Indian J. Genet., 69(4) (Spl. issue): 383-393 (2009)

Morphological characterization of forage sorghum [*Sorghum bicolor* (L.) Moench] varieties for DUS testing

D. C. Joshi, P. K. Shrotria, Ravindra Singh and H. S. Chawla*

Department of Genetics and Plant Breeding, G.B. Pant Univ. of Agric. & Tech., Pantnagar 263 145

Abstract

Twenty six varieties of forage sorghum [*Sorghum bicolor* (L.) Moench] which included 20 released and notified and 6 indigenous local varieties were characterized using 40 morphological descriptors adopted from the DUS guidelines of PPV & FR Authority and ICAR and subsequently examined for their Distinctiveness, Uniformity and Stability. Among the 26 visually assessed characters 2 characters were monomorphic, 10 characters were dimorphic and 14 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 the 26 varieties. COY-D analysis supported with MJRA analysis revealed that the slope of the MJRA curve and regression probability were too negligible which indicated that all the considered characteristics were independent and their interactions with environment as well as with themselves were negligible in both the years. This indicates the distinctiveness of all the candidate varieties. Combined Over Years Uniformity (COY-U) analysis revealed that all the released and notified varieties were more or less uniform for the 14 measurable characters. However, three local varieties *viz*., Rampur local, Gwalior local and Rajasthan local were not uniform for 7, 6 and 4 measurable characters respectively emphasizing the need for their further purification to attain a considerable level of homogeneity in their heterogeneous blend. The present experimental material possessed relatively low magnitude of differences between PCV and GCV, high heritability coupled with high to moderate genetic advance for most of the measurable descriptors, thus emphasizing their consistency and stability over the years and their utility in varietal characterization. On the basis of grouping characteristics unique morphological profiles could be established for 9 varieties. When all the 33 morphological descriptors of PPV & FR Authority and 7 morphological descriptors of ICAR were studied distinctiveness could be obtained for two more varieties *viz*., UPFS 38 and SSG 59-3. Thus out of a total of twenty six varieties unique morphological profiles could be obtained for 11 varieties. However, the rest of 15 varieties remained in groups of two or three varieties. 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 thought for complementing the morphological DUS descriptors.

Key words: Sorghum, morphological DUS descriptors, Combined Over Years Distinctiveness, Combine Over Years Uniformity, indigenous local varieties.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most important cereal crop providing food and fodder throughout the world [1]. Indian subcontinent is the secondary center of origin for this important cereal [2]. India has enormous diversity of millets including sorghum also called, great millet, in both cultivated and wild [3]. 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 obligation 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 the plant varieties against unauthorized multiplication of seeds or propagating materials for a specified period [4]. 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 sorghum varieties according to DUS test guidelines for sorghum prescribed by PPV and FR Authority [5].

*Corresponding author's e-mail: chawlahs_ patent@yahoo.com; chawlahs_pantnagar@rediffmail.com
Published by Indian Society of Genetics & Plant Breeding, F2, First Floor, NASC Complex, PB#11312, IARI, New Delhi 110 012
Online management by indianjournals.com

Keeping this in view, the study was taken up with the objective to characterize genotype for DUS testing in twenty six forage sorghum varieties for their protection under the PPV& FR Act.

Materials and methods

The experimental material consisted of 26 forage sorghum varieties (Table 1). This was a diverse group comprising 20 released and notified varieties and six indigenous local varieties collected from different parts of the country. The trials were conducted during the *kharif* seasons of 2006 and 2007 in the net wire fenced DUS test plot. The experiment was planted, as per DUS guidelines, in a randomized block design with four replications. Each variety accommodated in plot of 6 rows of 6m length spaced at 60 cm row to row and 15 cm plant to plant. Observations were recorded on 33 characteristics at seedling, morphological, physiological and matured seed stage with appropriate procedures as per the Indian DUS test guideline of PPV & FR Authority [5]. Besides, 6 visually assessed characteristics *viz*., flag leaf: extension of discolouration of mid rib, flag leaf: intensity of green colouration of mid rib, glume: anthocyanin colouration of pubescence, stalk: juiciness, grain: shattering, grain: form and measurable character as stalk: sweetness adopted from the ICAR national guidelines for the conduct of DUS test [6] were also considered in the present study. Thus observations were recorded for a total of 40 morphological characterstics which included 26 visually assessed characteristics and 14 measurable characteristics. For the assessment of distinctiveness and stability, observations were recorded on 40 plants or parts of 40 plants, which were divided among four replications (10 plant in each replication).

