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Morphological Characterization of Sorghum [*Sorghum bicolor* (L.) Moench] Germplasm for DUS Traits

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A B S T R A C T

A total of 75 sorghum germplasm lines including 74 Indigenous cultivar (IC) and one Exotic cultivar (EC) were characterized using 27 morphological descriptors provided by PPV & FRA for DUS testing in sorghum. Results revealed that maximum variation was present among genotypes for glume traits viz., colour (6 groups), neck of panicle (5 groups), length for flower with pedicel (5 groups), time of panicle emergence (4 groups), colour of dry anther (4 groups), panicle length of branches (4 groups), panicle shape (4 groups) and caryopsis colour (4 groups). Classification of genotypes on the basis of DUS traits provided identification of key characteristics of various genotypes.

Introduction

Sorghum [*Sorghum bicolour* (L.) Moench] is in the fifth position among cereal crop globally after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*) and barley (*Hordeum vulgare*). It is the very important dry land cereal crop for the semi-arid tropics. It is relative tolerant to drought and heat makes it an ideal crop for human being and animal consumption in areas with extreme unfavorable temperatures and in dry regions receiving minimum precipitation (Ratnavathi *et al.*, 2012). Several single cut, multi cut and dual purpose varieties have been released time to time for cultivation in diverse climatic regions of India. Still yield and quality needed to improve to meet growing demand and this is possible only by utilizing existing genetic variability.

The basic material utilized in finding genetic variability is germplasm. Germplasm is defined as the total gene pool of a species consisting of landraces, advanced breeding lines, popular cultivars, wild and weedy relatives (Upadhyaya *et al.*, 2010). Sorghum is supposed to have a wide range of diverse germplasm. Plant genetic resources play an important role in generating new crop

varieties with high yield and desired traits. Various research methodologies are employed in *in-situ* and *ex-situ* conservation of genetic diversity in plants (Shehzad *et al.,* 2014).

Morphological markers are based on traits which can be visually assessed such as flower color, seed shape, growth habits and pigmentation, and such markers do not require expensive technology. Collection of existing germplasm and their characterization is a prerequisite for identifying important genotypes for improvement of varieties and to avoid repetition in the germplasm collection. Morphological, biochemical and molecular markers have been deployed in characterization of crop genetic resources. Among these, morphological characterization of germplasm is the easiest and cheapest method of classification, estimating diversity and registering cultivar (Dossou-Aminon *et al.,* 2015).

To test for distinctness, uniformity and stability DUS Testing is one of the important criteria. It provides a detailed description of accessions which can be used for protection and identification of plant verities. Sorghum is one among the first set of 12 crop species notified by Govt. of India for registration under the Protection of Plant Varieties and Farmers' Rights Act, 2001 (PPVandFRA, 2007a).

Therefore, the present investigation was undertaken with objective to characterize Sorghum germplasm Morphologically for DUS traits.

Materials and Methods

The experimental material consists of 75 sorghum germplasm accessions. The trial was conducted during kharif season of 2015-16. The experiment was planted in a randomized block design with three replications. The total of 27 characters was selected for the characterization of the germplasm on the basis of DUS guidelines. The accessions were collected from the genetics and plant breeding department CCSHAU, Hisar. The lines were grown in the 3 meter length with 45 cm (row to row) and the 15 cm (plant to plant) distance. The accession used for the present study is listed in Table 1.

The data was taken on the basis of DUS guidelines for Sorghum Distinctiveness for the traits were also checked for the all the genotypes. The descriptors and the time and way of taking data are described in Table 2.

Grouping of sorghum germplasm was done by utilizing grouping characteristics which mentioned in the DUS test guidelines of PPV and FR Authority for sorghum.

Results and Discussion

The DUS descriptors for any plant variety are very important with purpose of rights over plant verities and their protection from unauthorized person. The data was collected on the basis of the DUS guidelines for sorghum was found that all the genotypes were distinctive with each other and have got different characteristics. These characteristics are useful to establish distinctiveness, uniformity and stability of a variety, based on which the variety is given protection. The genotypes were classified into distinctive classes on the basis of guidelines. Therefore, there is a great need to characterize genotypes to identify varietal purity, Protection of Plant Variety and Farmers' Right.

Seedling stage

Sorghum seedling anthocyanin colouraion of coleoptiles was examined at seedling stage for their characterization. Based on the variation observed in this character, it was possible to

distinguish all genotypes broadly into two categories: yellow green (15) and grayed purple (60 genotypes). Nagaraja *et al.,* (2000), Selvaraju *et al.,* (2000) and Raghuvanshi *et al.,* (2014) also studied similar traits.

