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Research Note

Heterosis studies for grain yield, fodder yield and their parameters in *rabi* sorghum hybrids (*Sorghum biocolor* (L.) Monech)

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Abstract
The present investigation involved the assessment of heterosis for grain yield and yield attributing traits in *rabi* sorghum (*Sorghum bicolor* (L.) Moench.) hybrids by line x tester analysis. Parental material (three females and five males) was planted to undertake crossing programme following line x tester mating design and the seeds of fifteen hybrids were obtained. The experiment on line x tester was confined to fifteen hybrids with eight parents i.e. three female and five males and one check (SPV-1595) by taking ten yield contributing characters. The high heterotic effects and the highest per se performance for grain yield and its attributes were noted in the crosses Phule Anuradha x 10593 and Phule Anuradha x 10515. The hybrid M-35-1 x 10593, Phule Anuradha x 10593 have high mean and high heterosis for fodder yield and other important yield parameters. Testers 10515 and 10593 and crosses Phule Anuradha x 10515, Phule Anuradha x 10538 and M-35-1 x 10593 show higher chlorophyll content. The hybrids showing high per se mean and higher heterosis may be tested at multilocations to study their stability performance for yield and yield contributing traits.

Key words
Sorghum, Heterosis, line x tester analysis.

Sorghum (*Sorghum bicolor* (L.) Monech) is an important staple food for more than 500 million people worldwide. It is the fifth most important cereal following rice, wheat, maize and barley across the world, which is mostly cultivated in the arid and semi-arid tropics for its better adaptation to various stresses. Sorghum is unique to adopt to environmental extremes of abiotic and biotic stress. So this makes the crop to minimize the risk and enables to fit to a sustainable and economically profitable dry land production system. Hybrid vigour and its commercial exploitation have paid rich dividends in *Kharif* sorghum leading to quantum jump in sorghum production. However, the progress in *rabi* sorghum is limited and there is a need for critical studies on combining ability and heterosis involving diverse source of germplasm and land races. The heterosis in sorghum hybrids has been reported from 9.7 to 50 per cent by several workers. Subsequently Rana *et al.* (1977) reported heterosis in popularly grown sorghum hybrids *viz*., CSH-5 (53.4%), CSH-9 (52.6%), CSH-11 (35.0%) and CSH-14 (39.0%). They reported the genetic gain from 7.02 to14.0% in early hybrids and 9.02 to 26.0% in medium group hybrids over the first commercial hybrid CSH-1 released for cultivation in India way back in 1964. Heterosis in sorghum has been reported by several workers including Harer and Bapat (1982), Hanvy *et al.* (2000) and Kulkarni and Patil (2004). The information on yield, growth components and physiological characters is important to improve grain yield, plant type and selection of better hybrid.

The present investigation was undertaken in sorghum (*Sorghum bicolor* (L.) Moench) at Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.) during *rabi* 2013. Elight 15 *rabi* sorghum F_1 along with parents (Parbhani Moti, M-35-1 and Phule Anuradha) and five testers (10515, 10593, 10538, 10704 and 4189) and check SPV- 1595 evaluated in randomized block design during *rabi* 2013-2014 for grain, fodder and their component trait. The row length was 4 m with 45 cm x 15 cm spacing between and within rows. Observations were recorded on five randomly selected plants in each entry from each replication. Observations were recorded for the ten characters viz., days to 50 % flowering, plant height (cm), number of leaves per plant, leaf area (cm^2), panicle length (cm), panicle breadth (cm), grain yield per plant (gm), fodder yield per plant (gm), chlorophyll content (%) and relative water content (%). Heterosis over mid parent was calculated as per usual procedure whereas heterobeltiosis was calculated as per suggested by Fonesca and Patterson (1968).

