RESEARCH ARTICLE Agricultural Science Digest, Volume 40 Issue 1: 10-18 (March 2020)

Grain Quality and Multivariate Analysis of Various Quality Parameters in Rice Genotypes

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ABSTRACT

Thirty-six rice genotypes were evaluated for thirteen different quality parameters along with yield/plant to assess genetic estimates of the traits and the extent of genetic diversity among the varieties. Analysis of variance was conducted to determine GCV, PCV, heritability and GA of the genotypes with respect to all characters. Significant variation was observed in many traits among the genotypes offering scope for selection. Correlation analysis determined the nature of relationship among these characters. UPGMA studies revealed six major clusters and cluster I and II were the largest with maximum number of genotypes. The study identified that the varieties namely, Black Gora, Kalinga-2, Dudheswar, ARC 10086, IR-36, IR-64 and Nipponbare possessed good quality traits and high yield performance. The current study indicated that developing rice varieties for consumer acceptance with good grain quality traits along with high yield will be very useful in rice breeding and in selection of parents for hybridization to combine both high yield and improved quality traits.

Key words: Correlation, Dendrogram, Genetic variability, Quality parameters, Rice.

INTRODUCTION

Rice, *Oryza sativa* is one of the most important staple food for more than half of the world's population (Jiang *et al.,* 2013). It is the only cereal crop cooked and consumed mainly as whole grain, so quality consideration is much more important than any other food crop (Hossain *et al.,* 2009). Better grain quality is required for increasing economy in the developing countries and earlier studies indicate that more emphasis was given for high yield and insect/disease resistance during varietal development. Previously in India, 705 rice varieties were released without assessing the quality characters (Thongbam *et al.,* 2012). In the current scenario, quality characters are also considered as an important breeding objective for varietal development and release. The nutritional values and processing properties of rice are beneficial for overall health of the people as well as socio-economic and commercial purposes of the rice growers. Grain quality plays pivotal role for market price, consumer's acceptance and finally the end users. Nowadays there is universally growing concern of enhancement of quality in rice as unattractive grain character and unsatisfactory cooking quality hampers the acceptance and spread of modern variety. So, rice breeders have focused and emphasized on improvement of yield along with economic values that depend on nutritional values, cooking and processing qualities. Physico-chemical properties, cooking and milling processes are very important determinants of market price and consumer's acceptance (Subudhi *et al.,* 2012).

The genetic parameters such as genotypic and phenotypic coefficient of variation are useful in detecting the amount of variability present in germplasms. Heritability coupled with high genetic advance helps in determining the influence of environment on the expression of the genotype and reliability of characters. Genotypic correlation among grain quality and its components will provide the information about their performance and association with one another. Correlation and Path coefficient analysis studies are essential to understand the association among the characters and direct and indirect effects on the dependent variable. Keeping of all this above background information, the present investigation was undertaken to evaluate 36 promising rice genotypes for quality characters and also to assess the genetic divergence which would help to identify desirable genotypes to be used as donors in breeding programme and popularize among the farmers.

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How to cite this article: Majumder, K., Nath, D., Mallick , R. and Dasgupta, T. (2020). Grain Quality and Multivariate Analysis of Various Quality Parameters in Rice Genotypes. Agricultural Science Digest. 40(1): 10-18.

Submitted:12-07-2019 **Accepted:** 21-10-2019 **Published:** 06-03-2020

MATERIALS AND METHODS

The physico-chemical and cooking quality parameters for thirty-six rice genotypes (Table 1) were carried out in the Department of Genetics and Plant Breeding, University of

Table 1: Mean performance of various quality characters along with yield/plant for 36 rice genotypes.

