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Post Harvest Evaluation of Rice Hybrids for Grain and Cooking Qualities

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ABSTRACT

Background: For commercial exploitation of rice hybrids, superior grain and cooking qualities are prerequisites. The current study evaluates thirty eight rice hybrids in terms of important grain and cooking quality parameters.

Materials and Methods: Performances associated with grain quality parameters like Hulling%, Milling%, Head rice recovery%, Kernel length, Kernel Breadth and L/B ratio were recorded. In case of cooking qualities, characters like Amylose content, Gel consistency, Alkali spreading value, Gelatinization temperature, Elongation ratio and water uptake were estimated. The data obtained from the quality performances were also compared with consumer preferences reported by earlier authors.

Results and Discussions: As per earlier reports, rice millers prefer 80 % Hulling, 70% milling and 65% head rice recovery. From the consumer's perspective long slender kernel, intermediate amylose, soft gel and intermediate gelatinization temperature are prerequisites. In the current investigation the hybrids like ADTRH1, GK5003 and Suruchi exhibited superior performances for all the grain qualities but lacked in one or more cooking quality parameters. On the contrary, hybrids like IR58025A x IR10198R, IR79156A x IR40750R, Sahyadri4, PSD 3 and PusaRH-10 exhibited superior cooking quality traits but lacked in one or more grain quality parameters. The hybrid IR80559A x IR6876-1 was the best performer fulfilling the criteria for most of the grain and cooking quality traits. A Correlation coefficient analysis was performed and significant correlations among the quality traits were elucidated. The analysis revealed that hulling (%) and head rice recovery (%) were significantly correlated with milling (%). Similarly Amylose content was negatively correlated with gel consistency.

Conclusions: The hybrids showing superior grain and cooking qualities can be recommended for commercial production. The vital correlations can be used as tools for selection in terms of grain and cooking qualities.

Key Words: Hybrid rice, Hulling, Milling, Head rice recovery, Amylose content, Gel consistency, Gelatinization temperature, Correlation coefficient analysis

INTRODUCTION

The high grain yield attributed by hybrid vigour will only be worthwhile if ultimately the rice obtained is of high quality in terms of grain and cooking properties. In the absence of adequate grain and cooking quality associated with the grain obtained, the hybrid rice finally produced from a breeding program will be commercially inefficacious. Compared to other cereals, grain quality of rice is of crucial importance and determines the market price since rice is consumed as a whole grain. Also, the preferences in terms of cooking quality vary from region to region. In general, few desirable quality parameters like high milling %, head rice recovery %, grain shape, appearance, cooking qualities, palatability, etc are emphasized across rice growing regions. In most countries including India 'long grain' type of rice which is soft and non-sticky upon cooking are preferred over 'short grained' Japonica types which are sticky on cooking resulting from a low amylose content. In case of hybrid rice, achieving superior grain and cooking quality is challenging. Firstly the consumed grains belong to F_2 generation. Secondly the sterile cytoplasm has significant influence on the quality traits associated with the grain as reported by Shivani *et al*. (2007), Yi and Cheng (1992), Virmani *et al*. (2003). The current study

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aims at evaluating 13 new hybrids (unreleased) and 25 commercially released hybrids for their physical grain and cooking qualities.

MATERIALS AND METHODS

The experiment was performed using 38 rice hybrids comprising of 13 newly identified and 25 released hybrids from public and private sectors. The list of germ plasm evaluated in the current experiment is mentioned in the Table 1. For the analysis of quality traits, post-harvest seeds kept at a moisture level of 12 to 15% were used. After 60 days of harvest, the grain and cooking qualities were estimated.

