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Research article

HETEROSIS STUDIES OF AROMATIC LINES FOR YIELD AND GRAIN QUALITY TRAITS IN RICE

Gonya Nayak. P, Sreedhar. M, Surender Raju. Ch, and Vanisree. S

Department of Genetics and Plant Breeding, College of Agriculture, Acharya N.G. Ranga Agriculture University, Rajendranagar, Hyderabad.

ABSTRACT: Sixteen crosses developed from four aromatic lines and four non scented testers were evaluated for various yield and grain quality traits to assess the heterosis of the crosses and to identify best combinations. The estimates of heterosis, heterobeltiosis and standard heterosis were variable among the crosses. Heterosis in desirable direction was recorded for important yield and quality attributes viz., Number of Panicles Plant^{-1}(69.57), Panicle Length (20.82), Number of Filled Grains Panicle^{-1}(30.14), 250 Grain Weight (23.12), Grain Yield plant^{-1} (89.25),Water Uptake (14.89), Alkali spreading value (45.32) and Protein (19.95). Some of these heterotic crosses have turned out to be best specific crosses and exhibited desirable *per se*. Among the heterotic crosses RNR 2354/BM-71(Number of panicles per plant, Panicle length), Ranbir Basmati/MTU-1010 (250 Grain weight, Protien), RNR2354/Sye632003 (Number of filled grains per panicle), Pusa 1121/MTU1010 (Grain yield), Yamini/MTU1081 (Water uptake) and Yamini/Sye632003(Alkali spreading value) were found to be superior, expressing heterosis, heterobeltiosis and standard heterosis in desirable direction. The results of the present study indicated the potential of these parental lines in the improvement of grain quality of rice hybrids.

Key words: Heterosis, Yield and Quality, Rice

INTRODUCTION

Aromatic rices constitute a small but special group which is considered as the best in quality. Popularity of such rices has been documented in the Orient and now becoming more popular in Middle East, Europe and United States. Although aromatic rices which are popular in world market are long grain types, majority of the Indian indigenous aromatic rices are small and medium grain types. With the advent of "Geographical Indications" under WTO regulations, basmati kind of aromatic rice is accepted internationally when it is produced from North-western part of India due to its location specific eating quality, thus necessitating research efforts to evolve scented rice genotypes suitable to local requirements. Successful application of biometrical procedures to understand genetics of quantitative characters helped the breeders to systematically plan for result oriented breeding programmes. The challenge of quality improvement also needs to be addressed by evolving cultivar genotypes that combined high yield potential with quality attributes meeting stringent national and international standards.

MATERIALS AND METHODS

The material for the present investigation comprised of eight parents and their corresponding 16 F_1crosses obtained following Line X Tester design (Kempthorne, 1957). The experiment was conducted in randomized block design with three replications at Rice Section, Agricultural Research Institute, ANGRAU, Rajendranagar, Hyderabad during *Rabi* 2010-11. All the parents and F_1 S' were planted in rows of 3 m length with 20 x 15 cm spacing. Recommended agronomic, cultural and plant protection practices were followed. Five competitive plants for each parent and F_1 per replication were randomly selected for data generation. The total number of days taken from the date of sowing to complete exersion of the panicle in 50 per cent of the total plants in the net plot. Number of tillers bearing ears at maturity were counted and recorded. The length of panicles from each plant was measured in centimeters from neck node to the tip of top most grain in a panicle and was expressed in cm.

The number of well filled grains were counted in each selected panicle per plant and expressed as filled grains per panicle. Two fifty well filled grains were counted from a random sample of each entry in each replication and weighed with the help of electronic top pan balance in grams. The matured panicles were harvested, threshed, cleaned and dried to 12-14% moisture level. The grain yield plant^{-1} was recorded in grams. The volume of the initial milled rice was measured by water displacement method in a measuring cylinder. Then the milled rice was put in to a test tube and cooked in boiling water for 20 minutes. Then the cooked rice was decanted on a filter paper to remove the excess water. The cooked rice volume was measured again by water displacement method. The volume expansion ratio is calculated by using following formula.

$$\text{Volume Expansion Ratio} = \frac{\text{Volume of cooked rice}}{\text{Volume of milled rice}} \times 100$$

The volume of water uptake was measured before and after cooking of the standard sample and the water uptake was worked out using the following formula.