	HL%	ML %	HRR %	L/B	ASV	GTGT	ER	VER	WUR	AMYL%	GC.	CP	SP	Y/P
IR 5882-23-1-3-1	75.1	70.6	65.6	2.1	2.9	HI	1.5	5.6	3.5	16.9	110	6.3	0.3	22.36
DAYA	79.1	69.1	63.8	4.1	3.6	HI	1.6	5.1	3.7	17.4	100.5	7.4	0.1	21.72
NIPPON BARE	74.9	69.2	59.8	2.4	3.2	HI	1.9	2.5	4.3	20.9	100	6.9	0.5	21.66
IR 64	76	70.5	58.1	3.7	3.5	HI	2.3	4.1	3.2	21.1	97.5	7.4	0.8	23.47
CN 1646-2	71.3	63.2	51.8	4.7	2.4	HI	1.4	3.6	4.1	17.8	109.5	6.3	0.5	18.39
IR 50	71.7	62.2	57.8	3	3.1	HI	1.4	5.3	3.7	17	107	5.4	0.5	20.11
IR 36	76.9	69	58.4	4	3.1	HI	1.8	3.3	4.7	20.8	90.5	7.5	0.3	22.39
ARC-10086	74.4	68.9	60	2.6	2.7	HI	2.0	5.2	3.1	20.1	99.6	8.6	0.6	20.67
CN 915	78.2	69.6	60.2	4.1	3.5	HI	1.6	5.8	4.6	15.6	114	7.4	0.5	20.36
PNR-519	79	71.2	62.9	4.7	4.8	I	1.6	3.2	3.8	18	105.5	6.6	0.4	19.36
TEQUING	74.6	67.9	57.4	2.5	3.1	I	1.8	5.3	4.8	14.9	116.5	6.2	0.5	16.33
RATHUWEE	78	70.6	64.8	3.4	3.4	HI	1.9	2.9	4.7	19.9	90.7	6.3	1.1	22.79
JALDI-13	77.8	71.4	59.9	2.3	5	I	1.8	3.3	4.7	16.8	109	6.8	0.8	20.47
KRISHNA HANSA	80.5	68.7	63.7	3.1	4	HI	1.7	5.5	4.5	17.1	106	6.1	2.1	20.67
ORYZICA-L-LONOS-5	69.9	65.8	58.9	4.5	3.3	HI	1.5	3.6	3.6	17.6	105	6.3	2.4	21.56
ASSAMLAYA	78.2	70.7	67.8	4.4	3.5	HI	1.4	5	3.7	19.4	89	5.2	2.1	21.38
CAROLINA-GOLD-SEL	76.4	68.9	60	3.3	3	HI	1.8	5.6	3.1	18.7	107	8.7	2.1	22.4
KALAPAHAR	69	67.2	57.8	4	3.2	HI	1.6	5.9	3.9	18.5	101.5	6.3	2.3	21.11
DUDHESHWAR	73.9	69.8	65.4	3.6	3	HI	1.8	5.2	4.3	21.3	92.4	5.7	2.2	22.96
KHARBELA	73.7	65.2	59.7	3.3	5.7	I	1.5	5.5	4.4	15.9	115	4.9	2.6	20.87
LEMONT	76.6	71.3	61.9	2.5	3.5	HI	1.4	5.5	4.4	18.2	100	6.2	2.8	16.53
TREMBESE	74.6	68.1	62.8	2.8	5.4	HI	1.9	4.9	3.9	17.4	107.5	7.8	3.9	20.91
PNR-546	70.6	63.9	56.9	4	4.6	I	1.6	4.1	4.5	20	92.5	7.8	2.2	20.37
KHITISH	74.8	67.7	56	3.8	3.1	HI	1.7	3.6	5	22.8	85	6.4	2.1	27.64
BLACK GORA	79	71.9	70	2.6	3	HI	1.5	3.4	4.4	22.7	94	4.7	1.5	26.66
SATABDI	71.1	65.8	59.4	3.6	3.4	HI	1.3	3.4	3.4	20.6	92.5	5.3	1.3	23.69
PADMINI	77.5	68.9	60.7	4.3	3.5	HI	1.6	5.3	3.8	19.6	103.5	5.5	0.8	21.09
TRIGUNA	69	60.9	52.1	4.4	4	HI	1.2	3.9	3.5	21.9	95	6.2	1.4	21.33
CO-39	72.7	67.6	60.1	4.3	3.1	HI	1.6	3.9	2.4	17.9	110	5.2	1.2	20.74
1-ZEO-TZE	74.6	68.9	62.7	2.1	5	I	1.9	4	3.4	19.3	102.5	6.5	1.6	18.38
PAROMA-AHU	77.4	69	60.2	2.7	3.1	HI	1.6	4	3.8	22.5	97.5	3.5	2	16.77
1ET-20144	70.3	60.6	54.3	3.7	4.1	HI	1.8	4	3.9	17.2	120	7.2	2.2	17.88
KALINGA-2	76	69.7	56.9	4.5	3.1	HI	2.1	3.8	4.1	22.8	90.5	5.5	2.4	21.79
AZUCENA	68.8	63.4	56.2	2.8	3	HI	1.5	5.1	4.1	18.3	108.5	6.6	2.6	15.87
ARC-10372	76.4	67.8	55.6	2.5	3.5	HI	1.9	5.7	4.3	17.6	119	7.1	2.6	19.75
ZHESHAN-2	70.5	65.8	61.1	5	5.7	I	1.7	5.1	5.1	16.9	118.5	4.8	3.7	19.98
MEAN	74.66	67.81	60.19	3.42	3.66		1.71	4.67	4.01	18.92	102.85	6.35	1.58	20.84
MAX	80.1	71.9	70	5	5.77		2.1	7.8	5.1	22.8	120	8.7	4	27.64
MIN	68.8	60.7	51.8	2.1	2.4		1.2	2.5	2.4	14.9	85	3.5	0.1	15.87
CD (5%)	0.98	0.87	0.75	0.97	0.57		1.29	0.74	0.22	0.61	23.96	0.22	0.74	6.02
CV (%)	0.81	0.79	0.77	17.26	8.50		46.63	9.83	3.55	2.04	14.83	2.21	29.23	18.5
SE	0.49	0.44	0.38	0.49	0.28		0.64	0.37	0.11	0.31	12.10	0.11	0.37	3.04

