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Genotypic variations in agro-morphological and physico-chemical traits in ethnic aromatic rice (*Oryza sativa*) landraces of Odisha

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ABSTRACT

Nineteen traditional aromatic rice (*Oryza sativa* L.) varieties of Odisha, India were assessed for morphological, agronomical, biochemical and cooking characteristics to identify superior genotypes for breeding with regard to quality characters. Significant variability was observed in morphological, agronomical and cooking characteristics among the rice varieties. Kalajira (IC 355057) had maximum number of grains per panicle (204 numbers) with high fertility (89.12%). Hence, this could be used as donor for improvement of indigenous aromatic varieties for higher productivity. Badsahbhog and Basumati possessed the intermediate alkali value and amylose content. Chatianaki possessed long kernel length after cooking and high elongation ratio. Gyanbhog showed high hulling, milling and head rice recovery. Therefore, the head rice recovery of Gyanbhog and amylose content of Basumati (23.5%) could be used as donor plants in rice improvement programmes.

Key words: Genotype, Germplasm, Landraces, Odisha, Scented rice

Aromatic rice (*Oryza sativa* L.) varieties are preferred world-wide since ages because of the excellent aroma and palatability. The demand for aromatic rice's for both local and improved varieties has increased markedly in recent years and consumers are willing to pay a premium for fragrance (Bounphanousay 2008). The pleasant aroma associated with aromatic varieties is not only released in cooked rice but is also often emitted in the field at the time of flowering (Widjaja *et al*. 1996, Weber *et al*. 2000). The aromatic compound d 2-acetyl-1-pyrroline (2-AP) is the primary component responsible for the fragrance of aromatic rice (Buttery *et al*. 1988, Weber *et al*. 2000). Thousands of traditional rices are being cultivated by the farmers of Odisha since time immemorial. The richness of variability even in a single district of Odisha is enormous. This led Ramiah and Ghose (1951) to consider Jeypore tract of Odisha as the secondary centre of diversity of rice. Among the diversity in cultivated rice of Odisha, aromatic rice occupies an important position. Farmers of each class/ community have different types of aromatic rices and unlike the Basmati of the northern India, the traditional aromatic rices of Odisha are mostly short bold to medium slender, photosensitive and emit excellent aroma during cooking (Joshi *et al*. 2011). Although the short grain indigenous types are poor yielders, prone to lodging and less susceptible to major pests and diseases still some of them are known for their distinctive quality characters. The desirable traits like kernel elongation, volume expansion and head rice recovery are more pronounced in local types and they also combine many yield attributing traits like longer panicle length, higher grain number with improved fertility, indicating their suitability as donors for improvement of grain yield and kernel quality (Das 2004). It has been observed that the local types available in many parts of Odisha can retain aroma for a longer period even under prolonged storage and therefore, has a better market demand. However, the chemical characterization and quantification of aroma has not been made so far systematically for transferring these traits into high yielding genetic background. Due to complex breeding behavior of quality traits and the role of environment in expression of characters like amylo-pectin, amylase, gelatinization temperature, translucency of grain and head rice recovery, it has not been possible to combine all the desirable quality traits in a single genotype in desired form. Hence, there is a need for basic research on genetics and breeding behavior of quality traits that would help in making breeding strategy more precise. Although, Joshi and Behera (2006) reported analysis of the genetic diversity applying SSR markers of 38 traditional indigenous non-Basmati aromatic rice cultivars and Sivaranjani *et al*. (2010) on 16 aromatic and 30 Basamati land races with SSR markers, the results obtained are not conclusive for a suitable breeding partner to transfer aroma

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Table 1 Grain characteristics and cooking qualities of local scented rice landraces, Odisha, India

