.

However predominance of additive gene action has also been reported by Prabhakar 2002, Nayeem and Bapat (1984). Rojas and Sprague (1952) reported that the variances for specific combining ability effects become relatively more important than variances for specific combining ability effects when the lines based under tests had subjected to previous testing and selections. Probably the high level of male female interaction may contribute to non additive gene action.

General combining ability (GCA) effects.

The estimates of GCA effects revealed that parental line Phule Anuradha among females and 10515 among testers were the best general combiner for grain yield and its attributing traits.

Significantly positive gca effects for grain yield per plant (3.23), fodder yield per plant (11.39) and panicle breadth (0.31) was observed in line Phule Anuradha , for panicle length (0.95) and number of primaries (5.90) in M-35-1. Among testers 10515 showed significantly positive gca effects for grain yield per plant (3.41) and its parameters viz., number of grains per primary branch (16.66), number of primaries (7.60) and panicle breadth (1.01). Significantly highest positive gca effect for grain yield (9.18) and fodder yield (12.25) was observed in tester 10593.

In general, good combiners for grain yield also had good or average combining ability for one or more of the yield components but not for all the traits. Kalpande *et al*., 2015 also reported significant gca effects for yield along with other component traits *i.e*. plant height, number of primaries per panicle, number of grains per panicle and 1000 grain weight in best combiner line AKMS 47. He also stated that it is not always possible to produce line showing significant GCA effects for all the traits together. In most of the parents high GCA effects were associated with high per se mean for yield and yield components. These results are in agreement with the results reported by Pillai *et al*. (1995), Badhe and Patil (1997), Khapre *et al*. (2000).

Female lines M-35-1 (-1.80) and Phule Anuradha (-1.40), exhibited significant and negative GCA effects for days to 50 % flowering. The lines Parbhani Moti (3.20) exhibited significant and positive GCA effects while none of the tester recorded significant GCA effects. Negative GCA effect for days to 50 per cent flowering in parents is desirable to breed early maturity hybrid. Premalatha *et al*. (2006) and Prabhakar *et al*. (2013) reported the importance of negative significant GCA for days to flowering in developing early maturing hybrids in rabi sorghum.

Physiological traits such as prevention of fatal relative water content and high cell membrane stability are well defined component of adaptation to water deficit in sorghum (Prema Chandra *et al*. (1989). Beltrano *et al*. (1999) also reported loss of chlorophyll, flag leaf yellowing and grain pre maturation due to severe drought stress during post flowering stages. In present study for drought parameters like chlorophyll content and relative water content line; M-35-1 had shown significantly positive gca effect and negative gca effect for leaf area showing tolerance of this line for stress condition.

Among testers 10515 (5.38) and 10538 (6.16) had shown significantly positive gca effects for chlorophyll content. However for relative water content none of the tester showed significant gca effects. For third leaf area tester 4189 showed significantly negative gca effects (-32.55) and 10515 showed significantly positive gca effect (23.53). Taye *et al*. (2008) reported the line Su Cr 57 1/1, with early flowering, excellent panicle exertion and PDL 16 with large number of leaves and excellent panicle exertion are associated with drought tolerance. Harer and Bapat (1982) stated that the per se performance of the parents with the nature of combining ability provide the criteria for the choice of parents for hybridization on this basis, the parents performing well for both per se performance and gca effects can be considered as good parents.

Specific combing ability (SCA) effects

The mean performance, specifc combining ability effects and heterosis of the hybrids for grain yield per plant are presented in Table 3. The crosses Phule Anuradha X 10515 and Parbhani Moti X 10704 showed significant sca effects (7.85 and 6.66) along with higher heterobeltiosis and standard heterosis over the check SPV 1595 (75.76, 115.32 and 50.91, 67.50 respectively) and per se performance (45.25 g and 30.50 g) for grain yield/plant.

Out of 15, three crosses; Phule Anuradha x 10704 (20.06), Parbhani Moti x 10704 (13.32) and Phule Anuradha x 10538 (13.03) recorded significantly positive SCA effect for fodder yield/plant. The latter two crosses have also recorded significant mean performance and heterotic effects, however the cross Phule Anuradha x 10704 had shown poor performance and heterosis. The parents with high sca, showed high X low and low X low combinations. But the parents with low gca effect for fodder yield per plant had shown significantly positive effect for plant height.

For days to 50% flowering, two crosses M-35-1 X 10515 and Parbhani Moti X4189, exhibited significant negative SCA effects which were high X low and low X low combinations. Breeding for early *rabi* sorghum verities and hybrids assume great significance in view of the crop grown under rain fed situation to overcome terminal drought stress (Prabhakar *et al.,* 2013)

The hybrids Phule Anuradha x 10515 with both the parents of high gca effects, might produce desirable segregants. Hence these hybrids may be desirable for biparental selection or intermating. Prabhakar *et al.,* (2013) reported that the combinations of poor X high and high X high combiners could result into the hybrids with high performance depending on the per se performance of the parents concerned. Premalata *et al*. (2006) and Ghorade *et al.,* (2014) also observed high X high ,low X high and low X low parental combinations in hybrids with high sca effects for grain yield per plant, 100 seed, number of leaves and grains per primary branch. She also reported low X low parental combinations might be suitable for selection in latter advanced generations.

For drought parameters crosses M-35-1 X 10593 and Parbhani Moti X 10538 showed significantly high sca effect for chlorophyll content , M35-1 X 10538 for number of leaves and crosses M35-1 X 10538, M-35-1 X 10515 and Parbhani Moti X 10704 showed significantly negative sca effect for third leaf area.

No significant differences were observed for relative water content. Mohammad *et al*. (2009) and TSuji *et al*. (2003) reported that drought tolerance in sorghum is associated with small leaf area however in drought condition optimum flag leaf area is important for photosynthetic activity. Early maturity, plant vigor and large number of leaves are related to drought tolerance (Taye *et al.,* 2008 and Ejeta *et al*. 1997). It is necessary to select crosses based on hetrosis and per se performance in addition to significant sca effects. So, the crosses Phule Anuradha X 10515 and Parbhani Moti X 10704 may be directly used to improve grain yield. While the crosses M-35-1 X 10593 had shown significant results for days to 50% flowering in desirable direction with higher sca effect for chlorophyll content, panicle length and non significant but positive sca effect for relative water content along with significant mean performance and high heterotic effect for most of the yield and drought parameter.

Thus the results from present investigation indicate, scope for utilizing parental lines; Phule Anuradha, 10515 and 10593 for breeding high yielding genotypes and M-35-1 and Phule Anuradha for developing early maturing genotypes. The cross combination Phule Anuradha X 10515, Parbhani Moti X 10704 and M-35-1 X 10593 may be advanced to further generations for selecting early maturity high yielding segregates, suited for stress conditions.

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