Calcutta. The experimental materials were grown at Baruipur Agricultural Experimental Farm, University of Calcutta during *Kharif* season of 2017. The harvested material was taken for analysis after drying in hot air oven until moisture content reaches up to 12-14%. The Physical Properties, hulling % and milling % and head rice recovery (HRR)% were done using Dehusker, Rice Miller and Test Rice Grader of Satake, Japan respectively and following the method of Cruz and Khush, (2000). Kernel length and breadth ratio were measured using a dial micrometer caliper calibrated in millimeters (mm) (Ramiah, 1969). Among the chemical properties, amylose content and gel consistency were estimated as per the method of Juliano, (1971) and Cagampang *et al.* (1973) respectively. Gelatinization temperature is estimated by the extent of alkali spreading value and was done following the method of Bhattacharya and Sowbhagya, (1972). The cooking characters like water uptake and volume expansion ratio were determined by the standard method (Sidhu *et al.*, 1975). The elongation ratio was measured by following the protocol of Azeez and Shafi, (1966). The crude protein and soluble protein content were estimated following the method of Kjeldahl, AOAC (2000) using Kelplus Nitrogen Analyzer (Juliano, 1973) and Lowry's method, (1953) respectively. The data was analyzed using the software SPAR.2.0 (Ahuja *et al.,* 2008) and path coefficient analysis was done using INDOSTAT 8.1 (Indostat Pvt. Ltd., Hyderabad, India). Clustering of genotypes was done following the software NTSYSPC Ver. 2.20 (Rohlf, 2007).

RESULTS AND DISCUSSION

Dehulling or dehusking is the most important process after harvesting of rice. The hulling % in these rice genotypes ranged from 68.8% in Azeucena to 80.5% in Krishna- hamsa (Table 1). Some varieties namely, Daya, CN 915, PNR-519, Krishna Hamsa, Black Gora, ARC- 10372, Rathuwee, Jaldi-13 etc showed more than 75% value of hulling. Rita and Sarawgi (2008) reported that more than 80 % value of hulling is preferred for any variety and head rice recovery increases with the increase of hulling percentage. Milling is another important property where the bran layer of the brown rice is removed. Apart from the amount of white rice recovered, milling degree influences the color and also the cooking behavior of rice. High milling and head rice recovery percentage of rice are preferred by the millers (Subudhi *et al.*, 2012). The milling % ranged from 60.6 % (I ET 20144) to 71.9% (Black Gora). Out of 36 varieties, 26 varieties showed high milling percentage (Table 1). High head rice recovery is one of the most important criteria for measuring milled rice quality and it is the volume or weight of head grain or whole kernel in the rice lot and it includes broken kernels that are 75-80% of the whole kernel. It mostly depends on the grain type, cultural practices and drying conditions (Asish *et al.,* 2006). HRR% is a heritable trait but it also depends on environmental factors and post-harvest handling (Fan *et al.*, 2000). HRR% varied from 51.7% in CN-1646-2 to 70 % in Black gora. The amount of variability observed in this present investigation for hulling (68.8-80.5%), milling (60.6-71.9%) and head rice out-turn (51.7-70 %) is satisfactorily comparable to the earlier reports for milling (64-70%) and HRR (61-82%) by Dipti *et al.*, (2002), milling (51.1-76.9%) and Hulling (67.3-79.6%) by Vanaja and Babu (2006), HRR (54.40-75.77%) by Parnsakhorn and Noomhorm (2008), hulling (63-81%) and HRR (45-74%) by Bhonsle and Sellappan (2010), HRR(54.1–63.1%) by Lee *et al.,* (2014) respectively. Consumer acceptability depends on grain shape, size and appearance and based on the average length and breadth of the kernel. Varieties were classified as slender or round by following the guidelines of IRRI, (1996). Among the studied genotypes, 23 showed slender grain out of which Padmini, Triguna, CO-39, Daya, CN 1646-2, CN 915, PNR-519, Oryzica-L-Lonos-5 etc showed L/B ratio above 4.0.

