Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 81 (2015) 31830-31834

ISSN: 2229-712X

Heterosis for Quality and Resistance Traits in Forage Sorghum [*Sorghum bicolor* (L.) Moench]

Pankaj Kumar, P.K. Shrotria, Girish Chandra and Shivji Singh

College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar-263 145, Uttarakhand, India.

ARTICLE INFO

Article history:

Received: 11 February 2015;
Received in revised form:
28 March 2015;
Accepted: 11 April 2015;

Keywords

Sorghum bicolor,
Heterosis,
Line x tester,
Quality and Resistance traits.

ABSTRACT

The magnitude of heterosis in fifty crosses (F_1s) made by crossing five sudan grass pollinators with ten cytoplasmic male sterile lines in a line x tester mating design in forage sorghum. Based on *per se* performance and heterotic response eleven crosses for resistance to shoot fly infestation over better parent and six crosses for total soluble solid, SP 55609 A x PC 8 for protein per cent, 2219 A x PC 8, 2219 A x CSV 15, MR 750 A_2 x CSV 15 for HCN content and ICSA 469 x PC 5 for IVDMD per cent were appeared best cross combinations for all three kinds of heterosis and could be used for commercial exploitation of good quality forage sorghum after multilocation testing.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] the fifth most important fodder crop of family *Poaceae*, is major source of feed, food and fodder throughout the world especially in arid and semi-arid tropics and also Northern and central part of India. For developing high yielding varieties or hybrids through hybridization, the choice of the right type of parents is of paramount importance. Improvement of sorghum quality is very important in meeting the demand of consumers for healthy and good quality. Most sorghum breeders feel that popular sorghum varieties in recent years are possessed with premium quality in terms of HCN content, TSS and digestibility. From many years, breeders have focused their attention on simultaneous improvement of yield and quality traits, but with limited success. High fodder yield with the good quality is more preferable by consumer. The importance of heterosis in developing high yielding forage sorghum hybrids is well documented but not is its importance in nutrirional aspects Maarouf and Nuha (2008).

Heterosis is an important tool for enhancing hybrid vigour for growth and yield traits. It can be expressed at morphological, physiological and molecular level. The better parent (heterobeltiosis), mid parent (relative heterosis) and check variety/hybrid (standard heterosis) estimated as percent increase and decrease of F_1 over better parent, percent deviation of the F_1 from its mid-parental value and percent increase and decrease of F_1 over standard variety, respectively. In hilly area irrigation is the major problem, where fodder also a problem for cattle's. Sorghum is drought tolerance crop is able to grow at reduced water level. With the higher fodder production the quality is also important aspects for cattle's feeding. In the present investigation the high protein per cent, digestibility, total soluble solid per cent and low HCN content and shoot fly infestation analyzed and to identify the best heterotic hybrid combinations based on their heterotic potential performance for quality aspects

Materials and Methods

The field experiments for present investigation were conducted at the Instructional Dairy Farm of the G.B. Pant University of Agriculture and Technology, Pantnagar (U.S. Nagar), India during *Kharif* seasons 2012 and 2013. The experimental materials consisted fifty F_1 crosses developed through line x tester mating design (Kempthorne 1957) between ten diverse *Sorghum bicolor* type CMS lines (female) and five *Sorghum sudanense /Sorghum bicolor* type forage sorghum pollinators (male). Three checks were also included to know the standard heterosis. The experimental material was planted in randomized block design with three replications. Each of 68 treatments were accommodated in 3.6 m^2 plot size (4 rows of 3m length spaced at 30 cm). Observations were recorded on qualitative and resistance characters of shoot fly infestation per cent, protein per cent, HCN content (ppm), total soluble solid per cent and *In-vitro* dry matter disappearance per cent.

