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Distinctness, Uniformity and Stability (DUS) Characterization Using Morphological Traits of Little Millet

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A research study for 50 accessions of little millet germplasm was carried out for DUS (Distinctness, Uniformity, and Stability) descriptors encompassing both qualitative and quantitative traits. The assessment adhered to guidelines from the International Union for the Protection of New Varieties of Plants (UPOV) and the Protection of Plant Varieties and Farmer's Rights Authority (PPV & FRA). The findings underscored substantial diversity among the germplasm accessions across all evaluated characteristics. This suggests a significant genetic diversity in the morphological profile of little millet germplasm. The outcomes of this study are valuable for breeders, researchers, and farmers in identifying and selecting germplasm accessions for crop enhancement. Additionally, they contribute to the conservation of beneficial genes and facilitate the pursuit of protection under the Protection of Plant Varieties and Farmer's Rights Act.

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Keywords: Distinctness; uniformity; stability; little millet; qualitative traits; quantitative traits.

1. INTRODUCTION

Little millet (*Panicum sumatrense L.* Roth. Ex. Roemer and Schultes*)* is a staple small-seeded cereal food crop belonging to the self-pollinated crop. The production of little millet dropped from the 1950s to the early 21st century. But, in recent years the crop gaining much attention because of its high climate-resilient in adapting to the diverse agro-climatic zones as well as nutrient-rich components compared to other cereal food crops (Joshi et al., 2021). Worldwide, little millet is cultivated in an area of 0.26 m.ha with a production of 0.12 mt (Bhat et al., 2018). In India, little millet was grown in an area of 2.34 lakh hectares with an annual production of 1.27 lakh tonnes and productivity of 544 kg ha^{-1}. In Andhra Pradesh, little millet is grown in an area of 7000 ha with a production of 3000 t and productivity of 354 kg ha^{-1} (Venkata Ratnam et al., 2019).

Qualitative traits play decisive factors for grouping of genotypes, as they show high heritability and stable expression (Smith and Smith, 1992). If qualitative characters showed association with yield attributes, it can serve as a marker in selection process which are less influenced by environmental fluctuations. Further, characterization and evaluation are essential pre-requisites for efficient utilization of germplasm (Upadhyaya et al., 2010). To commercially introduce a new plant variety, it is essential to register it by conducting DUS tests (distinctness, uniformity, and stability) to assess its uniqueness (Tommasini et al., 2003). DUS tests serve as the basis for plant variety protection and for distinguishing a new variety from existing ones in a reference collection (Kwon et al., 2005). The Indian Government enacted its own legislation, the "Protection of Plant Varieties and Farmers Act" (PPV&FRA), in 2001, as the existing UPOV models were not appropriate for Indian requirements. This act provides protection to plant varieties based on DUS tests and novelty (Patra, 2000). Therefore, the concept of distinctness, uniformity, and stability is essential in characterizing a plant variety as a unique creation. In this context, a study was conducted to evaluate 50 little millet germplasm accessions based on selected DUS characters and yield attributing traits.

2. MATERIALS AND METHODS

The research work was comprised of 50 little millet genotypes and were investigated during *Kharif,* 2023 in Randomized Block Design with three replications at Agricultural Research Station (ARS), Perumallapalle, Andhra Pradesh, India. Details of the genotypes studied in the present investigation are presented in Table 1. Each genotype was grown in a plot of two rows of 3 m length with a spacing of 22.5 **×** 7.5 cm. All the recommended practices were followed to ensure a good crop. For the estimation of Distinctness, Uniformity and Stability, observations were recorded on agro morphological descriptors *viz*., growth habit, plant pigmentation at leaf sheath, leaf sheath pubescence, leaf blade pubescence, ligule pubescence, inflorescence shape, culm branching, panicle compactness, peduncle length, flag leaf width, lodging, days to 50 per cent flowering, days to maturity, basal tillers, panicle length, grain yield per plot and test weight. Observations were recorded on five randomly chosen plants of each accession for growth, leaf and floral traits. Based on morphologically distinct features, a visual scoring was recorded for qualitative characters by Yu and Chung (2021).