Table 2: Mean sum of squares, genotypic and phenotypic coefficient of variation, heritability and genetic advance.

Characters	Source of Variance			GCV	PCV	Heritability (%)	GA (%)
	Replication (2)	Variety (35)	Error (70)				
Hulling percentage	2.56	32.35**	0.36	14.37	14.45	96.65	6.50
Milling percentage	2.22	36.70**	0.29	15.38	15.45	96.81	5.91
Head rice recovery %	3.26*	47.63**	1.21	16.62	16.67	98.65	4.07
Length-breadth ratio	2.94	7.13**	0.36	22.09	28.04	92.07	4.98
Alkali spreading value	1.15	8.54**	0.12	11.65	12.26	89.63	4.60
Elongation ratio	1.90	12.66**	0.04	20.33	21.98	94	1.60
Volume expansion ratio	1.83	4.89*	0.21	16.84	18.59	88.13	1.26
Water uptake ratio	1.11	3.78*	0.02	14.88	15.29	89.60	1.16
Amylose content	2.66	21.85**	0.14	11.61	12.81	93.40	9.92
Gel consistency	6.06*	291.47**	2.80	28.54	30.41	88.70	4.77
Crude protein	4.04*	25.74**	1.01	17.59	18.72	68.84	3.26
Soluble protein	0.50	3.98*	0.21	16.20	17.83	71.42	1.61
Grain Yield per plant	21.33**	88.17**	13.89	24.71	30.87	69.06	8.56

* Significant at 5% **Significant at 1%

Table 3: Correlation coefficient analysis of thirteen quality parameters along with yield/plant at both phenotypic and genotypic levels.

		HL%	ML%	HRR%	L/B	ASV	ER	VER	WUR	AMYL%	GC	CP	SP	Y/P
HL%	G	1												
	P	1												
ML%	G	0.83**	1											
	P	0.811**	1											
HRR%	G	0.599**	0.679**	1										
	P	0.602**	0.710**	1										
L/B	G	-0.234	-0.283	-0.253	1									
	P	-0.210	-0.263	-0.228	1									
ASV	G	0.137	0.045	0.116	-0.504**	1								
	P	0.124	0.043	0.103	-0.458**	1								
ER	G	0.139	0.188	0.287	-0.292	0.703**	1							
	P	0.231	0.238	0.193	-0.153	0.663**	1							
VER	G	0.028	0.090	0.013	0.081	0.123	0.461**	1						
	P	0.032	0.072	0.011	-0.073	0.119	0.448**	1						
WUR	G	0.139	0.063	-0.024	-0.043	0.071	-0.103	0.019	1					
	P	0.154	0.060	-0.018	-0.037	0.107	-0.137	0.014	1					
Amyl%	G	0.041	0.011	0.181	0.053	0.841**	0.847**	-0.421**	-0.056	1				
	P	0.079	0.119	0.183	0.052	0.806**	0.810**	-0.414**	-0.046	1				
GC	G	-0.045	-0.261	0.011	0.496**	-0.424**	0.889**	-0.261	-0.113	-0.718**	1			
	P	-0.038	-0.197	0.020	0.369*	-0.428**	0.836**	-0.268	-0.109	-0.667**	1			
CP	G	0.029	0.021	-0.239	-0.137	-0.028	0.521**	0.019	-0.083	-0.138	-0.253	1		
	P	0.024	0.013	-0.225	-0.117	-0.031	0.451**	0.014	-0.101	-0.133	-0.209	1		
SP	G	-0.295	-0.214	0.008	0.019	0.134	0.136	0.271	0.217	-0.026	0.228	-0.166	1	
	P	-0.301	-0.194	0.018	0.022	0.126	0.107	0.247	0.192	-0.018	0.182	-0.161	1	
Y/P	G	0.259	0.131	0.297	0.104	0.291	0.061	0.015	0.102	0.331*	0.173	0.335*	-0.196	1
	P	0.217	0.140	0.258	0.116	0.263	0.047	0.028	0.082	0.285	0.181	0.293*	-0.245	1