Variety	Indigenous collection no.	District	KL	KW (mm)	L/B	HL (%)	ML (%)	HR (%)	AL	WU	Kl AC	VE	ER (%)	AC
Badsahbhog	IC137587	Sundargarh	4.58	2.64	1.93	73.7	68.4	67.4	4.0, 3.0	265	8.40	4.0	1.83	18.48
Bodidhan	IC137553	Koraput	4.43	2.30	1.69	73.5	67.5	67.0	3.0, 2.0	290	8.60	4.2	1.94	19.00
Chatianaki	IC137536	Koraput	4.17	2.47	2.13	75.0	69.5	67.0	4.0, 3.0	210	9.60	4.0	2.30	16.13
Tulsidash	IC137569	Koraput	4.20	2.01	2.14	74.5	66.5	64.0	4.0, 3.0	250	8.20	3.7	1.93	17.91
Mirlo	IC145827	Koraput	4.15	1.94	1.94	75.0	70.0	67.0	4.0, 3.0	280	7.80	4.0	1.88	15.64
Dasahara-prasad	IC145826	Koraput	4.15	2.14	1.98	75.0	70.0	68.5	4.0, 3.0	250	8.00	4.2	1.93	18.21
Basnabhog	IC137562	Koraput	4.45	2.25	2.20	75.0	69.5	68.5	3.7, 2.7	155	8.20	4.0	1.84	18.74
Radhaballav	IC145828	Koraput	4.13	1.88	1.86	71.0	68.4	67.4	4.0, 3.0	250	8.00	4.0	1.94	16.10
Kalajira-1	IC145829	Koraput	4.11	2.21	1.99	72.0	59.1	57.1	3.0, 2.0	195	7.20	4.0	1.75	17.62
Laxmibilash	IC137559	Bolangir	3.90	1.96	1.78	76.0	71.0	70.0	4.0, 3.0	230	7.20	4.2	1.85	15.12
Kalakeshari	IC355042	Bolangir	4.57	2.57	2.35	76.5	69.0	67.0	4.0, 3.0	165	7.40	4.0	1.62	16.20
Kalajira-2	IC355057	Bolangir	5.25	2.23	2.12	75.0	67.5	66.0	4.0, 3.0	175	9.40	4.0	1.79	13.03
Kalakati	IC253427	Bolangir	4.42	2.08	1.95	76.5	72.0	71.0	4.0, 3.0	210	7.60	3.7	1.72	16.10
Kalajira-3	IC86147	Keonjhar	4.33	2.22	1.83	75.2	71.1	70.0	3.0, 2.0	185	7.00	3.7	1.62	20.11
Gyanbhog	IC98898	Kandhamal	4.00	2.19	2.00	78.0	73.3	72.0	3.5, 2.5	165	6.20	3.7	1.55	18.87
Chatianaki	IC98919	Kandhamal	4.38	2.19	1.95	77.0	73.0	71.8	3.0, 2.0	185	7.40	3.7	1.69	18.27
Parijatdeshi	IC99047	Bolangir	4.32	2.21	2.34	75.1	71.2	70.0	3.5, 2.5	245	7.20	3.7	1.66	20.74
Kantakapura	IC99315	Mayurbhanj	5.33	2.67	1.99	76.1	71.9	70.0	3.0, 2.0	170	7.60	3.9	1.80	19.49
Basumati	IC99373	Mayurbhanj	3.88	1.95	2.02	75.0	71.0	68.4	3.0, 2.0	195	7.67	3.7	1.60	23.5
Mean			4.4	2.2	2.0	75.0	69.5	67.9	5.5/2.6	214.2	7.8	3.9	1.8	17.9
Std Deviation			0.39	0.23	0.17	1.65	3.14	3.33	9.33/0.46	42.17	0.81	0.18	0.174	2.35