5th leaf stage

At 5th leaf stage genotypes were characterized on the basis of two characters, leaf sheath anthocyanin colouration and leaf midrib colour of 5th fully developed leaf. All genotypes exhibited similar colouration pattern as was observed in case of seedling anthocyanin colouration of coleoptiles except one. Genotype IC-484437 had anthocynin colouration at seedling stage but it was observed that it was absent at 5th leaf stage. Fifty nine genotypes had yellow green and 16 had grayed purple. On the basis of leaf midrib colour the genotypes were categorized into two groups: white (47 genotypes) and yellow green (28 genotypes). These results are in accordance with those of Sangwan *et al.,* (2005), Elangovan *et al.,* (2007), Reddy *et al.,* (2008), Habindavyi (2009), Raghuvanshi *et al.,* (2014).

Panicle emergence stage

Genotypes were characterized on the basis of time of panicle emergence (50% of plants with 50% flowering), natural height of plant up to the base of flag leaf and flag leaf yellow colouration of midrib at panicle emergence stage. Genotypes were grouped into four categories *viz.*, early (5 genotypes), medium (5 genotypes), late (7 genotypes) and very late (58 genotypes) for time of panicle emergence, whereas, genotypes were divided into two groups i.e. very short (6 genotypes), short (64 genotypes) and medium (5 genotypes) on the basis of plant height up to the base of flag leaf and 23 genotypes exhibited yellow colouration of midrib while 52 genotypes were without yellow colouration in midrib of flag leaf. These results are in accordance with those of Reddy *et al.,* (2008), Reddy *et al.,* (20090, Kannababu *et al.,* (2013) and Raghuvanshi *et al.,* (2014).

Flowering stage

Sorghum genotypes were classified into different groups based on lemma arista formation, stigma anthocyanin colouration, stigma yellow colouration, anther length, stigma length, colour of dry anther and flower with pedicel length of flower. Based on the lemma arista formation observed on this character, it was possible to distinguish all genotypes broadly into two categories: lemma arista present (20 genotypes) and absent (55 genotypes). Based on colour of dry anther, genotypes were classified into four categories *viz.*, yellow orange (26 genotypes), orange (33 genotypes) red orange (10 genotypes) and grayed orange (6 genotypes) while, on the basis of length for flower with pedicel length of flower, genotypes were also divided into five groups very short (5 genotypes), short (4 genotypes), medium (17 genotypes), long (39 genotypes) and very long (10 genotypes). However, on the basis of stigma yellow colouration and stigma anthocyanin colouration, genotypes were divided into two groups i.e. absent (49 and 6 genotypes) and present (26 and 69 genotypes), respectively. In case of stigma length genotypes fell under short (6 genotypes), medium (50 genotypes) and long (19 genotypes) stigma length. On the basis of anther length genotypes were divided into three categories *viz.*, short (18 genotypes), medium (53 genotypes) and long (4 genotypes). These results are in accordance with those of Kolberg (1999), Reddy *et al.,* (2006), Reddy *et al.,* (2009) and Joshi *et al.,* (2009).

Physiological maturity

Characters like, glume colour, panicle length of branches, panicle density at maturity, panicle shape, neck of panicle visible above

sheath, glume length and grain threshability were recorded for characterization of genotypes at physiological maturity. On the basis of glume colour genotypes were categorized into six groups *viz.*, green white (16 genotypes), yellow white (2 genotypes), grayed yellow (7 genotypes), grayed orange (5 genotypes), grayed red (6 genotypes), grayed purple (39 genotypes). However, on the basis of neck of panicle visible above sheath genotypes were also divided into five groups namely, very short (12 genotypes), short (11 genotypes), medium (33 genotypes), long (14 genotypes), very long (5 genotypes). Whereas, on the basis of panicle density at maturity genotypes could be divided into five categories *viz.*, very loose (IC-253535), loose (3 genotypes), semi loose (38 genotypes), semi compact (27 genotypes), compact (6 genotypes). Genotypes could be divided into four groups *viz.*, short (9 genotypes), medium (23 genotypes), long (10 genotypes) and very long (33 genotype) on the basis of glume length. Genotypes were characterized into four groups *viz.*, short (34 genotypes), medium (40 forty genotypes) and long (1 genotype) on the basis of panicle length of branches. In case of panicle shape genotypes were characterized into four groups *viz.*, panicle broader in upper part (1 genotype), symmetrical (18 genotypes), panicle broader in lower part (15 genotypes) and pyramidal in their panicle shape (41 genotypes). Genotypes were classified on the basis of threshability in three categories *viz.*, freely threshable (27 genotypes), partly threshable (12 genotypes) and difficult to thresh (36 genotypes). These traits are also studied and found diverse by Pahuja *et al.*, (2002) , Umakanth *et al.*, (2002) , Sangwan *et al.*, (2005), Elangovan *et al.*, (2006), Nabi *et al.*, (2006), Reddy *et al.*, (2009) and Missihoun *et al.*, (2015).

