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Phenotypic characterization of sorghum (*Sorghum bicolor* (L.) Moench) germplasm accessions for various DUS traits

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Abstract

Characterization of individuals, cultivars or germplasm is highly essential to avoid duplicates and to select suitable parents for the breeding program. The objective of this study is to characterize 108 sorghum germplasm accessions to obtain information on variations that exist among accessions and also to know the uniqueness of the genotypes. Characterization and grouping of accessions were done using the DUS descriptor provided by PPV&FRA for Distinctness, Uniformity, and Stability. Among the 33 characters assessed, six characters *viz.,* stigma anthocyanin pigmentation, stem diameter, stigma length, flag leaf yellow coloration, leaf sheath anthocyanin pigmentation, and leaf orientation were monomorphic while the other traits showed polymorphic variations. Maximum diversity was exerted for panicle traits, grain traits and also for leaf traits namely leaf length (31 cm to 77 cm) and leaf width (3 cm to 9 cm). These polymorphic lines might act as a reference genotype for future breeding work.

Keywords: *Sorghum germplasm*, characterization, DUS descriptor, polymorphic variations

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench), which belongs to the family Poaceae and tribe Andropogoneae, is an important cereal crop of semi-arid tropics (Verma *et al.* 2017) [1]. Though India is a secondary center, it has blessed with an enormous diversity of sorghum cultivars (Raghuvanshi *et al.* 2014) [2]. Sorghum ranks fifth among cereals globally *viz.,* after wheat, rice, maize, and barley (Prajapati *et al.* 2018) [3]. It is a dual-purpose crop as it is known for both food and fodder. Sorghum grains are embedded with a rich source of nutrition and also have gluten-free properties. Hence it can be given as a substitute diet for celiac patients due to the consumption of wheat (Dossou-Aminon *et al.* 2015) [4]. It has been cultivated in all three kinds of seasons in India *viz., Kharif, rabi,* and *summer* (Kamatar *et al.* 2011) [5].

The cultivated *Sorghum bicolor* has both wild and cultivated types with an enormous amount of genetic diversity for agronomically important traits (Kavithamani *et al.* 2019) [6]. Genetic diversity profound in germplasm resources. Germplasm comprises the totality of the gene pool and it acts as a raw material for any crop improvement program (Upadhyaya *et al.* 2010) [7]. For a variety to be characterized and released, it requires a constant protocol that should define the unique pattern of a particular variety. To be in consideration, the Government of India enacted the Protection of Plant Varieties and Farmer's Right Act (PPV&FRA) in 2001. This forms a framework for the protection of new varieties by framing four essential criteria namely Novelty, Distinctness, Uniformity, and Stability (DUS). It not only protects the variety but also a reward for plant breeders and farmers (Raghuvanshi *et al.* 2014 [2]; Joshi *et al.*2009 [8]; Reddy *et al.*2006 [9]).

Germplasm characterization is necessary to verify the identity and assess the varietal purity for seed production and certification. Hence it is pre-requisite to identify key traits for different genotypes (Bhusal *et al.* 2017) [10]. Keeping this view of the importance of characterization, the present study was conducted to characterize one hundred and eight sorghum germplasm accessions using DUS guidelines of PPV&FRA, (2007) [11].

Materials and Methods

From the Department of Plant Genetic Resources, Department of Millets, in TNAU, and Indian Institute of Millet Research, Hyderabad, the accessions were used for evaluation (Table 1). The experimental material includes 101 germplasm accessions with seven checks. The research study was carried out at the New area, Department of Millets, Tamil Nadu Agricultural University, Coimbatore. The trial was conducted during *Kharif* season 2018-19. The experimental unit was laid in Augmented Design II with 4 m of row length. Sowing was taken at the time of September 2018 and the field area was located in tropical climatic conditions.

The spacing followed was 45 cm x 15 cm. The experiment plot was divided into three blocks. The important package of practice was followed for the betterment of the crop. The observations were taken at different growth stages from five tagged plants of each genotype. The accessions were categorized as per the descriptor of PPV&FRA, 2007.