KL-Kernel length, KW-Kernel breadth, L/B ratio- Length breadth ratio, HL-Hulling (%), ML-Milling (%), HR- Head rice recovery, AL- Akali value, WU-Water uptake, KLAC- Kernel length after cooking, VE-Volume expansion, ER- Elongation ratio, AC – Amylose content

to long grain varieties. The complex breeding behavior of quality traits, the environmental effects and inter-group sterility factors impose restrictions in bringing together the complete array of quality traits into high yielding backgrounds. It is therefore, suggested to make use of convergent breeding techniques by utilizing diverse germplasm sources possessing genes for quality and resistance with improved agronomic base for the genetic enhancement of yield and quality in short grain aromatic rice. Further the problems of undesirable linkage for recovery of agronomically superior recombinants can be overcome through many innovative breeding and selection approaches like disruptive mating, recurrent selection, population improvement and male sterile facilitated recurrent selection to make rapid progress in yield and quality. Thus, in this paper, characterization and identification of nineteen diverse, elite and aromatic rice belonging to tribal and traditional farming system has been attempted to identify suitable lines for combinining high yield and other yield attributes in rice breeding programmes.

MATERIALS AND METHODS

A total number of nineteen traditional rice cultivars collected from six districts of Odisha were used for the present study (Table 1). Each accession were given a separate indigenous collection number to avoid confusion as different varieties may have the same traditional names but collected from different places and may differ in characters. These accessions were grown in the Experimental Farm of National Bureau of Plant Genetic Resources, Base Centre, Cuttack (NBPGR) and studied consecutively for two years for 21 morphological and 14 agronomical and 13 biochemical and cooking characteristics. The varieties were grown in an augmented design of 3 metre long rows. The row-to-row and plant-to-plant distances were 20 and 15 cm respectively. There were three rows for each entry. The fertilizer dose of 40:30:30 kg of N, P and K were applied. Standard agronomical practices were followed. Random samples of five competitive plants were selected for observations and record of data. Qualitative and quantitative characters were taken as per the IRRI-IBPGR descriptors (1980). Shannon diversity index are calculated with observed data in each Descriptor and descriptor states along with frequency. Rice grains of 100 g each of these varieties were dehulled using Stateke dehusker. Hulling, milling and head rice recovery were computed following the method of Govindaswamy and Ghosh (1969). Descriptive statistical analysis of quantitative and biochemical characteristics was carried out using SAS Enterprise Guide.

RESULTS AND DISCUSSION

Genotypic variations in respect of qualitative, quantitative and cooking characteristics of 19 different land races of aromatic rice revealed wide variation (Table 1). The spectrum of variability in respect of qualitative characters indicated that plants were erect with green leaf blade, mostly pubescent, ligule colour white, collar and auricle colour pale green, internodes green in majority of the cases, culm angle varied from erect, intermediate and open; culm strength differs from strong, moderately strong, intermediate to weak. Panicle type's mostly intermediate but open and compact types were also present, secondary branching either absent, light or heavy. Panicle axis mostly straight, apiculus colour purple followed by straw and white, stigma colour white in majority of the cases followed by light purple. Lemma palea are mostly straw but brown spots on straw, reddish to light purple/ red, purple and black were also observed. Seed coat colour predominantly white, with hairs on the upper portion of lemma and palea. Shattering percentage very low, easy threshability and mostly late and slow type leaf senescence. Shannon diversity index varied from 0.21 to 1.24 suggests existence of significant variability among the landraces/accessions.

The mean performance in respect of different metric traits indicated significant variation, viz. Plant height (110.9 to 173.6 cm), leaf length (36.6 to 63.5 cm), leaf breadth (0.5cm to 1.6cm), ear bearing tillers (4.2 to 8.8), days to 50% flowering (106 to 165 d), panicle length (19.9 to 36.5 cm), total spikelets/panicle (23-204.0), panicle weight (0.8-4.2 g), 100-grain weight (0.9-2.5g) and yield per plant (2.2-13.6g). High CV was observed in yield per plant (47.0%) followed by panicle weight (40.2%), total spikelets/panicle (34.1%), leaf breadth (31.9%), 100-seed weight (25.7%), EBT (23.0%), leaf length (17.0%) and plant height (14.4%). It was observed that Kalajira (IC 355057) had shown 204 numbers of grains per panicle with high fertility (89.12%). This could be used as donors for improvement of indigenous aromatic varieties for higher productivity.

