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Agro-morphological characterization and molecular diversity analysis of aromatic rice germplasm using RAPD markers

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ABSTRACT

Aromatic rice has special significance because of its special flavour and economic value. The present investigation was undertaken to analyze the relatedness and distances among forty five aromatic rice genotypes using twenty agro-morphological characters and forty five randomly amplified polymorphic DNA (RAPD) markers. The DNA amplification pattern revealed that out of 45 primers, 18 primers showed 100 % polymorphism and a total of 374 RAPD loci were amplified with an average of 8.31 loci per primer comprising 343 polymorphic loci (92 %) and 31 monomorphic loci (8.0 %). In the clustering pattern using RAPD primers all genotypes were grouped into two groups having forty three and two genotypes, respectively. The major cluster was further sub grouped into five small groups having three, seven, six, twelve and fifteen genotypes, respectively. Wide divergence was detected among all genotypes for twenty agro-morphological characters.

Key words: *aromatic rice, RAPD, morphological markers, genetic diversity*

Although, being a promising foreign exchange earner (Singh *et al*., 1997), the cultivation of aromatic rice has been largely restricted to the states of Uttar Pradesh, Punjab and Haryana. Varietal development leading to increase in production and productivity relies heavily on the genetic diversity of crop plants. India possesses an immense wealth of aromatic rice germplasm and landraces exhibiting a wide variability with respect to their morpho-physiological, agronomic, grain and cooking characteristics.

DNA markers in association with agro-morphological traits are found to be useful tools in assessing genetic diversity among genotypes (Lee, 1995; Almanza-pinzone *et al.,* 2003; Pani *et al*., 2008). The information generated through this technology can help to define the distinctiveness of germplasm and their ranking according to the number of close relatives and their phylogenetic position. Compared with pedigree information, DNA marker based diversity reflects actual DNA differences. Two basic types of marker system are available; those that rely on hybridization between probe and homologous DNA segment within genome (Restriction Fragment Length polymorphism (RFLPs), and those that use polymerase chain reaction (PCR) to exponentially amplify genome segments between arbitrary or specific oligo-nucleotide priming sites (Karp *et al.,* 1966). The random amplified polymorphic DNA (RAPD) is the widely used molecular marker where genome fragments are amplified through polymerase chain reaction (PCR) using short (usually 10 bases in length) synthetic primers of random sequence. It is relatively easy, speedy with high degree of polymorphisms as well as virtually inexhaustible pool of possible genetic markers that make the technique advantageous over other molecular techniques (Fristsch and Rieseberg, 1995). With this in view, the present study was undertaken to evaluate variability and relatedness in forty five genotypes based on twenty agro-morphological characters as well as by fingerprinting based on forty five RAPD markers.

MATERIALS AND METHODS

Forty five aromatic rice genotypes were used in the present investigation for molecular marker analysis and field evaluation during 2006-07 and 2010-11 at G.B. Pant University of Agriculture & Technology, Pantnagar, Uttaranchal, India.

Primer sequences were obtained from IRRI (courtesy Dr. G.S. Khush). They were got synthesized from Bangalore Genei Pvt. Ltd., Bangalore The details of operon code, sequence of the primers and GC content are given in Table-1**.** The isolation of genomic DNA from leaf sample was undertaken following the method described by Mukherjee (Mukherjee, 1999) with slight modifications. The PCR reaction was performed in a volume of 20 µl reaction set up having 30 ng of template DNA, 800ìM of dNTPs mix, 1.0 U of Taq DNA polymerase, 1x Reaction buffer, 0.3 µM of Primer and rest of deionized water. The PCR amplification was achieved in M.J Research Thermo cycler (PTC 200). The PCR conditions were initially 5 min denaturing step at 94^0C, followed by 41 cycles having denaturing at 94^0C for 1 min, annealing at 52^0C for 1 min, polymerization at 72^0C for 2 min and incubation at 72^0C for 5 min. A set of 10-25 mer nucleotides RAPD primers was used for PCR amplification.

Horizontal submerged gel electrophoresis unit was used for fractionating RAPD markers on Agarose gel (1.8 %), prepared by dissolving appropriate amount of Metaphore in 1x TAE/TBE buffer (Sambrook *et al.,* 1981) and adding ethidium bromide stain (1.5 µg ml^{-1}). For each well, DNA sample and DNA loading dye (6x) were mixed in ratio of 5:1, v/v and loaded with a micropipette. Electrophoresis was done at 80 V for 4 h in 1xTAE electrophoresis buffer. The gel image was viewed and stored in gel documentation (Bio-Rad) system.