Table 1. Pedigree details of little millet genotypes used in the study

S. No.	Genotypes	Pedigree	Centre
1	BL-2	CO-2 × OLM-56	Jagdalpur
2	BL-4	CO-2 × TNAU-97	Jagdalpur
3	BL-8	CO-2 × OLM-56	Jagdalpur
4	BL-41-3	Paiyur-2 × TNAU-97	Jagdalpur
5	BL-150	Paiyur-2 × DLM-369	Jagdalpur
6	CO-2	Pure line selection	Coimbatore
7	DhLtMV-10-2	-	Hanumanamatti
8	DhLtMV-14-1	CO-2 × TNAU-110	Hanumanamatti

S. No.	Genotypes	Pedigree	Centre
9	DhLtMV-21-1	CO-2 × TNAU-26	Hanumanamatti
10	DhLtMV-28-4	-	Hanumanamatti
11	DhLtMV-36-3	CO-4 × Paiyur-2	Hanumanamatti
12	DhLtMV-39-1	CO-4 × Paiyur-2	Hanumanamatti
13	DLM-8	-	Dindori
14	DLM-14	Pure line selection from Local Germplasm	Dindori
15	DLM-89	Pure line selection from Local Germplasm	Dindori
16	DLM-95	Selection from Local Germplasm	Rewa
17	DLM-103	Pure line selection from Local Germplasm	Dindori
18	DLM-186	-	Dindori
19	DhLt-28-4	CO-2 × TNAU-26	Hanumanamatti
20	GPUL-1	-	Bangalore
21	GPUL-2	Pure line selection from Peddasame	Bangalore
22	GPUL-3	-	Bangalore
23	GPUL-4	JK-8 × Peddasame	Bangalore
24	GPUL-5	JK-8 × Peddasame	Bangalore
25	GV-2-1	Mutant of Gujarat Vari-1	Waghai
26	IIMRLM-7012	Selection from IPMR-699	IIMR, Hyderabad
27	IIMRLM-7162	Selection from GPMR-1153	IIMR, Hyderabad
28	KADIRI-1	Selection from Kadiri local	Bangalore
29	KOPLM-53	IPS from local germplasm	Kolhapur
30	Nallasama	Selection from Local	ARS, Perumallapalle
31	OLM-217	Selection from Udayagiri Local	Berhampur
32	OLM-233	Selection from L55	Berhampur
33	RLM-37	Selection from Local germplasm No. 37	Rewa
34	RLM-238	-	Rewa
35	RLM-367	Selection from Local germplasm No. 367	Rewa
36	TNAU-152	Paiyur-1 × PM-29	Coimbatore
37	TNAU-159	TNAU-81 × TNAU-25	Coimbatore
38	TNAU -160	TNAU-91 × MS-4729	Coimbatore
39	TNPsu-167	CO-2 × TNAU-26	Coimbatore
40	TNPsu-170	CO-4 × IPM-113	Coimbatore
41	TNPsu-171	CO-2 × TNAU-28	Coimbatore
42	TNPsu-174	CO-2 × IPM-113	Coimbatore
43	TNPsu-183	CO-2 × MS-4729	Athiyandal
44	TNPsu-186	MS-507 × MS-1211	Athiyandal`
45	WV-125	Local collection from Waghai	Waghai
46	WV-126	Local collection from Dangas	Waghai
47	WV-167	Local selection from Subir	Waghai
48	BL-6	Paiyur-1 × OLM-29	Jagdalpur
49	JK-8	Selection from Local germplasm	Rewa
50	OLM-203	Pure line selection from Lakshmipur local	Berhampur

3. RESULTS AND DISCUSSIONS

The morphological traits were evaluated according to the DUS (Distinctiveness, Uniformity, and Stability) guidelines revealed significant variability across the studied germplasm. Based on the distinctiveness of these traits, the germplasm lines were classified into various groups. Detailed results for each trait can be found in Table 2, with graphical representation provided in Fig. 1. The characterization was conducted at different growth stages of the crop, as discussed below.

3.1 Qualitative Characters

3.1.1 Growth habit

In 50 little millet germplasm accessions, three growth habits were identified: erect, decumbent, and prostrate. Among these, 25 accessions (50%) exhibited an erect growth habit, 20 accessions (40%) were decumbent, and only 5 accessions (10%) showed a prostrate growth habit. Similar findings regarding the predominance of the erect growth habit have been previously documented by Reddy et al. (2009) and Harshiya Banu et al. (2018) in foxtail millet.

