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HETEROSIS IN PHYSICOCHEMICAL GRAIN QUALITY CHARACTERS IN INTERVARIETAL HYBRIDS IN RICE

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ABSTRACT

Manifestation of heterosis for three physicochemical grain quality characters in 102 F_1 rice hybrids is reported. Average heterosis of 2.2% for amylose content, –1.3% for gelatinization temperature, and –45.2% for gel consistency was recorded over the midparent in the japonica x indica crosses, and –5.2%, 1.1% and –23.0%, respectively, in the indica x indica crosses. Significant negative heterosis over better parent (BP) for gel consistency was demonstrated by all the hybrids in the japonica x indica group and by 81.2% in the indica x indica group. 72.9% of the indica x indica and 44.4% japonica x indica hybrids had significant negative midparent (MP) heterosis for amylose content. While no hybrid was lower than the lower parent in amylose content, 79.6% japonica x indica and 60.4% indica x indica hybrids were so for gel consistency. Correlations between the midparent mean and hybrid performance were highly significant for gelatinization temperature and amylose content, and were of sufficient magnitude for gelatinization temperature, which indicates that the MP values are an effective indicator of hybrid performance. The correlation coefficients between MP value and heterosis were also highly significant, of high magnitude, but negative.

Key words: Heterosis, amylose content, gelatinization temperature, gel consistency.

In view of the diverse consumer preferences, breeding for grain quality forms an important objective in the most rice breeding programmes. Cooking and eating characteristics of rice are largely determined by the properties of the starch, a polymer of glucose, constituting about 90% of the dry weight of milled rice. Amylose content, gelatinization temperature, and gel consistency are the principal determinants of cooking and eating qualities of milled rice [1-3].

While heterosis has been reported in rice for agronomic characters [4], physiological traits [5], low-temperature tolerance and productivity [6, 7] reports of heterosis for the

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physicochemical grain quality characters in rice are not available.

The present article reports heterotic manifestations in three physicochemical grain quality characters in rice, namely amylose content, gelatinization temperature, and gel consistency in 102 F_1 hybrids, involving low-temperature tolerant indica and japonica parents.

MATERIALS AND METHODS

Seventeen ecogeographically diverse rice cultivars and elite lines having low-temperature tolerance at different growth stages, were crossed as females to each of the six high yielding and/or blast resistant elite IRRI lines as pollinators, in a line x tester fashion, to generate 102 F_1 (seed generation) hybrid populations. On an average, 1,617 crossed seeds were produced per cross combination in the glasshouse facility of the International Rice Research Institute (IRRI), Los Banos, Philippines. The F_1 seeds were dried to 11% moisture and stored at controlled temperature and humidity for one year before being analysed for amylose content, gelatinization temperature and gel consistency.

Amylose content was estimated in 20 well filled and healthy rice kernels of each parent and F_1 hybrid, using the simplified assay for milled rice amylose on a Technicon autoanalyser [8], repeated four times. Gelatinization temperature was estimated by the extent of the spreading and clearing of milled rice treated with 1.7% solution of potassium hydroxide for 23 h at 30°C, using the procedure of Little et al. [9]. There were two repeats, and each replicate test sample comprised 12 grains per genotype. Gel consistency was determined in duplicate as per the procedure of Cagampang et al. [10]. This test is based on the consistency of cold 5.0% milled rice paste in 0.20 N KOH. Consistency was measured by the length in a test tube of the cold gel held horizontally for 0.5 to 1 h.

Heterosis was calculated as F_1 mean minus midparent (MP) or better parent (BP) mean, as percentage of the two parental values respectively [11].

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among parents and their hybrids for all the three physicochemical characters evaluated. The parents vs. hybrids comparison showed significance at $P = 0.01$ for gel consistency and amylose content and at $P = 0.05$ for gelatinization temperature. According to Kirby and Atkins [12], mean square for parents vs. hybrids and average heterosis may serve as a measure of nonadditive gene effects. Appreciable nonadditive gene effects playing an important role in the expression of gel consistency and amylose content were indicated where sizeable heterosis was observed, besides highly significant mean squares for the parents vs. hybrids component.

The tabulation of the levels of heterosis on an individual cross basis for 102 hybrids would be too voluminous to be presented, a summary of salient features is presented in Table 1. Since indica varieties have been reported to have higher amylose content in the grain than the japonica varieties [1, 13], and varietal differences in gel consistency and gelatinization temperature also exist, an attempt has been made to classify the various hybrids in japonica x indica and indica x indica crosses to ascertain the inherent differences in heterosis between the two groups.