In case of visually assessed characters for determining distinctiveness, differences between two varieties were considered clear if the expression of one or more characteristics fell into two different states in the test guidelines. Analysis of measurable characteristics was carried out with the help of DUSNT software [7] comprising of COY-D i.e. Combined Over Years Distinctiveness analysis for analysis of distinctiveness [8] and COY-U i.e. Combined Over Years Uniformity analysis for analysis of uniformity [9]. F_1 and F_2 ratios were calculated for COY-D analysis of 14 measurable characteristics which were variety MS by variety x year MS and variety x year MS by variety x replication MS respectively. Modified Joint Regression Analysis (MJRA) was also used as a part of COY-D analysis. This MJRA model took account of systematic

Table 1. Details of sorghum varieties studied with their origin/source

No.	Genotype	Pedigree/ parentage	Origin/Source
1	2219 B	-	Pantnagar
2	Pusa Chari 121	-	Delhi (IARI)
3	Pusa Chari 615	-	Delhi (IARI)
4	Rampur local	-	U.P./ Pantnagar
5	Gwalior local	-	M.P./ Pantnagar
6	Golden local	-	M.P./ Pantnagar
7	Jalana local	-	Maharashtra/ Pantnagar
8	Rajasthan local	-	Rajasthan/ Pantnagar
9	MP Chari red	-	M.P./Pantnagar
10	CSV-15	SPV 475 × SPV 462	NRCS, Hyderabad
11	UPFS 38	Rio× UPFS-22	Pantnagar
12	S 437-1	-	HAU
13	UP Chari 2	Vidhisa 60-1× IS 6593	Pantnagar
14	Pant Chari 3	Vidhisa 60-1 × IS 6953	Pantnagar
15	Pant Chari 4	IS 4776 × Rio	Pantnagar
16	Pant Chari 5	CS 3541 × IS 6953	Pantnagar
17	Pant Chari 6	Selection from SDSL 2140	Pantnagar
18	CSH-20 MF	2219 B × UPMC 503	Pantnagar
19	GFS 4	-	GAU
20	GFS 5	-	GAU
21	SSG 59-3	Non sweet Sudan grass × JS 263	HAU
22	HC 136	IS 3214(bicolor) × PC7R	HAU
23	HC 171	SPV8× IS 4776 (Durra)	HAU
24	HC 260	SPV 103 × PC 9	HAU
25	HC 308	SPV 8 × IS 4776 (Durra)	HAU
26	HJ 513	-	HAU

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 [10].

The COY-U analysis involves ranking reference and candidate varieties by the mean value of the characteristics. Each variety's 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 [11].

Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance were calculated from the pooled data of the measurable attributes over two years and compared for the analysis of stability. Glume length character was not taken into account because it was measured as the percentage of grain covered by glume.

Grouping of sorghum varieties was done by using grouping characteristics as mentioned in the DUS test guidelines of PPV and FR Authority for sorghum [5].

Results and discussion

The accurate description and identification of sorghum varieties are crucial for DUS testing. The identity/profiles of sorghum varieties were established by using a set of morphological characteristics prescribed in the DUS test guidelines of sorghum. These characteristics are useful to establish distinctiveness, uniformity and stability of a variety, based on which the variety is given protection.

Out of the twenty six visually assessed characters studied two characters were monomorphic, ten characteristics were dimorphic and fourteen characteristics were found to be polymorphic (Table 2). The dimorphic and polymorphic characters among the sorghum varieties indicated their potential for varietal characterization.

In general the six local cultivars under the study revealed narrow genetic diversity for visually assessed characters as they were monomorphic for ten characters, dimorphic for eleven characters and polymorphic for only five characters out of a total of twenty six characters (Table 2). However, the twenty released and notified cultivars revealed sufficient genetic diversity for visually assessed characters showing monomorphism for only two characters, dimorphism for ten characters and polymorphism for fourteen characters. This might be due to the fact that the local cultivars were domesticated in their respective ecological zones with narrow genetic base while the released and notified cultivars have different endemic and exotic sources in their pedigree that might have diverse ecological ranges. Similar attempts for germplasm characterization through qualitative characters have been made in sorghum [12, 13].

These visually assessed characteristics did not show any variation in their states of expression over two years of study. As per the DUS guideline, assessment of uniformity of characteristics on the plot as a whole shall be taken with aberrant number of plants or parts of plants shall not exceed 6 in 100. Since no off type plants were observed, these characters were considered to be uniform. Expression of each characteristic 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.* [14] held similar views for the morphological characterization of jute varieties over three years of study. Apart from this, during the development of sorghum varieties, breeders normally emphasize on the stability and uniformity of the qualitative characteristics.