Data analysis of RAPD primer based fingerprinting was done using Gel Compar-II, version 3.5 (Applied Maths. U.S.A). Initially all lanes were marked then reference lane (100 b.p ladder) were selected and different bands of 100 b.p ladder (100 b.p to 1000 b.p)were matched in all three reference lane. Then only distinctly visible bands were marked. After this all lanes were integrated and finally combined dendrogram based on all 45 RAPD markers was generated using Dice's coefficient of similarity and UPGMA cluster analysis.

Evaluation was undertaken using same set of 45 rice genotypes at Seed Production Center, G.B. Pant University of Agriculture & Technology, Pantnagar. The experiment was conducted in two replications; using randomized block design in a 20 m^2 (5 x 4 m^2) plot. Transplanting of 28 days old seedlings was done with plant-to-plant distance of 15 cm and row-to-row distance of 20 cm. Observation for twenty agro-morphological characters was recorded taking data of five plants from each replication. The mean values of two replications were used for data analysis.

RESULTS AND DISCUSSION

In the present investigation, both RAPD markers and agro-morphological traits were employed to assess the genetic diversity among 45 aromatic rice genotypes. The experiment for analyzing genetic relationship using 45 random primers revealed that 18 primers showed 100 % polymorphism with reproducible and informative profiles (Figure-1). A total of 374 RAPD loci were amplified with an average of 8.31 loci per primer comprising 343 polymorphic loci (92 %) and 31 monomorphic loci (8.0 %) (Table-2). The range of polymorphism was 71.4 (RAPD-16) to 100% (18 primers). At 55 % similarity all the genotypes were grouped into two major clusters (A and B) having two and forty three genotypes, respectively. Again at 60 % similarity level the major group B, was sub-grouped into two groups (B1 and B2) having three and forty genotypes, respectively (Figure-2). In this experiment, the UPGMA dendrogram based on Dice's coefficient of similarity and variation in agro-morphological characters indicated that the genotypes possess wide genetic base which could be used in breeding programme.

The mean values of twenty agro-morphological traits among forty five aromatic rice genotypes revealed existence of wide range of variation (Table-3). Plant height was ranged between 87.8 cm (Basmati-127) to 161.7 cm (Basmati-134; Panicle length varied from 20.9 cm (Kalanamak 3121) to 31.0 cm (Tilakchandan 3048); Panicle weight ranged from 1.39 g (Basmati-136) to 4.60 g (Hansraj 3074 U); no. of grains $panicle^{-1}$ ranged from 71.0 (Hansraj 3074 and Basmati 122) to 222.5 (Hansraj 3074 U). The filled grains $panicle^{-1}$ varied from 61 (Taraori Basmati) to 202 grains (Hansraj 3078) among different long-grained Basmati lines, similarly