Water uptake (ml) = Volume of initial water – Volume of final water

Alkali spreading value was estimated by the extent of the spreading of milled rice treated with a 1.7% solution of Potassium hydroxide for 23 hrs at 30^0c as given in "Rice improvement" by Jennings *et al*. (1979). Protein content of the rice grain was estimated following micro-kjeldhal digestion (NX 5.95).

RESULTS AND DISCUSSION

For days to 50 per cent flowering negative heterosis is considered important as induction of earliness is one of the desirable characters for aromatic rice genotypes. The mean values for days to 50% flowering averaged 93 days with a lower range of 86 days, higher range of 105 days. The means for the testers ranged from 94 (MTU-1081) to 104 days (BM-71), while the lines ranged from 90 in Yamini to 93 days in RNR-2354. In the hybrids it ranged from 86 in Ranbir Basmati x MTU-1010 to 100 days in RNR-2354 x Sye-632003. Sye-632003 combinations were found to be late, the check Sugandha Samba recorded 105 days as mean days for 50 per cent flowering. Compared to lines testers were late in flowering. Accordingly heterosis of desirable nature was recorded in 14 hybrids with a range from -3.19 per cent in (Yamini x MTU-1081) to -11.75 per cent in (Ranbir Basmati x MTU-1010), while 16 hybrids recorded significant negative heterobeltiosis ranging from -2.86 per cent in (Ranbir Basmati x MTU-1010) and -16.22 per cent in (Ranbir Basmati x MTU-1010) and 15 cross combinations recorded significant negative standard heterosis ranging from -4.81 per cent in (Ranbir Basmati x MTU-1010) to -18.17 per cent in (Ranbir Basmati x MTU-1010). Among the crosses studied, Ranbir Basmati x MTU-1010, RNR-2354 x MTU-1010 (Table 1) where in MTU-1010 was the common parent were important. Heterosis for earliness was also reported by Raju *et al.* (2006), Pandya and Tripathi (2006), Anjuchaudhary *et al*. (2007) and Eradasappa *et al.* (2007). The general mean for number of panicles plant^{-1} was 9.9 and the mean values ranged from 6.3 to 13 (Table 1). The mean number of panicles plant^{-1} for testers ranged from 7.6 (MTU-1081 and BM-7) to 8.6 (Sye-632003) while for the lines the range was from 7.6 (RNR-2354) to 12 (Yamini). In hybrids it ranged from7.3 (RNR-2354 x Sye-632003) to 13 (RNR-2354 x BM-7), while the check Sugandha Samba recorded 6.3 panicles plant^{-1}. Further, Verma *et al*. (2004), Pandya and Tripathi (2006), Eradasappa *et al.* (2007) and Narasimman *et al.* (2007) reported superiority of crosses over parents for productive tillers per hill. In the present investigation also for panicles per plant 11 hybrids recorded significant positive heterosis ranging from 9.68 per cent in (Yamini x Sye-632003) to 69.57 per cent in (RNR-2354 x BM-71). Seven hybrids recorded a significant positive heterobeltiosis which ranged from 30.77 per cent in (Ranbir Basmati x Sye-632003) to 69.57 per cent in (RNR-2354 x BM-71). All the hybrids studied recorded a significant positive standard heterosis and the range was from 36.84 per cent in (Ranbir Basmati x BM-71) to105.26 per cent in (RNR-2354 x BM-71). 13 hybrids exhibited more than 40 per cent standard heterosis. Hybrids viz., RNR-2354 x BM-71, Pusa-1121 x MTU-1081, Pusa-1121 x MTU-1010, Ranbir Basmati x MTU-1081, RNR-2354 x MTU-1010 and Ranbir Basmati x Sye-632003 recorded a significant heterosis, heterobeltiosis and standard heterosis of varying degrees.

