Seed Res., Vol. 43(1): 20-25, June 2015

Assessment of morpho-physiochemical and cooking traits of extant varieties of rice (*Oryza sativa*) of India

MONIKA A JOSHI*, S. K. CHAKRABARTY, YOGENDRA SINGH AND MALAVIKA DADLANI

Division of Seed Science & Technology,
ICAR-Indian Agricultural Research Institute, New Delhi-110012
*monikakshat622@yahoo.com

ABSTRACT Fifty eight prominent extant rice varieties of Indian origin that are in active seed production chain were screened for their grain, morphological, physiochemical and cooking properties, to establish relationship between them so as to predictthe cooking quality of a variety on the basis of phenotypic characteristics. The length and breadth of milled raw rice varied from 6.1 mm (Jaishree) to 10.7 mm (Pusa Basmati 1) and 1.97 mm (PKV-HMT) to 3.28 mm (Kranthi), respectively. Majority of the varieties were long bold (18) and short bold (11) in shape; with only nine of the extant varieties categorized as basmati type and only five as extra long slender. Considerable range was recorded for grain colour (white to greyish orange); with majority of them being greyish white in colour. The amylose content (AC) was intermediate to high in most of the varieties and ranged from 6.28% (Govind) to 29.7% (Ambey Mohar). The gelatinization temperature (GT), as indexed by the alkali disintegration pattern, revealed that most of the varieties had low alkali values. High heritability coupled with moderate to high genetic advance and genetic co-efficient of variation (GCV) indicate the predominance of additive gene action for these two traits *viz.* AC and GT, thereby, emphasizing that selection based methods would be rewarding. No variety with low amylose and high alkali value was observed, suggesting that the varieties in the seed chain are selected for their good cooking quality. Further, some varieties that were superior with high amylose and GT could be utilized in breeding programmes for improving the cooking quality.

Key words: Amylose content, cooking traits, gelatinization temperature, physicochemical properties, *Oryza sativa*

Rice quality is a complex character which is directly or indirectly linked to several other traits. Grain quality plays an important role in consumer acceptability since rice is mainly consumed as whole grain, especially in Asia. Varietal properties such as grain size, shape, thousand kernel weight, hardness and bulk density affect the grain quality. The cooking quality of rice is dependent to a large extent on the properties of starch, mainly amylose content. The ratio of amylose to amylopectin is its major determinant factor. During cooking, amylose leaches out of starch granule and retrogrades or stales when cooled, whereas amylopectin remains in the gelatinized granule. Cooked rice with low amylose is soft and sticky, while rice with high amylose is firm and fluffy [1].

Some of the best quality aromatic rice such as Basmati rice from India and Pakistan and Shimiao rice from China are universally prized. Although the preferences vary from country to country and even among regions within the same country, rice with soft to medium gel consistency, intermediate amylose content and gelatinization temperature and good grain elongation are preferred by most consumers [2]. Hence in order to meet the requirements of rice market and raised living standards, improvement of rice grain quality is one of the most important objectives of present day rice breeding. In lieu of the above, the present investigation was undertaken to study the morphological, physio-chemical and cooking properties of prominent extant rice varieties and to find a relationship between their physio-chemical properties and cooking qualities.

MATERIALS AND METHODS

The study was conducted on 58 prominent extant rice varieties, procured from ICAR- Indian Institute of Rice Research, Hyderabad, which are in the active seed production chain in India. An extant variety is a variety which has been notified under Section 5 of the Seed Act, 1966 and it may be a farmers' variety; or a variety about which there is common knowledge; or any other variety which is in public domain. All the varieties in the present study have also been listed as example varieties/reference material in the DUS test guidelines for rice.

The varieties were grown at the farm of Division of Seed Science & Technology, ICAR-Indian Agricultural Research Institute, New Delhi in the *Kharif*

*Corresponding Author

season of 2009 and 2010, by following all the recommended package of practices. After harvesting, the paddy samples were dehusked and data was recorded as per the DUS guidelines for rice. The grain characters *viz.* weight of 1000 fully developed grains, grain length (GL) and width (GW), decorticated grain characters *viz.* length (DGL), width/breadth (DGW), length/breadth (L/B) ratio, decorticated grain shape and colour, along with the cooking characters *viz.* amylose content (AC) and gelatinization temperature (GT) were recorded after harvest. The length and width/breadth of raw rice of 58 cultivars was measured using vernier caliper. The measurements were recorded in each sample on 10 grains. L/B ratio was used in combination with the kernel length to assess the grain shape. The 1000 kernels from each cultivar were counted randomly in triplicate and weighed separately to determine the 1000 kernel weight. The amylose content was determined following the simplified procedure developed by Juliano (1971) with [1]. The gelatinization temperature was assessed using the alkali spreading values (ASV) and the spreading of kernels was noted on a 7 point scale [3].