*Significant at 5% **Significant at 1%.

Table 4: Path coefficient analysis of thirteen grain quality characters on grain yield per plant at phenotypic level.

	HL%	ML%	HRR%	L/B	ASV	ER	VER	WUR	AMYL%	GC	CP	SP	Y/P
HL%	**1.369**	-0.299	-0.222	-0.077	0.042	-0.085	0.014	0.027	0.029	0.014	0.009	0.111	**0.258**
ML%	-0.034	**1.042**	-0.303	-0.041	0.081	-0.089	0.018	0.012	0.015	0.018	0.005	0.028	**0.189**
HRR%	-0.042	0.286	**-0.403**	-0.092	0.041	0.173	0.003	0.017	0.033	0.048	0.009	0.003	**0.297**
L/B	0.058	0.073	0.063	**-0.278**	-0.127	-0.042	0.017	0.018	0.014	0.102	0.012	0.016	**0.108**
ASV	0.025	0.009	0.023	0.103	**0.225**	0.012	0.026	0.024	0.025	-0.074	0.027	0.028	**0.235**
ER	0.053	-0.073	0.017	-0.082	0.019	**0.216**	0.026	0.012	0.085	0.044	0.017	0.021	**0.061**
VER	0.024	0.019	0.002	0.019	0.056	0.039	**0.061**	-0.001	0.058	0.037	0.012	0.034	**0.059**
WUR	0.035	0.014	0.004	0.008	0.024	0.011	-0.003	**0.003**	0.101	0.023	0.013	0.024	**0.098**
Amyl%	0.002	0.013	0.021	0.003	0.023	0.077	0.116	0.101	**0.256**	0.028	0.034	0.044	**0.225**
GC	0.042	0.074	0.025	0.038	0.022	0.101	0.004	0.027	0.011	**0.374**	0.048	0.068	**0.052**
CP	0.006	0.035	0.006	0.015	0.084	0.013	0.039	0.073	0.059	0.063	**0.089**	0.433	**0.179**
SP	0.033	0.072	0.021	0.055	0.038	0.062	0.104	0.169	0.045	0.044	0.093	**0.438**	**0.093**

Residual effect: 0.5

Chemical properties like amylose content, gel consistency and gelatinization temperature (GT) are the three important characters that influence consumption parameters and highly dependent on amount of starch present in grain. Amylose is the linear fraction of starch in the non-glutinous varieties and it is relatively resistant to digestion (Oko *et al.,* 2012). It determines the softness, cohesiveness, tenderness and colour of cooked rice. It is closely related to volume expansion and water absorption during cooking (Deyner *et al*., 2001). Intermediate amylose content (20-25%) is usually preferred by Indian consumers. In this study, maximum genotypes recorded amylose content in the range of 15-25 % which will provide dry and flaky rice (Table 1). Similar to this study, Shahidullah *et al.,* (2009) reported that the AC in all grades of rice ranged between 20.7-21.4%. Gel consistency measures gel viscosity of milled rice i.e. tendency of the cooked rice to get harden after cooling. Lower gel consistency is associated with harder cooked rice and is evident in high-amylose rice. In this experiment, all genotypes belonged to high gel consistency group with 61-100% range (Table 1) and were categorized as soft; this means the tendency of cooked rice to be soft on cooling. Gelatinization temperature has a negative relation to alkali spreading value. Wide variability among rice genotypes was observed in case of ASV from 2.4 for CN-1646-2 to 5.7 for Zheshan-2. Most of the genotypes showed intermediate ASV i.e. 3-5 point indicating intermediate amylose content which is mostly preferred by Indians. This study is similar to the results of Rathi *et al.,* (2010). The time required for cooking is determined by gelatinization temperature. GT of rice grain has the range of temperature where at least 90% of the starch granules swell irreversibly in hot water with loss of crystalline and birefringence. Final gelatinization temperature ranges from 55 to 79°C but environmental conditions (temperature during grain development) influence gelatinization temperature. It is measured by the alkali spreading value (Cruz and Khush, 2000). The intermediate ASV indicated the medium disintegration and classified as intermediate GT which is highly desirable for quality grain (Bansal *et al.,* 2006).