The heterosis was worked out by using overall mean value of each hybrid for each character. The better parent (BP), mid parent (MP) and standard heterosis (SP) estimated as percent increase and decrease of F_1 over respective parents was calculated as per Fonseca and Petterson (1968).

$$\text{Heterosis over better parent (\%)} = \frac{\overline{F_{1i}} - \overline{BP_i}}{\overline{BP_i}} \text{ x } 100$$

$$\text{Heterosis over mid parent (\%)} = \frac{\overline{F_{1i}} - \overline{MP_i}}{\overline{MP_i}} \text{ x } 100$$

$$\text{Heterosis over standard/ check parent (\%)} = \frac{\overline{F_{1i}} - \overline{SP_i}}{\overline{SP_i}} \text{ x } 100$$

where,

$\overline{F_{1i}}$ = Mean of the particular F_1 for i^{th} character

$\overline{BP_i}$ = Mean of the better parent of the cross for i^{th} character

$\overline{MP_i}$ = Mid parental value i.e. mean of both the parents of cross for i^{th} character = $(\overline{P_{1i}} + \overline{P}_{2i})/2$

Tele:
E-mail addresses: vaidya.pankaj4@gmail.com

Table 1. The range of heterosis and number of crosses showing significant heterosis in desired direction for 5 qualitative and resistance characters in pooled analysis

Characters	Range of heterobeltiosis	Range of relative heterosis	Range of standard heterosis	Number of crosses showing significant heterosis (pooled) in desired direction		
				Heterobeltiosis	Relative heterosis	Standard heterosis
Shoot fly infestation (%)	-29.18 to 36.15	-19.50 to 48.86	-17.04 to 25.35	11	4	-
HCN (ppm)	-46.18 to 16.48	-43.05 to 56.24	-33.25 to 41.14	35	19	14
TSS (%)	-41.81 to 56.65	-36.62 to 58.94	-28.44 to 39.11	18	10	11
Protein (%)	-16.01 to 12.05	-14.77 to 18.28	-12.94 to 11.18	4	11	6
IVDMD (%)	-18.77 to 13.37	-16.45 to 13.47	-16.52 to 10.85	2	6	4

Table 2. Heterotic potential of five qualitative and resistant traits during pooled over years.