In the present investigation the hulling percentage varied from 71.0 (Radhaballav) to 78.0 (Gyanbhog), milling percentage from 59.1 (Kalajira) to 73.0 (Gyanbhog) and head rice recovery from 57.1 (Kalajira) to 72 (Gyanbhog). For quality breeding a variety should have high hulling, milling, and head rice recovery. Since, Gyanbhog possess high hulling, milling and head rice recovery, therefore, may be used as donor for this character. With regards to grain shape and size, the kernel length varied from 3.88 mm (Basumati) to 5.33 mm in (Kantakapura). The width of the kernel varied from 1.88 mm (Radhaballav) to 2.64 mm (Badsahbhog). The L/B ration varied from 1.73 (Badsahbhog) to 2.35 Kalajira). The kernel colour found white in all the studied varieties.

Variation was also observed in cooking behavior of all the tested rice. The alkali spreading value varied from 3.0 to 4.0. Water uptake varied from 155% (Basnabhog) to 300% (Rattanchudi). The kernel length after cooking varied from 6.2 mm (Gyanbhog) to 9.6 (Kantakapura & Chatianaki). Similarly, the volume expansion varied from 3.7 (Kalajira) to 4.2 (Dasaharaprasad). The elongation ratio varied from 1.55 (Gyanbhog) to 2.30 (Chatianaki). The amylose content showed a range of variation between 13.0

Table 2. Correlation coefficient for cooking quality of different aromatic varieties of Odisha; Probability values, Pearson Correlation Coefficients, N=19, Prob>[r] under HO: Rho=0

	KL (mm)	KW(mm)	L/B	HL (%)	ML (%)	HR (%)	WU	Kl AC	VE	ER
KW(mm)	0.625									
	0.004									
L/B	0.197	0.273								
	0.418	0.257								
HL (%)	0.115	0.177	0.233							
	0.638	0.467	0.336							
ML (%)	0.023	–0.014	–0.023	0.725						
	0.924	0.952	0.922	0.001						
HR (%)	0.049	0.003	–0.098	0.675	0.978					
	0.840	0.989	0.688	0.001	<.001					
WU	–0.300	–0.282	–0.398	–0.483	–0.170	–0.153				
	0.210	0.241	0.090	0.036	0.485	0.529				
Kl AC	0.349	0.202	0.077	–0.361	–0.265	–0.278	0.251			
	0.143	0.406	0.753	0.128	0.271	0.248	0.299			
VE	0.055	0.133	–0.280	–0.378	–0.358	–0.306	0.348	0.417		
	0.820	0.586	0.245	0.110	0.131	0.202	0.144	0.075		
ER	–0.032	0.060	–0.126	–0.404	–0.245	–0.267	0.446	0.756	0.543	
	0.895	0.804	0.607	0.085	0.310	0.267	0.055	0.001	0.016	
AC (%)	–0.225	0.060	0.019	0.053	0.2149	0.202	–0.056	–0.379	–0.452	–0.394
	0.352	0.805	0.937	0.827	0.376	0.406	0.817	0.109	0.052	0.094

KL-Kernel length, KW-Kernel breadth, L/B ratio- Length breadth ratio, HL-Hulling (%), ML-Milling (%), HR- Head rice recovery, AL- Akali value, WU-Water uptake, KLAC- Kernel length after cooking, VE-Volume expansion, ER- Elongation ratio, AC – Amylose content

(Kalajira) to 23.5 (Basumati). The intermediate alkali value and intermediate amylose content are most preferred for Indian consumers. Badsahbhog and Basumati possess the same characteristics. Chatianaki may be used for long kernel length after cooking and high elongation ratio. Gyanbhog also possesses amylose content of 18.87% and high hulling, milling and head rice recovery. Therefore, the head rice recovery of Gyanhbog and amylose content of Badsahbhog and Basumati may be used as donors for this character. The evaluation of cooked kernels of different rice varieties revealed the presence of various types of scent with mild to strong intensity. Similar observations were made earlier by many researchers on other aromatic rice varieties of India (Malik *et al.*1994, Manjunath *et al.* 2008, Sharma *et al.* 2008).