Average MP heterosis to the extent of –45.22% for gel consistency, 2.2% for amylose content, and –1.3% for gelatinization temperature was recorded in the japonica x indica

Table 1. Heterotic response for three physicochemical characters in 54 japonica x indica (J x I) and 48 indica x indica (I x I) hybrids

Parameter	Cross	Amylose content (%)	Gelatinization temperature	Gel consistency
Range of MP heterosis (%)	J x I	68.4 – 27.8	–16.1 –20.0	–20.0 – –55.7
	I x I	19.9 – –20.9	–15.7 – 16.3	5.4 – –54.2
Range of BP heterosis (%)	J x I	–14.7 – –40.4	–1.1 – –27.0	–35.2 – –68.0
	I x I	–3.2 – –27.2	–27.0 – 13.4	4.6 – –38.8
Mean MP heterosis (%)	J x I	2.2	–1.3	–45.2
	I x I	–5.2	1.1	–23.0
Mean BP heterosis (%)	J x I	–24.8	–6.4	–60.2
	I x I	–11.1	–6.7	–30.7
F_1 with significant negative MP heterosis (%)	J x I	44.4	24.1	88.9
	I x I	72.9	25.0	84.5
F_1 with significant negative BP heterosis (%)	J x I	—	38.9	100.0
	I x I	—	47.9	81.2
F_1 with significant positive MP heterosis (%)	J x I	25.9	9.3	—
	I x I	22.9	29.2	—
F_1 with significant positive BP heterosis (%)	J x I	—	—	—
	I x I	—	6.2	—
F_1 exceeding BP (%):	J x I	—	1.8	—
	I x I	—	10.4	4.2
between BP and MP	J x I	42.6	27.8	—
	I x I	25.0	35.4	2.1
between MP and lower parent	J x I	57.4	57.4	20.4
	I x I	75.0	41.7	33.3
less than lower parent	J x I	—	13.0	79.6
	I x I	—	12.5	60.4

hybrids. In the indica x indica crosses also, gel consistency had the highest negative MP heterosis (–23.0%), suggesting dominance in negative direction as one of the causes in the manifestation of negative heterosis. Average BP heterosis of –60.2% for gel consistency, –24.8% for amylose content, and –6.4% for gelatinization temperature was recorded in the japonica x indica hybrids. The corresponding values for the indica x indica crosses were –30.7, –11.1, and –6.7%.

In respect of gel consistency, all the 54 japonica x indica hybrids and 39 of the 48 (81.2%) indica x indica hybrids showed significant negative BP heterosis (overdominance). While no hybrid had significantly negative BP heterosis for amylose content, 38.9% of the japonica x indica and 47.9% indica x indica hybrids had significant negative BP heterosis for gelatinization temperature. 72.9% of the indica x indica and 44.4% japonica x indica hybrids showed significantly negative MP heterosis for amylose content, indicating dominance of low amylose content. In the japonica x indica group, 57.4% hybrids had values between MP and lower parent for amylose content and gelatinization temperature. In the indica x indica group, however, 75.0% hybrids had values between MP and lower parent for amylose content and 41.7% for gelatinization temperature. The hypothesis of a dominant gene determining high amylose content does not, therefore, seem to hold good at least in the present material. Dominance of low amylose has also been observed by other workers [14, 15]. For gel consistency, 79.6% japonica x indica and 60.4% indica x indica hybrids had gels smaller than the smaller parent, revealing transgression towards hard gel consistency. A single dominant gene has been reported to govern hard gel consistency in two indica x japonica crosses [16] and two indica x indica crosses [17] with indication of maternal influence.

Average heterosis expressed by the hybrids involving 17 female parents in an array of crosses with 6 common IRRI lines as pollinators, is presented in Table 2. The performance of the hybrids and parents for the three physicochemical grain quality characters is also compared. On an average, the hybrids had lower (harder) gel consistency than the parent varieties. In respect of amylose content and gelatinization temperature, the average hybrids performance was similar to the MP values. The hybrids had 55.3% more amylose than the japonica lines, were similar to the indica lines, but 20.1% less than the IRRI tester parents. In gelatinization temperature, the hybrids were almost similar to the testers, had 7.7% higher alkali spreading score (lower gelatinization temperature) than the indica lines, and 10.2% lower score than the japonica lines. The values in hybrids deviated substantially from their corresponding parental values for gel consistency, being 9.8% lower than the testers, 37.7% lower than indica, and 61.7% lower than japonica lines.

The hybrids of japonica females revealed high negative MP and BP heterosis for gel consistency and moderately negative BP heterosis for amylose content as compared to hybrids of indica females. The performance with respect to gelatinization temperature was more or less similar in both the groups. Cv. Anna from Korea was the most potent parent

in producing highly heterotic hybrids for low amylose content in the crosses with high amylose testers. This would be expected as Anna was the only glutinous parent included in the study. Hybrids demonstrating negative heterosis for amylose content have also been produced by high- (ARC 6000, Leng Kwang, K39-96), intermediate- (Shoa-Nan-Tsan, China 988, Silewah), and low-amylose (Samgangbyeo, Suweon 287 and all japonicas) parents.