Table 1. RAPD primers used in the present study

S.N.	Operon Code	Sequences 5' to 3'	GC Content (%)
1	100SS20G28/LP0085	TCCTCTCCATGGTTCCTGAG	55
2	11SS20T39/CD098RA	ACCCTGAGGACTACAACACT	50
3	16SS20C44/RG16F	AGTACCTTGCGCTATCTCTC	50
4	4SS20C32/RZ143	ACAGCAGGTCGAGCATCTTC	55
5	10SS20T38/RFLP62F	CAAATGCTTGGGAGGGCCAT	55
6	99SS20T27/G379F	AGACGGTTGAGAGCACAGAT	50
7	91SS20G19/XRG207F	TGCTACGACGAAGATAGCTG	50
8	12SS20T40/RFLP61F	TTGTTACCACCCCTCTCCTT	50
9	82SS20A10 / G164F	CCAAATTGGCTGACCGATGA	50
10	77SS20G5 / G57F	CTCTTCACCTCCTCCACCTG	60
11	19 SS20G47/RG190F	CTGCATGTTCAGACAGCTTG	50
12	6SS20G34/GR386F	AGCAGAGTACTGTGCAACTG	50
13	9SS20C37/LP0135	TAGTGCTAACAAATCAAAGC	35
14	83SS20C11 / G323F	CTAGGCGAAGACTCCGATTC	55
15	18 SS20C46/XNpB181F	CAACCTAGCAGTCGCTTGGC	60
16	17 SSNpb181F	TCTCCAAAGGGGATGATGTC	50
17	84SS20A12 / G249F	CAGGGGAAAGGGACCAAGCA	60
18	85SS20C13/G177F	CAGGGGAAGAAATGGTGAGC	55
19	20 SS20G48/RG173F	AGCCGACAGTGACTGACCGTG	61.9
20	21 SS20T49/G148F	CAGTTTCAGTCCCATCTCCT	50
21	74SS20A2 / G302F	GTCTCTCGCCACCGTCCTGA	65
22	76SS20G4 / G270F	GCACGGTGAGCCTCTTCAAG	60
23	80SS20G8 /R2166F	AGGATCCCGAGGAGCTCATG	60
24	78SS20G6 / G132F	GGCTACACACATGACACATG	50
25	89SS20C17/RG556F	TAGCTGCTGCCGTGCTGTGC	60
26	7SS20C35/RZ698FB	GCCAATGCCACACCACCAAC	60
27	92SS23A20/RM163F	ATCCATGTGCGCCTTTATGAGGA	47.8
28	93SS24C21/RM164F	TCTTGCCCGTCACTGCAGATATCC	54.2
29	94SS20G22/G200F	TTCCGTTATGCCCAGTGATG	50
30	86SS20G14/G282F	CAGCAGAGCACAGAGTCAAG	55
31	98SS20C26/G338F	AAGTGAGGGGGAGAAGAAAC	50
32	96SS20A24/G122F	CACCATGACAGACCAAGCCA	55
33	2SS20T30/RG28FL	GATGGGGTAGACTAGACCAT	50
34	3SS20C31/LP0319	CATCACCTGCCAGCAACTCC	60
35	13SS20G41/RG257F	CTGAGGTTCTGGGGGTAAAG	55
36	75SS20G3 / G359F	TGGCACGAGGATCAGACATG	55
37	81SS21T9 /RM168F	TGCTGCTTGCCTGCTTCCTTT	55
38	97SS20C25/G12F	CGGAAGATGCGCGAGGTAAC	60
39	67ST10C12	AGGCGGGAAC	70
40	57ST10C2	GGGTAACGCC	70
41	90SS20T18/RG182F	GCATGAGACCAACTGGAGAT	50
42	63ST10A8	GTGTGCCCCA	70
43	66ST10G11	GCAGACTGAG	60
44	69ST10A14	CGGAGAGCGA	70
45	58ST10G3	AATGCCCCAG	60

Table-2. Number of RAPD loci and percentage of polymorphism in rice genomic DNA.

S.N	Primer Code	Range of lociscored (bp)	Total loci	Mono morphic loci	Polymorphism	
					No. of loci	%
1	RAPD 1	295-1310	10	1	9	90.0
2	RAPD 2	290-2000	9	0	9	90.0
3	RAPD 3	590-2400	8	0	8	100.0
4	RAPD 6	390-2500	10	0	10	100.0
5	RAPD 7	305-2600	8	2	6	75.0
6	RAPD 9	490-2400	7	1	6	85.7
7	RAPD 10	305-2600	8	1	7	87.7
8	RAPD 11	550-2650	9	1	7	88.9
9	RAPD 12	540-2800	9	0	9	100.0
10	RAPD 13	295-2400	8	1	7	87.5
11	RAPD 15	380-2800	10	1	9	90.0
12	RAPD 16	305-2550	7	2	5	71.4
13	RAPD 18	300-2400	9	2	7	77.8
14	RAPD 19	580-2800	8	1	7	87.5
15	RAPD 21	340-2100	8	1	7	87.5
16	RAPD 22	295-2350	9	1	8	88.8
17	RAPD 25	390-2300	8	0	8	100.0
18	RAPD 26	150-950	8	0	8	100.0
19	RAPD 27	530-2300	7	1	6	85.7
20	RAPD 28	300-2300	8	2	6	75.0
21	RAPD 30	295-200	9	1	8	88.8
22	RAPD 31	340-2200	8	0	8	100.0
23	RAPD 32	300-2250	7	1	6	85.7
24	RAPD 33	540-2350	8	0	8	100.0
25	RAPD 34	400-2400	7	1	6	85.7
26	RAPD 35	530-2300	6	0	6	100.0
27	RAPD 36	150-1000	7	0	7	100.0
28	RAPD 37	380-2200	9	1	8	88.8
29	RAPD 39	385-2500	7	1	6	85.7
30	RAPD 40	275-2200	8	0	8	100.0
31	RAPD 41	310-2250	10	1	9	90.0
32	RAPD 42	370-2200	8	0	8	100.0
33	RAPD 43	410-2500	9	0	9	100.0
34	RAPD 44	380-2200	8	0	8	100.0
35	RAPD 46	305-2400	8	1	7	87.5
36	RAPD 47	365-2250	9	0	9	100.0
37	RAPD 48	145-1050	9	0	9	100.0
38	RAPD 49	380-2300	9	1	8	88.8
39	RAPD 51	400-2300	10	1	9	90.0
40	RAPD 52	370-2250	8	0	8	100.0
41	RAPD 57	310-2100	12	2	10	83.3
42	RAPD 58	355-2150	8	1	7	87.5
43	RAPD 61	545-2450	8	0	8	100.0
44	RAPD 62	300-2200	8	1	7	87.5
45	RAPD64	510-2400	7	0	7	100.0

