Indian J. Genet., 70(1): 48-57 (2010)

Assessment of distinctiveness, uniformity and stability of basmati rice (*Oryza sativa* L.) varieties based on morphological descriptors

Nandita Patra, R. C. Agrawal[1] and H. S. Chawla

Department of Genetics and Plant Breeding, G.B. Pant Univ. of Agric. & Tech, Pantnagar 263 145
[1]National Bureau of Plant Genetic Resources, Pusa, New Delhi 110 012

(Received: September 2009; Revised: December 2009; Accepted: January 2010)

Abstract

Eighteen basmati rice varieties were characterized using morphological descriptors adopted from the DUS guidelines of PPV & FR Authority and subsequently examined for their Distinctiveness, Uniformity and Stability. Among the 46 visually assessed characters 26 characters were monomorphic, 11 characters were dimorphic and seven characters were polymorphic indicating their potential for varietal characterization and distinctiveness. No intra-varietal variation was observed for any of the visual characteristics and expression of characters in different varieties remained same for the two consecutive years confirming the uniformity and stability of the varieties. Combined Over Years Distinctiveness (COY-D) analysis was made on 14 measurable DUS descriptors which revealed distinctiveness for all varieties with respect to each other. COY-D analysis was complemented with MJRA analysis. The slope of the MJRA curves in both the years and regression coefficients indicated that all the considered characters were not completely independent and they are interacting with each other as well as with environment. Combined Over Years Uniformity (COY-U) analysis for five of the measurable characteristics revealed that 15 out of 18 varieties were almost uniform for the characters under study. However the other three varieties were non-uniform for one or two characters emphasizing the need for their further purification to attain a considerable level of homogeneity in their heterogeneous blend. On the basis of grouping characteristics unique morphological profiles could be established for seven varieties. When all the 60 morphological descriptors were studied two more varieties could be distinguished. Thus the morphological DUS descriptors could establish distinctiveness of some varieties but varieties showing overlapping of the expression for these characters could not be discriminated hence some other markers/ descriptors could be considered for complementing the morphological DUS descriptors for establishing the distinctiveness.

Key words: Rice, DUS descriptors, Combined Over Years Distinctiveness, Combine Over Years Uniformity, basmati varieties.

Introduction

Aromatic rice varieties constitute a special group of rice accessions well known for their aroma and/or superfine grain quality [1, 2]. India has an immense wealth of aromatic rice varieties, which are considered as nature's gift exclusive to Indian subcontinent [3]. The centre of diversity of Indian aromatic rices is the foothills of Himalayas in the Indian states of Uttar Pradesh, Bihar, *tarai* region of Uttarakhand and Nepal [4]. The farmers of Indian sub-continent have been growing scented rices for centuries and ancient texts and treatises abound such references [1, 5]. There are many known groups of aromatic varieties such as basmati rice from India and Pakistan and jasmine rice from Thailand. Many farmers in India grow local strains of basmati rice. Besides, basmati rice varieties with higher yield potentials have been developed by incorporating the desirable traits. Thus, there are a number of basmati rice varieties, both traditional and improved types, currently under production whose identity and distinctiveness need to be established. Obviously there is a need of consolidated system in the country to protect such a vast variability present in the species and proper sharing of benefits derived out of them. In this context, Government of India under the obligations of the TRIPS agreement has passed the Protection of Plant Varieties and Farmers' Rights Act, 2001 (PPV&FR Act) to encourage public/private investment in research and development of new plant varieties by giving protection to different categories of plant varieties against

[1]Corresponding author's e-mail: [1]chawlahs_patent@yahoo.com; chawlahs_pantnagar@rediffmail.com

unauthorized multiplication of seeds or propagating materials for a specified period [6]. The PPV&FR Act recognizes the farmers as breeders who bred new varieties as well as conserved the traditional varieties. The plant varieties must fulfill the distinctiveness, uniformity and stability (DUS) criteria for protection under the Act and hence, there is a need to characterize rice varieties according to DUS test guidelines for rice prescribed by PPV and FR Authority [7].

The variety identification serves the important goals, such as mitigating legal claims and confirming intellectual property rights and maintenance of genetic purity. Plant morphological characters have been recognized as the universally undisputed descriptors for DUS testing and varietal characterization of crop varieties**.** Use of morphological descriptors in sequential fashion is useful and convenient to discriminate the different varieties.