Volume expansion ratio is a very important character for lower income group as quantity is a vital criterion for them. However, more volume expansion ratio is related with less energy content per unit volume (Subudhi *et al*., 2012). Out of these 36 varieties, 23 varieties had ideal value for volume expansion ratio i.e. 4.0-5.0 and it was highest in Kalapahar (5.9), followed by CN 915(5.8), IR 5882-23-1-3-1(5.6), ARC- 10372(5.7) and lowest in Rathuwee (2.9) (Table 1). Elongation in length wise gives finer appearance and expansion in girth, though expresses coarse look. Higher elongation ratio (ER) of the cooked rice is preferred by the consumers reported by Shahidullah *et al.,* (2009). It ranged from 1.2 (Triguna) to 2.3 (IR-64). Water uptake during cooking is directly related to energy consumption as well as the appearance of cooked rice (Fan *et al.,* 2000). The estimated uptake ranged from 2.4 in CO-39 to 5.1 for

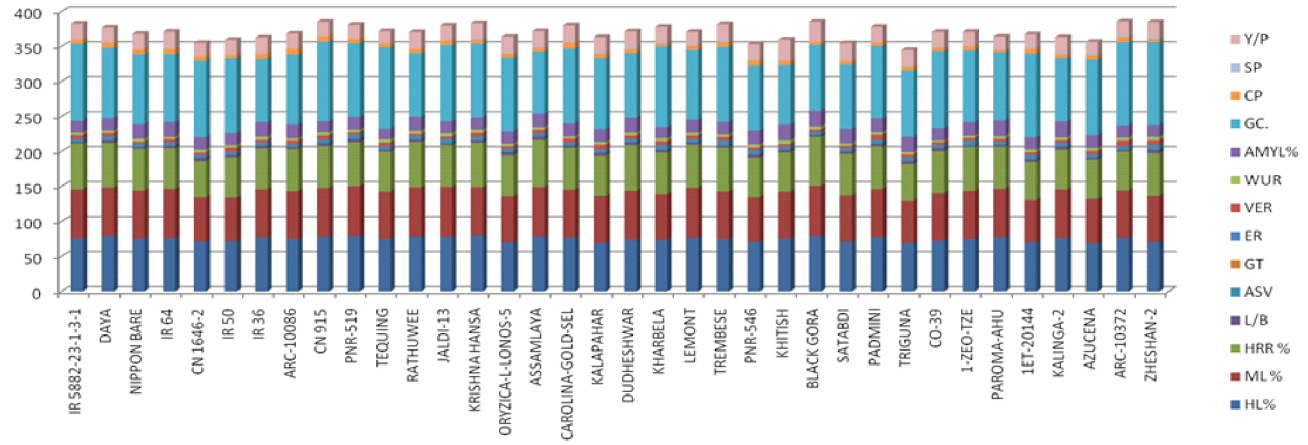

Fig 1: Diagrammatic representation based on mean performance of all characters for 36 rice genotypes.

Zheshan-2. Among the genotypes, 50% had intermediate WUR. High water uptake utilizes more energy for cooking so low water uptake is preferred by low income group of consumers.

Among the traits, crude protein content was maximum in Carolina-Gold-Sel (8.7 %) and minimum in Paroma-Ahu (3.5%). Soluble protein content ranged from 0.1 (Daya) to 3.9 (Tremebase). The variation in starch structure explains a significant proportion of the variation in rice eating quality but the endosperm of milled rice grains also contains from 4% to 10% protein which, based on solubility, is composed of four groups of proteins or “Osborne fractions” (Shewry and Casey, 1999).

Selection of parents based on higher genetic divergence in any hybridization program is expected to generate desirable segregants in segregating generation (Dasgupta and Das, 1985). So, identifying parents based on divergence would be more rewarding in any breeding program. The analysis of variance (ANOVA) revealed significant differences among the traits (Table 2). The genotypes were statistically significant at $P < 0.05$ and $P < 0.01$, which implies that the genotypes constitute a diverse pool of germplasm with adequate genetic variability.