Table.1 List of Accession used for study

Sr. No.	Accession number	Sr. No.	Accession number	Sr. No.	Accession number	Sr. No.	Accession number
1	IC-485120	21	IC-485237	41	IC-484542	61	IC-484949
2	IC-485121	22	IC-485242	42	IC-484588	62	IC-484951
3	IC-485251	23	EC-524468	43	IC-484623	63	IC-485054
4	IC-484363	24	IC-253535	44	IC-484640	64	IC-485099
5	IC-484374	25	IC-289225	45	IC-484643	65	IC-485115
6	IC-484410	26	IC-484369	46	IC-484684	66	IC-485124
7	IC-484438	27	IC-484437	47	IC-485170	67	IC587848
8	IC-484448	28	IC-484475	48	IC-485223	68	IC-587849
9	IC-484471	29	IC-484503	49	IC-484364	69	IC-587850
10	IC-484547	30	IC-484522	50	IC-484537	70	IC-587852
11	IC-484559	31	IC-484526	51	IC-484546	71	IC-587855
12	IC-484606	32	IC-484675	52	IC-484587	72	IC-587856
13	IC-484621	33	IC-484685	53	IC-484622	73	IC-587857
14	IC-484657	34	IC-484794	54	IC-484674	74	IC-587858
15	IC-484678	35	IC-485072	55	IC-484739	75	IC-587859
16	IC-484875	36	IC-485100	56	IC-484757		
17	IC-485113	37	IC-485231	57	IC-484777		
18	IC-485119	38	IC-484365	58	IC-484779		
19	IC-485132	39	IC-484390	59	IC-484889		
20	IC-485160	40	IC-484483	60	IC-484920		

Table.2 Descriptors used to characterize the present geneotypes

	Parameters	**States**	**Stage of observation**
2.1	Seedling anthocyanin colouration of coleoptiles	yellow green grayed purple	Seedling 7-8 days after sowing
2.2	Leaf sheath anthocyanin Colouration	yellow green grayed purple	5th leaf
2.3	Leaf mid rib colour (5th fully developed leaf)	white yellow green grayed yellow grayed purple	5th leaf
2.4	Time of panicle emergence (50% of the plants with 50% anthesis)	very early (<56 days) early (56-65 days) medium (66-75 days) late (76-85 days) very late (>85 days)	Panicle emergence
2.5	Plant height up to base of flag leaf	very short (<76 cm) short (76-150 cm) medium (151-225 cm) tall (226-300 cm) very tall (>300 cm)	Panicle emergence
2.6	Flag leaf yellow colouration of Midrib	absent present	Panicle emergence
2.7	Lemma arista formation	absent present	Flowering
2.8	Stigma anthocyanin colouration	absent present	Upper portion of the panicle at the end of flowering
2.9	Stigma yellow colouration	absent present	Flowering
2.10	Stigma length	short (<1mm) medium (1-2mm) long (>2mm)	Flowering
2.11	Flower with pedicel: length of Flower	very short short medium long very long	Flowering
2.12	Anther length	short (<3mm) medium (3-4mm) long (>4mm)	Flowering
2.13	Anther colour of dry anther	yellow orange orange orange red grayed orange	End of flowering
2.14	Glume colour	green white yellow white grayed yellow grayed orange grayed red grayed purple	Physiological maturity of grain
2.15	Panicle length of branches (middle third of panicle)	short (<5.1 cm) medium (5.1-10 cm) long (10.1-15 cm) very long (>15 cm)	Physiological maturity
2.16	Panicle density at maturity (ear head compactness)	very loose loose semi loose semi compact compact	Physiological maturity

2.17	Panicle shape	reversed pyramid panicle broader in upper part symmetric panicle broader in lower part pyramidal	Physiological maturity
2.18	Neck of panicle visible length above sheath	absent or very short (<5.1 cm) short (5.1-10 cm) medium (10.1-15 cm) long (15.1-20 cm) very long (>20cm)	Physiological maturity
2.19	Glume length	very short (25% of grain covered) short (50% of grain covered) medium (75% of grain covered) long (100% of grain covered) very long (longer than the grain)	Physiological maturity
2.20	Grain Threshability	freely threshable (<11% unthreshed grain) partly thresahble (11 – 50% unthreshed grain) difficult to thresh (>50% unthreshed grain)	Maturity
2.21	Caryopsis colour after threshing	white RHS 155 grayed white RHS156 yellow white RHS158 yellow orange RHS14-20 grayed orange RHS200	After threshing
2.22	Grain: shape (in dorsal view)	narrow elliptic elliptic circular	After threshing
2.23	Grain shape in profile view	narrow elliptic elliptic circular	After threshing
2.24	Grain size of mark of germ	very small small medium large very large	After threshing
2.25	Grain texture of endosperm (in longitudinal section)	fully vitreous (100% corneous) vitreous (75% corneous) half vitreous (50% corneous) farinaceous (25% corneous) fully farinaceous (0% corneous)	After threshing
2.26	Grain colour of vitreous albumen	grayed yellow RHS160-162 grayed orange RHS166 grayed purple RHSN187	After threshing
2.27	Grain luster	non-lustrous lustrous	After threshing