Table 1: The list of germplasm accessions used for the study

S. No	Accession number	S. No	Accession number	S. No	Accession number
1	SOR 6885	38	SSG 59-3	75	IS 29528
2	KO5 25	39	KO5 14	76	IS 8528
3	SO3 200	40	SO3 225	77	KO5 11
4	SO3 294	41	SO3 259	78	IS 4136
5	SO3 173	42	IS 4124	79	SOR 7609
6	KO5 128	43	SPV 105/1	80	SO3 253
7	SO3 287	44	SOR 6942	81	IS 3585
8	SO3 194	45	SPV 156	82	SPV 602
9	SOR 6894	46	KO5 110	83	SPV 29/2
10	SPV 753	47	SPV 594	84	SPV 707
11	R 2578/87	48	SPV 768	85	KO5 26
12	KO5 7	49	SO3 280	86	SPV 583
13	SPV 772	50	SPV 99	87	SPV 740
14	SPV 763	51	IS 2688	88	SO3 299
15	SOR 6971	52	SPV 558	89	SPV 590
16	R 2176	53	IS 19560	90	SPV 586
17	SPV 759	54	SOR 7014	91	SPV 741
18	R 2258	55	SOR 166	92	R 2501
19	SPV 754	56	SOR 1891	93	SPV 37
20	IS 19606	57	SO3 519	94	SPV 587
21	SPV 749	58	SPV 194	95	R 3026-32
22	IS 1036	59	IS 545	96	SPV 766
23	IS 88	60	IS 9753	97	SPV 541
24	IS 26685	61	SPV 887	98	R 2294
25	IS 8120/1	62	SPV 162	99	R 3063
26	IS 165	63	SPV 195	100	SPV 747
27	HC 308	64	SPV 178	101	R 2476
28	SO3 208	65	SOR 7091	Checks	
29	SO3 266	66	SPV 126		
30	KO5 75	67	SPV 86		
31	SOR 711	68	SPV 459	102	TNS 648
32	SPV 750	69	R 2317	103	CO 28
33	IS 18459	70	M 472	104	CO 30
34	SO3 251	71	SO3 256	105	K 12
35	KO5 44	72	KO5 33	106	TNS 663
36	R 2448	73	SPV 132	107	TNS 667
37	SPV 168	74	SPV 341/1	108	PAIYUR 2

Results and discussion

The characteristics of sorghum accessions under study were depicted in Table 2.

Table 2: Percentage contribution of genotypes under each category for particular morphological DUS trait by PPV & FRA

S. No.	Characteristics	Traits	Number of germplasm	Percentage
1	Seedling: Anthocyanin colouration of coleoptile	Yellow Green	66	61.1
		Greyed purple	42	38.9
2	Leaf sheath: Anthocyanin colouration	Yellow Green	108	100.0
		Greyed purple	Nil	Nil
3	Leaf: Midrib colour (5th fully developed leaf)	White	48	44.4
		Yellow Green	59	54.6
		Greyed yellow	1	0.9
		Greyed purple	Nil	Nil
4	Plant: Time of panicle emergence (50% of plants with 50% anthesis)	Very early (<56 days)	56	51.9
		Early (56 – 65 days)	24	22.2
		Medium (66 – 75 days)	15	13.9
		Late (76 – 85 days)	13	12.0
		Very late (> 85 days)	Nil	Nil
5	Flag leaf: Yellow colouration of midrib	Absent	102	94.4
		Present	6	5.5
6	Lemma: Arista formation	Absent	67	62.0
		Present	41	38.0
7	Stigma: Anthocyanin colouration	Absent	108	100