Characterization of Grain physical parameters:

The vital grain quality characters like Hulling and Milling %, Length of Kernel, Breadth of Kernel, Length-breadth ratio and Head Rice Recovery% were evaluated. For estimating hulling % (HL) Paddy de husker (Satake, Japan Model – THU-35B) was used. For estimating Milling % (ML), replicated paddy seeds were milled using the rice miller (Satake, Japan Model – TMO 5C & TM – 05). Head rice recovery % (HRR) was estimated using 4 months old seeds as suggested by Khush *et al*. (1978). Head rice was separated using the (Satake Japan, Model no.TRGO58). The hulling %, milling % and Head rice recovery% were calculated as per Singh (2000). The Kernel Length (KL) and Kernel Breadth (KB) were measured using Dial Thickness Gauge (Mitutoyo, Japan, Range: 0.01- 20 mm). The LB ratio was calculated by dividing KL by KB. The Kernel Length was classified as ≥7.50mm (very long), 6.61 to 7.50(Long), 5.51 to 6.60 (Medium or intermediate) and ≤5.50 (short). The LB ratio was classified as ≥3.0 (slender), 2.1 to 3.0 (medium), ≤ 2.0 (bold).

Characterization of hybrids with respect to cooking quality parameters

Cooking quality and palatability of rice are influenced predominantly by the properties of starch, which corresponds to 90% of the milled rice recovered. The physical and chemical properties of starch can be approximated by the amylose content, gel consistency and alkali spreading value observed in the milled rice. In the current study Amylose Content (AC) was estimated following Sadasivam and Manikam (1992). Classification of grain type based on amylose content into waxy (0-2%), very low (3-9%), Low (10-19%), intermediate (20-25%) and High (>25%) was done following Kumar and Khush (1986). For determining the texture of the cooked rice, gel consistency (GC) was estimated and classified following Cagampang *et al*.(1973). For determining the cooking temperature of the milled rice the gelatinization temperature (GT) was estimated using the Alkali spreading value (ASV). ASV was determined following Little (1958). The ASV and GT was scored following Singh (2000). The cooked rice properties like Elongation ratio (ER) and Water uptake (WU) were also estimated. The ER was estimated by dividing length of cooked rice by uncooked Azeez and Shafi (1966).

RESULTS AND DISCUSSION:

The performances of the hybrids in terms of grain physical qualities are discussed in Table 2. In terms of hulling and milling percentages the best performing hybrid was Indira Sona with 84.22% and 75.24 % hulling and milling recovery respectively. The highest head rice recovery% was observed in GK5003 (69.24 %). For the new crosses, the highest HL and ML was observed in IR69897A x CNR102 with 82.47 % and 75.21% hulling and milling recovery respectively. The highesr HRR (%) among the new crosses was observed in IR80559A X IR6876-1 (65.27 %). In terms of grain physical appearance, a long grained rice (long slender/medium) are highly marketable Kaul (1970), Singh *et al*. (2000). The grain type revealed that 26 out of 38 hybrids were long grained of which 24 are long slender and 2 hybrids were long medium.

The cooking quality parameters of the hybrids were evaluated and discussed in Table3. The elongation ratio of the cooked rice was calculated. The highest elongation ratio (ER) was observed in PA 6444 (1.9). In case of amylose content, an intermediate value (20 to 25 %) is preferred by the consumers in the Indian sub continent. In the current study 28 out of 38 hybrids exhibited an intermediate level of amylose. For determining the texture of the cooked rice, gel consistency was estimated. The Gel consistency suggests that 6 out of 38 hybrids exhibited a soft gel with a gel migration of ≥ 61mm. These hybrids can be presumed to maintain a soft texture in the cooked rice which is highly desired by consumers Tang *et al*. (1991). For determining the temperature required for cooking, Alkali spreading value indicating the GT was estimated. In case of Gelatinization temperature, 29 out of 38 hybrids exhibited an intermediate range of 70 to 74 ºC. An intermediate cooking temperature is desired by the consumers Bansal *et al*. (2006).