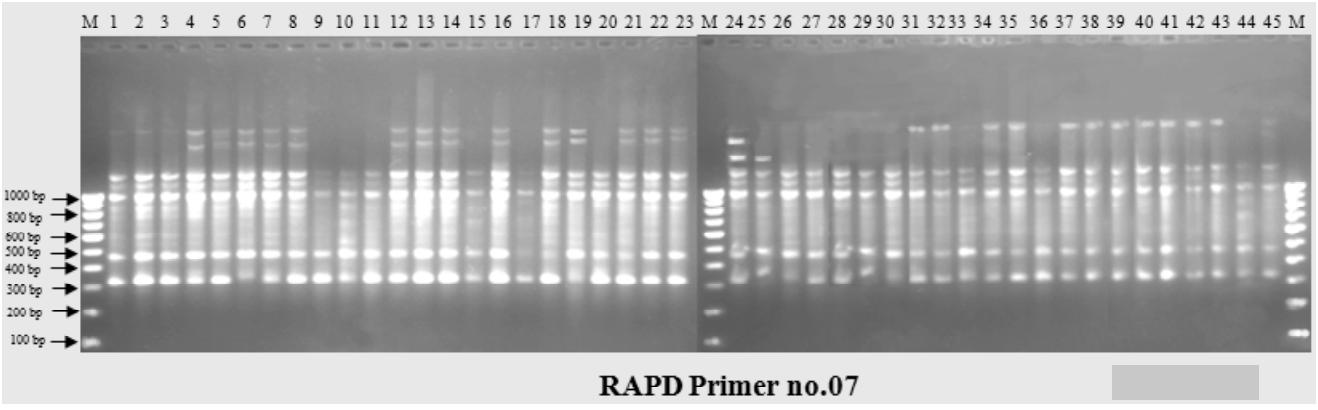

Fig. 1. Amplification profile of the DNA of 45 rice genotypes using the primer- 07

1-Tilak Chandan 3048, 2-Kalanamak 3121, 3-Pokkali(U), 4-Basmati 3317-1, 5-Basmati 370, 6-Basmati 3034, 7-Basmati 3085, 8-Dehradun Basmati 3020, 9-Taraori Basmati, 10-Basmati 3032AR575(U), 11-Basmati 3065AR 1409(U), 12-Dehradun Basmati 3020 (U), 13-Basmati 217, 14-Basmati 107, 15-Basmati 136, 16-Basmati Uzearpka (U), 17-Basmati 124-10, 18-Basmati 127, 19-Basmati 3065 AR 771(U), 20-Basmati 6129, 21-Basmati Nepal, 22-Basmati 1-1 A, 23-Basmati 433, 24-Basmati 134, 25-Basmati Mohan 381, 26-Basmati 43 A, 27-Basmati 106, 28-Basmati 122, 29-Basmati 5836, 30-Basmati 5875, 31-Basmati Sufaid 100, 32-Basmati C-622, 33-Basmati 376, 34-Basmati Sathi, 35-Basmati 375 A, 36-Type-3, 37-Hansraj 3078, 38-Hansraj 3072-2, 39-Hansraj 3072-1, 40-Hansraj 3067, 41-Hansraj 3086, 42-Hansraj 3077, 43-Hansraj 3074, 44-Hansraj3072-2(U), 45-Hansraj 3074(U)

the unfilled grains panicle^{-1} ranged from 3.5 (Basmati C 622) to 46.5 (Basmati Nepal). The range of 1000-grain weight was recorded as 14.9 g (Basmati Nepal) to 26.05 g (Taraori Basmati). The highest yield was recorded for Hansraj 3074 U (5.48 t ha^{-1}) and lowest yield was for Basmati 3034 (1.73 t ha^{-1}). Flag leaf length of different aromatic rice varied in the range of 19.6 cm (Hansraj 3072-2 U) to 32.4 cm (Kalanamak