Obviously more number of productive tillers would contribute to the higher yields owing to the fact that, there will be a substantial increase in panicle number. However, a genotype with greater panicle length is also desirable, since the spikelets attached to primary and secondary branches would increase proportionately with the enhancement in the panicle length. The mean values for panicle length ranged from 18.87 to 29.94 cm with a general mean of 26.48 cm (Table 5). The mean panicle length for testers ranged from 19.8 (Sye-632003) to 27.4 cm (BM-7). Among the lines RNR-2354 recorded the lowest mean panicle length of 23.8 cm and highest of 27.9 cm was recorded in Pusa-1121. In the hybrids the range was from 23.1 in RNR-2354 x Sye-632003 to 29.9 cm in RNR-2354 x BM-7. The check Sugandha Samba recorded a mean panicle length of 18.8 cm. Results indicated that RNR-2354 combinations registered maximum length. Pandya and Tripathi (2006), Roy *et al.* (2009) and Panwar and Mashiat Ali (2010) reported greater panicle length in hybrids over mid parent, better parent and standard checks. The results of the present investigation are also indicative of same trends as evidenced by 15 hybrids which recorded a significant positive heterosis with a lowest of 4.92 per cent in Ranbir Basmati x BM-71 and highest of 20.82 per cent in RNR-2354 x MTU-1010. Heterobeltiosis was significant and positive in seven hybrids ranging from 4.78 (Yamini x MTU-1081) to 17.31 (RNR-2354 x MTU-1010). All the 16 hybrids recorded a significant positive standard heterosis which ranged from 22.47 per cent in (RNR-2354 x Sye-632003) to 58.65 per cent in (RNR-2354 x BM-71). Fifteen hybrids recorded more than 40 per cent standard heterosis. Seven hybrids RNR-2354 x MTU-1010, RNR-2354 x BM-71, Ranbir Basmati x MTU-1081,RNR-2354 x MTU-1081, Ranbir Basmati x MTU-1010, Yamini x MTU-1081 and Pusa-1121 x BM-71 exhibited significant heterosis, heterobeltiosis and standard heterosis of varying degrees in desirable direction (Table1).

Table 1. Estimates of Heterosis (H_1), Heterobeltiosis (H_2) and Standard heterosis (H_3) for Days to 50% Flowering, Number of Panicles Plant^{-1} and Panicle Length in rice

Cross	Days to 50% Flowering			Number of Panicles Plant^{-1}			Panicle Length (cm)		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
Yamini x BM-71	-3.90**	-10.61**	-11.33**	-1.69	-19.44**	52.63**	2.23	0.05	45.55**
Yamini x MTU-1010	-6.80**	-12.69**	-14.72**	-1.64	-16.67**	57.89**	10.41**	2.30	42.46**
Yamini x Sye-632003	-5.32**	-11.43**	-13.21**	9.68*	-5.56	78.95**	17.29**	3.02	42.47**
Yamini x MTU-1081	-3.19**	-5.59**	-15.22**	18.64**	-2.78	84.21**	8.75**	4.78*	45.92**
Pusa-1121 x BM-71	-8.58**	-14.32**	-15.01**	13.73*	3.57	52.63**	7.73**	6.80**	58.09**
Pusa 1121 x MTU-1010	-7.23**	-12.43**	-14.47**	43.40**	35.71**	100.00**	9.46**	-1.35	46.03**
Pusa-1121 x Sye-632003	-3.83**	-9.36**	-11.17**	11.11*	7.14	57.89**	10.56**	-5.37*	40.07**
Pusa 1121 x MTU-1081	-5.26**	-6.88**	-16.38**	49.02**	35.71**	100.00**	10.98**	3.89	53.78**
Ranbir Basmati x BM-71	-5.16**	-10.61**	-11.33**	6.12	0.00	36.84**	4.92*	3.47	50.53**
Ranbir Basmati x MTU-1010	-11.75**	-16.22**	-18.17**	1.96	0.00	36.84**	15.93**	6.64**	50.87**
Ranbir Basmati x Sye-632003	-0.95	-6.12**	-8.00**	30.77**	30.77**	78.95**	16.16**	1.34	43.36**
Ranbir Basmati x MTU-1081	-7.25**	-8.29**	-17.65**	42.86**	34.62**	84.21**	16.34**	11.26**	57.40**
RNR-2354 x BM-71	-2.87**	-8.06**	-8.80**	69.57**	69.57**	105.26**	16.82**	9.06**	58.65**
RNR-2354 x MTU-1010	-11.50**	-15.61**	-17.58**	41.67**	36.00**	78.95**	20.82**	17.31**	47.97**
RNR-2354 x Sye-632003	2.04	-2.86*	-4.81**	-10.20	-15.38*	15.79	5.80*	-2.91	22.47**
RNR-2354 x MTU-1081	-5.10**	-5.74**	-15.36	52.17**	52.17**	84.21**	16.15**	14.82**	48.23**
SE ±	1.01	1.17	1.17	0.47	0.55	0.55	0.49	0.57	0.57

* significant at p= 0.05, ** significant at p= 0.01.