From the commercial perspective earlier reports indicated specific criteria which are to be fulfilled in terms of quality parameters. Fulfillment of these criteria can ensure marketability for the hybrids. Bisne and Sarawgi (2008) indicated 80% hulling percentage is required for marketability of a rice cultivar. Similarly 70% milling recovery and 65% head rice recovery was suggested by Cruz and Khush (2000), Bhonsle and Sellappan (2010) respectively. For cooking qualities, intermediate amylose (20-25%), Soft gel consistency and intermediate gelatinization temperature were recommended Cruz and Khush (2000) Tang *et al*. (1991), Bansal *et al*.(2006) respectively. Based on the fulfillment of such standards, performances of the hybrids in terms of quality traits were scored in the form of presence (+) or absence (-) in Table 4. It reveals that, none of the hybrids could fulfill all the criteria suggested. The hybrids IR58025A x IR10198R, IR79156A x IR40750R, Sahyadri 4, PSD 3 and Pusa RH-10 exhibited superior cooking qualities in addition to long (slender/medium) grain types but lacked in traits like hulling, milling and head rice recovery. Whereas ADTRH1, GK5003 and Suruchi fulfilled the superior grain quality parameters like hulling, milling and head rice recovery but lacked in one or more cooking qualities. The hybrid IR80559A x IR6876-1 fulfilled almost all the criteria for high performance with respect to both grain and cooking qualities only drawback being slightly low hulling percentage.

Since the grain and cooking quality parameters are highly complex, prediction of performance becomes highly challenging and tedious. In such cases understanding the mutual association between the quality traits is very helpful. Thus based on the performances of the hybrids, a correlation coefficient analysis was performed (Table 5).

The correlation coefficient analysis indicated that the hulling % and head rice recovery % are positively correlated with milling %. Such correlations were also observed by Manonmani and Khan (2003). Hulling % and Head rice recovery % were also observed to be positively correlated. Influence of hulling percentage upon head rice recovery % was mentioned by Bisne and Sarawgi, (2008) who suggested that 80 % hulling percentage can enhance head rice recovery expected in the hybrids. From such observation it can be suggested that superior performance for any one of these three traits can indicate a desirable performance for the others. A significantly positive correlation was observed between Kernel length and L/B ratio. Similarly a significantly negative correlation at 1% probability was observed in case of kernel length and kernel breadth as well as between kernel breadth and L/B ratio. Thus from such observations it can be suggested that larger kernel length can indirectly ensure reduction of grain breadth and increase of L/B ratio. Such hybrids can be expected to produce long slender or long medium grain type. Significant correlations among the characters associated with grain shape has been also reported by Hussain *et al*.(1987), Naik *et al*.(2005), Rajamani *et al*. (2004).

Since cooking quality of rice is highly influenced by the grain amylose content, the correlations involving amylose content is worth analyzing. The amylose content of the grains were found to be positively correlated at significantly high probabilities with alkali spreading value. Such observations suggest that selection for the intermediate levels of amylose can indirectly ensure the intermediate GT. Such Intermediate GT within a range of 70 to 74ºC is a desired attribute in terms of cooking quality. The positive association between the two traits was also suggested by Jennings *et al*.(1979).

Another strong correlation associated with amylose was observed in case of Gel consistency. The two traits were negatively correlated at high probabilities. Thus increase of amylose will lead to hard gel consistency with short gel flow and for low amylose the gel will be soft with a longer gel flow. This occurs as a result of the retrogradation behavior of amylose during cooling as suggested by Rani *et al*. (2006). Gel consistency determines the texture of the cooked rice after cooling down of rice following the completion of the cooking process. Thus selection of hybrids for desirable amylose content can ensure desirable texture for the cooked rice. The negative correlations between gel consistency and amylose content was reported earlier by Khatun *et al*. (2003). Apart from the above mentioned correlations which can be exploited for determining the desired grain and cooking quality parameters, many other correlations have been observed between the grain and quality traits. These correlations indicate the nature of interactions among the traits and the complex network of genetic interactions which influence these quality characters.

CONCLUSIONS

The performances of the hybrids in terms of important quality traits provided vital inputs on the expected marketability of the hybrids. The study suggested that the cross combination IR80559A x IR6876-1 was the best performer showing desirable results for both grain and cooking qualities. Thus the hybrid can be expected to be commercially desirable. Other crosses like IR58025A x IR10198R, IR79156A x IR40750R, Sahyadri 4, PSD 3 and Pusa RH-10 exhibited superior cooking qualities but lacked in grain qualities. The loss of head rice recovered in these lines can be avoided if they are consumed as brown rice. Similarly hybrids like ADTRH1, GK5003 and Suruchi performed well in terms of grain qualities but showed drawbacks in case of cooking qualities. These hybrids can be used for making rice based products. The results from the correlation coefficient analysis identified the traits which can influence multiple grain and cooking qualities. Evaluation of hybrids for these traits can in turn provide an approximate idea about the performances for other quality traits.