In addition, an attempt was also made to assess the extent of genetic variability for all these traits studied. The heritability estimates coupled with expected genetic advance indicate the mode of gene action in the expression of a trait. Hence, the replicated mean values were used to compute genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance (GA), following the method suggested by Johnson *et al.* [4].

The correlation between physio-chemical characters of the rice kernel and the cooking quality was also studied for these 58 extant varieties. The main objective was to establish the relationship between these characters so as to predict the cooking quality of a variety on the basis of phenotypic characteristics.

RESULTS AND DISCUSSION

Characterization of extant varieties for morpho-physiochemical and cooking traits and variation thereof

The complete data for the morpho-physiochemical and cooking traits for the 58 extant varieties is presented in Table 1. The length and breadth of milled raw rice varied from 6.1 mm to 10.7 mm and 1.97 mm to 3.28 mm, respectively (Table 1). Pusa Basmati 1 had the highest length, whereas Jaishree had the smallest kernel. Twenty seven cultivars were categorized as short (6.1- 8.5 mm) grain, 30 as medium (8.6-10.5 mm) and only one (Basmati 386; 10.7 mm) as long(10.6-12.5 mm). Similarly, with respect to grain width, PKV HMT was categorized as very narrow (1.97 mm), 22 as narrow (2.1-2.5 mm), 30 in the medium range (2.6 mm -3.0 mm) and six as broad (3.1-3.5 mm); the broadest being Kranthi (3.28mm).

Cultivars with a kernel length <6.0 mm and L/B ratio *viz.* >3.0; <2.5 and 2.5-3.0 were categorized as short slender, short bold and medium slender, respectively. Accordingly, only two cultivars *viz.* Vibhava and PKV HMT were classified as short slender, 11 as short bold and seven as medium slender. 24 cultivars with kernel length >6.0 mm and L/B ratios *viz.* >3.0 and <3.0 were categorized as long slender (six cultivars) and long bold (18 cultivars), respectively. A total of nine cultivars with kernel length >6.61 mm and L/B ratio of >3.0 were classified as Basmati type and five cultivars with kernel length >7.5 mm and L/B ratio of >3.0 as extra long slender.

With respect to decorticated grain colour, majority of the varieties showed varying shades of grey ranging from grayish white (41) to grayish orange (5). Others were classified as white (4), green white (2) and grayish green (6).

Amylose content (AC), along with gelatinization temperature (GT) is considered as a prime determinant of cooking quality. Rice genotypes with high AC show high volume expansion and high degree of flakiness. The kernels cook dry and become hard upon cooling. In contrast, rice with low AC cooks moist and sticky. Intermediate amylose rice are preferred by consumers in most rice growing areas of the world as it cooks fluffy and remains soft on cooling. The amylose content of extant varieties screened in the present study varied significantly and ranged from 6.28% to 29.7%. Similar wide range for amylose content has also been reported earlier in the Indian cultivars [5]. Govind showed the lowest amylose content whereas Ambey Mohar showed the highest amylose content. Twenty varieties had intermediate amylose content (20-25%) and 15 varieties had high AC (26-30%), which is a desirable trait.