Cross	Shoot fly infestation (%)			Protein (%)			HCN content (ppm)			TSS (%)			IVDMD (%)		
	BP	MP	SD	BP	MP	SD	BP	MP	SD	BP	MP	SD	BP	MP	SD
L_1 x T_1	3.10	3.56	3.13	-14.59**	-2.77	-4.43	-0.48	5.96*	25.05**	0.92	8.96	-2.67	4.79	5.14	2.28
L_1 x T_2	-10.99	-7.30	-10.97	-11.47**	-5.37	-0.94	-34.18**	-10.56**	-27.35**	9.06	24.21**	39.11**	2.21	4.03	-0.90
L_1 x T_3	-13.18	-3.83	-13.16	-12.60**	-5.85	-2.20	-39.90**	-39.58**	-32.94**	18.43*	31.79**	14.22*	-6.01	-5.41	-7.69*
L_1 x T_4	7.59	7.87	7.62	-16.01**	-14.77**	-6.02	-46.18**	-43.05**	-33.25**	-2.65	-0.68	-2.22	4.25	4.57	1.71
L_1 x T_5	-0.82	1.80	4.60	-5.07	-2.39	6.22	-5.01	11.98**	4.85	14.22*	16.29**	14.22*	-8.93**	-8.75**	-11.70**
L_2 x T_1	-26.86**	-16.78**	-4.30	-5.07	5.45	0.45	-3.38	6.03*	21.42**	5.41	12.39	-13.33	-7.66*	-4.52	-3.53
L_2 x T_2	-15.71*	-1.04	10.29	-2.78	1.21	2.88	-25.06**	-0.33	-22.53**	-21.60**	0.22	0.00	-3.54	1.77	0.77
L_2 x T_3	-8.63	13.09	19.56	-13.50**	-9.23**	-8.47*	-5.43	-1.82	5.52	35.84**	40.30**	4.44	-3.47	-0.50	0.84
L_2 x T_4	-29.14**	-19.50**	-7.28	0.70	2.02	9.39*	-6.52*	1.97	15.93**	10.18	28.35**	10.67	-9.64**	-6.55*	-5.60
L_2 x T_5	-22.21**	-13.85*	1.79	3.38	3.41	9.39*	-20.04**	-8.29*	-17.34**	-4.44	11.11	-4.44	-13.69**	-10.31**	-9.84**
L_3 x T_1	-13.60**	1.03	20.56	-4.05	7.74*	4.02	-35.04**	-25.54**	-18.37**	-8.97	-0.49	-9.78	-1.55	-1.38	-3.58
L_3 x T_2	-18.40**	-1.68	13.85	-10.03**	-5.25	-2.47	-16.23**	7.65	-21.60**	-7.67	3.92	17.78*	-2.47	-0.25	-4.48
L_3 x T_3	-22.44**	-1.67	8.22	-11.45**	-6.00	-4.00	-3.46	5.01	7.73*	-8.97	2.53	-9.78	-2.44	-2.31	-4.19
L_3 x T_4	-28.25**	-16.24**	0.11	-5.92	-5.82	2.20	-24.70**	-14.17**	-6.61*	19.03**	19.82**	19.56**	8.25*	8.46**	6.02
L_3 x T_5	-18.93**	-7.66	13.11	-7.51*	-6.37*	0.27	4.59	14.85**	-2.11	9.33	9.82	9.33	-2.53	-1.85	-4.54
L_4 x T_1	15.96	17.12*	14.96	-8.79*	0.36	-5.53	3.22	11.86**	29.71**	16.76*	22.38**	-4.00	-3.74	-0.27	-6.05
L_4 x T_2	14.19	17.28*	10.97	-15.94**	-13.39**	-12.94**	16.40**	56.24**	23.69**	-24.04**	-4.18	-3.11	2.47	4.00	-4.11
L_4 x T_3	36.15**	48.86**	32.31	7.35*	11.50**	11.18**	16.48**	19.33**	29.97**	56.65**	58.94**	20.44**	1.37	5.33	-0.44
L_4 x T_4	4.59	5.83	4.07	-8.34*	-6.16	-0.43	-8.22**	-1.15	13.82**	14.16*	30.96**	14.67*	0.30	3.90	-2.14
L_4 x T_5	-6.11	-2.28	-0.99	-6.72	-5.74	-1.35	-24.52**	-12.41**	-19.79**	15.11*	31.81**	15.11*	0.62	3.72	-2.82
L_5 x T_1	17.05*	19.40**	16.04	12.05**	18.28**	6.08	-7.71**	-7.31**	15.98**	-19.25**	-13.57*	-23.56**	-6.31*	-3.34	-2.58
L_5 x T_2	-1.93	-0.26	-6.60	6.47	8.02*	3.78	-2.82	37.07**	21.08**	-21.25**	-9.60	0.44	-0.48	4.76	3.48
L_5 x T_3	10.48	19.68*	5.21	-1.28	-0.66	-5.37	5.34*	11.15**	31.25**	6.57	17.62*	0.89	-18.77**	-16.45**	-15.54**
L_5 x T_4	3.19	5.46	2.68	-3.23	3.41	5.12	-8.55**	-8.33**	13.95**	-11.50	-8.88	-11.11	-3.57	-0.50	0.26
L_5 x T_5	-1.40	3.62	3.98	-9.65**	-4.65	-4.45	-19.45**	-0.37	0.37	-21.33**	-19.18**	-21.33**	-2.89	0.69	0.97
L_6 x T_1	-9.32	-4.48	0.03	0.00	8.72*	0.88	-8.03**	-4.52*	24.74**	-27.80**	-21.08**	-28.44**	13.37**	13.47**	10.85**
L_6 x T_2	-16.08*	-8.50	-7.42	-0.40	1.31	0.47	-33.34**	-3.66	-9.59**	-35.89**	-27.84**	-18.22**	-6.51	-4.46	-8.59**
L_6 x T_3	-8.75	5.46	0.66	2.67	5.29	3.57	-3.70	5.67*	30.62**	7.17	20.71**	6.22	-12.13**	-11.94**	-13.70**
L_6 x T_4	-14.27	-9.86	-5.43	-7.76*	-4.34	0.20	-14.52**	-10.70**	15.94**	12.39	13.14*	12.89	-14.63**	-14.53**	-16.52**
L_6 x T_5	7.87	10.30	19.00	-5.87	-3.64	-0.45	-35.05**	-17.09**	-11.91**	-7.11	-6.70	-7.11	3.10	3.73	0.80
L_7 x T_1	-16.32**	-13.51	-17.04	-1.70	8.58*	2.69	-27.47**	-23.72**	1.09	-7.17	4.27	-2.22	0.92	4.51	5.75
L_7 x T_2	-6.02	-5.69	-12.88	-1.72	1.69	2.67	-16.70**	21.29**	16.11**	-13.24*	-4.96	10.67	-4.25	1.16	0.33
L_7 x T_3	1.11	8.19	-6.26	-3.24	0.92	1.08	1.26	12.47**	41.14**	0.84	16.59*	6.22	-10.69**	-7.80**	-6.42