ANOVA result confirmed that the high variations exist within water uptake and elongation ratio, length breadth ratio, kernel breadth, volume expansion, kernel length after cooking, amylose content, head rice recovery, hulling % and milling % with a number of attributes (Table 3). However, standard deviation was not significantly prominent in kernel length after cooking as compared to other significant parameters. These characters might be of interest for selection of characters for future breeding programme. The highest correlation between panicle length and plant height (r = 0.81) followed by leaf width and leaf area (r = 0.73) were obtained among the studied germplasm of rice. These attributes might be useful to select the genetically distant breeding partners for transfer of useful characters in rice.

Pearson correlation matrix along with significance values (P values) for the cooking quality is provided in Table 2. The Ward's minimum variance dendrogram generated for the above mentioned traits indicated that the presence of two major groups. The Cluster-I consists of two varieties (Basnabhog and Dasaharaprasad) and the rest 17 varieties clustered together in Cluster-II which divided into two major sub-clusters, i.e. Sub-cluster A and Sub-cluster B (Fig 1). The genotypes of the sub-cluster-I showed high genetic distance than the cluster-II which definitely indicates the genetic closeness of the groups of aromatic rice varieties. In the breeding programme the distantly related genotypes should be of much interest to get a wide genetic characteristic. The Kalajira collected from different area showed genetic variation and Kalajira 2 group as a separate genotype under Sub-cluster B with a closer similarity with Mirlo. However, Kalajira 1 and Kalajira 2 although grouped in sub-cluster A but former grouped differentially with Laxmibilash and latter grouped with Kalakeshari (Fig. 1). Similarly, Chatianaki 1 and Chatianaki 2 perhaps had different agronomic traits and found genetically quite apart from the other with a common genetic backup. The out group of sub-cluster-A was the landraces Chatianaki 1 and Badsahbhog of sub-cluster B showing high heterogeneity among all the studied landraces of aromatic rice which might be a very good donor for transferring the desirable characters of Badsahbhog like

Table 3 ANOVA of different quantitative characters of aromatic rice varieties of Odisha

Source of variation	DF	SS	MS	F	P
Between groups	10	790 124.126	79 012.413	480.553	<0.001
Residual	198	32 555.116	164.420		
Total	208	822 679.241			

All Pair wise Multiple Comparison Procedures (Tukey Test): power of performed test with alpha = 0.050: 1.000