The alkali spreading values, which were used as indices to assess the gelatinization temperature, also varied widely and most of the extant varieties had low alkali values (high GT) suggesting that these cultivars are more resistant during cooking, thus indicating their superior cooking quality. No consistent

Table 1. Morpho- physiochemical and cooking characteristics for 58 extant varieties

S.No.	Cultivar	Grain L	Grain W	1000seed wt.	DGL	DGW	L/B ratio	D grain shape	D grain colour	Amylose Content	GT
1	Tulasi	7.85	2.85	22.30	7.0	2.1	2.86	long bold	greyish white	21.00	High
2	Vikash	9.55	2.60	23.97	7.7	2.0	3.35	basmati type	greyish white	25.00	High
3	Nidhi	8.60	2.37	18.31	7.3	1.8	3.50	long slender	greyish white	22.94	High
4	Annada	7.10	2.97	22.52	6.3	2.6	2.04	short bold	greyish white	24.70	High
5	Krishna Hamsa	9.70	2.60	23.15	7.3	1.9	3.32	long slender	greyish green	26.80	High
6	ADT 37	6.90	3.00	19.21	6.0	2.5	2.00	short bold	greyish white	21.20	High
7	Suraksha	7.20	2.67	22.66	6.5	2.3	2.61	medium slender	greyish green	24.19	High
8	Vibhava	8.45	2.40	16.04	7.0	1.9	3.11	short slender	greyish green	26.03	Low
9	MandyaVijaya	8.85	2.97	29.83	7.5	2.3	2.83	long bold	greyish orange	28.00	High
10	Phalguna	9.50	2.93	32.34	8.5	2.2	3.41	extra long slender	greyish green	21.20	High
11	Pant Dhan 4	8.40	2.95	30.60	7.5	2.2	2.95	long bold	greyish white	19.30	High
12	Vikramarya	9.80	3.05	29.49	7.9	2.4	2.88	long bold	greyish white	18.80	High
13	sali vahana	6.90	2.9	20.15	6.0	2.4	2.29	short bold	green white	8.86	High
14	Ravi	8.00	3.08	29.54	7.0	2.5	2.40	short bold	greyish white	11.07	Medium
15	PKV HMT	7.25	1.97	14.80	6.7	1.5	3.80	short slender	greyish white	14.43	High
16	Vasumati	9.90	2.10	23.34	8.3	1.7	4.29	basmati type	greyish white	19.03	High
17	Shanti	9.55	2.15	23.03	7.4	1.6	3.37	long slender	greyish white	13.40	High
18	Pusa Basmati 1	10.70	2.15	22.84	8.8	1.7	4.59	extra long slender	greyish white	10.42	High
19	Tarori Basmati	10.25	2.30	22.54	9.1	1.8	4.17	extra long slender	greyish white	21.50	High
20	VL Dhan 221	7.70	2.60	23.92	6.8	2.2	2.82	long bold	greyish white	29.20	High
21	Heera	9.40	3.10	30.92	7.8	2.4	2.83	long bold	white	17.40	High
22	Govind	8.70	2.40	25.48	7.7	1.9	3.53	basmati type	greyish white	6.28	High
23	Pant Dhan 11	8.70	2.95	28.32	7.2	2.2	2.82	long bold	greyish white	12.00	High
24	CSR 27	9.25	2.60	28.35	7.9	2.3	3.00	basmati type	greyish white	6.70	High
25	VL Dhan 81	8.55	2.73	29.89	7.3	2.2	2.86	long bold	greyish white	13.72	High
26	CSR 10	7.90	3.00	26.17	6.6	2.6	2.15	short bold	greyish white	7.24	High
27	VL Dhan 206	7.80	2.90	26.25	7.0	2.3	2.61	medium slender	greyish white	20.04	High
28	Vivek Dhan 62	6.95	2.87	25.10	6.1	2.6	2.12	short bold	greyish white	6.71	High
29	Sugandha	8.80	3.08	27.82	7.8	2.5	2.72	long bold	greyish white	29.80	High
30	Jaishree	6.10	2.08	16.80	5.2	2.1	2.24	short bold	greyish white	28.90	High
31	Rasi	7.75	2.75	22.80	6.5	2.2	2.50	medium slender	greyish white	26.40	High
32	Poornima	8.85	2.43	24.43	7.8	1.9	3.57	basmati type	greyish white	25.00	High
33	Mahamaya	9.00	3.14	31.30	7.6	2.5	2.64	long bold	white	27.20	High
34	Shyamala	9.65	2.9	27.9	8.1	2.2	3.55	basmati type	greyish white	23.56	High
35	Kranthi	7.83	3.28	29.17	6.9	2.8	2.11	short bold	greyish white	25.00	High