Keeping this in view, the study was taken up with the objective to determine the relative extent of distinctiveness, uniformity and stability of different morphological DUS descriptors in 18 basmati rice varieties for their protection under the PPV& FR Act.

Materials and methods

The experimental material consisted of 18 basmati rice varieties (Table 1). The trials were conducted during two *kharif* seasons in randomized block design with 3 replications. Each replication consisted of 3 rows of 6 m length with 30×20 cm spacing. The observations were recorded on 60 of the 62 DUS characters at specified stages of crop growth period when characteristics under study had full expression. Two characteristics viz. polished grain: expression of white core and culm attitude (for floating rice) were not applicable to the material under study. Among the 60 morphological characteristics studied, 46 were visually assessed and 14 were measured.

Table 1. Basmati rice genotypes used in the study

S.No.	Genotypes
1	Hansraj-3078
2	Hansraj
3	Lal Basmati
4	Super Basmati
5	Yamini
6	Kastoori
7	Basmati-386
8	Bas-98/69-7-2
9	KLS-24
10	Pusa Basmati-1
11	Tapovan Basmati
12	Taroari Basmati
13	Type-3
14	PSD-17
15	PSD-15
16	Pusa Sugandh-2
17	Pusa Sugandh-3
18	Basmati-370

For determining distinctiveness in case of visually assessed characters, differences between two varieties were considered clear if the expression of one or more characteristics fell into two different states as per test guidelines. Analysis of measurable characteristics was carried out with the help of DUSNT software [8] comprising of COY-D (Combined Over Years Distinctiveness) for analysis of distinctiveness [9] and COY-U (Combined Over Years Uniformity) for analysis of uniformity [10]. Modified Joint Regression Analysis (MJRA) was also used as a part of COY-D analysis. This MJRA model took account of systematic annual increases or decreases in character expression across all varieties by fitting extra terms, one for each year, in the analysis of variance. Each term represented the linear regression of the observations for the year against the variety means over all years, as described by Digby [11].

The COY-U analysis involves ranking reference and candidate varieties by the mean value of the characteristics. Each variety's standard deviation (SD) is taken and the mean SD of the most similar varieties is subtracted. This procedure gives, for each variety, a measure of its uniformity expressed relative to that of comparable varieties [12].

Grouping of rice varieties was done by using grouping characteristics as mentioned in the DUS test guidelines of PPV and FR Authority for rice [7].

Results and discussion

The accurate description and identification of rice varieties are crucial for DUS testing. The identity/profiles of rice varieties were established by using a set of morphological characteristics prescribed in the DUS test guidelines of rice. Out of the 46 visually assessed DUS descriptors studied, 26 were found to be monomorphic, 11 characteristics were dimorphic and 7 characteristics were polymorphic (Table 2). These visually assessed characteristics did not show any variation in their states

Table 2. Characterization of rice varieties based on visual morphological DUS descriptors