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Table 1: Hybrids evaluated in terms of grain and cooking quality parameters.

Sl. No.	Hybrids	Origins
1	IR58025A X IR10198R	New Cross
2	IR58025A X MTU9992	New Cross
3	IR58025A X CNR57	New Cross
4	IR69897A X CNR45	New Cross
5	IR69897A X CNR102	New Cross
6	IR79156A X IR10198R	New Cross
7	IR79156A X IR40750R	New Cross
8	IR79156A X IR6876-1	New Cross
9	IR80559A X IR10198R	New Cross
10	IR80559A X IR6876-1	New Cross
11	APMS6A X IR6876-1	New Cross
12	IR58025A X CNR93	New Cross
13	IR58025A X CNR98	New Cross
14	US312	Seed Works India Pvt. Ltd

Table 1: *(Continued)*

Sl. No.	Hybrids	Origins
15	Sahyadri2	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli
16	DRRH2	Directorate of Rice Research, Hyderabad
17	DRRH3	Directorate of Rice Research, Hyderabad
18	Sahyadri3	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli
19	Sahyadri4	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli
20	JRH4	JNKVV, Jabalpur,M.P, India
21	PA 6129	Bayer Bio-Science
22	PA 6444	Bayer Bio-Science
23	APHR2	Andra Pradesh Rice Research Institute, Maruteru, India
24	MGR-1	Tamil Nadu Agricultural University, Coimbatore
25	PSD 1	G. B. Pant University of Agriculture and Technology, Pantnagar
26	PSD 3	G. B. Pant University of Agriculture and Technology, Pantnagar
27	ADTRH1	Tamil Nadu Agricultural University, Coimbatore
28	Sahyadri	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli
29	PA6201	Bayer Bio-Science
30	GK5003	Ganga Kaveri Seeds
31	NSD3	Narendra Deva University of Agricultre and Technology
32	AJAY	Central Rice Research Institute (CRRI), Cuttack, India
33	JRH5	JNKVV, Jabalpur,M.P, India
34	PAC835	Advanta India Ltd
35	HRI-157	Bayer Bio-Science
36	Pusa.RH-10	Indian Agricultural Research Institute, New Delhi
37	Ind. Sona	Indira Gandhi Krishi Vishwa Vidyalaya, Raipur
38	Suruchi	Mahyco

Table 2: Grain quality parameters of thirty eight hybrids

Sl No.	Hybrids	HL%	ML%	HRR %	KL	KB	LB R	GS	GY
1	IR58025A X IR10198R	79.38	70.14	60.21	6.70	2.09	3.21	LS	34.14
2	IR58025A X MTU9992	75.59	68.41	62.37	6.69	2.02	3.31	LS	36.55
3	IR58025A X CNR57	77.22	72.14	64.2	6.90	2.2	3.14	LS	37.21
4	IR69897A X CNR45	81.32	74.21	61.55	6.80	2.01	3.38	L.S	39.69
5	IR69897A X CNR102	82.47	75.21	63.32	6.60	1.92	3.44	L.S	40.95
6	IR79156A X IR10198R	67.31	60.24	55.78	5.97	1.91	3.13	MS	41.37
7	IR79156A X IR40750R	70.49	68.32	56.17	6.60	2.1	3.14	LS	42.38
8	IR79156A X IR6876-1	78.49	71.31	64.28	5.98	1.92	3.11	MS	45.43
9	IR80559A X IR10198R	69.33	64.27	55.21	5.89	1.9	3.10	MS	41.33
10	IR80559A X IR6876-1	79.21	70.18	65.27	6.62	2.12	3.12	LS	38.47
11	APMS6A X IR6876-1	81.24	72.38	63.41	5.88	1.89	3.11	MS	33.90
12	IR58025A X CNR93	77.32	71.42	60.87	6.94	2.23	3.11	LS	46.69
13	IR58025A X CNR98	78.39	70.14	61.22	6.82	2.24	3.04	LS	46.30
14	US312	75.32	67.18	65.12	6.12	1.97	3.11	MS	40.32
15	Sahyadri2	81.17	68.33	59.14	7.08	2.07	3.42	LS	39.10
16	DRRH2	72.14	68.28	59.32	6.63	1.89	3.51	LS	40.30
17	DRRH3	77.21	68.47	60.33	5.73	1.87	3.06	MS	36.67