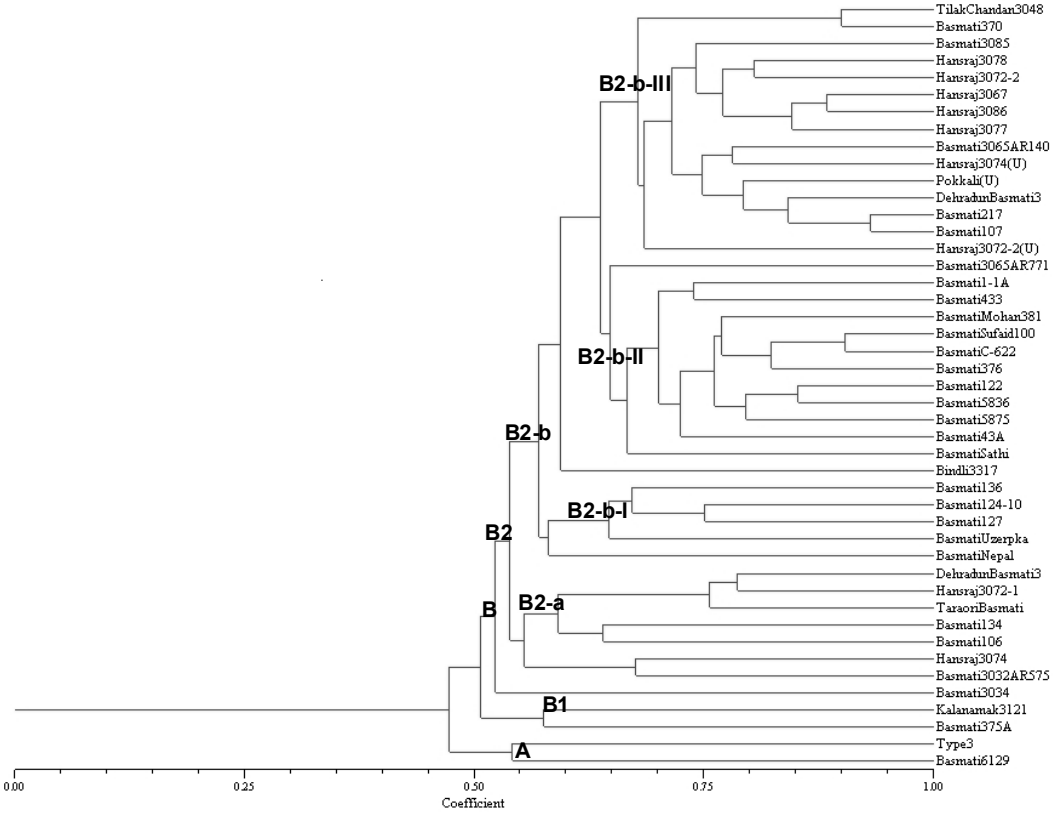

Fig. 2. Dendrogram of rice genotypes based on RAPD markers

Table-3. Mean values of agro-morphological characters of aromatic rice germplasm

Germplasm	Flag leaf length (cm)	Flag leaf breadth (cm)	L/B ratio	First leaf length (cm)	First leaf breadth (cm)	L/B ratio	No. of tillers hill^{-1}	E.B.T hill^{-1}	Panicle exersion	Panicle type	Days to 50% flower-ing	Days to maturity	Plant height (cm)	Panicle length (cm)	Grains panicle^{-1} Total	Filled	Unfilled	1000 grain weight (gm)	Yield ha^{-1} (Q)
Tilak Chandan 3048	22.40	1.05	21.25	45.38	0.97	46.75	7.80	5.40	4.00	1.00	90.5	129.0	126.0	31.00	177.0	164.5	12.5	22.50	33.25
Kalanamak 3121	32.40	1.20	27.00	48.60	1.00	48.60	13.40	9.40	3.00	5.00	110.0	140.0	120.3	20.95	164.0	146.0	18.0	21.30	54.5
Pokkali (U)	30.75	1.17	26.15	45.05	0.90	49.75	16.20	9.45	7.00	5.00	105.0	129.0	96.1	21.20	175.5	147.0	28.5	22.40	54.75
Basmati 3317-1	27.45	1.05	26.50	39.00	0.88	44.30	8.60	7.00	1.00	5.00	82.0	106.0	115.3	34.50	131.5	118.0	13.5	21.00	35.10
Basmati 370	31.35	1.02	30.70	48.40	0.85	56.90	8.00	4.70	2.00	9.00	85.5	115.5	154.0	27.40	108.5	98.0	10.5	21.20	20.00
Basmati 3034	31.90	1.05	30.25	47.65	0.88	54.15	8.80	6.10	1.00	5.00	91.0	117.5	146.5	25.00	77.0	69.0	8.0	20.25	17.30
Basmati 3085	27.25	0.99	27.35	33.90	0.78	43.45	12.25	9.50	1.00	5.00	96.0	115.0	130.0	24.90	103.5	91.5	12.0	20.50	30.85
Dehradun Basmati 3020	29.85	1.05	28.30	42.75	0.79	54.10	13.20	7.90	1.00	5.00	91.0	115.0	160.0	26.20	104.5	92.5	12.0	23.15	30.50
Taraori Basmati	26.00	0.96	26.90	40.00	0.77	51.10	11.80	8.80	1.00	5.00	91.0	115.0	146.5	25.00	74.0	61.0	13.0	26.05	26.40
Basmati 3032 AR 575 (U)	24.00	1.06	22.95	39.95	0.88	45.15	16.20	9.35	7.00	5.00	97.0	117.0	102.0	23.75	106.5	95.5	11.0	23.45	45.75