3.1.2 Leaf traits

Among 50 little millet genotypes studied, only two entries, namely DhLtMV-36-3 and WV-126, exhibited plant pigmentation at the leaf sheath. In contrast, the remaining 48 genotypes (96%) showed no plant pigmentation at the leaf sheath. Regarding leaf sheath pubescence, the majority of accessions (49 out of 50, 98%) did not exhibit pubescence, indicating a lack of hairiness. One genotype, DhLtMV-36-3, showed pubescence, which is known to confer resistance to insect pests Jagadeesh Babu et al. (2008). These findings are in consistent with those reported by Harshiya Banu et al. (2018) in foxtail millet germplasm.

In terms of leaf blade and ligule pubescence, all 50 genotypes (100%) showed absence of pubescence. Similar results were previously documented in foxtail millet by Reddy et al. (2006) and in finger millet by Chandrasekhar Hardari (2009).

3.1.3 Floral traits

Regarding inflorescence shape, 31 accessions (62%) of little millet exhibited a diffused type, while 19 accessions (38%) showed an arched type, consistent with findings in foxtail millet as reported by Vetriventhan (2011). Inflorescence compactness, an important trait influencing grain yield by Reddy et al. (2009), was categorized into three types: open (25 accessions, 50%), compact (20 accessions, 40%), and intermediate (5 accessions, 10%) at the dough stage. This distribution aligns with earlier findings by Amarnath et al. (2019).

Genotypes were assessed for degree of lodging, resulting in three categories: absent in 39 genotypes (78%), semi lodging in nine genotypes, and lodging observed in four genotypes (DhLtMV-28-4, RLM-238, TNAU-152, and DLM-14) at flowering. These observations corroborate with those reported by Reddy et al. (2009).

3.1.4 Quantitative characters

50 little millet germplasm accessions evaluated in the study, all genotypes (100%) exhibited short peduncle length (<20 cm), aligning with findings from Reddy *et al*. (2006), Amgai et al. (2011), and Amarnath et al. (2019). Culm branching was observed in 38 genotypes (76%), consistent with Ashok et al. (2016). All genotypes (100%) displayed narrow flag leaf width (cm), was similar to results reported in pearl millet by Ahmed et al. (2017) and Nehra et al. (2016).

Days to 50% flowering ranged from 46 days (OLM-233, OLM-203, TNAU-159, TNAU-152, and TNAU-160) to 83 days (GPUL-4), with a mean of 53 days. Plant height varied, with 26 accessions tall (>120 cm) and 24 medium (80-120 cm), similar to findings by Nehra *et al.* (2016). Basal tiller number ranged from 5 (IIMRLM-7012) to 9 (RLM-238 and TNpsu-170), with an average of 7.00. Panicle length spanned from 21.5 cm (IIMRLM-7162) to 32.8 cm (DhLtMV-14-1), with a mean of 26.9 cm. Test weight (g) ranged between 1.50 (DhLtMV-36-3) and 2.91 (Nallasama), with a mean of 2.24. Grain yield per plot (g) ranged from 70 (GPUL-2) to 280 (BL-6), averaging 0.18, consistent with findings in foxtail millet by Nirmala Kumari et al. (2010) and in pearl millet by Nehra et al. (2016); Dalsaniya et al. (2024); Vetriventhan et al. (2020).

Table 2. Genotyping of 50 little millet genotypes based on DUS characters

S. No.	Name of the descriptor	Stage of observation	Descriptor state	No. of accessions	Frequency (%)
1	Growth habit	Two to Four leaf stage	Erect Decumbent Prostrate	25 20 5	50 40 10
2	Plant pigmentation at leaf sheath	Flowering	Present Absent	2 48	4 96
3	Leaf sheath pubescence	Flowering	Present Absent	1 49	2 98
4	Leaf blade pubescence	Flowering	Present Absent	0 50	0 100
5	Ligule pubescence	Flowering	Present Absent	0 50	0 100
6	Inflorescence shape	Flowering	Diffused Arched	31 19	62 38
7	Lodging	Maturity	Absent Semi lodge Lodging	39 9 4	78 18 8
8	Culm branching	Dough	Present Absent	38 12	76 24
9	Panicle compactness	Dough	Open Compact Intermediate	25 20 5	50 40 10
10	Peduncle length (cm)	Flowering	Short (<20) Medium(20.0-30.0) Long (30.0-40) Very long (>40)	50 0 0 0	100 0 0 0
11	Flag leaf width (cm)	Flowering	Narrow (<1.5) Medium (1.5-3.0) Long (>3.0)	50 0 0	100 0 0
12	Panicle length (cm)	Maturity	Short (<10) Medium(10.0-15.0) Long (>15)	0 0 50	0 0 100
13	Plant height (cm)	Maturity	Short (<80) Medium (80-120) Compact (> 120)	0 25 25	0 50 50