		Present	Nil	Nil
8	Stigma: Yellow colouration	Absent	65	60.2
		Present	43	39.8
9	Stigma: Length	Short (< 1mm)	108	100
		Medium (1-2 mm)	Nil	Nil
		Long (> 2 mm)	Nil	Nil
10	Flower with Pedicel: Length of flower	Very short	Nil	Nil
		Short	19	17.6
		Medium	52	48.1
		Long	27	25.0
		Very long	10	9.3
11	Anther: Length	Short (< 3 mm)	32	29.6
		Medium (3 – 4 mm)	76	70.4
		Long (> 4 mm)	Nil	Nil
12	Anther: Colour of dry anther	Yellow orange	Nil	Nil
		Orange	49	45.4
		Orange Red	59	54.6
		Greyed Orange	Nil	Nil
13	Glume: Colour	Green white	Nil	Nil
		Yellow white	20	18.5
		Greyed yellow	50	46.3
		Greyed orange	14	13.0
		Greyed red	4	3.7
		Greyed purple	20	18.5
14	Plant: Total height	Very short (<76 cm)	Nil	Nil
		Short (76 – 150 cm)	14	13.0
		Medium (151 – 225 cm)	56	51.9
		Long (226 – 300 cm)	36	33.3
		Very long (> 300 cm)	2	1.9
15	Stem: Diameter (at lower one third height of plant)	Small (< 2 cm)	108	100
		Medium (2-4 cm)	Nil	Nil
		Large (>4 cm)	Nil	Nil
16	Leaf: Length of blade (the third leaf from top including flag leaf)	Short (< 41 cm)	4	3.7
		Medium (41 – 60 cm)	38	35.2
		Long (61 -80 cm)	66	61.1
		Very long (> 80 cm)	Nil	Nil
17	Leaf: Width of blade (the third leaf from top including flag leaf)	Narrow (< 4.1 cm)	2	1.9
		Medium (4.1 – 6.0 cm)	51	47.2
		Broad (6.1 – 8.0 cm)	50	46.3
		Very broad (> 8.0 cm)	5	4.6
18	Panicle: Length without peduncle	Very short (< 11 cm)	3	2.7
		Short (11 – 20 cm)	54	50.0
		Medium (21 – 30 cm)	45	41.7
		Long (31 – 40cm)	6	5.6
		Very long (>40 cm)	Nil	Nil
19	Panicle: Length of branches (middle third of panicle)	Short (< 5.1 cm)	21	19.4
		Medium (5.1 -10 cm)	68	63.0
		Long (10.1 – 15 cm)	16	14.8
		Very long (>15 cm)	3	2.8
20	Panicle: Density at maturity (ear head compactness)	Very loose	Nil	Nil
		Loose	25	23.1
		Semi loose	26	24.1
		Semi compact	43	39.8
		Compact	14	13.0
21	Panicle: Shape	Reverse pyramid	Nil	Nil
		Panicle broader in upper part	8	7.4
		Symmetric	58	53.7
		Panicle broader in lower part	42	38.9
		Pyramidal	Nil	Nil
22	Neck of panicle: Visible length above sheath	Absent or very short (< 5.1 cm)	4	3.7
		Short (5.1 – 10 cm)	4	3.7
		Medium (10.1 – 15 cm)	13	12.0
		Long (15.1 – 20cm)	23	21.3
		Very long (>20 cm)	64	59.3
23	Glume: Length	Very short (25% of grain covered)	Nil	Nil
		Short (50% of grain covered)	19	17.6
		Medium (75% of grain covered)	36	33.3
		Long (100% of grain covered)	53	49.1
		Very long (longer than the grain)	Nil	Nil

24	Grain: Threshability	Freely threshable (11% unthreshed grain)	60	55.6
		Partly threshable (11% unthreshed grain)	25	23.1
		Difficult to thresh (>50% unthreshed grain)	23	21.3
25	Caryopsis: colour after threshing	White	5	4.6
		Greyed white	10	9.3
		Yellow white	42	38.9
		Yellow orange	25	23.1
		Greyed orange	26	24.1
26	Grain: Shape (in dorsal view)	Narrow elliptic	23	21.3
		Elliptic	38	35.2
		Circular	47	43.5
27	Grain: Shape in profile view	Narrow elliptic	23	21.3
		Elliptic	51	47.2
		Circular	34	31.5
28	Grain: size of mark of germ	Very small	1	0.9
		Small	1	0.9
		Medium	43	39.8
		Large	47	43.5
		Very large	16	14.8
29	Grain: Texture of endosperm (in longitudinal section)	Fully vitreous (100 % corneous)	6	5.6
		¾ vitreous (75% corneous)	25	23.1
		Half vitreous (50% corneous)	30	27.8
		¾ farinaceous (25% corneous)	31	28.7
		Fully farinaceous (0% corneous)	16	14.8
30	Grain: Colour of vitreous albumen	Greyed yellow	58	53.7
		Greyed orange	35	32.4
		Greyed purple	15	13.9
31	Grain: Lustre	Non-lustrous	89	82.4
		Lustrous	19	17.6
32	Stay green trait	Very lightly senescent	13	12.0
		25 percent senescent	57	53.0
		50 percent senescent	30	28.0
		75 percent senescent	5	4.6
		Completely senescent	5	4.6
33	Leaf orientation	Erect	Nil	Nil
		Drooping	108	100

The majority of traits exist in significant variations except for stigma anthocyanin pigmentation, stem diameter, stigma length, flag leaf yellow coloration, leaf sheath anthocyanin pigmentation, and leaf orientation. In the evaluation of the seedling trait, sixty-six germplasm was yellow-green and the remaining forty-two germplasm were greyed purple pigmentation on coleoptile (Fig 1). The analyzed genetic variability was in par with Prajapati *et al.* (2018) [3] and Rohila *et al.* (2018) [12].