Basmati 3065 AR 1409(U)	28.60	1.11	25.75	50.10	0.91	55.00	16.50	8.05	1.00	5.00	83.0	115.5	114.7	27.25	106.0	88.0	18.0	23.05	32.20
Dehradun Basmati 3020 (U)	32.00	1.12	28.50	39.15	0.77	50.90	11.40	8.50	1.00	5.00	91.0	115.5	105.8	24.70	124.5	106.0	18.5	22.50	40.50
Basmati 217	24.45	1.17	20.80	46.10	1.03	44.70	12.30	7.30	1.00	9.00	91.0	115.5	150.2	28.55	143.5	130.0	13.5	20.30	38.45
Basmati 107	26.40	1.16	22.60	43.10	1.01	42.65	11.00	8.25	1.00	5.00	91.0	117.5	150.5	25.10	114.5	97.5	17.0	21.95	35.50
Basmati 136	22.85	1.10	20.70	40.30	1.05	39.70	13.40	9.20	1.00	9.00	91.0	117.5	149.4	22.20	92.5	77.5	15.0	20.65	29.25
Basmati Uzearpka (U)	28.85	1.10	26.05	45.40	1.00	45.40	15.60	10.90	1.00	5.00	90.0	116.0	137.3	26.40	142	129	13.0	19.50	50.25
Basmati 124-10	29.85	1.20	24.85	41.60	1.05	39.60	15.40	7.25	1.00	5.00	90.0	116.0	139.8	25.25	132.0	108.0	24.0	19.60	29.15
Basmati 127	29.60	1.17	25.30	51.30	1.05	48.60	14.80	8.60	6.00	5.00	97.0	117.5	97.8	27.50	123.5	105.5	18.0	19.35	33.40
Basmati 3065 AR 771 (U)	31.40	1.17	26.80	40.00	0.71	56.30	15.20	7.60	3.00	1.00	94.5	116.0	141.9	24.75	129.0	108.5	20.5	21.90	35.75
Basmati 6129	25.45	1.17	21.75	48.80	1.02	47.80	14.20	8.80	3.00	9.00	91.0	116.0	140.0	25.00	88.0	81.0	7.0	19.90	29.00
Basmati Nepal	29.65	1.18	25.10	51.85	1.01	51.05	12.70	8.80	5.00	5.00	94.5	140.0	135.0	23.25	158.0	111.5	46.5	14.95	36.55
Basmati 1-1 A	25.40	1.09	23.19	44.10	1.00	44.10	12.60	9.70	3.00	9.00	91.0	116.0	148.2	24.90	96.0	83.5	12.5	22.40	35.25
Basmati 433	27.00	1.09	24.70	44.20	0.96	46.00	15.20	10.20	3.00	9.00	91.00	116.0	140.3	24.50	93.0	79.0	14.0	22.55	39.40
Basmati 134	27.35	1.12	24.50	48.60	1.02	47.60	15.90	9.40	1.00	9.00	91.0	116.0	161.7	25.05	124.5	113.0	11.5	21.85	43.75
Basmati Mohan 381	31.75	1.12	28.35	58.00	1.02	56.55	13.70	8.40	1.00	7.00	91.0	116.0	156.5	26.60	94.0	80.5	13.5	21.50	29.50

Table-3 contd.