Line	Seedling anthocynin	Leaf sheath anthocyanin colouration	Leaf mid rib colour	Days to panicle emergence	Height of the plant up to the base of flag leaf	Flag leaf yellow colouration of mid rib	Lemma arista formation	Stigma anthocyanin colouration	Stigma yellow colouration	Stigma Length	Flower with pedicel: length of flower	Anther length	Anther colour of dry anther
IC-485120	Absent	Absent	Yellow Green	Very late	Short	Present	Absent	Absent	Absent	Medium	Medium	Long	Yellow orange
IC-485121	Absent	Absent	Yellow Green	Very late	Short	Present	Absent	Present	Absent	Medium	Medium	Medium	Orange
IC-485251	Absent	Absent	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Medium	Medium	Orange
IC-484363	Present	Present	Yellow Green	Very late	Short	Absent	Absent	Present	Present	Medium	Long	Medium	Orange
IC-484374	Present	Present	White	Very late	Short	Absent	Absent	Present	Present	Medium	Long	Medium	Orange
IC-484410	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Yellow orange
IC-484438	Present	Present	White	Very late	Short	Absent	Absent	Absent	Absent	Medium	Medium	Medium	Yellow orange
IC-484448	Present	Present	White	Very late	Short	Absent	Present	Present	Present	Long	Long	Medium	Yellow orange
IC-484471	Absent	Absent	Yellow Green	Late	Very Short	Absent	Absent	Present	Absent	Medium	Medium	Short	Red orange
IC-484547	Present	Present	White	Very late	Short	Absent	Absent	Present	Present	Medium	Medium	Medium	Yellow orange
IC-484559	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Medium	Medium	Orange
IC-484606	Present	Present	Yellow Green	Late	Medium	Absent	Present	Present	Absent	Long	Long	Medium	Orange
IC-484621	Present	Present	Yellow Green	Medium	Short	Absent	Absent	Present	Absent	Very Short	Long	Mediumediu Medium	Yellow orange
IC-484657	Present	Present	White	Very late	Short	Absent	Present	Present	Absent	Long	Long	Long	Orange
IC-484678	Absent	Absent	Yellow Green	Very late	Short	Present	Absent	Present	Absent	Long	Long	Medium	Yellow orange
IC-484875	Present	Present	White	Very late	Short	Absent	Absent	Present	Present	Medium	Long	Medium	Yellow orange
IC-485113	Present	Present	White	Early	Short	Absent	Absent	Present	Present	Medium	Very Long	Medium	Orange
IC-485119	Present	Present	White	Medium	Short	Absent	Absent	Present	Present	Medium	Long	Medium	Yellow orange
IC-485132	Present	Present	White	Early	Short	Absent	Present	Present	Present	Medium	Long	Medium	Red orange
IC-485160	Absent	Absent	Yellow Green	Very late	Very Short	Absent	Absent	Present	Absent	Long	Medium	Medium	Yellow orange
IC-485237	Present	Present	White	Very late	Short	Present	Present	Present	Absent	Long	Long	Medium	Yellow orange
IC-485242	Present	Present	White	Very late	Short	Absent	Absent	Present	Present	Medium	Long	Medium	Greyed orange
EC-524468	Absent	Absent	White	Very late	Short	Absent	Present	Present	Present	Long	Very long	Medium	Yellow orange
IC-253535	Present	Present	White	Late	Medium	Absent	Absent	Present	Present	Medium	Medium	Short	Red orange
IC-289225	Present	Present	White	Early	Short	Absent	Absent	Present	Absent	Medium	Very long	Short	Greyed orange
IC-484369	Present	Present	Yellow Green	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Short	Orange