Highest GCV (28.54) and PCV (30.41) were observed for gel consistency followed by yield/plant, grain length/ breadth ratio and elongation ratio (Table 2). The GCV and PCV agreed closely with each other indicating that environment plays little role in the genetic expression of these quality traits. The difference between GCV and PCV was quite large incase of yield per plant. This highlighted that the environment interacted with genotypes to express PCV. The narrow difference between GCV and PCV observed for the traits like hulling %, milling % and HRR % suggests a very little environmental effect. So, these traits can be improved through simple selection methods. Similar findings were also recorded earlier by Vanisree *et al.,* (2013). High heritability was observed for all the traits along with low genetic advance indicating the role of non-additive gene action which can be used in predicting the contributing for selection of superior varieties. It was recorded between 68.84% (Crude protein content) to 98.65% (HRR percentage). High heritability was recorded for milling percentage (96.81%) followed by hulling percentage (96.65%), elongation ratio (94%), amylose content (93.40%), length-breadth ratio of grains (92.07%) which suggests that the traits with high heritability can be given more emphasis during selection procedure. Similar results of high heritability were reported by Kumar *et al.* (2006).

In the present study, both genotypic and phenotypic correlation of thirteen quality parameters along with yield/ plant estimated (Table 3). It was evinced that among all traits a highly positive significant correlation was observed between milling % and hrr %, hulling % and hrr % as well as between hulling % and milling %. Similar finding was previously reported by Manonmani *et al.* (2010). Similarly, a very significant positive correlation was observed between elongation ratio with respect to volume expansion ratio, amylose content, gel consistency and alkali spreading value. The positive significant relationship between amylose and ASV was observed in this study which was also reported by Nayak *et al.,* (2003). The varieties with high amylose content generally had high ASV with low gelatinization temperature. Amylose content correlated significantly and negatively with gel consistency which suggest that those varieties with high amylose content shows hard and shorter length of gel due to retrogradation behavior of amylose during the cooling of gel (Rani *et al.,* 2006). The same negative findings were reported earlier by Khatun *et al.* (2003). In addition to that, the yield parameter is the most vital concern in any study which is a complex character. It was found that different quality parameters were positively correlated with yield, but all were non-significant. It is concluded that quality parameters had less influence on improving yield potential but quality rice with high yield potential will always attract the premium customers and market as well. So, both the traits can be improved simultaneously for a successful future breeding program. The path coefficient analysis showed that the Hulling % and Milling % had highly positive direct effect on yield (Table 4). HRR had negative direct effect on yield potential. The findings were in concordance with the report