Basmati 43 A	25.10	1.15	21.80	46.20	1.02	45.20	12.90	6.80	1.00	5.00	91.0	117.5	129.5	28.55	113.5	104.5	9.0	20.50	32.00
Basmati 106	29.95	1.13	26.50	48.65	1.01	47.90	10.60	6.70	2.00	5.00	91.00	117.5	140.0	26.60	110.5	97.0	13.5	20.30	21.85
Basmati 122	27.35	1.13	23.80	46.60	1.02	45.60	10.20	7.40	1.00	9.00	91.0	117.5	145.3	22.90	71.0	64.0	7.0	21.10	18.20
Basmati 5836	23.80	1.15	20.70	41.40	1.01	40.90	9.70	7.70	1.00	5.00	84.5	117.5	133.7	22.90	100.0	89.0	11.0	18.10	25.60
Basmati 5875	23.00	1.10	20.90	42.20	1.01	41.70	11.80	7.80	1.00	5.00	83.00	116.0	137.4	25.00	132.0	116.5	15.5	18.50	32.35
Basmati Sufaid 100	21.70	1.07	20.30	42.60	1.00	42.60	13.00	9.50	1.00	5.00	83.00	116.0	135.7	25.30	86.0	80.5	5.5	21.65	34.00
Basmati C-622	26.00	1.18	22.00	47.00	1.07	43.30	11.25	6.70	1.00	5.00	84.5	117.5	144.8	25.05	105.0	101.5	3.5	21.35	18.45
Basmati 376	31.15	1.12	27.60	47.10	0.94	50.10	14.40	7.80	1.00	9.00	91.0	116.0	148.0	25.80	104.5	94.0	10.5	22.20	18.17
Basmati Sathi	31.00	1.11	27.92	51.40	1.00	51.40	12.80	10.30	1.00	9.00	91.0	116.0	144.0	27.30	108.0	94.0	14.0	21.75	45.10
Basmati 375 A	25.35	1.12	22.55	42.30	1.03	41.00	11.80	6.00	1.00	9.00	91.0	117.5	143.3	27.80	115.5	103.5	12.0	20.75	26.75
Type-3	26.60	0.95	27.95	41.30	0.79	52.25	10.75	8.70	1.00	5.00	84.5	111.0	13.0	24.8	115.5	98.0	17.5	18.90	30.50
Hansraj 3078	25.60	1.10	22.80	40.80	0.91	44.80	11.20	7.20	6.00	3.00	97.0	126.0	93.0	25.9	218.0	202.5	15.5	21.70	48.50
Hansraj 3072-2	19.85	0.91	21.80	40.40	0.73	49.90	11.60	8.20	3.00	5.00	97.0	126.0	115.0	28.2	161.0	146.0	15.0	21.66	46.25
Hansraj 3072-1	22.90	0.98	25.35	35.30	0.75	42.15	15.40	8.70	1.00	5.00	97.00	126.0	117.0	25.80	128.0	109.5	18.5	21.30	39.25
Hansraj 3067	27.00	1.01	26.85	40.00	0.79	50.05	9.70	8.80	2.00	7.00	82.20	106.0	139.5	27.0	111.5	100.0	11.5	21.00	30.55
Hansraj 3086	26.80	1.01	26.55	40.20	0.76	52.85	14.00	6.90	1.00	5.00	91.00	115.0	151.9	24.0	93.0	86.0	7.0	20.55	23.40
Hansraj 3077	31.60	1.01	28.70	48.40	0.83	58.25	16.00	9.98	1.00	5.00	82.20	106.0	159.0	26.30	102.0	92.0	10.0	21.00	33.60
Hansraj 3074	28.55	1.01	28.05	46.40	0.82	56.15	18.45	7.6	1.00	9.00	91.0	115.0	142.1	25.2	71.0	62.0	9.0	21.50	24.10
Hansraj 3072-2 (U)	19.60	0.95	20.60	38.00	0.65	58.00	15.10	8.30	3.00	1.00	98.5	117.0	101.9	28.00	154.0	92.0	12.0	21.50	50.00
Hansraj 3074 (U)	27.85	1.22	22.80	43.90	0.89	49.05	14.00	8.80	1.00	3.00	83.00	115.5	160.2	27.40	222.5	188.5	34.0	21.10	54.85
CD @ 1 %	0.59	0.31	1.20	3.20	0.39	4.05	1.22	0.81	2.27	1.40	3.77	3.79	3.19	1.24	10.61	27.92	9.57	0.65	1.86
CD @ 5 %	0.44	0.23	0.93	2.46	0.29	3.03	0.91	0.60	1.69	1.05	2.82	2.84	2.39	0.93	7.94	20.90	7.16	0.49	1.39