Filled grains per panicle is an important yield contributing factor so far hybrids are concerned. The mean values for this character ranged from 42 to 138 with a general mean of 98 the mean number of filled grains per panicle for testers ranged from 99 (MTU-1010) to138 (Sye-632003) while for the lines the range was from 42 (Yamini) to 135 (RNR-2354) indicating that testers were having more number of filled grains per panicle. For the hybrids, the mean values ranged from 79 in Pusa-1121 x BM-71 to 129 in RNR-2354 x Sye-632003, while the check variety Sugandha Samba recorded a mean value of 136. Heterosis for filled grains per panicle is closely related to the manifestation of heterosis for grain yield.

Out of 16 hybrds, six hybrids recorded a significant positive heterosis for filled grains per panicle and the values ranged from 11.76 per cent in (Ranbir Basmati x MTU-1010) to 30.14 per cent in (Yamini x MTU-1081), while four hybrdis recorded significant negative heterosis. Positive heterosis reported by Akarsh Parihar *et al*. (2008) and Panwar and Mashiat Ali (2010). For another important yield attribute i.e., 250 grain weight the mean values for ranged from 2.7 to 7.2 g with a general mean of 5.3 g. The mean values for the testers ranged from 2.7 (Sye-632003) to 5.7 g in MTU-1010, while for the lines the means ranged from 3.7 (RNR-2354) to 6.5 g (Yamini and Pusa-1121). The mean values for the hybrids ranged from 3.3 g in RNR-2354 x Sye-632003 to 7.2 g in Yamini x MTU-1010. Sugandha Samba recorded a mean value of 3.2 g for 250 grain weight. For 250 grain weight 11 hybrids recorded a significantly positive heterosis with a range from 12.71 per cent (Yamini x BM-71) to 23.12 per cent (Pusa-1121 x BM-71) (Table 2). Heterobeltiosis values were significantly positive in five hybrids and it ranged from 6.50 per cent in (Pusa-1121 x BM-71) to 10.90 percent in (Ranbir Basmati x MTU-1010). Standard heterosis was significantly positive in 15 hybrids which ranged from 33.47 per cent (Ranbir Basmati x Sye-632003) to 125.70 per cent (Yamini x MTU-1010), 14 hybrids recorded more than 40 per cent standard heterosis. While, five hybrids viz., Pusa-1121 x BM-71, Yamini x MTU-1010, Pusa-1121 x MTU-1010, RNR-2354 x MTU-1081 and Ranbir Basmati x MTU-1010 recorded a significantly over mid, better parent and standard heterosis of varying degrees. Positive heterosis for this trait reported by Pandya and Tripathi (2006), Akarsh Parihar *et al.* (2008) and Panwar and Mashiat Ali (2010). On an average grain yield per plant was 19.2 g, with a mean range from 12.9 to 27.5 g. The range of testers was 12.9 (Sye-632003) to 19.0 g (MTU-1010), while for the lines the lowest was 13.1 g in Yamini and highest mean was 17.3 in Pusa-1121 with an average yield of 15.1 g indicating that testers recorded higher grain yield compared to lines. The mean values for hybrids ranged from 13.9 g (RNR-2354 x Sye-632003) to 27.5 g (Pusa-1121 x MTU-1010). Combinations with Yamini, Pusa-1121 recorded higher grain yields. The mean values for check Sugandha Samba was recorded as 13.2 g. Significantly positive heterosis was recorded in 15 hybrids for grain yield, which ranged from 21.35 percent (Pusa-1121 x Sye-632003) to 89.25 percent (Yamini x Sye-632003). Heterobeltiosis was significantly positive in 14 hybrids, while significantly negative