L_7 x T_4	1.46	5.05	0.96	0.70	2.66	9.39*	-14.60	-9.62**	19.03**	1.69	4.10	7.11	-0.22	3.34	4.55
L_7 x T_5	18.87**	26.52**	25.35	-3.74	-3.16	1.80	-20.70**	2.22	10.54**	-5.06	-2.60	0.00	-4.77	-0.90	-0.22
L_8 x T_1	-4.51	-4.44	-5.34	-3.50	5.12	-2.22	-4.86	-2.27	26.25**	-18.57*	-13.42	-24.00**	-2.53	1.35	3.01
L_8 x T_2	16.64*	20.87**	15.45	6.20	8.26*	7.61*	-34.07**	-5.30	-12.50**	-26.48**	-15.09**	-6.22	1.70	7.88**	7.49*
L_8 x T_3	15.46	27.29**	14.28	0.02	2.79	1.35	2.00	10.82**	35.36**	3.81	13.84	-3.11	-7.99*	-4.62	-2.76
L_8 x T_4	10.52	10.82	9.98	-8.19*	-5.00	-0.27	-5.28*	-2.08	25.69**	-21.68**	-18.81**	-21.33**	-4.52	-0.71	0.91
L_8 x T_5	4.71	8.03	10.43	-3.32	-1.25	2.24	-27.77**	-8.52**	-4.14	-1.78	1.61	-1.78	-3.97	0.36	1.50
L_9 x T_1	2.98	3.94	4.01	10.11*	16.23**	4.22	-15.41**	-9.30**	22.85**	-20.83**	-10.59	-15.56*	-5.97	-3.57	-3.42
L_9 x T_2	7.53	12.51	8.61	6.74	8.31*	4.04	-25.18**	10.15**	8.66*	-41.81**	-36.62**	-25.78**	-11.90**	-7.80**	-9.51**
L_9 x T_3	-5.47	5.16	-4.52	2.66	3.31	-1.59	-25.41**	-15.63**	8.33*	-11.25	3.15	-5.33	4.07	6.40*	6.89*
L_9 x T_4	-9.97	-9.30	-9.07	-1.77	4.99	6.71	-6.21**	1.19	36.22**	-31.25**	-29.18**	-26.67**	3.06	5.71*	5.86
L_9 x T_5	-1.81	0.31	3.55	-2.06	3.36	3.57	-7.17**	21.40**	34.82**	-17.92**	-15.27**	-12.44	-6.36*	-3.48	-3.82
L_{10} x T_1	10.16	13.62	9.21	1.37	7.35*	-3.39	5.78*	12.92**	32.92**	-21.01**	-11.11	-16.44*	-8.76**	-4.28	-1.77
L_{10} x T_2	18.77*	19.43*	10.56	3.54	4.70	0.92	-17.28**	12.21**	-9.19**	-12.54*	-4.38	11.56	1.21	8.29**	8.97**
L_{10} x T_3	24.65**	33.63**	16.04	9.20*	9.51**	4.67	-12.42**	-11.70**	-2.27	10.08	27.49**	16.44*	-10.44**	-6.33*	-3.58
L_{10} x T_4	8.99	12.62	8.45	1.94	8.60**	10.73**	-32.49**	-28.38**	-16.28**	7.14	9.91	13.33	-17.28**	-13.21**	-10.94**
L_{10} x T_5	9.45	16.27*	15.42	-0.56	4.61	5.16	-9.97**	5.90	-1.17	-20.17**	-17.93**	-15.56**	-16.89**	-12.38**	-10.52**