IC-484437	Present	Absent	Yellow Green	Very late	Short	Absent	Present	Absent	Absent	Long	Long	Medium	Yellow orange
IC-484475	Absent	Absent	Yellow Green	Early	Very Short	Present	Present	Present	Present	Long	Very long	Medium	Orange
IC-484503	Absent	Absent	Yellow Green	Very late	Very Short	Present	Absent	Present	Absent	Medium	Long	Short	Orange
IC-484522	Absent	Absent	Yellow Green	Very late	Very Short	Present	Absent	Present	Absent	Very Short	Medium	Medium	Greyed orange
IC-484526	Absent	Absent	Yellow Green	Very late	Very Short	Present	Absent	Present	Absent	Very Short	Short	Short	Orange
IC-484675	Present	Present	Yellow Green	Very late	Short	Present	Absent	Present	Present	Medium	Medium	Short	Orange
IC-484685	Absent	Absent	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Yellow orange
IC-484794	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Red orange
IC-485072	Present	Present	White	Medium	Short	Absent	Absent	Present	Absent	Medium	Long	Short	Orange
IC-485100	Present	Present	Yellow Green	Very late	Short	Present	Absent	Present	Absent	Medium	Medium	Short	Orange
IC-485231	Present	Present	White	Early	Short	Absent	Present	Absent	Absent	Long	Medium	long	Yellow orange
IC-484365	Present	Present	White	Late	Short	Present	Absent	Present	Absent	Medium	Very Long	Medium	Red orange
IC-484390	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Yellow orange
IC-484483	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Very Short	Long	Medium	Red orange
IC-484542	Present	Present	White	Very late	Short	Absent	Present	Present	Present	Long	Medium	Medium	Red orange
IC-484588	Present	Present	Yellow Green	Very late	Short	Absent	Absent	Present	Present	Long	Very short	Medium	Red orange
IC-484623	Present	Present	Yellow Green	Very late	Medium	Present	Absent	Present	Present	Medium	Long	Medium	Greyed orange
IC-484640	Present	Present	Yellow Green	Very late	Short	Present	Absent	Present	Present	Long	Long	Medium	Greyed orange
IC-484643	Present	Present	White	Very late	Short	Absent	Absent	Present	Present	Very Short	Very long	Medium	Orange
IC-484684	Present	Present	White	Very late	Short	Present	Absent	Present	Present	Medium	Very long	Short	Orange
IC-485170	Present	Present	Yellow Green	Very late	Short	Absent	Absent	Present	Present	Medium	Medium	Short	Yellow orange
IC-485223	Present	Present	White	Very late	Short	Absent	Absent	Absent	Absent	Medium	Long	Short	Yellow orange
IC-484364	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Very Short	Very Long	Medium	Orange
IC-484537	Present	Present	White	Very late	Short	Present	Absent	Present	Absent	Medium	Long	Medium	Orange
IC-484546	Present	Present	White	Very late	Short	Absent	Absent	Present	Present	Medium	Long	Medium	Orange
IC-484587	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Short	Short	Orange
IC-484622	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Orange
IC-484674	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Orange

IC-484739	Present	Present	White	Late	Short	Absent	Absent	Present	Absent	Medium	Short	Medium	Yellow orange
IC-484757	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Long	Short	Medium	Orange
IC-484777	Present	Present	White	Very late	Short	Absent	Absent	Present	Present	Medium	Long	Medium	Orange
IC-484779	Present	Present	Yellow Green	Very late	Short	Absent	Present	Absent	Absent	Medium	Very short	Short	Orange
IC-484889	Absent	Absent	White	Very late	Short	Present	Absent	Present	Absent	Medium	Medium	Short	Orange
IC-484920	Present	Present	White	Medium	Medium	Absent	Absent	Present	Present	Medium	Very short	Medium	Orange
IC-484949	Absent	Absent	White	Medium	Short	Absent	Absent	Present	Absent	Medium	Very short	Medium	Greyed orange
IC-484951	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Very short	Short	Yellow orange
IC-485054	Absent	Absent	Yellow Green	Very late	Short	Present	Absent	Present	Absent	Medium	Long	Medium	Yellow orange
IC-485099	Present	Present	White	Late	Short	Absent	Absent	Present	Absent	Medium	Medium	Short	Orange
IC-485115	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Yellow orange
IC-485124	Present	Present	White	Very late	Short	Absent	Absent	Present	Absent	Medium	Long	Medium	Orange
IC587848	Present	Present	Yellow Green	Very late	Short	Present	Present	Present	Absent	Medium	Very long	Medium	Orange
IC587849	Present	Present	White	Very late	Short	Absent	Present	Present	Present	Medium	Long	Medium	Red orange
IC587850	Present	Present	Yellow Green	Very late	Medium	Present	Present	Present	Present	Long	Very long	Long	Yellow orange
IC587852	Present	Present	Yellow Green	Late	Short	Absent	Present	Present	Absent	Long	Long	Short	Yellow orange
IC587855	Present	Present	White	Very late	Short	Absent	Present	Present	Present	Long	Long	Medium	Red orange
IC587856	Present	Present	Yellow Green	Very late	Short	Present	Present	Present	Absent	Long	Long	Medium	Orange
IC587857	Present	Present	Yellow Green	Very late	Short	Present	Present	Present	Absent	Medium	Long	Medium	Yellow orange
IC587858	Present	Present	Yellow Green	Very late	Short	Present	Present	Present	Absent	Long	Long	Medium	Yellow orange
IC587859	Present	Present	White	Very late	Short	Present	Present	Present	Absent	Medium	Long	Medium	Orange