Varieties	Coleoptile colour	Leaf: pubsence of blade surface	Basal leaf sheath colour	Leaf intensity of green colour	Leaf senes cence	Panicle curvature of main axis	Panicle awns	Panicle length of longest awn	Panicle secondary branching	Panicle exertion	Panicle colour of awns	Panicle secondary branching	Panicle distribution of awns	Panicle attitude of bran-ches	Stem antho-cyanin colour of nodes	Spikelets colour of stigma
Hansraj-3078	Colourless	Weak	Green	Light	Late	Deflexed	Absent	-	Present	Mostly exerted	-	Cluster	-	Semi-erect	Absent	White
Hansraj	Colourless	Weak	Green	Light	Late	Deflexed	Present	Long	Present	Well exerted	Yellowish white	Cluster	Upper half only	Semi-erect	Absent	White
Lal Basmati	Colourless	Weak	Green	Light	Late	Deflexed	Absent	-	Present	Mostly exerted	-	Strong	-	Semi-erect	Absent	White
Super Basmati	Colourless	Weak	Green	Light	Late	Semi-straight	Present	Medium	Present	Well exerted	Yellowish white	Strong	Whole length	Erect to Semi-erect	Absent	White
Yamini	Colourless	Weak	Green	Light	Late	Deflexed	Present	Medium	Present	Well exerted	Yellowish white	Weak	Upper half only	Erect to Semi-erect	Absent	White
Kastoori	Colourless	Weak	Green	Light	Late	Deflexed	Present	Long	Present	Mostly exerted	Yellowish white	Weak	Tip only	Erect to Semi-erect	Absent	White
Basmati-386	Colourless	Weak	Green	Light	Late	Semi-Straight	Absent	–	Present	Mostly exerted	-	Weak	-	Erect to Semi-erect	Absent	White
Bas-98/69-7-2	Colourless	Weak	Green	Light	Late	Semi-Straight	Present	Medium	Present	Well exerted	Yellowish white	Weak	Tip only	Erect to Semi-erect	Absent	White
KLS-24	Colourless	Weak	Green	Light	Late	Straight	Absent	-	Present	Well exerted	-	Cluster	-	Semi-erect	Absent	White
Pusa Basmati-1	Colourless	Weak	Green	Light	Late	Straight	Present	Long	Present	Well exerted	Yellowish white	Strong	Whole length	Semi-erect	Absent	White
Tapovan Basmati	Colourless	Medium	Green	Light	Late	Straight	Absent	-	Present	Well exerted	-	Strong	-	Erect to Semi-erect	Absent	White
Taroari Basmati	Colourless	Weak	Green	Light	Late	Straight	Present	Medium	Present	Mostly exerted	Yellowish white	Cluster	Whole length	Semi-erect	Absent	White
Type-3	Colourless	Weak	Green	Light	Late	Deflexed	Present	Medium	Present	Mostly exerted	Yellowish white	Weak	Upper half only	Erect to Semi-erect	Absent	White
PSD-17	Colourless	Weak	Green	Light	Late	Straight	Present	Medium	Present	Well exerted	Yellowish white	Cluster half only	Upper	Semi-erect	Absent	White
PSD-15	Colourless	Weak	Green	Light	Late	Straight	Absent	-	Present	Mostly exerted	-	Strong	-	Semi-erect	Absent	White
Pusa Sugandh-2	Colourless	Weak	Green	Light	Late	Straight	Absent	-	Present	Well exerted	-	Strong	-	Semi-erect	Absent	White
Pusa Sugandh-3	Colourless	Weak	Green	Light	Late	Semi-Straight	Absent	-	Present	Well exerted	-	Weak	-	Erect to Semi-erect	Absent	White
Basmati-370	Colourless	Weak	Green	Light	Late	Semi-Straight	Present	Medium	Present	Well exerted	Yellowish brown	Strong	Upper half only	Erect to Semi-erect	Absent	White

Table 2. Contd .....

Variety	Lemma: Antho cyanin colouration of apex	Lemma: antho cyanin colouration of keel	Lemma: antho cyanin colouration below apex	Lemma: and palea colour	Sterile lemma colour	Spikelet: Density of pubescence	Spikelet colour tip of lemma	Phenol reaction of lemma	Male sterility	Culm: attitude	Decorticated grain: aroma	Decorticated grain colour	Decorticated grain shape	Endosperm presence of amylose	Gelatinization temperature through alkali spreading value
Hansraj-3078	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Erect	Present	White	Extra long slender	Present	Low
Hansraj	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Semi-erect	Present	White	Extra long slender	Present	Low
Lal Basmati	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Semi-erect	Present	White	Long slender	Present	Low
Super Basmati	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Absent	Absent	Erect	Present	White	Long slender	Present	Medium
Yamini	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Absent	Absent	Erect	Present	White	Extra long slender	Present	High medium
Kastoori	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Horizontal	Present	White	Long slender	Present	High
Basmati-386	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Absent	Present	Horizontal	Present	White	Long slender	Present	High
Bas-98/69-7-2	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Erect	Present	White	Extra long slender	Present	Low
KLS-24	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Erect	Present	White	Extra long slender	Present	Low
Pusa Basmati-1	Absent	Absent	Absent	Straw	Straw	Weak	White	Present	Present	Erect	Present	White	Extra long slender	Present	Low
Tapovan Basmati	Absent	Absent	Absent	Brown	Straw	Weak	Brown	Present	Absent	Erect	Present	White	Long slender	Present	High medium
Taroari Basmati	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Absent	Absent	Erect	Present	White	Extra long slender	Present	Medium
Type-3	Absent	Absent	Absent	Straw	Straw	Medium	Yellowish white	Absent	Present	Semi-Erect	Present	White	Extra long slender	Present	Medium
PSD-17	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Erect	Present	White	Extra long slender	Present	Low
PSD-15	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Absent	Absent	Erect	Present	White	Extra long slender	Present	Medium
Pusa Sugandh-2	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Semi-Erect	Present	White	Extra long slender	Present	Low
Pusa Sugandh-3	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Erect	Present	White	Extra long slender	Present	Low
Basmati-370	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Absent	Present	Semi-Erect	Present	White	Extra long slender	Present	High

Table 2. Contd .....