Table 2: *(Continued)*

18	Sahyadri3	75.14	70.21	60.38	7.48	2.3	3.25	LS	42.12
19	Sahyadri4	75.39	66.28	54.74	6.82	1.8	3.79	LS	33.46
20	JRH4	72.47	67.32	53.14	6.61	2.35	2.81	LM	36.44
21	PA 6129	81.22	70.28	60.73	6.67	1.72	3.88	LS	37.10
22	PA 6444	80.12	73.14	60.23	6.24	2.02	3.09	MS	37.18
23	APHR2	77.47	64.23	50.23	6.64	2.11	3.15	LS	37.93
24	MGR-1	71.22	66.3	59.29	5.9	1.9	3.11	MS	38.20
25	PSD 1	81.12	68.27	56.22	7.3	2.08	3.51	LS	35.78
26	PSD 3	79.3	65.21	60.22	7.01	2.12	3.31	LS	35.09
27	ADTRH1	80.21	74.23	67.48	6.8	2.12	3.21	LS	37.43
28	Sahyadri	72.22	63.18	53.28	7.01	2.17	3.23	LS	37.20
29	PA6201	80.51	69.45	62.74	6.08	2.01	3.02	MS	38.34
30	GK5003	80.24	75.11	69.24	6.41	1.9	3.37	MS	37.89
31	NSD3/2	77.39	68.38	50.44	6.71	2.19	3.06	LS	39.48
32	AJAY	81.42	75.23	63.52	7.29	2.01	3.63	LS	38.57
33	JRH5	72.23	69.41	52.24	6.7	2.19	3.06	LS	30.91
34	PAC835	76.14	72.51	61.45	6.1	2	3.05	MS	36.41
35	HRI-157	78.36	69.43	62.52	6.7	2.28	2.94	LM	37.91
36	Pu.RH10	83.39	66.44	60.32	6.8	1.71	3.98	LS	31.47
37	Ind. Sona	84.22	75.24	54.29	7.12	2.1	3.39	LS	37.61
38	Suruchi	80.41	70.36	65.27	5.52	1.8	3.07	MS	39.67
	Mean	77.47	69.50	59.89	6.58	2.03	3.25		38.34
	Minimum	67.31	60.24	50.23	5.52	1.71	2.81		30.91
	Maximum	84.22	75.24	69.24	7.48	2.35	3.98		46.69
	CD at 5%	1.63	1.90	1.59	0.98	0.67	1.63		3.11

HL= Hulling %, ML= Milling %, HRR %= Head Rice Recovery, KL= Kernel Length, KB= Kernel Breadth, LBR= L/B ratio, GS=Grain shape,GY= Grain tield/plant

Table 3: Cooking quality parameters of thirty eight rice hybrids.