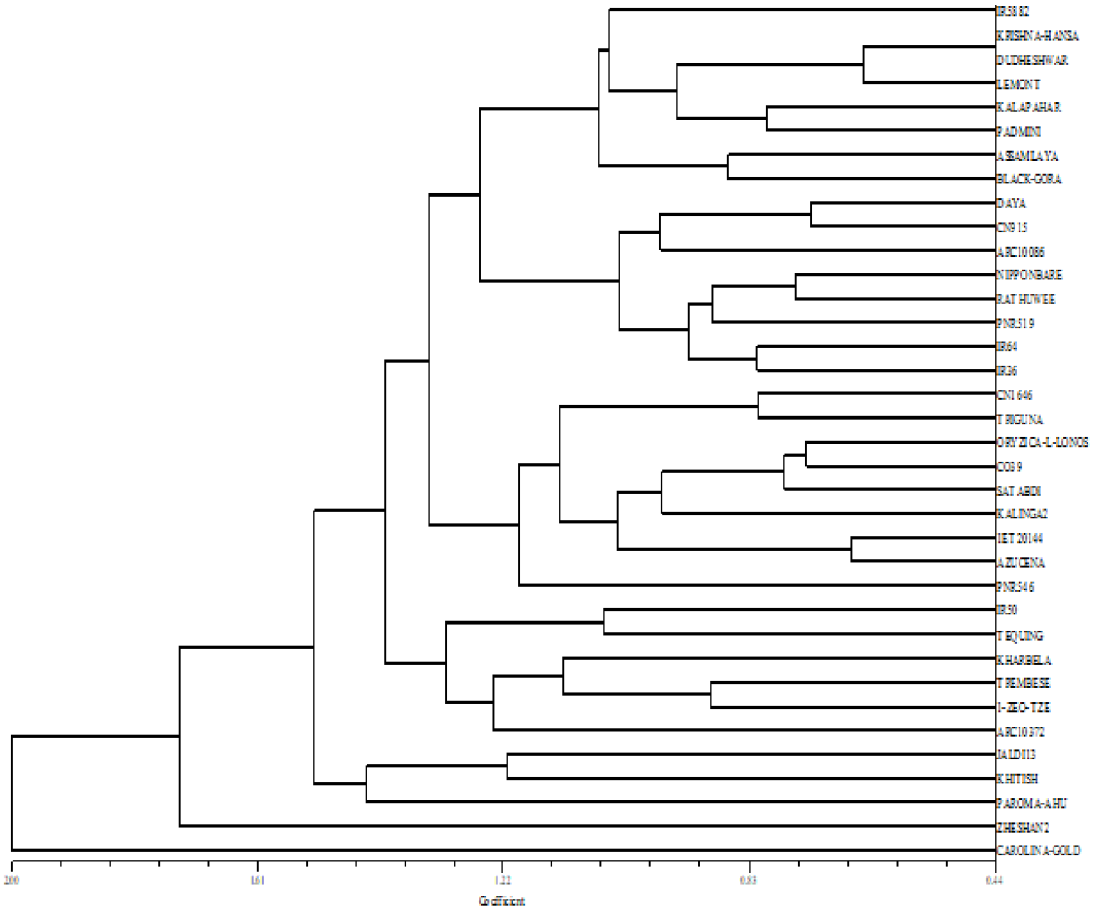

Fig 2: Dendrogram of 36 rice genotypes based on thirteen quality parameters along with yield/plant.

of Singh *et al.* (2013). Amylose content, gel consistency and ASV had a low positive direct effect and supported the findings of Nandan *et al.* (2010). Hence, the quality parameters like Hulling %, Milling %, ASV, Amylose content, gel consistency and elongation ratio should be given priority in selection of genotypes thereby to improve quality in accordance with consumer acceptance.

The grouping of 36 rice genotypes showed that the genotypes constituted 6 major clusters following UPGMA (Fig 2). Cluster I and II were the largest group containing 16 and 9 genotypes respectively. Cluster V and VI were smallest having only one genotype each namely Zheshan-2 and Carolina-gold-sel respectively. It was observed that the genotypes present in cluster I and II had intermediate amylose content with a gel consistency greater than 90%. So, the cooked rice belonging to these two clusters will have a good soft texture and also showed a high grain yield per plant on an average of 14-20 gm. In case of cluster III, both amylose content and gel consistency were intermediate. The varieties in the group of IV, V and VI were characterized with lower amylose content and high gel consistency. The yield /plant was found to be higher in cluster I, II and III and genotypes were associated with intermediate amylose content and gel consistency which discharged dry, flaky and soft rice with having intermediate ASV and it shows medium disintegration. They are termed as intermediate GT which are highly desirable for quality grain and are mostly preferred by Indians. The diversity study helped in generating information on diverse groups and identification of diverse genotypes as potential donors which can be utilized in future breeding programs for genetic enhancement of cooking quality along with better yield.

CONCLUSION

Development of high yielding rice varieties combined with superior quality traits is highly desirable in rice varieties. Breeding for high yield has been quite successful over the years and quality improvement along with yield is usually overlooked due to lack of potential genotypes which can be utilized in hybridization programs. For successful breeding, a genetically diverse germplasm population is required for accurate selection of parents. This study provided a basic information about the diversity of the population in terms of morphological and quality parameters. The correlation analysis between yield and quality traits provide vital information which can be helpful in selection of characters for development of new lines. In the present investigation, it was found that the quality traits like Hulling%, Milling%, ASV, Amylose Content, gel consistency and elongation ratio were highly correlated with yield. This study revealed that the

varieties namely, Black Gora, Kalinga-2, Dudheswar, ARC 10086, IR-36, IR-64 and Nipponbare were enriched with high quality traits with intermediate amylose content along with soft gel consistency and better elongation ratio. These genotypes performed better for hulling, milling recovery and yield and hence these rice varieties can fetch good price in the market because of its high yield potential with valuable quality traits.

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