Variety	Leaf: Antho cyanin colour-ation	Leaf sheath: antho cyanin coloura-tion	Leaf: distribu-tion of antho cyanin coloura-tion	Leaf sheath intensity of antho-cyanin coloura-tion	Leaf: collar	Leaf: anthocy-nin colo-uration of collar	Leaf Ligule	Leaf: colour of Ligule	Leaf shape of Ligule	Leaf: Auricles	Leaf: anthocya-nin colour of Auricle	Flaf leaf attitude of blade	Stem intensity of antho-cyanin coloura-tion of nodule	Stem: antho-cyanin colouration of interrades	Flag leaf (Attitude of blade) (L)
Hansraj-3078	Absent	Absent	Absent	Straw	Straw	Weak	Yellowish white	Present	Absent	Erect	Present	White	Extra long slender	Present	Low
Hansraj	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Semi-erect
Lal Basmati	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Semi-erect
Super Basmati	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Erect
Yamini	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Erect	Absent	Absent	Erect
Kastoori	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Erect	Absent	Absent	Horizontal
Basmati-386	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Semi-erect
Bas-98/69-7-2	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Erect
KLS-24	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Erect	Absent	Absent	Erect
Pusa Basmati-1	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Erect
Tapovan Basmati	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Erect	Absent	Absent	Erect
Taroari Basmati	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Erect
Type-3	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Erect	Absent	Absent	Semi-erect
PSD-17	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Erect
PSD-15	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Erect
Pusa Sugandh-2	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Semi-erect
Pusa Sugandh-3	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Semi-erect	Absent	Absent	Erect
Basmati-370	Absent	Absent	Absent	Absent	Present	Absent	Present	White	Split	Present	Absent	Erect	Absent	Absent	Semi-erect

Table 3. Pairwise distinctiveness matrix of 18 basmati rice varieties obtained from COY-D analysis

S.No.	Varieties	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Hansraj-3078	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
2	Hansraj	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
3	Lal Basmati	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
4	Super Basmati	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D
5	Yamini	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D
6	Kastoori	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D
7	Basmati-386	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D
8	Bas-98/69-7-2	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D
9	KLS – 24	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D
10	Pusa Basmati-1	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D
11	Tapovan Basmati	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D
12	Taroari Basmati	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D
13	Type-3	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D
14	PSD-17	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D
15	PSD -15	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D
16	Pusa Sugandh-2	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D
17	Pusa Sugandh-3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D
18	Basmati-370	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-
	No. of ND varieties	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Overall distinctiveness	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

of expression over two years of study. Further, no off type plants were observed hence, these characters were considered to be uniform. Expression of each characteristics was found to be stable in both the two years for the respective varieties, thus confirming their consistency and stability. The stability of visually assessed characteristics can be attributed to a low genotype x environment interaction in their expression. This is due to the fact that most of the visually assessed characters are controlled by single or two genes with simple dominant or recessive relationship. Kumar *et al.* [13] held similar views for the morphological characterization of jute varieties over three years of study.

Data recorded on 14 measurable characteristics were subjected to COY-D statistical analysis at 1% level of significance. Each variety was considered to be a candidate variety and compared to rest of the 17 varieties as reference varieties to obtain a pair wise distinctiveness matrix using COY-D analysis (Table 3). Analysis revealed that all the varieties showed distinctiveness with respect to each other.

COY-D analysis of 14 measurable characteristics using MJRA model was also carried out (Table 4). F_1 ratio (ratio of variety MS to Var x Year MS) was significant for all the characters indicating less role of environment in their expression. The significant F_2 ratio (Ratio of Variety x Year MS to Var x Rep MS) was observed only for the characters leaf length and leaf width of blade, and stem thickness indicating their inconsistent behaviour over the years because of the greater role of environment in its expression thereby limiting their scope to establish distinctiveness among the present set of 18 basmati rice varieties and these traits should be tested in another year or location before coming to any conclusion. The slope of MJRA curves in both the years and regression probability indicates that all the considered characters were not completely independent rather they are interacting with each other as well as with the environment. These results emphasize the need for testing the present experimental material in another year and other locations. Ruiz *et al.* [14] also reported distinctness among the 16 ryegrass (*Lolium perenne* L.) varieties by using MJRA model.