Sl No.	Hybrids	ER	AC	GC	ASV	GT
1	IR58025A X IR10198R	1.82	21.80	62	3.2	Intermediate (70 to 74ºC)
2	IR58025A X MTU9992	1.74	23.80	53	4.1	Intermediate (70 to 74ºC)
3	IR58025A X CNR57	1.68	23.40	48	5.1	Intermediate (70 to 74ºC)
4	IR69897A X CNR45	1.52	25.90	50	5.5	Intermediate (70 to 74ºC)
5	IR69897A X CNR102	1.63	22.10	59	3.5	Intermediate (70 to 74ºC)
6	IR79156A X IR10198R	1.58	24.90	45	5.2	Intermediate (70 to 74ºC)
7	IR79156A X IR40750R	1.61	20.80	67	3.7	Intermediate (70 to 74ºC)
8	IR79156A X IR6876-1	1.69	26.90	38	6.2	Low (55-69 ºC)
9	IR80559A X IR10198R	1.52	23.20	57	4.4	Intermediate (70 to 74ºC)
10	IR80559A X IR6876-1	1.66	22.90	64	4.2	Intermediate (70 to 74ºC)
11	APMS6A X IR6876-1	1.77	23.28	49	4.7	Intermediate (70 to 74ºC)
12	IR58025A X CNR93	1.80	24.10	39	4.6	Intermediate (70 to 74ºC))
13	IR58025A X CNR98	1.79	23.51	47	5.1	Intermediate (70 to 74ºC)
14	US312	1.41	23.40	55	5.2	Intermediate (70 to 74ºC)
15	Sahyadri2	1.49	23.40	47	6.1	Low (55-69 ºC)
16	DRRH2	1.44	26.20	37	6.8	Low (55-69 ºC)
17	DRRH3	1.48	24.60	50	4.2	Intermediate (70 to 74ºC)

Table 3: *(Continued)*

18	Sahyadri3	1.57	24.90	53	3.9	Intermediate (70 to 74ºC)
19	Sahyadri4	1.49	21.60	69	5.8	Intermediate (70 to 74ºC)
20	JRH4	1.42	26.10	39	6.9	Low (55-69 ºC)
21	PA 6129	1.5	24.50	45	6.3	Low (55-69 ºC)
22	PA 6444	1.9	23.70	57	4.7	Intermediate (70 to 74ºC)
23	APHR2	1.64	27.38	33	7.3	Low (55-69 ºC)
24	MGR-1	1.6	29.80	30	7.4	Low (55-69 ºC)
25	PSD 1	1.41	24.02	58	3.1	Intermediate (70 to 74ºC)
26	PSD 3	1.77	20.70	63	4.2	Intermediate (70 to 74ºC)
27	ADTRH1	1.74	25.30	39	4.8	Intermediate (70 to 74ºC)
28	Sahyadri	1.68	21.90	58	4.3	Intermediate (70 to 74ºC)
29	PA6201	1.82	24.70	55	3.5	Intermediate (70 to 74ºC)
30	GK5003	1.77	24.60	59	4.1	Intermediate (70 to 74ºC)
31	NSD3/2	1.81	22.70	51	5.4	Intermediate (70 to 74ºC)
32	AJAY	1.49	25.90	39	6.5	Low (55-69 ºC)
33	JRH5	1.59	25.10	42	5.5	Intermediate (70 to 74ºC)
34	PAC835	1.61	25.10	37	6.2	Low (55-69 ºC)
35	HRI-157	1.52	24.70	51	5.1	Intermediate (70 to 74ºC)
36	Pu.RH10	1.79	24.80	61	5.1	Intermediate (70 to 74ºC)
37	Ind. Sona	1.51	22.91	59	4.8	Intermediate (70 to 74ºC)
38	Suruchi	1.71	24.80	44	5.7	Intermediate (70 to 74ºC)
	Mean	1.63	24.19	50	5.06	
	Minimum	1.41	20.70	30	3.10	
	Maximum	1.90	29.80	69	7.40	
	CD at 5%	0.30	0.91	2.33	1.34	

ER= Elongation Ratio, AC %= Amylose Content, GC (mm) = Gel Consistency, ASV= Alkali spreading value, GT=Gelatinization temperature.

Table 4: Scoring of hybrids based on presence or absence of grain and cooking qualities recommended by earlier reports

Hybrids	80 % Hulling % [a]	70 % milling % [b]	65% head rice recovery [c]	20 -25% amylose [d]	Soft Gel (≥61mm) [e]	Intermediate ASV and GT [f]	Long grained (LM/LS)[g]
IR58025A X IR10198R	-	+	-	+	+	+	+
IR58025A X MTU9992	-	-	-	+	-	+	+
IR58025A X CNR57	-	+	-	+	-	+	+
IR69897A X CNR45	+	+	-	-	-	+	+
IR69897A X CNR102	+	+	-	+	-	+	+
IR79156A X IR10198R	-	-	-	+	-	+	-
IR79156A X IR40750R	-	-	-	+	+	+	+
IR79156A X IR6876-1	-	+	-	-	-	-	-