Data recorded on fourteen measurable characteristics were subjected to COY-D statistical analysis at 0.1 percent level of significance. Each variety at a time was considered to be a candidate variety and compared to rest of the twenty five varieties as reference varieties to obtain a pair wise distinctiveness matrix using COY-D analysis (Table 3). Analysis revealed that all the varieties were showing distinctiveness with respect to each other. COY-D analysis of fourteen measurable characteristics using MJRA model was also carried out (Table 4). The non significance of F_1 ratio for glume length indicated its inconsistent behaviour over the years because of the greater role of environment in its expression. The slope of MJRA curve in both the years and regression probability was found to be too negligible which showed that all the considered characteristics were independent and their interactions with environment as well as with themselves were negligible in both the years. This further confirmed the distinctiveness of all the candidate varieties. Ruiz *et al.* [15] also reported distinctness among the 16 ryegrass (*Lolium perenne* L.) varieties by using MJRA model.

Table 2. Characterization of 26 sorghum varieties based on visually assessed characteristics

Candidate variety	Anthocyanin colouration of the coleoptile	Basal leaf sheath colour	Midrib colour (5th fully developed leaf)	Flag leaf: yellow colouration of midrib	Flag leaf: extension of discolouration of midrib	Flag leaf: intensity of green colouration of midrib	Stigma yellow colouration	Stigma anthocynin colouration	Flower with pedicel: length of flower	Lemma arista formation	Colour of dry anther	Glume colour	Glume: anthocyanin colourations of pubescence
2219B	Yellow green	Yellow green	Yellow green	Absent	Weak	Paler	Absent	Absent	Medium	Absent	Yellow orange	Yellow white	Absent
Pusa Chari 121	Yellow green	Grayed purple	White	Absent	Medium	Paler	Absent	Absent	Very long	Present	Grayed orange	Grayed purple	Absent
Pusa Chari 615	Grayed purple	Grayed purple	White	Absent	Strong	Paler	Absent	Absent	Long	Present	Grayed orange	Grayed purple	Absent
Rampur local	Grayed purple	Grayed purple	White	Absent	Weak	Paler	Absent	Absent	Long	Present	Yellow orange	Grayed purple	Absent
Gwalior local	Grayed purple	Grayed purple	White	Absent	Medium	Paler	Present	Absent	Medium	Present	Grayed orange	Grayed purple	Absent
Golden local	Grayed purple	Grayed purple	White	Absent	Very strong	Paler	Absent	Absent	Medium	Present	Grayed orange	Grayed purple	Absent
Jalana local	Grayed purple	Grayed purple	White	Absent	Weak	Paler	Absent	Absent	Long	Present	Orange	Grayed purple	Absent
Rajasthan local	Grayed purple	Grayed purple	Yellow green	Absent	Absent	Same col.	Absent	Absent	Long	Present	Grayed orange	Grayed purple	Absent
MP Chari red	Grayed purple	Grayed purple	White	Absent	Very strong	Paler	Absent	Absent	Medium	Absent	Grayed orange	Grayed purple	Absent
CSV 15	Yellow green	Yellow green	Yellow green	Absent	Medium	Same col.	Absent	Absent	Medium	Absent	Grayed orange	Grayed yellow	Absent
UPFS 38	Grayed purple	Yellow green	Yellow green	Absent	Weak	Same col.	Absent	Absent	Medium	Absent	Orange	Grayed yellow	Absent
S 437-1	Grayed purple	Yellow green	Yellow green	Absent	Weak	Same col.	Present	Present	Medium	Present	Orange	Yellow white	Absent
UP Chari 2	Yellow green	Yellow green	Yellow green	Absent	Weak	Same col.	Absent	Absent	Medium	Present	Yellow orange	Yellow white	Absent
Pant Chari 3	Yellow green	Yellow green	Yellow green	Absent	Absent	Paler	Absent	Absent	Medium	Present	Grayed orange	Yellow white	Absent
Pant Chari 4	Grayed purple	Grayed purple	Yellow green	Absent	Absent	Same col.	Absent	Absent	Medium	Absent	Grayed orange	Grayed purple	Present
Pant Chari 5	Yellow green	Yellow green	Yellow green	Absent	Absent	Same col.	Absent	Absent	Medium	Present	Grayed orange	Grayed yellow	Absent
Pant Chari 6	Grayed purple	Grayed purple	Yellow green	Absent	Absent	Same col.	Absent	Absent	Medium	Present	Grayed orange	Grayed yellow	Absent
CSH-20 MF	Grayed purple	Yellow green	Yellow green	Absent	Absent	Paler	Absent	Absent	Long	Absent	Grayed orange	Grayed yellow	Absent
GFS 4	Yellow green	Grayed purple	White	Absent	Medium	Paler	Absent	Absent	Very long	Present	Grayed orange	Yellow white	Absent
GFS 5	Yellow green	Yellow green	Yellow green	Absent	Weak	Same col.	Absent	Absent	Very long	Absent	Grayed orange	Yellow white	Absent
SSG 59-3	Grayed purple	Yellow green	Yellow green	Absent	Absent	Same col.	Present	Present	Very long	Present	Grayed orange	Yellow white	Absent
HC 136	Grayed purple	Yellow green	Yellow green	Absent	Absent	Same col.	Present	Absent	Short	Present	Grayed orange	Grayed purple	Absent
HC 171	Grayed purple	Yellow green	Yellow green	Absent	Absent	Same col.	Absent	Absent	Short	Present	Grayed orange	Grayed yellow	Absent
HC 260	Yellow green	Yellow green	White	Absent	Strong	Paler	Absent	Absent	Short	Present	Grayed orange	Yellow white	Absent
HC 308	Grayed purple	Yellow green	Yellow green	Absent	Very strong	Paler	Absent	Absent	Medium	Present	Grayed orange	Yellow white	Absent
HJ 513	Yellow green	Yellow green	White	Absent	Strong	Paler	Present	Absent	Very long	Present	Grayed orange	Yellow white	Absent