Table 3. Quantitative variations for seven descriptors of little millet genotypes

S. No.	Genotypes	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Basal tillers	Test weight (g)	Grain yield plot^{-1} (g)
1	BL-2	58	88	123.7	32.5	6	2.37	140
2	BL-4	58	88	104.0	23.3	6	2.09	130
3	BL-8	52	83	114.0	29.8	7	2.84	220
4	BL-41-3	49	79	124.0	32.2	7	2.58	220
5	BL-150	59	90	120.7	25.4	7	2.09	200
6	CO-2	55	85	134.7	26.9	7	2.46	230
7	DhLtMV-10-2	61	91	141.0	25.0	8	2.52	170
8	DhLtMV-14-1	54	82	135.0	32.8	7	2.39	210

S. No.	Genotypes	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Basal tillers	Test weight (g)	Grain yield plot^{-1} (g)
9	DhLtMV-21-1	60	93	122.7	29.4	8	2.21	230
10	DhLtMV-28-4	65	95	128.0	24.7	6	1.82	90
11	DhLtMV-36-3	54	86	117.3	26.0	8	1.50	180
12	DhLtMV-39-1	59	89	114.3	27.5	8	2.53	180
13	DLM-8	49	79	108.0	27.3	6	2.34	180
14	DLM-14	50	80	116.7	27.9	8	2.27	220
15	DLM-89	55	85	111.3	23.9	7	2.15	200
16	DLM-95	54	84	117.3	25.4	7	1.88	180
17	DLM-103	66	96	114.3	23.0	7	1.71	150
18	DLM-186	50	80	126.3	30.5	7	2.50	200
19	DhLt-28-4	52	82	111.7	25.7	7	2.81	170
20	GPUL-1	54	87	124.0	25.0	6	2.41	210
21	GPUL-2	77	107	99.0	23.3	7	2.27	70
22	GPUL-3	74	104	90.0	24.2	6	1.73	160
23	GPUL-4	84	110	115.7	27.9	6	2.42	120
24	GPUL-5	49	79	125.0	26.0	6	2.26	190
25	GV-2-1	48	78	122.3	24.2	6	1.91	160
26	IIMRLM-7012	78	108	111.7	21.7	5	1.81	70
27	IIMRLM-7162	61	95	114.3	21.5	7	1.94	130
28	KADIRI-1	60	90	122.3	26.7	7	2.47	230
29	KOPLM-53	47	77	125.7	26.8	7	2.37	140
30	Nallasama	64	93	127.3	29.9	6	2.91	170
31	OLM-217	72	102	116.0	27.0	6	2.28	120
32	OLM-233	46	77	110.0	28.0	8	2.18	160
33	RLM-37	75	105	98.3	22.2	7	1.88	80
34	RLM-238	79	109	111.0	24.9	9	1.78	150
35	RLM-367	48	77	115.7	24.8	7	2.31	170
36	TNAU-152	46	76	112.7	23.7	7	2.17	150
37	TNAU-159	46	76	112.7	28.0	7	2.26	160
38	TNAU -160	46	76	106.3	25.2	7	2.09	110
39	TNPsu-167	54	84	128.7	28.8	7	2.34	160
40	TNPsu-170	54	84	138.3	32.2	9	2.14	180
41	TNPsu-171	51	81	121.0	26.3	8	2.59	210
42	TNPsu-174	69	99	125.7	23.9	7	2.15	220
43	TNPsu-183	52	82	127.3	32.0	7	2.35	190
44	TNPsu-186	51	81	127.0	31.8	6	2.42	200
45	WV-125	52	81	129.0	30.8	8	2.70	240
46	WV-126	63	93	123.3	32.5	7	2.56	270
47	WV-167	52	82	127.0	25.5	6	2.50	190
48	BL-6	80	110	125.7	27.2	7	1.71	280
49	JK-8	72	102	121.3	27.2	7	1.83	120
50	OLM-203	46	76	115.0	24.5	7	2.08	250
	Mean	58	88	119.1	26.9	7	2.24	175
Range	Minimum	46	76	90.0	21.5	5	1.50	70
	Maximum	84	110	141.0	32.8	9	2.91	280
	CV%	5.92	4.04	4.77	6.49	9.32	6.46	12.73