heterobeltiosis recorded in only one hybrid RNR-2354 x Sye-632003. To have the practical value standard heterosis is a must and it was observed in 15 hybrids ranging from 38.23 per cent (Pusa-1121 x Sye-632003) to 107.09 percent (Pusa-1121 x MTU-1010). Over all, 14 hybrids recorded more than 40 percent standard heterosis, 14 hybrids exhibited significant superiority over mid, better parent and standard check of varying degrees. Crosses viz., Yamini x Sye-632003, Yamini x MTU-1081 and Yamini x BM-71 performed exceedingly well for grain yield. Heterosis for grain yield for these crosses (Table 2) was mainly due to the expression of heterosis for filled grains per panicle. Deoraj *et al.* (2007), Eradasappa *et al.* (2007) and Panwar and Mashiat Ali (2010) reported positive heterosis for this trait. The quality parameters viz., volume expansion, water uptake etc., contribute to the overall cooking behaviour of a rice variety. Besides strongly dependent on physical quality attributes, these indicators possess direct relation with traits like gelatinization temperature and kernel amylose content. The ratio of expansion in volume of cooked rice indirectly gives an idea about the water uptake capacity. The mean values for volume expansion ratio ranged from 3.49 to 5.80 with a general mean of 4.58. The mean values for testers ranged from 3.76 (MTU-1010) to 5.20 (MTU-1081), while for the lines the means ranged from 4.19 (Ranbir Basmati) to 5.06 (Yamini). The mean values for hybrids ranged from 3.49 (Pusa-1121 x BM-71) to 5.30 (Pusa-1121 x MTU-1081). The mean values for the check Sugandha Samba was recorded as 5.80. Among the hybrids evaluated, three hybrids recorded a significantly positive heterosis for volume expansion ratio ranging from 11.45 per cent (Pusa-1121 x MTU-1081) to 22.10 per cent in (Pusa-1121 x Sye-632003) and significantly negative heterosis was recorded in two hybrids (Table 3). Heterobeltiosis values were significantly positive in two hybrids Pusa-1121 x MTU-1010 (13.82%) and Pusa-1121 x Sye-632003(22.01%) and four hybrids recorded significantly negative heterobeltiosis ranging from-16.71 (Ranbir Basmati x MTU-1081) to -21.00 percent in (RNR-2354 x MTU-1081). Standard heterosis was significantly negative in 13 hybrids which ranged from -11.08 per cent in (Yamini x MTU-1010) to -39.84 per cent in (Pusa-1121 x BM-71), none of the hybrids recorded significantly positive standard heterosis for volume expansion ratio. Similarly, in respect of water uptake, the values ranged from 25.25 to 29.50 ml with a general mean of 26.87 ml. For testers it ranged from 25.58 (MTU-1081 and Sye-632003) to 28.75 ml (BM-71) recording a mean of 26.99 ml, while for the lines water uptake ranged from 25.33 (RNR-2354) to 28.41 ml (Pusa-1121) with a mean of 26.78 ml. The mean value for hybrids was 26.7 ml which ranged from 25.25 (Ranbir Basmati x BM-71) to 29.50 ml (Yamini x MTU-1081). The mean values for check Sugandha Samba was recorded as 29.25 ml. Among the 16 hybrids studied for water uptake (ml), four hybrids recorded significantly positive heterosis with a range of 5.07 per cent (RNR-2354 x MTU-1081) to 14.89 per cent (RNR-2354 x Sye-632003) and significantly negative heterosis were recorded in seven hybrids (Table 3) ranging from -3.75 percent (Yamini x MTU-1010) to -10.79 percent in (Pusa-1121 x BM-71).