Table 2. Contd .....

Candidate variety	Anthocyanin colouration of the coleoptile	Basal leaf sheath colour	Midrib colour (5th fully developed leaf)	Flag leaf: yellow colouration of	Flag leaf: extension of discolouration of midrib	Flag leaf: intensity of green colouration midrib	Stigma yellow colouration of midrib	Stigma anthocynin colouration	Flower with pedicel: length of	Lemma arista formation flower	Colour of dry anther	Glume colour	Glume: anthocyanin colourations of pubescence
2219B	Semi compact	Symmetric	Freely	Yellow threshable	Medium white	Single	Circular	Circular	Medium	Half	Grayed yellow vitreous	Non lustrous	Juicy
Pusa Chari 121	Semi loose	Symmetric	Partly threshable	Grayed white	Strong	Single	Circular	circular	Large	Full vitreous	Grayed purple	Lustrous	Dry
Pusa Chari 615	Very loose	Pyramidal	Difficult to thresh	Grayed orange	Low	Single	Elliptic	elliptic	Large	Full vitreous	Grayed purple	Lustrous	Dry
Rampur local	Semi loose	Pyramidal	Freely threshable	Grayed white	Strong	Single	Circular	circular	Medium	Full vitreous	Grayed purple	Lustrous	Dry
Gwalior local	Semi loose	Pyramidal	Freely threshable	Grayed white	Strong	Single	Circular	Circular	Medium	Full vitreous	Grayed purple	Lustrous	Dry
Golden local	Semi loose	Broader in lower part	Freely threshable	Yellow white	Strong	Single	Circular	Circular	Medium	Full vitreous	Grayed purple	Lustrous	Juicy
Jalana local	Semi loose	Symmetric	Freely threshable	Yellow white	Medium	Single	Circular	circular	Medium	¾ vitreous	Grayed yellow	Lustrous	Juicy
Rajasthan local	Semi compact	Symmetric	Freely threshable	Yellow white	Strong	Single	Circular	circular	Very large	¾ vitreous	Grayed yellow	Lustrous	Dry
MP Chari red	Semi loose	Symmetric	Difficult to thresh	Grayed white	Low	Single	Elliptic	elliptic	Medium	Full vitreous	Grayed yellow	Lustrous	Dry
CSV 15	Semi compact	Symmetric	Freely threshable	Yellow white	Strong	Single	Circular	circular	Small	Half vitreous	Grayed purple	Lustrous	Juicy
UPFS 38	Semi loose	Pyramidal	Freely threshable	Yellow white	Medium	Single	Circular	circular	Very small	¾ vitreous	Grayed purple	Lustrous	Dry
S 437-1	Semi loose	Pyramidal	Difficult to thresh	Yellow white	Low	Single	Circular	circular	Medium	Full vitreous	Grayed purple	Lustrous	Juicy
UP Chari 2	Semi compact	Symmetric	Freely threshable	Grayed white	Medium	Single	Circular	circular	Large	Half vitreous	Grayed purple	Non lustrous	Juicy
Pant Chari 3	Semi loose	Pyramidal	Freely threshable	Grayed white	Medium	Single	Circular	circular	Large	¾ vitreous	Grayed purple	Non lustrous	Juicy
Pant Chari 4	Semi loose	Broader in upper part	Difficult to thresh	Grayed white	Low	Single	Elliptic	elliptic	Medium	Full vitreous	Grayed purple	Non lustrous	Juicy
Pant Chari 5	Semi compact	Symmetric	Freely threshable	Yellow white	Medium	Single	Circular	circular	Small	Half vitreous	Grayed purple	Lustrous	Juicy
Pant Chari 6	Semi loose	Symmetric	Partly threshable	Grayed orange	Medium	Single	Elliptic	circular	Small	Half vitreous	Grayed purple	Lustrous	Juicy
CSH-20 MF	Semi loose	Symmetric	Freely threshable	Yellow orange	Low	Single	Elliptic	elliptic	Small	Half vitreous	Grayed purple	Lustrous	Juicy

Table 2. Contd .....