S.No.	Cultivar	Grain L	Grain W	1000seed wt.	DGL	DGW	L/B ratio	D grain shape	D grain colour	Amylose Content	GT
36	**Indira Sugandhit Dhan 1**	8.60	2.60	21.05	7.2	1.9	3.26	long slender	greyish white	26.36	High
37	**IR 8**	9.05	2.98	30.06	7.7	2.4	2.79	long bold	greyish white	26.00	High
38	**Basmati 386**	10.15	2.43	23.90	8.6	1.7	4.47	extra long slender	greyish white	23.24	High
39	**PR 113**	9.05	3.00	29.87	7.9	2.4	2.87	long bold	greyish white	22.76	High
40	**CSR 13**	8.55	2.42	23.12	7.3	1.9	3.31	long slender	greyish white	23.68	High
41	**Sambha Mahsuri**	8.00	2.10	15.64	6.8	1.5	3.70	medium slender	greyish white	18.84	High
42	**Basmati 370**	9.10	2.13	20.12	7.9	1.7	4.05	basmati type	greyish white	23.16	High
43	**Lochit**	7.30	2.85	24.29	6.4	2.4	2.29	short bold	greyish white	27.2	High
44	**Kushal**	8.95	2.60	23.31	7.7	2.1	5.48	basmati type	greyish white	20.5	High
45	**Jaya**	7.55	2.80	28.84	6.5	2.4	2.58	long bold	white	27.2	High
46	**Krishna Veni**	8.10	2.60	21.10	6.9	2.2	2.68	medium slender	white	12.00	High
47	**Vijetha**	9.30	2.60	28.70	7.0	2.1	2.62	medium slender	greyish white	19.38	High
48	**NDR 359**	8.65	2.95	31.24	7.5	2.5	2.6	long bold	greyish white	22.85	High
49	**Bhadra**	7.65	2.97	25.02	6.6	2.5	2.24	short bold	greyish orange	19.25	High
50	**Aruna**	7.52	2.32	24.12	6.5	2.0	2.68	medium slender	greyish orange	20.80	High
51	**Makom**	8.70	2.97	29.47	7.4	2.4	2.66	long bold	greyish orange	21.64	High
52	**Remya**	7.45	2.60	25.10	6.6	2.1	2.33	short bold	greyish white	15.98	High
53	**Mangala**	9.70	2.67	24.62	8.5	2.1	3.5	basmati type	green white	12.54	High
54	**Barh Avrodhi**	8.25	2.95	22.52	7.1	2.3	2.65	long bold	greyish green	17.75	High
55	**PR 106**	8.10	2.65	25.94	7.2	2.0	3.25	long slender	greyish white	17.70	High
56	**Ambey Mohar**	6.70	2.47	12.94	6.0	2.1	2.62	medium slender	greyish green	29.70	Low
57	**Jyothi**	7.85	2.95	29.02	7.0	2.4	2.71	long bold	greyish orange	29.20	High
58	**Sugandhamati**	10.15	2.40	25.04	8.8	1.8	4.33	extra long slender	greyish white	29.40	High
	RANGE	**6.15 to 10.65**	**1.97 to 3.28**	**12.94 to 32.34**	**5.20 to 9.10**	**1.55 to 2.80**	**2.00 to 5.48**	**Short slender to extra long slender**	**White to greyish orange**	**6.28 to 29.7**	**Low to high**
	MEAN	**8.53**	**2.72**	**25.11**	**7.28**	**2.19**	**3.13**	-	-	**20.45**	-
	STANDARD DEVIATION	**1.02**	**0.286**	**4.019**	**0.804**	**0.268**	**0.632**	-	-	**6.84**	-

Where **Grain L** : grain length; **Grain W:** grain width; **DGL:** decorticated grain length; **DGW:** decorticated grain width; **L/B ratio:** length/breadth ratio; **D grain shape:** decorticated grain shape; **D grain colour:** decorticated grain colour; **GT:** gelatinization temperature.

relationship was observed between alkali spreading values and amylose content, though several extant varieties had high amylose and low alkali values. No variety had low amylose and high alkali spreading value. This indicated that the released Indian rice varieties have good cooking quality.