Heterobeltiosis values were significantly positive in three hybrids ranging from 4.56 (RNR-2354 x MTU-1081) to 14.33 per cent in case of RNR-2354 x Sye-632003, while nine hybrids recorded significantly negative heterobeltiosis ranged from -4.40 per cent in (Pusa-1121 x MTU-1081) to -12.17 per cent in (Ranbir Basmati x BM-71). Standard heterosis was significantly negative in 12 hybrids which ranged from -7.12 per cent in (Pusa-1121 x MTU-1081) to -13.68 per cent in (Ranbir Basmati x BM-71), none of the hybrids recorded significantly positive standard heterosis. Three hybrids viz., RNR-2354 x Sye-632003, Yamini x MTU-1081 and RNR-2354 x MTU-1081 recorded a significant heterosis, heterobeltiosis of varying degrees. Singh and Lal (2005) and Shivani *et al.* (2009) documented manifestation of heterosis for volume expansion ratio and water uptake.

Table 2. Estimates of Heterosis (H_1), Heterobeltiosis (H_2) and Standard heterosis (H_3) for Number of Filled Grains Panicle^{-1}, 250 Grain Weight and Grain Yield plant^{-1} in rice

Cross	Number of Filled Grains Panicle^{-1}			250 Grain Weight (g)			Grain Yield plant^{-1} (g)		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
Yamini x BM-71	25.73**	-11.22*	-33.42**	12.71**	-2.49	98.96**	66.44**	57.83**	74.68**
Yamini x MTU-1010	17.07**	-16.67**	-39.18**	17.98**	10.61**	125.70**	51.54**	28.20**	83.83**
Yamini x Sye-632003	18.27**	-22.93**	-21.46**	-2.52	-31.13**	40.52**	89.25**	87.24**	85.79**
Yamini x MTU-1081	30.14**	-11.23**	-24.65**	14.33**	-7.82**	88.08**	76.24**	72.01**	79.29**
Pusa-1121 x BM-71	-8.65	-22.25**	-41.69**	23.12**	6.50*	117.41**	34.53**	24.22**	62.37**
Pusa 1121 x MTU-1010	-4.43	-17.73**	-39.95**	16.60**	9.29**	123.11**	51.11**	44.42**	107.09**
Pusa-1121 x Sye-632003	-17.12**	-37.14**	-35.94**	15.85**	-18.17**	67.05**	21.35**	5.75	38.23**
Pusa 1121 x MTU-1081	-3.35	-21.69**	-33.53**	19.46**	-3.71	96.58**	48.85**	33.77**	74.86**
Ranbir Basmati x BM-71	14.90**	-1.15	-25.87**	-3.56	-13.02**	61.24**	32.99**	26.93**	40.49**
Ranbir Basmati x MTU-1010	11.76*	-2.74	-29.01**	12.98**	10.90**	105.60**	35.05**	14.90**	64.75**
Ranbir Basmati x Sye-632003	6.49	-18.52**	-16.96**	-1.00	-28.00**	33.47**	65.03**	62.17**	63.15**
Ranbir Basmati x MTU-1081	-3.87	-21.33**	-33.23**	1.50	-15.04**	57.51**	49.90**	47.28**	53.52**
RNR-2354 x BM-71	-32.68**	-41.02**	-41.20**	16.73**	3.62	54.40**	29.29**	27.28**	45.40**
RNR-2354 x MTU-1010	-29.12**	-38.62**	-38.81**	17.41**	-3.31	72.64**	29.08**	15.96**	66.28**
RNR-2354 x Sye-632003	-5.50	-6.53	-4.75	4.15	-9.96*	4.04	-1.08	-8.49*	4.54
RNR-2354 x MTU-1081	-7.18*	-14.07**	-14.34**	13.49**	9.20*	36.48**	59.98**	52.97**	74.76**
SE ±	3.96	4.57	4.57	0.15	0.17	0.17	0.51	0.59	0.59

* significant at p= 0.05, ** significant at p= 0.01.

Rice is categorized into broad groups based on the complimentary evaluation of alkali spreading value (Jennings *et al*. 1979). Most of the quality evaluation programmes follow alkali spreading score to determine the gelatinization temperature. A high score of 6 to 7 is suggestive of low gelatinization temperature and is desirable. In the study of F_1 hybrids along with parents, alkali spreading value ranged from 3.04 to 7.0 with a general mean of 4.90. The values for testers ranged from 3.64 in BM-71 to 5.60 in MTU-1081 with a mean of 4.70, while for the lines it ranged from 3.49 (Ranbir Basmati) to 5.63 (RNR-2354) with an average of 4.84. The score for hybrids ranged from 3.04 (Ranbir Basmati x Sye-632003) to 6.0 (Pusa-1121 x BM-71, Yamini x Sye-632003 and Pusa-1121 x MTU-1081) (Table 6) with a mean of 4.82, while the check recorded 7.0. Out of 16 hybrids, eight hybrids recorded significantly positive heterosis ranging from 3.86 per cent in (Pusa-1121 x Sye-632003) to 45.32 per cent in (Ranbir Basmati x MTU-1010, Table 4). Heterobeltiosis values were significantly positive in five hybrids which ranged from 7.02 per cent in (Pusa-1121 x MTU-1081) to 32.47 per cent in (Ranbir Basmati x MTU-1010). Standard heterosis in desirable direction was not registered in the crosses studied indicating the superiority of Sugandha Samba for this trait. Jennings *et al*. (1979) suggested that despite the positive aspects of nutritional quality of rice, it is still important to further enhance the inherent protein content of rice grain.

Table 3. Estimates of Heterosis (H_1), Heterobeltiosis (H_2) and Standard heterosis (H_3) for Volume Expansion Ratio and Water Uptake in rice