Comparison	Differences of Means	p	q	P	P<0.050
WU vs ER	212.408	11	72.206	<0.001	Yes
WU vs L/B	212.201	11	72.135	<0.001	Yes
WU vs KW	211.994	11	72.065	<0.001	Yes
WU vs VE	210.295	11	71.487	<0.001	Yes
WU vs ER	209.855	11	71.338	<0.001	Yes
WU vs KLAC	206.386	11	70.158	<0.001	Yes
WU vs AC	196.355	11	66.748	<0.001	Yes
WU vs HR	146.311	11	49.737	<0.001	Yes
WU vs ML	144.742	11	49.203	<0.001	Yes
WU vs HL	139.205	11	47.321	<0.001	Yes
HL vs ER	73.203	11	24.885	<0.001	Yes
HL vs L/B	72.995	11	24.814	<0.001	Yes
HL vs AC	72.789	11	24.744	<0.001	Yes
HL vs VE	71.089	11	24.166	<0.001	Yes
HL vs KL	70.650	11	24.017	<0.001	Yes
HL vs KLAC	67.181	11	22.837	<0.001	Yes
HL vs AC	57.149	11	19.427	<0.001	Yes
HL vs HR	7.105	11	2.415	0.832	No
HL vs ML	5.537	11	1.882	0.964	Do Not Test
ML vs ER	67.666	11	23.002	<0.001	Yes
ML vs L/B	67.458	11	22.932	<0.001	Yes
ML vs KW	67.252	11	22.862	<0.001	Yes
ML vs VE	65.553	11	22.284	<0.001	Yes
ML vs KW	65.113	11	22.134	<0.001	Yes
ML vs KLAC	61.644	11	20.955	<0.001	Yes
ML vs AC	51.613	11	17.545	<0.001	Yes
ML vs HR	1.568	11	0.533	1.000	Do Not Test
HR vs ER	66.098	11	22.469	<0.001	Yes
HR vs L/B	65.890	11	22.399	<0.001	Yes
HR vs KW	65.684	11	22.328	<0.001	Yes
HR vs VE	63.984	11	21.751	<0.001	Yes
HR vs KL	63.545	11	21.601	<0.001	Yes
HR vs KLAC	60.075	11	20.422	<0.001	Yes
HR vs AC	50.044	11	17.012	<0.001	Yes
AC vs ER	16.054	11	5.457	0.005	Yes
AC vs L/B	15.846	11	5.387	0.007	Yes
AC vs KW	15.639	11	5.316	0.008	Yes
AC vs VE	13.940	11	4.739	0.033	Yes
AC vs ER	13.501	11	4.589	0.046	Yes
AC vs LKAC	10.031	11	3.410	0.359	No
KLAC vs ER	6.023	11	2.047	0.936	No
KLAC vs L/B	5.815	11	1.977	0.949	Do Not Test
KLAC vs KW	5.608	11	1.907	0.960	Do Not Test
KLAC vs VE	3.909	11	1.329	0.998	Do Not Test
KLAC vs KW	3.469	11	1.179	0.999	Do Not Test
KL vs ER	2.553	11	0.868	1.000	Do Not Test
KL vs L/B	2.345	11	0.797	1.000	Do Not Test
KL vs KW	2.139	11	0.727	1.000	Do Not Test
KL vs VE	0.439	11	0.149	1.000	Do Not Test
VE vs ER	2.114	11	0.719	1.000	Do Not Test
VE vs L/B	1.906	11	0.648	1.000	Do Not Test
VE vs KW	1.699	11	0.578	1.000	Do Not Test
KW vs ER	0.414	11	0.141	1.000	Do Not Test
KW vs L/B	0.206	11	0.0701	1.000	Do Not Test
L/B vs ER	0.208	11	0.0707	1.000	Do Not Test