Table 4: ***(Continued)***

IR80559A X IR10198R	-	-	-	+	-	+	-
IR80559A X IR6876-1	-	+	+	+	+	+	+
APMS6A X IR6876-1	+	+	-	+	-	+	-
IR58025A X CNR93	-	+	-	+	-	+	+
IR58025A X CNR98	-	+	-	+	-	+	+
US312	-	-	+	+	-	+	-
Sahyadri2	+	-	-	+	-	-	+
DRRH2	-	-	-	-	-	-	+
DRRH3	-	-	-	+	-	+	-
Sahyadri3	-	+	-	+	-	+	+
Sahyadri4	-	-	-	+	+	+	+
JRH4	-	-	-	-	-	-	+
PA 6129	+	+	-	+	-	-	+
PA 6444	+	+	-	+	-	+	-
APHR2	-	-	-	-	-	-	+
MGR-1	-	-	-	-	-	-	-
PSD 1	+	-	-	+	-	+	+
PSD 3	-	-	-	+	+	+	+
ADTRH1	+	+	+	-	-	+	+
Sahyadri	-	-	-	+	-	+	+
PA6201	+	-	-	+	-	+	-
GK5003	+	+	+	+	-	+	-
NSD3/2	-	-	-	+	-	+	+
AJAY	+	+	-	-	-	-	+
JRH5	-	-	-	-	-	+	+
PAC835	-	+	-	-	-	-	-
HRI-157	-	-	-	+	-	+	+
Pu.RH10	+	-	-	+	+	+	+
Ind. Sona	+	+	-	+	-	+	+
Suruchi	+	+	+	+	-	+	-

[a]Bisne and Sarawgi (2008); [b]Cruz and Khush(2000); [c]Bhonsle and Sellappan (2010); [d]Cruz and Khush (2000); [e]Tang *et al.* (1991); [f]Bansal *et al.* (2006); [g]Kaul (1970); Singh *et al* (2000)

Table 5: Correlation coefficient analysis among ten grain and cooking quality parameters

		HL	ML	HRR	KL	KB	LBR	ER	ASV	AC	GC
HL	G	1									
	P	1									
ML	G	**0.71****	1								
	P	**0.65****	1								
HRR	G	**0.51****	**0.58****	1							
	P	**0.43****	**0.56****	1							
KL	G	0.25	0.18	-0.24	1						
	P	0.24	0.15	-0.20	1						
KB	G	-0.16	0.08	-0.25	**-0.52****	1					
	P	-0.14	0.04	-0.24	**-0.51****	1					
LBR	G	0.21	0.11	0.06	**0.48****	**-0.57****	1				
	P	0.18	0.08	0.04	**0.42****	**-0.55****	1				
ER	G	0.24	0.18	0.23	-0.14	0.07	**0.31***	1			
	P	0.23	0.16	0.21	-0.12	0.06	**0.28***	1			
ASV	G	-0.16	0.01	-0.01	**-0.31***	-0.21	0.24	-0.24	1		
	P	-0.13	0.05	-0.06	**-0.27***	-0.19	0.21	-0.23	1		
AC	G	-0.14	0.04	0.18	0.08	-0.18	-0.09	**0.39****	**0.49****	1	
	P	-0.12	0.02	0.12	-0.05	-0.16	-0.08	**0.28***	**0.45****	1	
GC	G	0.15	0.16	0.11	0.21	0.14	0.09	**0.42****	**0.30***	**-0.52****	1
	P	0.13	0.144	0.09	0.16	0.11	0.06	**0.39****	**0.28***	**-0.48****	1

HL= Hulling %, ML= Milling %, HRR %= Head Rice Recovery, KL= Kernel Length, KB= Kernel Breadth, ER= Elongation Ratio, ASV= Alkali spreading value, AC %= Amylose Content, GC (mm) = Gel Consistency.* significant variation at 5% probability, ** significant variation at 1% probability.