Table 4. Combined over years distinctiveness analysis of fourteen measurable characteristics using modified joint regression analysis (MJRA)

	Leaf: length of blade (cm)	Leaf: width of blade (cm)	Time of heading (days)	Stem: thickness (cm)	Stem: length (excluding panicle) (cm)	Panicle length of main axis (cm)	Panicle number per plant	Time of maturity (days)	1000-grain weight (g)	Grain length (mm)	Grain width (mm)	Decor-ticated grain length (mm)	Decor-ticated grain width (mm)	Content of amylose (%)
Year MS	4.482	0.039	0.083	0.004	2.339	0.009	3.413	1.121	0.006	90.009	0.000	0.000	0.000	0.037
Variety MS	166.458	0.078	214.286	0.001	2425.453	50.183	7.984	276.263	116.700	96.734	0.479	5.007	0.140	28.280
Var. Year MS	7.257	0.003	0.944	0.000	39.063	1.009	0.332	0.944	0.120	2.624	0.001	0.005	0.003	0.135
F1 Ratio	22.939	23.280	292.693	4.415	62.091	49.730	24.069	292.696	970.441	36.859	838.246	913.435	44.830	209.437
Var. Rep MS	2.823	0.001	2.303	0.000	33.401	2.148	0.134	2.303	0.474	88.832	0.006	0.007	0.005	1.179
F2 Ratio	2.571	2.646	0.410	3.430	1.170	0.470	2.480	0.410	0.253	0.030	0.099	0.763	0.623	0.115
Between SE	1.100	0.024	0.397	0.006	2.552	0.410	0.235	0.397	0.142	0.661	0.010	0.030	0.023	0.150
With SE	0.686	0.015	0.620	0.003	2.359	0.598	0.149	0.620	0.281	3.848	0.031	0.035	0.029	0.443
Mjra Slope	0.978	0.882	0.979	0.692	1.067	0.940	1.104	0.979	1.008	0.041	0.990	1.001	0.996	1.023
Mjra Slope	1.022	1.118	1.021	1.286	0.933	1.060	0.896	1.021	0.992	1.935	1.010	0.999	1.004	0.977
Regr F Val	0.177	7.353	2.349	8.149	5.980	3.418	5.406	2.349	1.202	561.050	1.393	0.018	0.014	2.039
Regr Prob	67.968	1.540	14.490	1.147	2.641	8.306	3.354	14.490	28.924	0.000	25.521	89.355	90.847	17.255

$= \frac{\qquad\qquad}{\qquad\qquad}$ $= \frac{\qquad\qquad}{\qquad\qquad}$

Table 5. Combined over years uniformity analysis using standard deviation of eighteen basmati rice varieties

S.No.	Variety	Leaf length	Leaf width	Stem thickness	Stem length	Panicle No./plant
1	Hansraj-3078	120	109	128:2	89	90
2	Hansraj	95	84	103 1	91	99
3	Lal Basmati	89	100	86	111	103
4	Super Basmati	95	82	103	85	92
5	Yamini	97	88	91	102	105
6	Kastoori	94	96	99	102	91
7	Basmati-386	98	95	110	85	107 1
8	Bas-98/69-7-2	96	91	104	105	100
9	KLS – 24	109	93	114 1	127+2	95
10	Pusa Basmati-1	101	100	96	117 1	101
11	Tapovan Basmati	96	80	80	115 1	102
12	Taroari Basmati	89	127:1	103	82	101
13	Type-3	94	131:1	87	99	97
14	PSD-17	95	105	82	98	100
15	PSD -15	98	102	89	106 1	108
16	Pusa Sugandh-2	94	112	108	88	108
17	Pusa Sugandh-3	155+1	92	103	87	97
18	Basmati-370	104	115	113 1	113 1	103

Symbols:
* -SD exceeds over-years Criterion after 3 Years with probability 0.01
+ -SD exceeds over-years Criterion after 2 Years with probability 0.01
: -SD not yet acceptable after 2 years with probability 0.05
1, 2, 3 – The number of occasions the within-years SD exceeds the UPOV criterion

COY-U analysis carried out for five measurable characteristics is shown in Table 5. It revealed that seven out of a total of 18 varieties were completely uniform and eight varieties were more or less uniform for the five measurable characteristics under study. According to the UPOV criteria, non-uniformity among the three varieties namely Hansraj-3078 for stem thickness, Taroari Basmati and Type-3 with respect to leaf width was not within the acceptable limits as the standard deviation for the mentioned characters in their respective varieties was not yet acceptable after two years with probability of 5%. Such a high level of non-uniformity in these varieties emphasizes the need for their further purification to attain sufficient level of homogeneity in their heterogeneous blend.