Cross	Volume Expansion Ratio			Water Uptake (ml)		
	H_1	H_2	H_3	H_1	H_2	H_3
Yamini x BM-71	7.27	0.13	-12.748	0.15	-2.03	-3.70
Yamini x MTU-1010	16.99**	2.04	-11.08*	-3.75*	-4.75*	-8.55**
Yamini x Sye-632003	2.60	-5.01	-17.22**	-4.55**	-7.88**	-13.39**
Yamini x MTU-1081	-4.68	-6.02	-15.73**	11.15**	7.27**	0.85
Pusa-1121 x BM-71	-19.72**	-20.36**	-39.84**	-10.79**	-11.30**	-12.82**
Pusa 1121 x MTU-1010	21.57**	13.82*	-15.38**	-10.32**	-10.85**	-13.39**
Pusa-1121 x Sye-632003	22.10**	22.01**	-9.30	7.10**	1.76	-1.14
Pusa 1121 x MTU-1081	11.45*	1.92	-8.61	0.62	-4.40*	-7.12**
Ranbir Basmati x BM-71	-5.32	-7.37	-30.02**	-7.62**	-12.17**	-13.68**
Ranbir Basmati x MTU-1010	0.71	-4.45	-30.94**	-5.25**	-8.90**	-12.54**
Ranbir Basmati x Sye-632003	-5.09	-6.34	-30.48**	0.97	0.32	-11.11**
Ranbir Basmati x MTU-1081	-7.76	-16.71**	-25.32**	0.97	0.32	-11.11**
RNR-2354 x BM-71	-5.20	-11.37	-23.02**	-2.62	-8.41**	-9.97**
RNR-2354 x MTU-1010	-6.77	-18.57**	-29.28**	-4.21*	-8.90**	-12.54**
RNR-2354 x Sye-632003	-4.28	-11.24	-22.90**	14.89**	14.33**	0.00
RNR-2354 x MTU-1081	-19.74**	-21.00**	-29.16**	5.07*	4.56*	-8.55**
SE ±	0.24	0.28	0.28	0.47	0.54	0.54

* significant at p= 0.05, ** significant at p= 0.01.

Table 4. Estimates of Heterosis (H_1), Heterobeltiosis (H_2) and Standard heterosis (H_3) for Alkali spreading value and Protein in rice

Cross	Alkali spreading value			Protein (%)		
	H_1	H_2	H_3	H_1	H_2	H_3
Yamini x BM-71	6.74	-5.00**	-36.67**	10.18**	3.79**	-3.33**
Yamini x MTU-1010	-4.87**	-9.21**	-39.48**	19.95**	14.86**	3.36**
Yamini x Sye-632003	19.36**	11.39**	-14.29**	12.83**	7.59**	-2.33**
Yamini x MTU-1081	-11.94**	-19.32**	-35.38**	9.92**	2.11**	-1.99**
Pusa-1121 x BM-71	30.01**	7.33**	-14.29**	9.40**	6.22**	-1.06
Pusa 1121 x MTU-1010	16.31**	2.27	-18.33**	12.42**	11.01**	-0.10
Pusa-1121 x Sye-632003	3.86**	-5.61**	-24.62**	1.67**	-0.04	-9.26**
Pusa 1121 x MTU-1081	7.17**	7.02**	-14.29**	0.28	-4.04**	-7.88**
Ranbir Basmati x BM-71	27.54**	24.91**	-35.05**	-1.18*	-7.40**	-1.34**
Ranbir Basmati x MTU-1010	45.32**	32.47**	-19.76**	11.56**	2.90**	9.63**
Ranbir Basmati x Sye-632003	-31.51**	-43.56**	-56.57**	5.21**	-2.57**	3.81**
Ranbir Basmati x MTU-1081	15.43**	-6.36**	-25.00**	4.54**	-0.64	5.86**
RNR-2354 x BM-71	-22.50**	-36.21**	-48.67**	6.09**	4.27**	-2.88**
RNR-2354 x MTU-1010	-3.65**	-15.56**	-32.05**	3.11**	3.09**	-7.23**
RNR-2354 x Sye-632003	-30.61**	-32.13**	-45.38**	4.17**	3.70**	-5.86**
RNR-2354 x MTU-1081	-19.87**	-20.06**	-35.67**	2.95**	-0.29	-4.29**
SE ±	0.06	0.07	0.07	0.05	0.05	0.05

* significant at p= 0.05, ** significant at p= 0.01.

This is particularly so in Asia, where rice consumption is as much as 80 per cent of calorie intake. The mean values for protein content ranged from 8.0 to 10.66 with a general mean of 9.37 per cent. The protein content for testers ranged from 8.75 in MTU-1010 to 9.33 in MTU-1081 with a mean of 8.98 per cent, while for the lines maximum of 8.0 per cent was recorded in Yamini and a minimum of 10.36 per cent in Ranbir Basmati with an average of 8.90 per cent.