	Glume colour	**Panicle length of branches**	**Panicle density at maturity**	**Panicle shape**	**Neck of panicle visible above sheath**	**Glume length**	**Grain threshability**	**Caryopsis colour**	**Grain shape in dorsal view**	**Grain shape in profile view**	**Grain size of mark germ**	**Grain texture of endosperm**	**Grain colour of vitreous albumen**	**Grain luster**
IC-485120	Green White	Short	Semi compact	symmetrical	Short	Medium	Freely threshable	White	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Present
IC-485121	Yellow White	Short	Semi compact	symmetrical	Very Short	Medium	Freely threshable	Yellow white	Eleptical	Eleptical	Medium	¾ farinaceous	Greyed yellow	Absent
IC-485251	Green White	Short	Semi compact	symmetrical	Medium	Short	Freely threshable	Yellow orange	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Present
IC-484363	Grayed Purple	Medium	Semi loose	pyramidal	Very long	Very Long	Difficult to thresh	Yellow orange	Eleptical	Eleptical	Medium	½ vitreous	Greyed purpule	Absent

IC-484374	Grayed Purple	Medium	Semi loose	pyramidal	long	Very Long	Difficult to thresh	Yellow orange	Eleptical	Eleptical	Medium	½ vitreous	Greyed purpule	Present
IC-484410	Grayed Purple	Medium	Semi loose	pyramidal	long	Very Long	Difficult to thresh	Yellow orange	Eleptical	Eleptical	Medium	½ vitreous	Greyed purpule	Absent
IC-484438	Grayed Red	Short	Compact	Broader base	long	Medium	Partly threshable	Greyed white	Eleptical	Eleptical	Medium	½ vitreous	Greyed yellow	Absent
IC-484448	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	Greyed orange	Nerrow eleptical	Nerrow eleptical	Medium	½ vitreous	Greyed yellow	Absent
IC-484471	Green White	Short	Semi compact	symmetrical	Medium	Short	Partly threshable	Yellow orange	Circular	Circular	Large	¾ farinaceous	Greyed orange	Present
IC-484547	Grayed Purple	Medium	Semi loose	pyramidal	long	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Large	½ vitreous	Greyed yellow	Absent
IC-484559	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Large	½ vitreous	Greyed yellow	Present
IC-484606	Grayed Red *	Short	Semi compact	Broader base	Medium	Medium	Freely threshable	Yellow white	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Absent
IC-484621	Grayed Purple	Medium	Semi loose	pyramidal	Very Short	Very Long	Difficult to thresh	Greyed white	Eleptical	Eleptical	Medium	½ vitreous	Greyed yellow	Absent
IC-484657	Grayed Purple	Medium	Semi loose	pyramidal	long	Very Long	Difficult to thresh	Greyed white	Eleptical	Eleptical	Large	½ vitreous	Greyed yellow	Absent
IC-484678	Green White	Short	Semi compact	pyramidal	Medium	Medium	Freely threshable	Yellow white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Absent
IC-484875	Grayed Purple	Medium	Semi loose	pyramidal	long	Very Long	Difficult to thresh	Greyed orange	Eleptical	Eleptical	Large	½ vitreous	Greyed orange	Absent
IC-485113	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	Greyed orange	Eleptical	Eleptical	Medium	Full farinaceous	Greyed purpule	Absent
IC-485119	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Large	¾ farinaceous	Greyed yellow	Present
IC-485132	Grayed Purple	Medium	Semi loose	pyramidal	Short	Long	Difficult to thresh	White	Eleptical	Eleptical	Medium	½ vitreous	Greyed yellow	Present
IC-485160	Green White	Short	Semi compact	symmetrical	Medium	Short	Freely threshable	Yellow white	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Absent
IC-485237	Grayed Purple	Medium	Semi loose	pyramidal	Very long	Very Long	Difficult to thresh	White	Eleptical	Circular	Medium	½ vitreous	Greyed yellow	Absent
IC-485242	Grayed Purple	Medium	Semi loose	pyramidal	long	Very Long	Freely threshable	Yellow white	Eleptical	Eleptical	Medium	½ vitreous	Greyed yellow	Present
EC-524468	Yellow White	Medium	Loose	pyramidal	Medium	Long	Partly threshable	White	Eleptical	Eleptical	Medium	½ vitreous	Greyed yellow	Present
IC-253535	Grayed Purple	long	Very Long*	pyramidal	Very long	Medium	Freely threshable	Yellow white	Circular	Circular	Large	½ vitreous	Greyed purpule	Present
IC-289225	Grayed Yellow	Medium	Loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Large	Full farinaceous	Greyed yellow	Present
IC-484369	Grayed Red *	Short	Compact	Broader base	very short	Medium	Partly threshable	White	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC-484437	Grayed Yellow	Short	Semi compact	Broader base	Medium	Medium	Freely threshable	Yellow white	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Absent
IC-484475	Green White	Medium	Semi loose	Broader at top	Very short	Medium	Freely threshable	Greyed white	Eliptical	Circular	Medium	¾ farinaceous	Greyed yellow	Absent
IC-484503	Green White	Short	Semi compact	Broader base	Very short	Long	Freely threshable	Yellow white	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Present
IC-484522	Grayed Yellow	Short	Semi compact	symmetrical	Short	Short	Freely threshable	Greyed white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Absent
IC-484526	Green White	Short	Semi compact	symmetrical	Medium	Long	Freely threshable	Greyed white	Circular	Circular	Large	¾ farinaceous	Greyed purpule	Absent