A major objective of varietal characterization is to establish the distinctiveness among the varieties so that official regulatory bodies have a basis on which they can assign rights and protect the interests of plant breeders and farmers [15]. Keeping this in view, varieties were characterized to establish their unique identification profiles on the basis of grouping characteristics prescribed by DUS guidelines of PPV & FR Authority. DUS guidelines have included eight characteristics in rice as grouping characteristics. Amongst the 18 rice varieties studied it was observed that the decorticated grain colour, basal leaf sheath colour and decorticated grain aroma were monomorphic in the varieties. Thus, grouping of varieties was based on 4 characteristics viz. time of heading, stem length, decorticated grain length and endosperm content of amylose. In the varieties studied decorticated grain length character and decorticated grain shape exhibited similar grouping pattern in basmati varieties and hence decorticated grain length character was used for grouping. Distinctive profiles were obtained for Pusa Basmati-1, Pusa Sugandh-2, Type-3, Basmati-370, Basmati-386, Hansraj-3078, Hansraj 3072-2 and PSD-15. The rest of the ten varieties remained in three different groups (Table 6). When all the sixty morphological descriptors were considered two more varieties Tapovan Basmati and Kastoori were delineated. However, rest eight varieties remained within

groups of two to four varieties and no further distinctive profile was obtained. Although for some of the varieties which were discriminated by grouping characters, additional distinctive descriptors were obtained (Table 6). In short, the cultivars in the present study showed overlapping of morphological descriptors in various combination traits, but still the identity of some of the cultivars could be established individually. Similar attempts for establishment of distinctiveness have also been made in soybean [16], oat [17], rapeseed-mustard [18,19], pearl millet [20] and jute [21].

It may be concluded from the present investigation that the morphological DUS descriptors can be effectively used for identification and grouping of varieties and varieties satisfying the DUS criteria for these morphological descriptors could be registered under the PPV & FR Act for obtaining Plant Breeders and Farmers' rights. However, it seems morphological descriptors alone may not be sufficient for DUS criteria. Hence, some other markers/ descriptors may be considered for complementing the morphological DUS descriptors for establishing distinctiveness of closely related varieties.

Table 6. Morphological profiles generated for 18 basmati rice varieties based on grouping characteristics prescribed in Test Guidelines of PPV & FR Act, 2001

S.No.	Varieties	Characteristics
1	Pusa Basmati-1	Medium (Time of heading) Medium (Stem length)
2	Pusa sugandh-2	Medium (Time of heading) Short (Stem length)
3	Type-3	Late (Time of heading) Medium (Stem length)
4	Basmati-370	Late (Time of heading) Long (Stem-length)
5	Basmati-386	Late (Time of heading) Short (Stem length) Long (Decorticated grain length)
6	Hansraj-3078	Late (Time of heading) Very short (Stem length) Long (Decorticated grain length) High (Endosperm content of amylose)
7	Hansraj	Late (Time of heading) Very short (Stem length) Extra long (Decorticated grain length) High (Endosperm content of amylose)
8	Pant Sugandh Dhan-15	Late (Time of heading) Short (Stem-length) Extra long (Decorticated grain length) Low (Endosperm content of amylose)
9	Lal Basmati Pusa Sugandh-3 Kastoori, PSD-17 Super Basmati Tapovan Basmati	Late (Time of heading) Very short (Stem-length) Long (Decorticated grain length) Medium (Endosperm content of amylose)
10	Yamini B-98/69-7-2	Late (Time of heading) Very short (Stem-length) Extra long (Decorticated grain length) Medium (Endosperm content of amylose)
11	KLS-24 Taroari Basmati	Late (Time of heading) Short (Stem-length) Extra long (Decorticated grain length) Medium (Endosperm content of amylose)