The protein content values for hybrids ranged from 8.82 (Pusa-1121 x Sye-632003) to 10.66 per cent (Ranbir Basmati x MTU-1010) with a mean of 9.56 per cent The mean values for check Sugandha Samba was recorded as 9.72 per cent. For protein content 14 hybrids recorded significantly positive heterosis ranging from 1.67 per cent (Pusa-1121 x Sye-632003) to 19.95 per cent in (Yamini x MTU-1010, Table 4). Heterobeltiosis values were significantly positive in ten hybrids which ranged from 2.11 per cent in (Yamini x MTU-1081) to 9.63 per cent in (Ranbir Basmati x MTU-1010). Standard heterosis were significantly positive in four hybrids which ranged from 3.36 per cent (Yamini x MTU-1010) to 9.63 per cent in (Ranbir Basmati x MTU-1010). Singh and Lal (2005) and Krishna Veni *et al*. (2005) reported positive heterosis for alkali spreading value and protein content.

Table 5.Top ranking desirable crosses for sca and their *per se* performance along with magnitude of heterosis (H_1), heterobeltiosis (H_2) and Standard heterosis (H_3)

S.No Character	Cross combinations	*Per se* performance	gca of parents	Hetertosis (%)		
				H_1	H_2	H_3
Yield characters						
Days to 50% flowering	Pusa-1121 x BM-71	89.29	High x Low	-8.58	-14.32	-15.01
	RNR-2354 x MTU-1010	86.60	Low x High	-11.50	-15.61	-17.58
	Yamini x Sye-632003	91.19	Low x Low	-5.32	-11.43	-13.21
Number of panicles plant^{-1}	RNR-2354 x BM-71	13.00	Low x Low	69.57	69.57	105.26
	Ranbir Basmati x Sye-632003	11.33	Low x Low	30.77	30.77	78.95
	Pusa-1121 x MTU-1010	12.66	High x Low	43.40	35.71	100.00
	Yamini x Sye-632003	11.33	Low x Low	9.68	-	78.95
Panicle length (cm)	Yamini x Sye-632003	27.07	Low x Low	17.29	-	42.47
	RNR-2354 x BM-71	29.94	Low x High	16.82	9.06	58.65
Number of filled grains panicle^{-1}	RNR-2354 x Sye-632003	129.19	High x High	-	-	-
	RNR-2354 x MTU-1081	116.18	High x High	-	-	-
	Ranbir Basmati x Bm-71	100.54	High x Low	14.90	-	-
250 grain weight (g)	Ranbir Basmati x MTU-1010	6.61	Low x High	12.98	10.90	105.60
Grain yield plant^{-1} (g)	Ranbir Basmati x Sye-632003	21.69	Low x Low	65.03	62.17	63.15
	Yamini x Sye-632003	24.70	High x Low	89.25	87.24	85.79
	RNR-2354 x MTU-1081	23.23	Low x High	59.98	52.97	74.76
	Pusa-1121 x MTU-1010	27.53	High x High	51.11	44.42	107.09

Table 6.Top ranking desirable crosses for sca and their *per se* performance along with magnitude of heterosis (H_1), heterobeltiosis (H_2) and Standard heterosis (H_3)

S.No Character	Cross combinations	*Per se* performance	gca of parents	Hetertosis (%)		
				H_1	H_2	H_3
Quality characters						
Volume expansion ratio	RNR-2354 x BM-71	4.47	Low x Low	-	-	-
	Pusa-1121 x MTU-1081	5.30	High x Low	11.45	-	-
Water uptake (ml)	RNR-2354 x Sye-632003	29.25	Low x High	14.89	14.33	-
	Pusa-1121 x Sye-632003	28.91	Low x High	7.10	-	-
	Yamini x MTU-1081	29.50	High x High	11.15	7.27	-
	Yamini x BM-71	28.16	High x Low	-	-	-
Alkali spreading value	Yamini x Sye-632003	6.00	Low x Low	19.36	11.39	-
	Ranbir Basmati x MTU-1010	5.61	High x Low	45.32	32.47	-
	Pusa-1121 x BM-71	6.00	High x Low	30.01	7.33	-
	Ranbir Basmati x MTU-1081	5.25	Low x High	15.43	-	-
Protein (%)	Pusa-1121 x BM-71	9.62	Low x Low	9.40	6.22	-
	RNR-2354 x BM-71	9.44	Low x Low	6.09	4.27	-
	Ranbir Basmati x MTU-1010	10.66	High x High	11.56	2.90	9.63

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