Genetic parameters

The coefficient of variability, heritability and genetic advance as per cent of mean for various quality traits are presented in Table 2. For the various quantitative morpho-physiological traits studied in the present context, the highest genotypic co-efficient of variation (GCV) was observed for alkali spreading value (21.10), followed by amylose content (19.42), thereby, indicating better scope for genetic improvement in these traits. The proximity of GCV and PCV in addition to high heritability, for both these traits *viz.* gelatinization temperature (98.5%) and amylose content (95.0%) indicates minimal influence of environment on the expression of these characters, which is in line with the earlier findings [6]. However, moderate to high heritability (80.96% to 89.98%) and low to moderate GA (8.73 to 24.28) for grain characters *viz.* 1000 grain weight, length and width of grain as well as that of decorticated grain indicates equal importance of both additive and non-additive gene effects in the inheritance of these traits. Similar results have also been reported in earlier studies in rice [7 & 8].

Heritability estimates combined with genetic advance is more helpful in predicting the gain under selection. High heritability coupled with moderate to high genetic advance and high GCV indicate the predominance of additive gene action for these traits. Hence, selection based on both these traits will be highly rewarding. Thus, the present experimental material possessed considerable variability and heritability coupled with moderate to high genetic advance for the grain characters, thereby emphasizing their utility for establishing distinctiveness of rice varieties based on the DUS test guidelines for the purpose of obtaining protection of such varieties.

Correlation pattern

The objective of the study was to establish relationship between the physiochemical characters for predicting the cooking quality of a variety on the basis of phenotypic characteristics. Grain length and width were observed to be positively correlated with decorticated grain length and width as well as with 1000 seed weight (Table 3). However, the decorticated grain length was negatively correlated with decorticated grain width. The positive significant correlation of length with the L/B ratio of grain and negative significant correlation with width indicates that when grain size increases, its shape also increases, but its boldness is reduced.

The positive correlation of amylose content with alkali spreading value indicates that high amylose rice varieties will absorb more water at low gelatinization temperature and will produce a greater volume of cooked material [9 & 10]. The negative significant correlation between length and amylose content and the absence of correlation between amylose content, breadth and L/B ratio explain the reduced amount of amylose in slender grains.

Table 2. Genetic parameters for grain physio-chemical characters of rice varieties

Characters	PCV	GCV	h^2 (%)	GA (%)
Grain length	6.36	5.70	81.88	7.73
Grain width	4.43	3.97	80.96	10.84
Decorticated grain length	8.81	7.76	85.83	9.78
Decorticated grain width	7.40	6.34	82.23	9.43
1000 grain weight	11.79	10.98	89.98	24.28
Amylose content	19.53	19.42	95.00	37.70
Alkali spreading value/GT	21.56	21.10	98.50	38.50

Where: PCV - Phenotypic coefficient of variation
GCV - Genotypic coefficient of variation
h^2 - Heritability percent
GA - Genetic advance

Table 3. Correlation coefficient among physio-chemical and cooking characters

Character	GL	GW	L/B ratio	1000 SW	DGL	DGW	AC	ASV
GL	1.00	-0.132	0.961*	0.423**	0.929**	-0.379**	-0.419**	-0.265*
GW		1.00	-0.913**	0.627**	-0.059	0.888**	-0.039	-0.041
L/B ratio			1.00	-0.886*	0.834*	-0.823*	-0.12	-0.11
1000 SW				1.00	0.430**	0.463**	-0.113	-0.112
DGL					1.00	-0.314*	0.098	0.089
DGW						1.00	-0.112	0.120
AC							1.00	-0.291*
ASV								1.00

***: p = 0.05; **: p = 0.01**
Where, **GL** – grain length; **GW** – grain width; **1000 SW** – 1000 seed weight;
DGL – decorticated grain length; **DGW** – decorticated grain width;
AC – amylose content; **ASV** – alkali spreading value

Alkali spreading value (ASV) which is an indirect measure of gelatinization temperature, showed a significant positive association with amylose content, suggesting that GT decreases when the amylose content of a variety increases. The present study also showed a significant negative association between ASV and kernel length while no association between ASV, grain width and grain shape (L/B ratio) was detected. It indicates that long grains have reduced amylose content and require a higher GT than bold grains.

Hence, the correlation studies on physiochemical characters and cooking qualities revealed that high amylose rice varieties absorb more water with low GT and produce more cooked material. When amylose content of a variety increases, cooking time increases. Hence, the selection for improved amylose content would result in a correlated improved response in other cooking qualities.

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