Fig 1: Variations observed for seedling coleoptile anthocyanin pigmentation (from left) – yellow-green and greyed purple

The major variation found for leaf midrib color was the white (48) and yellow-green color (59). Regarding the time of panicle emergence, most of the accessions had a very early flowering period. Nearly, 56 accessions had very early flowering (< 56 days) and 24 accessions had early flowering (56-65 days). Hence, these accessions are desirable and to be utilized in the development of short duration genotypes. Prajapati *et al.* (2018) [3], Verma *et al.* (2017) [1], Rohila *et al.* (2018) [12], Elangovan *et al.* (2007) [13], and Durrishahwar *et al.* (2012) [14] enumerated the same kind of variations.

Flower characters *viz.*, stigma anthocyanin coloration, stigma length, anther length, dry anther color, flower length, stigma yellow coloration, lemma arista formation was observed. In the evaluation of lemma arista formation, nearly one-half of accessions had awns while the remaining sixty accessions do not have awns (Fig 2). It indicates that these accessions without awns will enhance yield potential in grain sorghum and reduce evapotranspiration in dry lowland areas. The awned genotypes though low yielders were found to be resistant from bird infestation (Verma *et al.* 2017) [1]. Two different groups namely orange (49) and orange-red (59) were identified in terms of dry anther color. In the case of stigma yellow coloration (Fig 3), it was grouped into the present (43) and absent (65) category. Based on anther length, 32 were short and 76 were medium. Flower length was grouped into short (19), medium (52), long (27), and very long (ten).

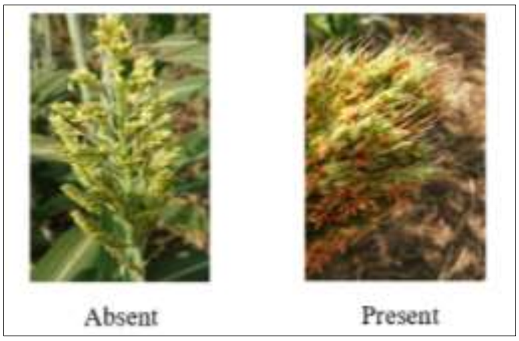

Fig 2: Variations detected for lemma arista formation-absent and present

Nugraheni *et al.* (2020) [15], Prajapati *et al.* (2018) [3], Rohila *et al.* (2018) [12], Bhusal *et al.* (2017) [10], and Verma *et al.* (2017) [1] also observed variations for these traits.

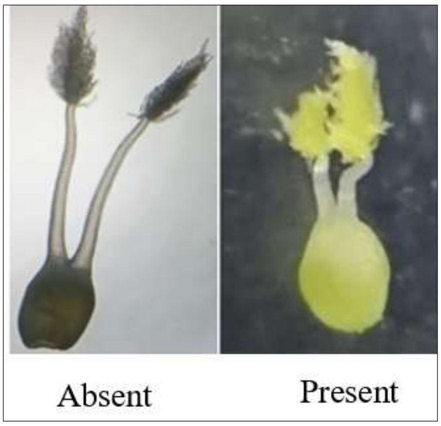

Fig 3: Variation in Stigma yellow coloration-a). Absent b). Present

Great variation was observed for different yield attributing traits *viz.,* plant height, leaf length, and leaf width. Similar findings were reported by Elangovan *et al.* (2007) [13]. Plant height varies from short to very long. Higher the plant height, more the chance of lodging. In terms of plant height, 14 genotypes were short, 56 were medium, 36 were long and two were very long. It is better to choose short or medium plant types to avoid lodging problems. The variation in leaf length and leaf width denotes how a plant can manufacture its food through effective photosynthesis for its growth and development. The germplasm accessions like KO5 75, SO3 251, SPV 168, and R 3062-32 had long and very broader leaves. Stem diameter decides the strength of the plant such that it can withstand lodging. The trait stem diameter contributes least to genetic diversity. All the accessions had very less stem diameter (< 2cm).