Candidate variety	Anthocyanin colouration of the coleoptile	Basal leaf sheath colour	Midrib colour (5th fully developed leaf)	Flag leaf: yellow colouration of	Flag leaf: extension of discolouration of midrib	Flag leaf: intensity of green colouration midrib	Stigma yellow colouration of midrib	Stigma anthocynin colouration	Flower with pedicel: length of	Lemma arista formation flower	Colour of dry anther	Glume colour	Glume: anthocyanin colourations of pubescence
GFS 4	Semi loose	Pyramidal	Freely threshable	Grayed white	Strong	Single	Elliptic	elliptic	Large	Full vitreous	Grayed purple	Non lustrous	Dry
GFS 5	Semi compact	Pyramidal	Freely threshable	Yellow white	Strong	Single	Circular	circular	Medium	Half vitreous	Grayed purple	Lustrous	Juicy
SSG 59-3	Very loose	Pyramidal	Difficult to	Grayed thresh	Low orange	Single	Narrow elliptic	Narrow elliptic	Medium	¾ farinaceous	Grayed Orange	Lustrous	Juicy
HC 136	Compact	Symmetric	Freely threshable	Yellow white	Medium	Single	Circular	circular	Large	Full vitreous	Grayed yellow	Lustrous	Juicy
HC 171	Loose	Pyramidal	Partly threshable	Yellow white	Low	Single	Circular	circular	Large	¾ farinaceous	Grayed purple	Non lustrous	Juicy
HC 260	Semi loose	Pyramidal	Partly threshable	Grayed white	Medium	Single	Circular	circular	Large	Half vitreous	Grayed purple	Lustrous	Juicy
HC 308	Semi loose	Pyramidal	Freely threshable	Yellow white	Low	Single	Circular	circular	Very large	¾ farinaceous	Grayed purple	Lustrous	Juicy
HJ 513	Semi loose	Broader in	Difficult to lower part	Yellow thresh	Low white	Single	Circular	circular	Large	Half vitreous	Grayed purple	Lustrous	Juicy

COY-U analysis revealed that all the varieties under the study were completely uniform with respect to anther length. While, glume length was the only character for which all the varieties revealed nonuniformity and in all the varieties standard deviation for the mentioned character exceeded the over years criteria after two years with a probability of 0.01 (Table 5). This inconsistent behaviour of glume length over two years of experiment indicates greater role of environmental factors in its expression which is also supported by MJRA analysis as it was the only character out of the fourteen measurable characters having non significant F_1 ratio. In general the twenty released and notified varieties were more or less uniform with respect to measurable characters. However, three out of six local varieties viz. Rampur local, Gwalior local and Rajasthan local were non uniform for 7, 6 and 4 measurable characters respectively. Such a higher level of non uniformity in these local varieties is evident by the fact that, these local varieties are being maintained without strict application of principles of maintenance breeding. Thus farmer's varieties and landraces may not have the same level of genetic and phenotypic homogeneity like the released and notified cultivars, to meet the stringent requirements of DUS testing with regard to uniformity [16]. Thus such a high level of non uniformity in these local varieties emphasizes the need of their further purification to attain considerable level of homogeneity in their heterogeneous blend.

The pooled analysis of measurable characters revealed that out of a total of 13 measurable characters 9 characters have relatively low magnitude of difference between PCV and GCV indicating less environmental influence in their expression, thereby emphasizing their consistency and stability (Table 6). However the rest of the characters *viz.*, anther length, length of leaf blade, visible length of panicle neck above the sheath and 1000 seed weight have relatively greater magnitude of difference between GCV and PCV indicating greater

Table 3. Pairwise distinctiveness matrix of twenty six sorghum varieties obtained from COYD analysis

S.No.	Candidate Varieties	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	2219B	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
2	Pusa Chari 121	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
3	Pusa Chari 615	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
4	Rampur local	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
5	Gwalior local	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
6	Golden local	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
7	Jalana local	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
8	Rajasthan local	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
9	MP Chari Red	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
10	CSV 15	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
11	UPFS 38	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
12	S 437-1	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D
13	UP Chari 2	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D	D
14	Pant Chari 3	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D	D
15	Pant Chari 4	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D	D
16	Pant Chari 5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D	D
17	Pant Chari 6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D	D
18	CSH-20 MF	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D	D
19	GFS 4	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D	D
20	GFS 5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D	D
21	SSG 59-3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D	D
22	HC 136	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D	D
23	HC 171	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D	D
24	HC 260	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D	D
25	HC 308	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-	D
26	HJ 513	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	-
Over all distinctiveness		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

role of environmental factors in their expression. Hence these characters were considered relatively less stable as compared to other nine measurable characteristics. Joshi *et al*. [17] also followed the same approach for determining stability of morphological descriptors in rice.