*,** significant at 5 and 1 % probability levels, respectively

$\overline{P_{1i}}$ = Mean value of parent P_1 for i^{th} character

$\overline{P_{2i}}$ = Mean value of parent P_2 for i^{th} character

$\overline{SP_i}$ = Mean value of standard/ check variety

The significance of heterosis was tested by 't' test as

$$t = \frac{\text{Estimate of heterosis}}{\text{SE of estimate}}$$

The SE of estimate was calculated for mid parental heterosis, better parental heterosis and standard heterosis as follows:

SE for mid parental heterosis = $\sqrt{\frac{3EMS}{2r}}$

SE for better parent heterosis and standard heterosis = $\sqrt{\frac{2EMS}{r}}$

The significance was tested against 't' value from 't' Table of Fisher and Yates (1963) at error of freedom of ANOVA table at 5% and 1% levels of probability.

Results and Discussion

Variable magnitude of three types of heterosis *viz.*, better parent, relative and standard heterosis as exhibited by different cross combinations for all the characters indicated the presence of different degree of divergence in the parental materials. The range of heterobeltiosis, mid parent and economic heterosis varied from one character to another (Table1). The estimates of these three kinds of heterosis pooled over years are presented in (Table 2).

For shoot fly infestation per cent the estimates of pooled analysis over years, where eleven crosses showed significant negative heterosis for heterobeltiosis and four crosses 32 A_2 x PC 5, 32 A_2 x CSV 15, 32 A_2 x HC 260 and 11 A_2 x CSV 15 for mid parent heterosis but none of the cross could perform significantly better than check variety CSH 20 MF for this character. The estimates of heterosis over better parent, mid parent and standard check suggested that the preponderance of non additive gene action and role of over dominance for shoot fly resistance for this character in sorghum. These findings of the present investigation agree with the earlier reports Agarwal and Shrotria, (2005), Madhusudhana *et al.,* (2007), Bhatt, (2008), Pandey and Shrotria, (2012).

Pooled analysis for protein per cent indicated that four crosses SP 55609 A x PC 8, ICSA 293 x PC 5, ICSA 264 x PC 5 and MR 750 A_2 x PC 8 for better parent, eleven crosses for mid parent and six crosses for standard heterosis showed significant and positive heterosis. The cross SP 55609 A x PC 8 showed significant and positive heterosis for all the three types of heterosis. For quality character the protein content, where the positive estimates of heterosis are desired, relatively low amount of positive heterobeltiosis, mid parent heterosis and standard heterosis suggested that the presence of non additive gene action. Similar results were reported Agarwal and Shrotria (2005), Bhatt (2008), Paliwal (2012).

Heterosis estimates based on the pooled analysis over the years indicated thirty five, nineteen and fourteen crosses showed significant and negative heterosis for the heterobeltiosis, mid parent and standard heterosis, respectively for HCN content. Nine crosses showed significant estimates in desirable direction for all the three types of heterosis. The estimates of heterosis over better parent, mid parent and standard check suggested that the preponderance of non additive gene action and role of over dominance in negative direction for inheritance of HCN content in sorghum. These findings of the present investigation agree with the earlier reports of Mohanraj *et al.,* (2006), Paliwal (2012), Pandey and Shrotria (2012).