Based on glume color, the accessions were grouped into yellow-white (20), greyed yellow (50), greyed orange (14), greyed red (4), and greyed purple (20). Darker glumes will be less prone to grain mold incidence and also be resistant (Elangovan *et al.*2007) [13]. Depending upon panicle density (Fig 4), accessions were grouped into loose (25), semi-loose (26), semi-compact (43), and compact (14). Genotypes were grouped into a panicle broader at the upper part (eight), symmetric (58), and panicle broader at the lower part (42) for panicle shape (Fig 5). Panicle density and shape decide the yield performance of a genotype and also helps in varietal identification (Verma *et al.*2017) [1].

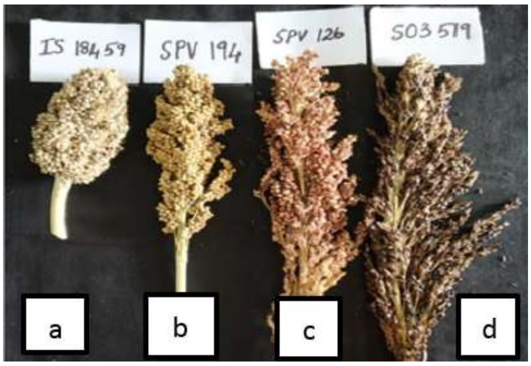

Fig 4: Variation observed for panicle density (from left) – a) compact b). Semi-compact c). Semi-loose d). Loose

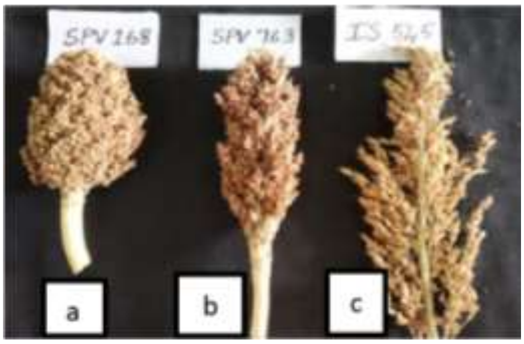

Fig 5: Variation observed for panicle shape (from left) - a). Panicle broader at upper part b). Symmetric c). Panicle broader at lower part

Grain characters contribute much genetic variation and it decides the unique identification pattern of genotypes. Grain threshability will enhance the ease of harvest. The findings revealed that 60 genotypes were freely threshable while 25 and 23 were partially and difficult to thresh respectively. The coverage of glumes decides the threshability. Complete coverage of glume results in poor threshability. The difficulty in threshing will be maximum in fodder types. Caryopsis color after threshing were grouped into white color (5), greyed white color (10), yellow-white color (42), yellow-orange color (25), and greyed orange (26). Grain color decides the quality of produce. White sorghum was mostly preferred for porridge making whereas red grains were preferred for brewing traditional beer (Verma *et al.* 2017) [1].

Variations for grain shape both in dorsal and profile views were evaluated. In dorsal view, 23 were narrow elliptic, 38 were elliptic, and 47 were circular. The profile view (Fig 6) was grouped into three classes namely, narrow elliptic (23), elliptic (51), and circular (34). On basis of grain size of mark of germ (Fig 7), it was sorted into very small (one), small (one), medium (43), large (47), and very large (16).

Fig 6: Grain shape in profile view

Fig 7: Variation for a grain size of the mark of germ (from left) – a). Medium b). Large c). Very Large

The texture of grain endosperm (Fig 8) decides the quality. In this study, six were fully vitreous type, twenty-five were ¾ vitreous types, thirty were half vitreous, thirty-one were ¾ farinaceous and sixteen were fully farinaceous. Grain color of vitreous albumen was sorted into greyed yellow (58), greyed orange (35), and greyed purple (15). Grain luster was grouped into lustrous (19) and non – lustrous (89).

Fig 8: Variations on grain texture of endosperm

The importance of leaf orientation is to help increase the biomass and grain production. Erect growth of leaves aids in better light distribution even to lower canopy and reduces shading. In this study, leaf orientation was drooping for all the germplasm accessions. Stay green trait or non-senescence is an important trait related to drought tolerance. Stay green shows the characteristics of green leaves and stems even under water limiting conditions. Based on the study, thirteen accessions were slightly senescent and hence these accessions can be used in drought-prone regions. The above results were supported by Prajapati *et al.* (2018) [3], Rohila *et al.* (2018) [12], and Verma *et al.* (2017) [1].

Characterization follows 33 traits based on DUS criteria under PPV & FRA. The present findings indicate that those genotypes that excel in these Distinctness, Uniformity, and Stability criteria can be used for further crop improvement programs, and with proper selection, the variety can be released and registered under this act.

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