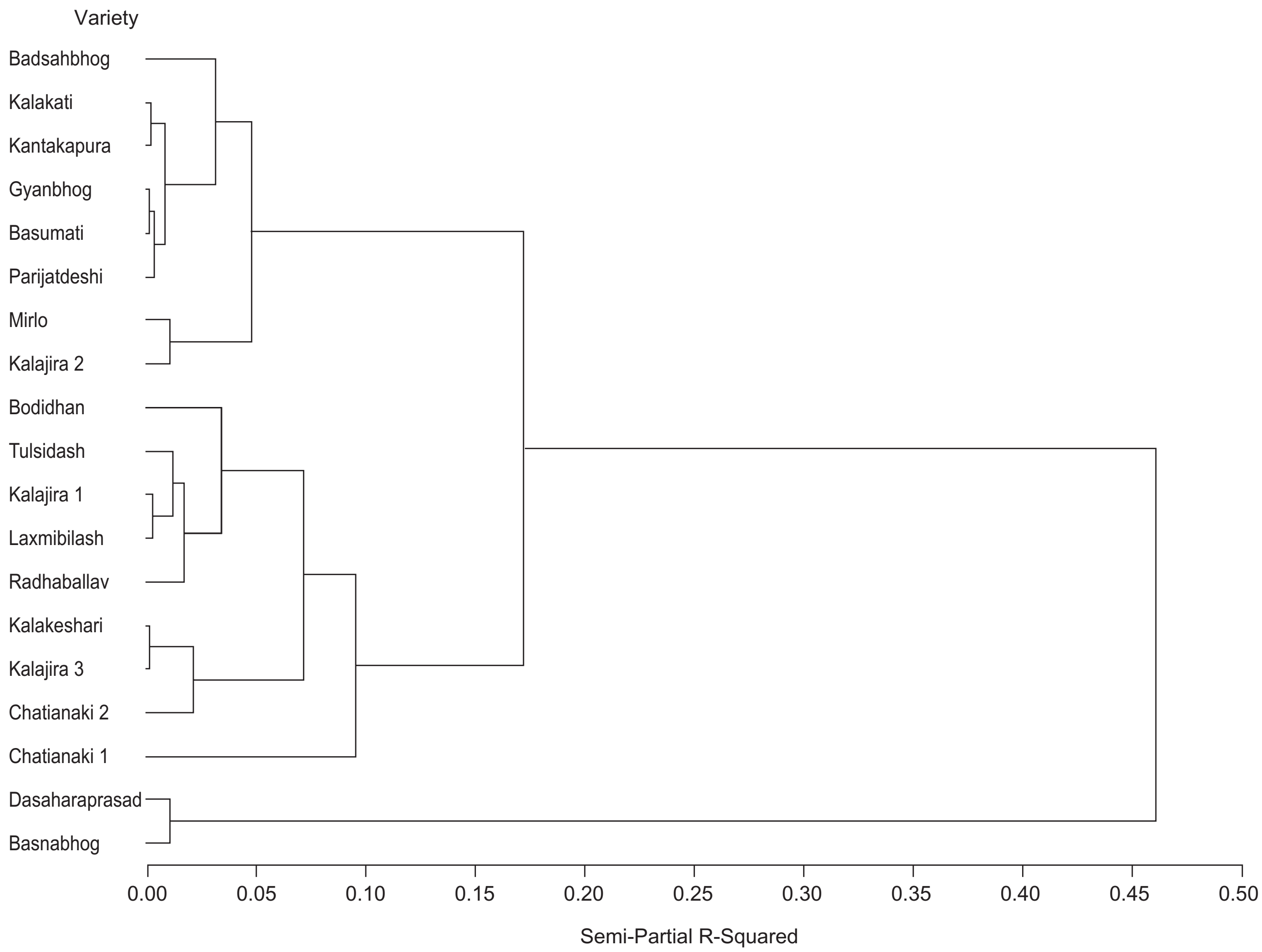

Fig. 1 Ward's minimum variance dendrogram generated for the scented rice varieties

height (165 cm), days of 50% flowering and high spikelet per panicle (190 nos.) to the dwarf varieties. Furthermore in the same Cluster-I, genotypes like Basnabhog of (110 cm) with very high yielding variety with early flowering variety (45 days) can also be used as a potential donor to the genotypes of Cluster-I with any variety of Cluster-II. Differences of genetic differentiation may have been associated with differences in sampling methods and accession handling. Such type of observation also noted in our earlier study in the analysis of 105 genotypes of rice landraces of Jharkhand (Dikshit *et al*. 2012) as well as in Odisha (Singh *et al*. 2010).

The present study indicates that considerable diversity in scented rice landraces populations is maintained on farm. Jarvis *et al*. (2008) reported that considerable crop genetic diversity continues to be maintained on farm, in the form of traditional crop varieties. Breeding approach may lead for possible improvement in yield and quality of the cultivars. This may fetch prosperity for the farmers and satisfaction to the consumers. Among the quality traits, aroma has been much studied and its recessive mode of inheritance has been confirmed with conventional and molecular tools. Although aroma gene (*fgr*) has been mapped and cloned but its uniform expression is desirable for developing aromatic rices which can be cultivated in non-basmati growing areas. The genetic resources of scented varieties of rice could be tapped and used in the breeding programme which necessitates the on-farm maintenance of landraces. In this study a number of potential landraces of scented rice were identified for their valuable agronomic characters towards the contribution of genetic traits in rice breeding programme.

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