References

1. **Ahuja S. C., Panwar D. V. S., Ahuja U. and Gupta K. R.** 1995. Basmati rice the scented pearl. Directorate of Publications, CCS Haryana Agricultural University, Hisar.
2. **Singh R. K., Singh U. S., Khush G. S., Rohilla R., Singh J. P., Singh G. and Shekhar K. S.** 2000**.** Small and medium grained aromatic rices of India. In: Aromatic rice. Singh R.K., Singh U.S. and Khush G.S. (eds.). Oxford and IBH, New Delhi: 155-177.
3. **Glaszmann J**. **C.** 1987. Isozymes and classification of Asian rice. Theor. Appl. Genet., **74**: 21-30.
4. **Jain S., Jain R. K. and Mc Couch S. R.** 2004. Genetic analysis of Indian aromatic and quality rice (*Oryza sativa* L.) germplasm using panels of fluorescently-labelled microsattellite markers. Theor. Appl. Genet., **109:** 965-977.
5. **Nene Y. L.** 1998. Basmati rice: a distinct variety (cultivar) of the Indian Subcontinent. Asian Agric. Hist., **2:** 175-188.
6. **Anonymous.** 2001**.** Protection of Plant Varieties and Farmers' Rights Act (no 53 of 2001). Deptt. of Agriculture and Co-operation. Ministry of Agriculture, Govt. of India, Krishi Bhavan, New Delhi.
7. **Anonymous.** 2007**.** PPV and FR Authority specific DUS test guidelines for twelve notified crops-Rice (*Oryza sativa* L.). Plant Var. J. India, **1:** 151-169.
8. **Watson S., Ward J. and Weathurup S. T. C.** 1998**.** Distinctness, uniformity and stability trail (DUST) analysis system. UPOV TWC 16/9.
9. **Anonymous.** 2008 a**.** Examining distinctness. *In*: UPOV TGP/9/1. 1-36.
10. **Anonymous.** 2008 b**.** Examining uniformity. *In*: UPOV TGP/10/1. 1-14.
11. **Digby P. G. N.** 1979**.** Modified Joint Regression Analysis for incomplete variety environment data. J. Agric. Sci., **93:** 81–86.
12. **Prakash S., Sharma S. P. and Dadlani M.** 2007**.** Testing of Plant Varieties for Distinctiveness, Uniformity and Stable- Principles and Application. Team of Excellence, Division of Seed Science & Technology, IARI, New Delhi. 37-41.
13. **Kumar D., Mahato P., Lakshman S. S. and Mandi S.** 2006**.** Morphological characterization of jute varieties and their application for DUS testing. Ind. J. Genet., **66:** 319-323.
14. **Ruiz I. R., van Eeuwijk F. A., Gilliland T. J., Dubreuil P., Dillmann C., Lallemand J., De Loose M. and Baril C. P.** 2001**.** A comparative study of molecular and morphological methods of describing relationships between perennial ryegrass (*Lolium perenne* L.) varieties. Theor. Appl. Genet., **103:**1138–1150.
15. **Joshi M. A., Sarao N. K., Sharma R. C., Singh P. and Bharaj T. S.** 2007**.** Varietal characterization of Rice (*Oryza sativa* L.) based on Morphological Descriptors. Seed Res., **35:** 188-193.
16. **Ravikumar M. and Naraayanswamy S.** 1999. Identification of soybean varieties based on seed morphological characters. Curr. Res., **28:** 50-52.
17. **Kumar Y., Ram H. and Gulia S. K.** 2002. Varietal identification in oat based on- field parameters. Forage Res., **28:** 73-76.
18. **Gupta N., Sharma R. C., Singh G., Mahajan M. and Samra J. S.** 2003. Preliminary studies on varietal characterization of rapeseed mustard. JNKV Res. J., **37:** 34-42.
19. **Yadav S. K.** 2004. Importance of rapeseed mustard and taramira seedling characters- in cultivar characterization. Plant Archives, **4:** 311-318.
20. **Kumar M. B. A., Sherry R. J., Dadlani M., Varier A. and Sharma S. P.** 2004. Characterization of pearl millet hybrids and parental lines using morphological characters. Seed Res., **32:** 15-19.
21. **Kumar D., Agrawal R. C. and Begum T.** 2008. Analysis for identification of distinct and uniform extant jute (*Chorchorus olitorius* L. and *C. capsularis* L.) varieties. Seed Res., **36:** 121-134.