IC-484675	Grayed Orange	Short	Semi compact	symmetrical	Short	Short	Freely threshable	Yellow white	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Absent
IC-484685	Green White	Short	Semi compact	pyramidal	Short	Medium	Freely threshable	Yellow orange	Circular	Circular	Large	¾ farinaceous	Greyed orange	Present
IC-484794	Grayed Purple	Medium	Semi loose	pyramidal	Short	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Medium	Full farinaceous	Greyed yellow	Present
IC-485072	Grayed Purple	Medium	Semi loose	pyramidal	Short	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Large	½ vitreous	Greyed yellow	Present
IC-485100	Green White	Short	Semi compact	symmetrical	Short	Short	Freely threshable	Yellow white	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Present
IC-485231	Grayed Purple	Short	Compact	Broader base	Very Short	Medium	Freely threshable	Yellow white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC-484365	Grayed Purple	Medium	Loose	pyramidal	Medium	Long	Difficult to thresh	Yellow orange	Circular	Circular	Large	¾ farinaceous	Greyed orange	Present
IC-484390	Grayed Red *	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Large	½ vitreous	Greyed yellow	Present
IC-484483	Grayed Purple	Medium	Semi loose	pyramidal	Long	Very Long	Difficult to thresh	White	Eleptical	Eleptical	Medium	½ vitreous	Greyed yellow	Present
IC-484542	Grayed Orange	Short	Compact	Broader base	Short	Short	Partly threshable	Yellow orange	Circular	Circular	Large	¾ farinaceous	Greyed orange	Present
IC-484588	Grayed Purple	Short	Semi compact	pyramidal	Medium	Medium	Partly threshable	Yellow white	Eleptical	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC-484623	Grayed Purple	Short	Semi compact	symmetrical	Medium	Long	Partly threshable	Yellow white	Eleptical	Eleptical	Large	½ vitreous	Greyed yellow	Present
IC-484640	Grayed Purple	Short	Semi compact	symmetrical	Short	Long	Partly threshable	Yellow white	Eleptical	Eleptical	Large	½ vitreous	Greyed yellow	Present
IC-484643	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	Greyed orange	Eleptical	Eleptical	Medium	Full farinaceous	Greyed yellow	Absent
IC-484684	Grayed Purple	Medium	Semi loose	pyramidal	Short	Very Long	Difficult to thresh	Greyed orange	Eleptical	Eleptical	Medium	½ vitreous	Greyed orange	Absent
IC-485170	Green White	Short	Semi compact	symmetrical	Medium	Medium	Freely threshable	Yellow white	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Absent
IC-485223	Green White	Short	Compact	symmetrical	Medium	Medium	Partly threshable	White	Circular	Circular	Medium	¾ farinaceous	Greyed yellow	Absent
IC-484364	Grayed Purple	Medium	Semi loose	pyramidal	Long	Very Long	Difficult to thresh	White	Eliptical	Circular	Large	½ vitreous	Greyed yellow	Present
IC-484537	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Present
IC-484546	Grayed Purple	Medium	Semi loose	pyramidal	Long	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Medium	Full farinaceous	Greyed yellow	Present
IC-484587	Grayed Purple	Medium	Semi loose	pyramidal	Very long	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Present
IC-484622	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Medium	Difficult to thresh	White	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Present
IC-484674	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Long	Difficult to thresh	White	Eliptical	Eliptical	Medium	½ vitreous	Greyed yellow	Present
IC-484739	Grayed Purple	Medium	Semi loose	pyramidal	Long	Long	Difficult to thresh	White	Eliptical	Eliptical	Large	¾ farinaceous	Greyed orange	Present
IC-484757	Grayed Purple	Medium	Semi loose	pyramidal	Long	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Large	½ vitreous	Greyed orange	Absent
IC-484777	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Present
IC-484779	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	Greyed orange	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Absent