For *In-vitro* dry matter disappearance (IVDMD per cent) the pooled analysis over years revealed that the best cross combination were found two crosses 11 A_2 x CSV 15 and ICSA 469 x PC 5 for heterobeltiosis, six crosses for relative heterosis and four crosses ICSA 469 x PC 5, ICSA 276 x PC 6, ICSA 264 x PC 8 and MR 750 A_2 x PC 6 for standard heterosis showed significant and positive estimates of heterosis. The only one cross ICSA 469 x PC 5 was significant positive estimates for all three kinds of heterosis. The moderate heterosis showed for IVDMD character where significant positive estimates indicated that the non additive gene action was predominant. The results are similar to the findings of earlier workers Agarwal and Shrotria (2005), Bhatt (2008), Paliwal (2012), Pandey and Shrotria (2012).

Total soluble solid (T.S.S. per cent) exhibited the heterosis estimates based on the pooled analysis over the year it indicated eight, fifteen and nine crosses showed significant and positive heterosis for the heterobeltiosis, mid parent and standard heterosis, respectively. Six crosses showed significant estimates in desirable direction for all the three types of heterosis for this character. The estimates of heterosis over better parent, mid parent and standard check suggested that the preponderance of non additive gene action for T.S.S. character in sorghum. These findings of the present investigation agree with the earlier reports Agarwal and Shrotria (2005), Premalatha *et al.,* (2006), Bhatt (2008), Paliwal (2012), Pandey and Shrotria (2012), Rani *et al.,* (2013).

Conclusion

The objective of the investigation is to identify the superior and high heterotic hybrids for quality and resistance traits is concluded that based on *per se* performance and heterotic response eleven crosses for resistance to shoot fly infestation over better parent and six crosses for total soluble solid, SP 55609 A x PC 8 for protein per cent, 2219 A x PC 8, 2219 A x CSV 15, MR 750 A_2 x CSV 15 for HCN content and ICSA 469 x PC 5 for IVDMD per cent were appeared best cross combinations for all three kinds of heterosis. These hybrids could be used for commercial exploitation of good quality fodder after multilocation testing.

References

1. Kempthorne, D (1957). An introduction to genetic statistics. John Wiley & Sons. New York. pp. 468-471.
2. Fisher RA, Yates F 1963. Statistical Tables. Olever and Boyd. Edinburgh.
3. Fonseca S, Petterson, F (1968). Hybrid vigour in a seven parent diallel cross in common wheat. Crop Sci 8(1): 58-88.
4. Agarwal M, Shrotria PK (2005). Heterosis and inbreeding depression in forage sorghum [*Sorghum bicolor* (L.) Moench]. Indian J Genet 65(1): 12-14.
5. Mohanraj K, Gopalan A, Shanmuganathan M (2006). Genetic parameters for hydrocyanic acid content in forage sorghum [*Sorghum bicolor* (L.) Moench]. J Agric Sci 2(1): 59-62.
6. Premalatha N, Kumaravadivel N, Veerabadhiran P (2006). Heterosis and combining ability for grain yield and its components in sorghum [*Sorghum bicolor* (L.) Moench]. Indian J Genet 66(2): 123-126.
7. Bhatt A 2008. Studies on hetrosis and inbreeding depression in forage sorghum [*sorghum bicolor* (L.) Moench]. Agric Sci Digest 28(4): 258-261.

8. Maarouf I Mohammed, Nuha H Talib (2008). Heterosis and combining ability for Quality traits in forage sorghum. Australian J Basic and Applied Sci 2(1): 99-104.
9. Paliwal A (2012). Studies on combining ability and heterosis in forage sorghum [*Sorghum bicolor* (L.) Moench] hybrids developed on alternate cytoplasms, Ph.D. thesis, G.B. Pant University of Agriculture and Technology, Pantnagar. US Nagar, Uttarakhand India.
10. Pandey S, Shrotria PK (2012). Heterosis and inbreeding depression in forage sorghum [*Sorghum bicolor* (L.) Moench]. Forage Res 38(1): 35-39.
11. Rani C, Umakanth AV, Iraddi V, Tanmay VK (2013). Heterosis studies for ethanol yield and its related traits in F_1 hybrids of sweet sorghum [*sorghum bicolor* (L.) Moench]. Madras Agric J 100(1-3): 1-8.