Panicle exersion codes: 1=Well exerted, 3=Moderated exerted, 5=Just exerted, 7=Partially exerted, 9=Enclosed
Panicle type codes: 1=Compact, 5=Intermediate, 9=Open, E.B.T= Ear Bearing Tillers, CD = critical difference

3121), while flag leaf breadth varied in the range of 0.91 cm (Hansraj 3072-2) to 1.18 cm (Basmati Nepal and Basmati C 622) and L/B ratio was varied from 20.3 (Basmati Sufaid 100) to 30.7 (Basmati 370). The range of first leaf length was recorded from 33.9 cm (Type 3) to 58.0 cm (Basmati Mohan 381), The breadth of first leaf ranged from 0.71 cm (Basmati 3065 AR 771 U) to 1.07 cm (Basmati C 622). There was a wide variation in tillering capacity of different lines, the tillers hill^{-1} varied from 7.8 (Tilakchandan 3048) to 18.4 (Hansraj 3074); number of ear bearing tillers hill^{-1} ranged from 4.7 (Basmati 370) to 10.9 (Basmati Uzearpka). In most of genotypes (39) the panicles were well exerted. All aromatic rice genotypes varied for panicle type from compact (Hansraj 3072-2 U, Basmati 3065 AR 771 U) to open (Basmati 370, Hansraj 3074, Basmati 217, Basmati136, Basmati 6129, Basmati 1-1 A, Basmati 134, Basmati 376, Basmati Sathi, Basmati 375 A). Among all aromatic rice genotypes 50 % flowering varied from 82 days (Hansraj 3067, Basmati 3317-1 and Hansraj 3077) to 116 days (Basmati Nepal) and the maturity time varied from 106 days (Hansraj 3067, Basmati 3317-1) to 148days (Basmati Nepal).

The concept of "genetic distance" has been of vital utility (Arunachalam, 1981). Many farmers in India still grow local germplasm under different names and they also introduce some varieties from distant places and start cultivating them with local names. A number of medium to long-grained scented rice varieties in India are named after Basmati. This may create adulteration in germplasm/variety and may affect export of basmati rice as well as affect crop improvement programmes. It was also observed that combination of agro morphological traits with RAPD primers was found useful in assessment of genetic diversity. Such type of combination has been used by Ndjiondjop *et. al.,* (2010) in characterizations of *Oyrza glaberrima* germplasm from Mali. RAPD markers alone are used by various workers in different study. An agro morphological marker for genetic diversity has been reported in *Paniccum antidotale* (Kumar *et al.,* 2010) in his study of application of RAPD markers in identification of blast resistance in rice genotypes.Wang *et. al.,* (2010) used RAPD markers for identification of albino tea cultivars in china. Similarly Malode *et. al.,* during 2010 has used RAPD markers for genetic diversity analysis of Indian Brassica sp. RAPD based genetic divergence in cotton has been reported by Barrett *et al.*, 1998. The accurate estimation of genetic diversity among germplasm sources may increase the efficiency of plant breeding/ crop improvement (Manjarrez-Sandoral *et al.,* 1997). Similarly, evaluation of genetic diversity can provide predictive estimate of genetic variation among segregating progeny for pure line cultivar development (Barbosa-Nato, *et al.,* 1996). It can also help in predicting the degree of heterosis or combining ability in the progeny of some parental combinations (Moghaddam *et al.,* 2005)

In our study strong relationship between RAPD diversity analysis and agro-morphological data clustering was not observed, although the degree of relationship was stronger. Similar results have been reported for agro-morphological trait with respect to AFLPs in case of bread wheat (Ndjiondjop. *et al*.2010). In present study we found that different indigenous rice germplasm/varieties named after Basmati vary widely in their agro-morphological and molecular characteristics. However, a number of Dehradun Basmati and Hansraj selections show high degree of similarity indicating that Hansraj, which was once grown widely in Bijnore, Pilibhit and Bareilly of U.P. and Udham Singh Nagar of Uttaranchal is a Basmati.

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