The analysis of variance revealed that variation among the genotypes was highly significant for all the characters. Lines showed significant variances for days to flowering and plant height while testers were non-significant. The component of line x tester variance was significant for most of traits except 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, panicle breadth, leaf area, number of leaves per plant, relative water content, days to flowering and plant height, presence of considerable variability was due to line x tester interaction. These results are in agreement with those published earlier 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.,* 2000). Mean performance of male parents, female parents and their crosses is represented in Table 1. Crosses with their mid parent and better parent heterosis are represented in Table 2. Higher heterotic effect for grain yield per plant was observed in the crosses involving Phule Anuradha, and Parbhani Moti as the female parents and 10593, 10515 and 10538 as the male parents. The manifestation of seed yield heterosis over mid parent and better parents ranges from -23.84 % (Phule Anuradha x 10704) to 84.26% (Phule Anuradha x 10515) and -28.01% (Phule Anuradha x 10704) to 75.76 % (Phule Anuradha x 10515), respectively. For fodder yield, heterosis over mid parent and better parent ranged from -16.97 % (M-35-1 x 4189) to 37.01 % (Phule Anuradha x 10538), respectively. For relative water content, average heterosis ranged from -8.28 % (M-35-1 x 4189) to 7.86 % (Phule Anuradha x 10538) and heterobeltiosis ranged from -11.97 % (Parbhani Moti x 10538) to 4.60 % (M-35-1 x 10515). For chlorophyll content, average heterosis ranged from -3.95 % (Parbhani Moti x 10593) to 48.60 % (M-35-1 x 10593) and better parent heterosis ranged from -9.02 % (Parbhani Moti x 10593) to 46.10 % (M-35-1 x 10515). Most of the hybrids showed significant negative heterosis for days to 50 % flowering and days to maturity which is desirable to produce early flowering hybrids. Almost all the hybrids based on Phule Anuradha recorded significant heterosis for earliness, suggesting use of this line to breed short duration hybrids. Maheshwari *et al.* (1993), Prabhakar (2001), Tiwari *et al.* (2001) and Premalata *et al.* (2006) also obtained negative heterosis for days to 50% flowering. High heterotic effect for fodder yield was observed in Phule Anuradha x 10538, M-35-1 x 4189, M-35-1 x 10593, Phule Anuradha x 10515 and Phule Anuradha x 10593 over mid parent and better parent. The cross Parbhani Moti x 10593, M-35-1 x 10515 showed positive heterosis for plant height, number of leaves and leaf area which contribute to fodder yield. The hybrids based on female lines, Phule Anuradha and M-35-1 and testers, 10593, 10515 and 10538 showed high heterotic effect for fodder yield. Bhatt Arun (2008), Tarique *et al* (2012) and Prakash *et al*. (2010) also recorded heterobeltiosis and standard heterosis for fodder yield.

The range of mid parent heterosis and heterobeltiosis and number of hybrids showing significant heterosis are presented in Table 3. Heterosis for grain yield is due to simultaneous heterosis in more than one components of yield. In the present study average heterosis and better parent heterosis for yield and its attributing traits are positive and significant. Panicle length is an important yield component trait. Significant positive average heterosis and heterobeltiosis were observed in five and four crosses, respectively. Panicle breadth is also important yield attributing character and four and six hybrids showed significant positive average heterosis and better parent heterosis for this character and these results are in conformity with Kaul *et al*. (2003) and Hemalatha *et al.* (2003).

Heterosis for end product *i.e*., fodder yield is being manifested as the cumulative effect of heterosis for the component traits. In the present investigation, the elaborative study of 15 crosses revealed this fact as most of crosses showed significant mid parent and better parent heterosis for fodder yield and its component traits i.e., number of leaves per plant and leaf area. Two and five hybrids for number of leaves per plant, three and seven hybrids for leaf area and five and four hybrids for for fodder yield exhibited positive significant mid parent and better parent heterosis, respectively. Similar finding was also reported by Jey Prakash and Das (1994) and Desai *et al*. (1985). Earliness is a desirable character that helps to develop early varieties. Significant negative mid parent heterosis and heterobeltiosis for days to 50% flowering was observed in 5 and 11 hybrids respectively. Plant height is desirable to develop semi dwarf high yielding varieties that will be lodging resistant and fertilizer responsive. Nine and eight hybrids exhibited significant negative mid parent and better parent heterosis for plant height. These findings are in conformity with Kaul *et al*. (2003). Physiological characters like total chlorophyll content and relative water content are contributing traits of yield characters. Seven crosses exhibited positive and highly significant average and better parent heterosis for total chlorophyll. Two and five hybrids exhibited positive and highly significant average and better parent heterosis for relative water content respectively. These findings are in accordance with Grewal *et al.* (2003) and Deshpande *et al.* (2003).

The hybrids Parbhani Moti x 10704, M-35-1 x 10593, Phule Anuradha x 10593 and Phule Anuradha x 10515 having high mean and high heterosis were identified superior for most of the grain yield, fodder yield, physiological and quality characters, which could be utilized commercially for the exploitation of heterosis of these characters.

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Table 1. Mean performances of parents, hybrids and check for grain and fodder yield and yield parameters.