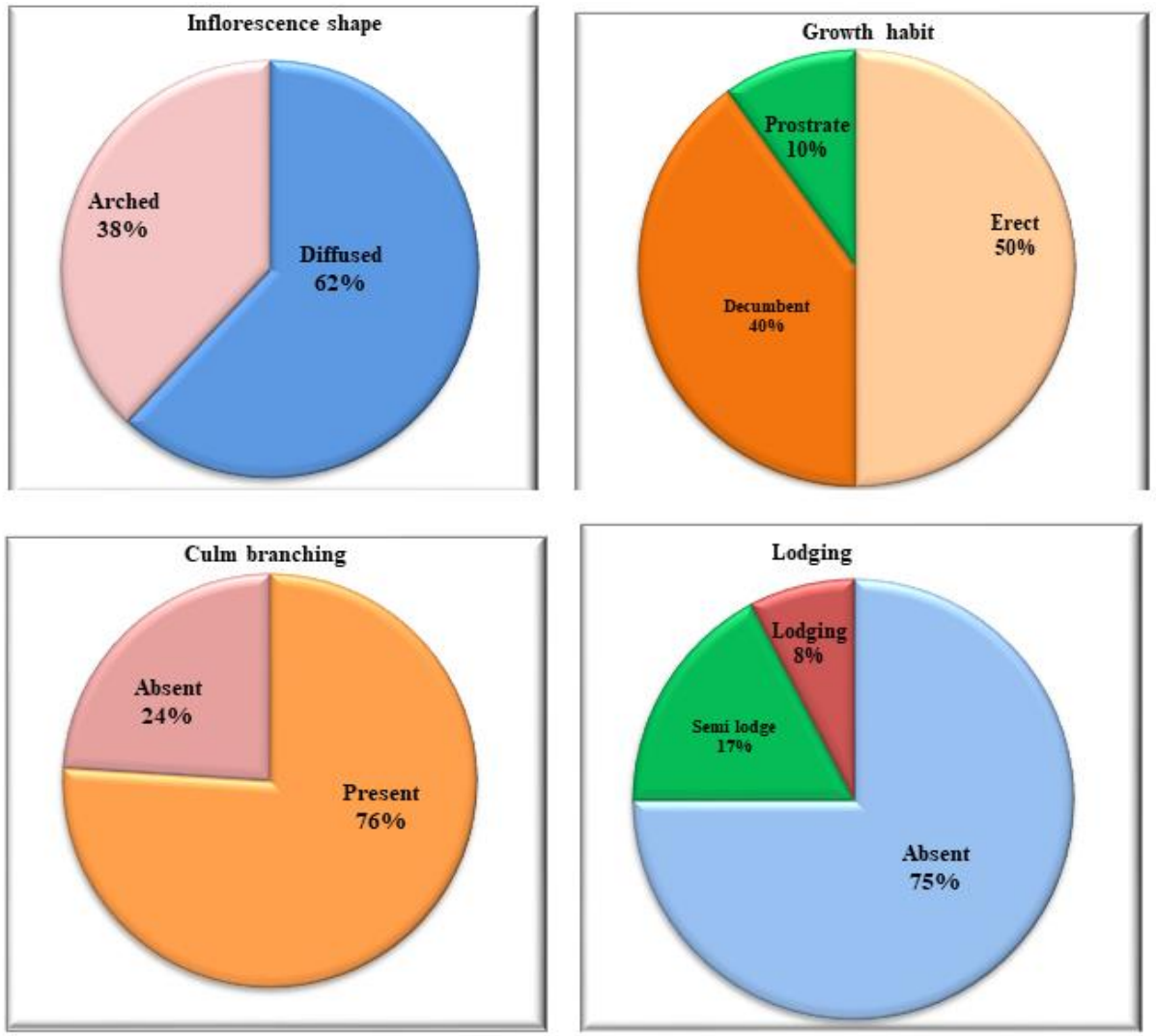

Fig. 1. Pie diagram depicting variability for qualitative traits

Plate 1. Phenotypic variation observed in inflorescence shape and colour in different Little millet genotypes

4. CONCLUSIONS

Characterizing qualitative and quantitative traits in 50 little millet germplasm accessions demonstrated notable polymorphism. These findings indicate that morphological DUS descriptors are valuable for identifying, documenting, and categorizing varieties. Plant breeders can effectively use these descriptors to visually assess and select desirable genotypes. Accessions showing significant differences in specific traits can serve as valuable resources for developing mapping populations to map QTLs. Morphological descriptors thus hold great potential to support efforts in crop improvement.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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