High heritability and moderate genetic advance were observed for time of panicle emergence (99.87%, 36.66%), natural height of foliage upto base of flag leaf (87.58%, 36.84%), stigma length (99.68%, 49.34%), total height of plant at maturity (99.97%, 41.12%), stem diameter (99.88%, 37.57%), stalk sweetness (99.71%, 17.68%), length of leaf blade (73.34%, 20.60%) and width of leaf blade (99.80%, 36.70%), indicating equal importance of both additive and non-additive gene effects in the inheritance of these traits. Moderate heritability (36.98%) coupled with low magnitude of genetic advance (9.88%) was observed for the character anther length indicated preponderance of non-additive gene effects and greater environmental influence in its expression, thus, revealing the inconsistent behaviour of the character and thereby limiting its stable performance over the years. In nutshell, the studies on different genetic parameters of thirteen measurable DUS descriptors revealed that the present experimental material possessed considerable variability and heritability coupled with moderate to high genetic advance for all the DUS descriptors except anther length, thus emphasizing their utility in the characterization of sorghum varieties.

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

	50% flowering	Plant height at panicle emergence	Stigma length	Anther length	Plant total height at maturity	Stem dia.	Stalk sweet-ness	Leaf: blade length	Leaf: blade width	Panicle length	Panicle: length of branches	Panicle: neck	Glume length	1000-seed weight
Year MS	34.980	475.23	0.028	0.011	1797.74	0.073	0.106	111.51	1.096	38.77	1.20	1.88	0.000	48.46
Variety MS	1697.806	28373.523	3.470	1.607	34613.031	1.491	136.712	651.482	12.547	803.842	114.359	162.983	7568.35	144.264
Var.Year MS	1.016	176.71	0.044	0.006	128.37	0.032	0.174	1.093	0.085	1.027	0.135	0.265	0.000	9.032
F_1 ratio	1671.39	160.557	79.592	81.145	269.620	46.543	784.338	595.876	148.135	783.072	849.041	615.477	0.000	15.973
Var.Rep MS	1.505	698.17	0.09	0.12	115.59	0.046	0.173	2.397	0.244	2.59	1.098	1.09	32.05	9.5
F_2 ratio	0.675	0.253	0.441	0.047	1.111	0.693	1.010	0.456	0.347	0.395	0.123	0.328	0.000	0.950
Between SE	0.356	4.70	0.074	0.027	4.006	0.063	0.148	0.370	0.103	0.358	0.130	0.182	0.000	1.063
Within SE	0.434	9.342	0.111	0.124	3.801	0.076	0.147	0.547	0.175	0.570	0.371	0.317	2.002	1.090

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 [17]. 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. One, characteristic *viz.*, *kharif* or *rabi* adaptation among the five grouping characteristics was found to be monomorphic. Hence grouping of varieties was based on only four characteristics since all the varieties exhibited *kharif* adaptation. Unique morphological profiles were obtained for nine varieties namely GFS 4, CSH 20 MF, HC 260, 2219B, Pant Chari 6, Pant Chari 4, Rajasthan local, UP Chari 2 and HC 136 (Fig.1). When, 33 morphological descriptors of PPV & FR Authority and 7 descriptors of ICAR were considered distinctiveness could also be obtained for two more varieties UPFS 38 and SSG 59-3. Variety UPFS 38 showed very small size of mark of germ and SSG 59-3 variety showed very loose panicle density of maturity, narrow elliptic grain shape in dorsal view, narrow elliptic grain shape in profile view and grayed orange colour of vitreous albumen. Varieties *viz.*, 2219B and HC 136 which were already distinguished on the basis of grouping characters could further be delineated on the basis of very short height of foliage upto to base of flag leaf and compact density of panicle respectively. However, rest of the fifteen varieties remained within groups of two or three varieties. 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 [18], oat [19], rapeseed-mustard [20, 21] and pearl millet [22].

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, morphological descriptors alone may not be sufficient for DUS criteria. Hence, some other markers/ descriptors could be considered for complementing the morphological DUS descriptors.

Acknowledgments

The financial assistance provided by DST is duly acknowledged.