Table 2. Midparent (MP) and better parent (BP) heterosis of 102 rice hybrids from japonica x indica and indica x indica crosses, averaged over six common male parents for three physicochemical traits

Female parent	Origin of female parent	Heterosis (%) for different characters					
		amylose content		gelatinization temperature		gel consistency	
		MP	BP	MP	BP	MP	BP
Japonica group:							
Suweon 235	Korea	–4.6	–24.6	1.6	–5.7	–48.6	–63.8
SR 5204-91-4-1	Korea	0.2	–22.1	–1.8	–8.7	–48.4	–63.9
SR 3044-78-3	Korea	–3.6	–21.3	–2.0	6.9	–48.6	–64.2
Anna	Korea	–17.1	–31.0	–2.3	–9.5	–51.2	–67.0
Barkat	Kashmir	1.4	–21.9	–2.7	–9.5	–27.8	–39.7
K332	Kashmir	–4.4	–26.9	–0.3	–7.3	–47.8	–62.9
K 84	Kashmir	59.8	–20.1	–2.5	–9.3	–48.2	–64.1
Shimokita	Japan	–2.3	–25.6	0.2	–7.2	–47.4	–63.3
Stejaree 45	USSR	–9.1	–30.0	–2.2	–9.3	–38.4	–53.1
Group mean		2.2	–24.8	–1.3	–6.4	–45.2	–60.2
Indica group:							
Suweon 287	Korea	7.1	14.8	6.5	–1.6	–47.9	–63.9
Samgangbyeo	Korea	12.9	–15.2	–3.5	–10.1	–59.6	–64.4
China 988	India	–7.1	–14.4	11.7	2.6	–6.3	–12.7
ARC 6000	India	–12.9	–13.5	–4.2	–11.7	–24.5	–36.4
K 39-96	Kashmir	–13.4	–15.8	1.7	–6.2	–4.7	–8.5
Leng Kwang	China	–6.5	–9.0	–5.1	–12.3	–8.2	–11.8
Shoa-Nan-Tsan	China	–13.3	–17.5	7.0	–1.7	–8.8	–12.5
Silewah	Indonesia	–8.5	–18.1	–5.1	–12.7	–24.4	–35.0
Group mean		–5.2	–11.1	1.1	–6.7	–23.0	–30.7
Hybrids as:							
% of midparents		96.7		99.8		61.6	
% of testers		79.9		102.5		90.1	
% of japonica lines		155.3		89.8		38.3	
% of indica lines		97.9		107.7		62.3	

Heterosis, therefore, appeared to be associated with differences in the "base" performance of the parent varieties per se, as reported in sorghum [12], because of the diversity of the parents crossed. Heterosis for gel consistency has been inversely proportional to the gel consistency of the female parents. Greater heterosis for hard gel consistency was revealed by the hybrids of japonica females and the indica females Suweon 287 and Samgangbyeo, having soft gel consistency, lesser by the parents with medium gel consistency (Barkat, Silewah and ARC 6000), and the minimum by parents with hard gel consistency (China 988, K39-96, Leng Kwang and Shoa-Nan-Tsan). The japonica rices with low gelatinization temperatures and the indica strains with low and intermediate gelatinization temperatures were equally potent in producing heterotic hybrids with regard to gelatinization temperature.

The correlation coefficients between the MP value and hybrid performance (Table 3) were highly significant for gelatinization temperature and amylose content. The correlation coefficient between the parental performance per se and the performance of their hybrids being of a high magnitude ($r=0.77^{**}$) for gelatinization temperature, it would transpose to a high coefficient of determination. The prediction of hybrid performance from parental values should therefore prove effective. Virmani et al. [18] suggested that a high correlation between hybrid performance and MP value can generally be expected when the hybrid vigour expression is predominantly caused by additive and additive x additive gene effects.

The correlation coefficients between MP value and heterosis for gel consistency and amylose content were also highly significant, but negative. The value of $r= -0.92^{**}$ for MP gel consistency and MP heterosis and $r= -0.96^{**}$ for MP gel consistency and better parent heterosis indicated a close relationship between parental performance and heterosis. The negative association would suggest that the increase over MP of the hybrids tends to decrease as the average contribution of MP increases. The lack of association between MP value and MP heterosis for gelatinization temperature could, however, be due to mutual cancellation of positive and negative heterotic effects of the hybrids.

Table 3. Simple correlation coefficients between midparent value, hybrid performance and heterosis

Pairs of parameters	r values for different characters		
	amylose content	gelatinization temperature	gel consistency
MP & hybrid performance	0.39**	0.77**	0.16
MP & MP heterosis	–0.79**	–0.01	–0.92**
MP & BP heterosis	–0.88**	–0.61**	–0.96**

**Difference from zero significant at 1% level.

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