IC-484889	Grayed Orange	Short	Semi compact	symmetrical	Medium	Short	Freely threshable	Yellow white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC-484920	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Large	¾ farinaceous	Greyed yellow	Present
IC-484949	Green White	Medium	Semi loose	pyramidal	Medium	Very Long	Partly threshable	White	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Present
IC-484951	Grayed Purple	Medium	Semi loose	pyramidal	Very long	Very Long	Difficult to thresh	Greyed orange	Eliptical	Eliptical	Medium	½ vitreous	Greyed orange	Absent
IC-485054	Green White	Short	Semi compact	symmetrical	Long	Medium	Freely threshable	Yellow white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC-485099	Grayed Red *	Medium	Semi loose	pyramidal	Very short	Very Long	Partly threshable	White	Eliptical	Eliptical	Medium	½ vitreous	Greyed yellow	Absent
IC-485115	Grayed Purple	Medium	Semi loose	pyramidal	Medium	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Present
IC-485124	Grayed Purple	Medium	Semi loose	symmetrical	Medium	Very Long	Difficult to thresh	White	Eliptical	Eliptical	Medium	½ vitreous	Greyed yellow	Absent
IC587848	Grayed Orange	Short	Semi loose	Broader base	Medium	Medium	Difficult to thresh	White	Eliptical	Eliptical		½ vitreous	Greyed yellow	Absent
IC587849	Green White	Short	Compact	Broader base	Very short	Medium	Partly threshable	Yellow orange	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC587850	Grayed Yellow	Short	Semi compact	Broader base	Long	Medium	Freely threshable	White	Eliptical	Eliptical	Large	½ vitreous	Greyed yellow	Present
IC587852	Grayed Yellow	Short	Semi compact	Broader base	Very short	Medium	Freely threshable	Green white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC587855	Grayed Orange	Short	Semi compact	Broader base	Very short	Medium	Freely threshable	Yellow orange	Circular	Circular	Large	¾ farinaceous	Greyed orange	Present
IC587856	Grayed Red *	Short	Semi compact	Broader base	Medium	Long	Freely threshable	Yellow white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Absent
IC587857	Grayed Yellow	Short	Semi compact	Broader base	Very short	Medium	Freely threshable	White	Eliptical	Eliptical	Large	Full farinaceous	Greyed yellow	Present
IC587858	Grayed Yellow	Short	Semi compact	Broader base	Very short	Short	Freely threshable	Yellow white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Present
IC587859	Green White	Short	Semi compact	symmetrical	Medium	Medium	Freely threshable	Yellow white	Circular	Circular	Large	¾ farinaceous	Greyed yellow	Absent

After threshing

After threshing genotypes were classified on the basis of caryopsis colour, grain shape in dorsal view, grain shape in profile view, grain size of mark of germ, grain texture of endosperm (in longitudinal section), grain colour of vitreous albumen and grain luster. Genotypes were characterized into four groups *viz.*, white (31 genotypes), yellow white (20 genotypes), yellow orange (10 genotypes), greyed white (7 genotype) and grayed orange (7 genotypes) on the basis of caryopsis colour. However, on the basis of grain textures of endosperm genotypes were divided into four groups namely, ¾ vitreous (26 genotypes), ½ vitreous (36 genotypes), ¾ farinaceous (7 genotypes) and full farinaceous (6 genotypes). On the basis of grain shape in dorsal view genotypes were characterized into three groups namely, circular (28 genotypes), elliptic (46 genotypes) and narrow elliptic (1 genotype). Whereas, on the basis of grain shape in profile view genotypes were also divided into three groups *viz.*, circular (32 genotypes), elliptic (42 genotypes) and narrow elliptic (1 genotype). Genotypes were divided into two categories namely, medium (32 genotypes) and large (43 genotypes) on the basis of grain size of mark of germ. On the basis of grain colour of vitreous albumen genotypes were characterized into three groups *viz.*, grayed yellow (59 genotypes), grayed orange (10 genotypes) and grayed purple (6 genotypes). Genotypes could be divided into two groups namely, lusterous (44 genotypes) and non lusterous (31 genotypes) on the basis of grain luster.) These characterization are in accordance with those Ram *et al.,* (1998), Nagaraja *et al.,* (2000), Selvaraju *et al.,* (2000), Thangavel *et al.,* (2005), Elangovan (2006) and Missihoun *et al.,* (2015).

From the present investigation it may be concluded 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 and FR Act for obtaining Plant breeders and Farmers' rights. However, morphological descriptors alone may not be sufficient for DUS criteria.

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