Genotypes	Days to 50% flowering	Plant height (cm))	No. of leaves per plant	Leaf area (cm^2)	Panicle length (cm)	Panicle breadth (cm)	Grain yield/ plant (gm)	Fodder yield/ plant (gm)	Chlorophyll content (%)	Relative water content (%)
Female (lines)										
M-35-1	74.50	187.50	12.50	483.47	17.60	7.30	21.59	72.82	42.30	75.26
PARBHANI MOTI	76.50	183.00	12.50	526.49	15.65	7.90	22.82	81.46	40.65	69.91
PHULE ANURADHA	70.00	191.50	12.50	436.92	17.85	6.55	25.79	96.91	43.70	71.70
Male (testers)										
10538	78.00	167.50	12.00	428.37	18.20	6.65	23.57	82.25	41.50	77.00
4189	78.50	167.50	12.00	327.37	18.25	5.60	16.15	80.40	38.95	78.67
10515	78.50	177.50	11.50	395.34	19.05	7.90	23.32	95.00	41.15	78.60
10704	76.50	155.50	11.50	458.93	17.35	7.00	22.96	76.38	42.25	76.20
10593	75.50	166.50	11.50	454.44	17.95	7.05	27.64	111.51	45.45	77.76
Crosses										
M-35-1 x 10538	70.00	171.00	13.00	402.76	18.35	6.50	32.40	98.97	52.50	78.57
M-35-1 x 4189	74.00	203.50	11.00	338.91	22.50	5.90	22.76	63.61	41.80	70.59
M-35-1 x 10515	69.50	212.50	11.00	427.38	20.70	8.75	22.03	102.09	61.80	82.22
M-35-1 x 10704	73.00	207.50	12.50	498.15	17.20	6.45	23.99	88.47	41.70	74.22
M-35-1 x 10593	69.00	200.00	11.50	498.21	21.08	7.60	38.95	79.70	65.20	80.78
P.MOTI x 10538	78.00	191.00	11.50	505.58	22.15	7.05	24.51	72.45	58.56	67.79
P.MOTI x 4189	73.50	217.50	13.00	438.08	16.10	6.20	22.25	74.09	41.60	70.01
P.MOTI x 10515	78.50	206.50	11.50	507.47	19.80	8.50	35.20	83.10	52.20	71.11
P.MOTI x 10704	75.00	190.50	10.50	430.24	17.80	6.65	30.50	95.64	42.74	70.79
P.MOTI x 10593	75.50	200.00	12.50	463.92	15.05	6.55	38.70	110.48	41.35	69.12
P.ANURADHA x 10538	72.00	182.50	10.50	447.85	20.32	8.20	37.50	122.73	52.30	80.20
P.ANURADHA x 4189	70.50	182.50	12.50	427.50	17.60	6.20	26.43	82.17	43.95	74.76
P.ANURADHA x 10515	74.00	179.50	12.00	497.31	17.95	7.30	45.25	112.65	51.70	71.75
P.ANURADHA x 10704	70.50	176.00	13.00	441.10	20.40	7.05	18.56	79.42	43.90	69.29
P.ANURADHA x 10593	70.50	190.00	11.00	423.91	18.10	8.70	42.15	114.63	44.70	77.43
Checks										
SPV-1595	80.00	191.50	11.00	489.13	17.55	7.05	21.01	66.68	40.45	73.34
SE $\pm$	0.99	4.16	0.48	18.21	0.93	0.30	1.94	5.45	2.29	2.33
CD at 5%	2.92	12.19	1.42	53.27	2.73	0.88	5.96	15.95	6.72	6.84

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Table 2. Estimation of heterosis over mid parent and better parent for yield and yield parameters

Genotypes	Days to 50% flowering		Plant height (cm)		No. of leaves per plant		Leaf area(cm^2)		Panicle length (cm)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
M-35-1 x10538	-8.20**	-3.66	-3.66	0.82	6.12	4.00	-11.66*	-16.69**	2.51	0.82
M-35-1 x4189	-3.27	14.65**	14.65**	23.25**	-10.20	-12.00*	-1.75	-17.61**	25.52**	23.25**
M-35-1 x10515	-9.15**	16.44**	16.44**	8.66	-8.33	-12.00*	-2.74	-11.60*	12.96	8.66
M-35-1 x10704	-3.31	20.99**	20.99**	-2.27	4.17	0.00	5.72	3.04	-1.57	-2.27
M-35-1 x10593	-8.00**	12.99**	12.99**	17.44*	-4.17	-8.00	6.24	3.05	18.59*	17.44*
P.MOTI x10538	0.97	8.99**	8.99**	21.70**	-6.12	-8.00	5.90	-3.97	30.87**	21.70**
P.MOTI x4189	-5.16**	24.11**	24.11**	-11.78	6.12	4.00	2.61	-16.79**	-5.01	-11.78
P.MOTI x10515	1.29	14.56**	14.56**	3.94	4.17	-8.00	10.10	-3.61	14.12*	3.94
P.MOTI x10704	-1.96	12.56**	12.56**	2.59	12.50*	-16.00*	-12.68*	-18.28**	7.88	2.59
P.MOTI x10593	-0.66	14.45**	14.45**	-16.16*	4.17	0.00	-5.41	-11.88*	-10.42	-16.16*
P.ANURADHA x10538	-2.70	1.67	1.67	11.68	-14.29*	-16.00*	3.51	2.50	12.76	11.68
P.ANURADHA x4189	-5.05*	1.67	1.67	-3.56	-2.04	0.00	11.87	-2.16	-2.49	-3.56
P.ANURADHA x10515	-0.34	-2.71	-2.71	-5.77	0.00	-4.00	19.51**	13.82*	-2.71	-5.77
P.ANURADHA x10704	-3.75	1.44	1.44	14.29	8.33	4.00	-1.52	-3.89	15.91*	14.29
P.ANURADHA x10593	-3.09	6.15	6.15	0.84	-8.33	-12.00*	-4.89	-6.72	1.12	0.84
Minimum	-9.15	-2.71	-2.71	-16.16	-14.29**	-16.00**	-12.68	-18.28	-10.42	-16.16
Maximum	1.29	24.11**	24.11**	27.70	12.50	0.00	19.51	13.82	30.87	27.70