Table 5. Combined over years uniformity analysis of fourteen measurable characteristics in sorghum varieties

Candidate	50% flowering	Natural height of foliage up to base of flag leaf	Stigma length	Anther length	Plant total height at maturity	Stem diameter	Stalk sweetness	Leaf: blade length	Leaf: blade width	Panicle length	Panicle length of branches	Visible length of panicle neck above the sheath	Glume length	100 seed weight
2219B	317:2	73	128 1	106	83	126	69	105	121	99	98	115	152+	88
Pusa Chari 121	239 1	109 1	85	108	106	109	66	97	116 1	108	108	97	152+	83
Pusa Chari 615	312	116:1	89	100	104 1	132	145 +1	116 1	114	104 1	118	96	152+	93
Rampur local	143	87	51	124	133+2	77	110 1	123:1	134:2	108	106	109 1	152+	99
Gwalior local	161	106	128 1	108	125:2	106 1	71	112 1	114 2	94	105	105	152+	110 1
Golden local	89	93	113	103	91	109	78	105	157+2	105	95	112 2	152+	91
Jalana local	250	94	148 1	140	76	103	95	91	84	106	96	97	152+	57
Rajasthan local	250	99	98	51	111	161:1	87	115	103	89	122:1	116 1	152+	97
MP Chari red	420+1	117:1	149	122	115	111	86	103	89	97	93	75	3317+2	93
CSV 15	91	117:1	65	106	106	105	94	102	56	91	88	74	152+	113 1
UPFS 38	87	113 1	97	99	106	101	90	87	115 1	94	101	88	152+	92
S 437-1	62	106 1	82	94	94	111	84	84	86	87	105	94	152+	90 1
UP Chari 2	75	90	93	101	93	114	103	86	86	88	86	113	152+	123 1
Pant Chari 3	99	87	230+1	67	85	38	97	95	70	98	91	122	152+	110
Pant Chari 4	78	97	96	111	88	98	102	84	118 1	100	76	71	152+	127
Pant Chari 5	50	104	114	42	89	117	105	98	110	83	78	139	152+	106
Pant Chari 6	56	104 1	99	57	110	104	99	86	93	83	143+2	83	152+	102
CSH-20 MF	68	95	80	92	96	33	89	91	69	73	102	74	152+	109
GFS 4	75	102	137	138	112	41	81	82	96	91	81	73	152+	98
GFS 5	15	111	119	54	81	81	100	104 1	98	132+1	101	118	152+	95
SSG 59-3	5	91	78 1	37	95	126	63	101	88	132+1	131+2	80	152+	85
HC 136	15	103	51	93	102	69	108	107	116 1	94	111	227+2	152+	95
HC 171	40	103	114	104	85	104	95	83	97	105	77	92	152+	68
HC 260	56	87	7	107	88	34	142:1	111 1	100	130+1	99	66	152+	40
HC 308	79	103	90	78	105	82	72	71	77	119	96	70	152+	42
HJ 513	23	90	56	118	82	208+1	129 1	94	87	92	87 2	93	152+	79

Symbols: * -SD exceeds over-years Criterion after 3 Years with probability 0.0100; + -SD exceeds over-years Criterion after 2 Years with probability 0.0100; : -SD not yet acceptable after 2 years with probability 0.0500; 1, 2, 3 – The number of occasions the within-years SD exceeds the UPOV criterion