*, ** Significant at 5 and 1 per cent level, respectively

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Table 2. Contd…

Genotypes	Panicle breadth		Grain yield/ plant (gm)		Fodder yield/ plant (gm		Chlorophyll content (%)		Relative water content (%)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
M-35-1 x10538	-6.81	-10.96	43.49**	37.46**	27.64	20.33	25.30**	24.11*	3.20	2.03
M-35-1 x4189	-8.53	-19.18**	20.64	5.44	-16.97	-20.89*	2.89	-1.18	-8.28*	-10.26*
M-35-1 x10515	15.13**	10.76	-1.88	-5.53	21.67*	7.47	4.11**	46.10**	6.87	4.60
M-35-1 x10704	-9.79	-11.64	7.71	4.49	18.58	15.82	-1.36	-1.42	-2.00	-2.60
M-35-1 x10593	5.92	4.11	58.22**	40.89**	-13.52	-28.53**	48.60**	43.45**	5.57	3.88
P.MOTI x10538	-3.09	-10.76	5.68	4.01	-11.48	-11.91	42.57**	41.11**	-7.72	-11.97*
P.MOTI x4189	-8.15	-21.52**	14.20	-2.50	-8.45	-9.05	4.52	2.34	-5.76	-11.00*
P.MOTI x10515	7.59	7.59	52.55**	50.91**	-5.18	-12.53	27.63**	26.85**	-4.24	-9.54*
P.MOTI x10704	-10.74	-15.82*	33.22**	32.81**	21.18*	17.41	3.12	1.17	-3.11	-7.11
P.MOTI x10593	-12.37*	-17.09**	53.36**	39.99**	14.50	-0.93	-3.95	-9.02	-6.39**	-11.12*
P.ANURADHA x10538	24.24**	23.31**	51.94**	45.41**	37.01**	26.64**	22.77**	19.68*	7.86	4.15
P.ANURADHA x4189	2.06	-5.34	26.06*	2.50	-7.32	-15.21	6.35	0.57	-0.57	-4.97
P.ANURADHA x10515	1.04	-7.59	84.26**	75.76**	17.40*	16.24	21.86**	18.31*	-4.53	-8.72
P.ANURADHA x10704	4.06	0.71	-23.84*	-28.01*	-8.34	-18.05*	2.15	0.46	-6.30	-9.07
P.ANURADHA x10593	27.94**	23.40**	57.76**	52.47**	19.59**	11.76	0.28	-1.35	3.61	-0.43
Minimum	-12.37	-21.52	-23.84	-28.01	-16.97	-28.53	-3.95	-9.02	-8.28	-11.97
Maximum	27.94	23.40	84.26	75.76	37.01	26.64	48.60	46.10	7.86	4.60

*, ** Significant at 5 and 1 per cent level, respectively

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Table 3. Range of mid parents heterosis and better parent heterosis for yield and other characters and number of hybrids showing significant heterosis.

Sr. No.	Characters	Range		No. of hybrids showing desirable significant heterosis	
		MP	BP	MP	BP
1.	Days to 50 % flowering	-9.15 to 1.29	-11.46 to 0.00	5	11
2.	Plant height	-2.71 to 24.11	-8.80 to 18.85	9	8
3.	Number of leaves per plant	-14.29 to 12.50	-16.00 to 0.00	2	5
4.	Leaf area (cm2)	-12.68 to 19.51	-18.28 to 13.82	3	7
5.	Panicle length	-10.42 to 30.87	-16.16 to 27.70	5	4
6.	Panicle breath	-12.37 to 27.94	-21.52 to 23.40	4	6
7.	Grain yield per plant	-23.84 to 84.26	-28.01 to 75.76	10	9
8.	Fodder yield per plant	-16.97 to 37.01	-28.53 to 26.64	5	4
9.	Total chlorophyll content	-3.95 to 48.60	-9.02 to 46.10	7	7
10.	Relative water content (%)	-8.28 to 7.86	-11.97 to 4.60	2	5