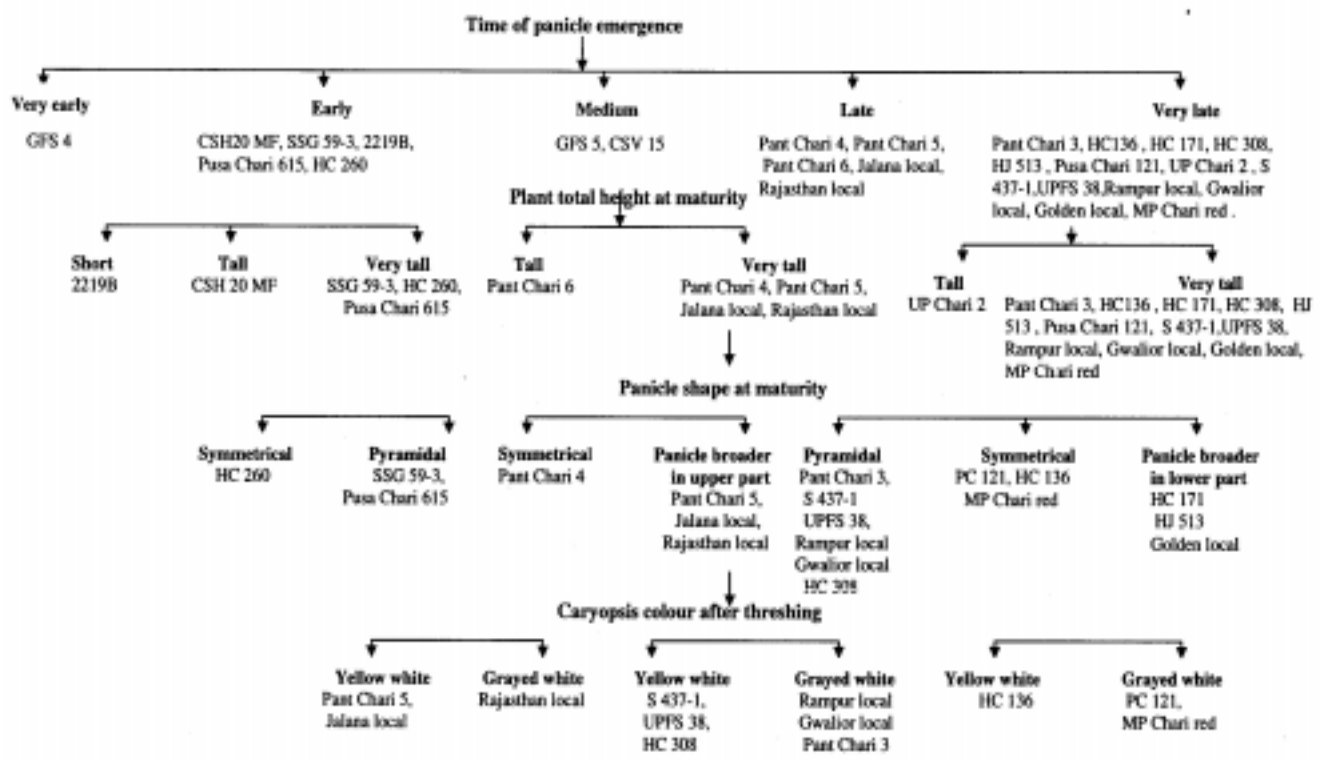

Fig. 1. Grouping of sorghum varieties based on the grouping characteristics proposed in the DUS test guidelines.

References

1. **Doggett H.** 1988. Sorghum, 2nd ed. Longman, UK.
2. **Vavilov N. I.** 1926. Studies on the origin of cultivated plants. Bulletin of Applied Botany and Plant Breeding, **16**: 1-245.
3. **Mahadevappa M.** 2008. Need for protection of plant varieties act. The Hindu Survey of Indian Agriculture, 2008, Section 2, **(**http://hindu.com/books/sia/2008/agri08b.htm**)**.
4. **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.
5. **Anonymous.** 2007. General Guidelines to the examination of DUS and the development of harmonized descriptors of plant varieties. Plant Variety Journal India, **1**: 192-201.
6. **Anonymous.** 2004. National Guidelines for the Conduct of tests for Distinctness, Homogeneity and Stability of sorghum (*Sorghum bicolor* L.). ITG/03 sorghum, 28/10/03.1-16 (http://agricoop.nic.in/SeedTestguide/sorghum.htm).
7. **Watson S.** 2004. Using the DUS software. WORKSHOP ON DATA HANDLING organized by the International Union for the Protection of New Varieties of Plants (UPOV) in cooperation with the State Forestry Administration of China, the Ministry of Agriculture of China and the State Intellectual Property Office of China with the financial assistance of the Ministry of Agriculture, Forestry and Fisheries of Japan. Beijing, June 9 to 11, 2004. UPOV/DATA/BEI/04/ **12**: 2-19.
8. **Anonymous.** 2008a**.** Examining distinctness. *In*: UPOV TGP/9/1. 1-36.
9. **Anonymous.** 2008 b**.** Examining uniformity. *In*: UPOV TGP/10/1. 1-14.
10. **Digby P. G. N.** 1979. Modified joint regression analysis for incomplete variety environment data. J. Agric. Sci., **93**: 81-86.
11. **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.
12. **Geleta N. and Labuschagne M. T.** 2005. Qualitative traits variation in sorghum [*Sorghum bicolor* (L.) Moench] germplasm from eastern highlands of Ethiopia. Biodiversity and Conservation, **14**: 3055-3064.
13. **Elangovan M., Prabhakar and Reddy D. C. S.** 2007. Characterization and Evaluation of Sorghum [*Sorghum bicolor* (L.) Moench] Germplasm from Karnataka, India. Karnataka J. Agric. Sci.*,* **20**: 840-842.

14. **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.

15. **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.

16. **Saxena S. and Singh A. K.** 2006. Revisit to definitions and need for inventorization or registration of landrace, folk, farmers' and traditional varieties. Curr. Sci., **91**: 1451-1454.

17. **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.

18. **Ravikumar M. and Naraayanswamy S.** 1999. Identification of soybean varieties based on seed morphological characters. Curr. Res. Bangalore, **28**: 50-52.

19. **Kumar Y., Ram H. and Gulia S. K.** 2002. Varietal identification in oat based on- field parameters. Forage Res., **28**: 73-76.

20. **Yadav S. K.** 2004. Importance of rapeseed mustard and taramira seedling characters- in cultivar characterization. Plant Archives, **4**: 311-318**.**

21. **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.

22. **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.