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Studies on Morphological Qualitative (DUS) characters in Barnyard millet genotypes during *kharif*-2023 and *summer*-2024 season

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Abstract
Barnyard millet (*Echinochloa frumentacea*) is one of the quickest growing minor cereal crops grown by tribal and poor farmers in marginal soils under rainfed conditions. In the present study, eighteen barnyard millet genotypes including two check varieties (Phule Barti-1 and DHBM-93-3) were evaluated during *Kharif* 2023 and *summer* 2024 with Randomized Block Design having three replications with spacing 30 cm x 10 cm, for seven key morphological Qualitative (DUS) characters such as Plant: Growth habit, Inflorescence: Colour, Plant: Pigmentation at leaf sheath, Inflorescence: Shape, Lodging, Grain colour and Panicle: Compactness. The genotypes of barnyard millet examined during *Kharif* and *Summer* season show considerable diversity in morphological qualitative traits. Traits such as pyramidical inflorescence shape, green inflorescence colour, erect growth habit, light gray grain colour and intermediate panicle compactness were dominant in the population, which are desirable features for grain productivity and harvestability. The absence of lodging in the majority of genotypes and plant pigmentation at leaf sheath were present codomintaly during the *kharif* and *summer* season.

Keywords: Barnyard millet, Morphological diversity, DUS characterization, Qualitative traits, Genotypic evaluation

Introduction
A variety of annual cereal crops with tiny seeds are together referred to as “millets”. According to Dwivedi *et al.* (2012) [3], they consist of a variety of grasses that are used as food, fodder, and biofuel, including foxtail millet (*Setaria italica*), finger millet (*Elucine coracana*), pearl millet (*Pennisetum glaucum*), proso millet (*Panicum miliaceum*), kodo millet (*Paspalum scorbiculatum*) and barnyard millet (*Echinocloa sp*.). Millets are the group of small seeded cereal crops majorly cultivated for its highly nutritious grains as well as fodder. They are among the earliest crops still being grown today and play a significant role in dry land agriculture. (Chandrasekara and Shahidi, 2012) [1]. Millets have been cultivated for more than 5000 years and are being cultivated in many parts of the world (Gowda *et al.*, 2006) [6]. Millets have been a staple meal in many developing nations, like in Africa where millions of people are dependent on millets as their main source of protein and energy (Rawat *et al.*, 2020) [11]. A collection of extremely diverse grass species from several families, millets were first domesticated in tropical and subtropical regions of Asia and Africa (Hilu *et al.*, 1979) [5]. Depending on the type, millets are spherical cereal seeds that occur naturally in a wide range of colours and sizes (Sharma and Niranjan 2018) [17]. Barnyard millet (*Echinochloa frumentacea*) (2n=36, 54) is an important minor cereal crop widely cultivated in various regions of Asia, particularly in India, China, Nepal and Japan. Indian barnyard millet is also known as billion-dollar grass. The two main species of barnyard millet are *Echinochloa esculenta* and *Echinochloa frumentacea* (Kaur and Sharma, 2020) [7]. Self-pollinating, barnyard millet belongs to the Poaceae family, the Panicoideae subfamily (Renganathan *et al.*, 2020) [15]. It holds significant nutritional and ecological value due to its resilience to adverse growing conditions and its ability to thrive in diverse agro-climatic zones.

As a drought-tolerant and low-input crop, barnyard millet plays a crucial role in food security, especially in regions prone to erratic rainfall patterns and marginal agricultural lands. With an average productivity of 1034 kg/ha over the previous three years, India is the world's largest producer of barnyard millet, both in terms of area (0.146 m ha^{-1}) and output (0.147 mt) (IIMR, 2018). Barnyard millet stem as well as leaves being green in colour. Its leaves are flat, ligule-free, and glabrous or slightly hairy. The inflorescence is usually narrow thickened with densely crowded unawned spikelets in 3-5 rows. The second lemma bears hermaphrodite flowers with three stamens. The grain is caryopsis and white or yellow in colour (Prasad, 2005) [10]. The crop plant is a robust, tall annual that may grow up to 220 cm in height. It has the fastest growth rate of any small millet, according to Denton (1987) and Padulosi *et al*, (2009) [2, 8].

Material and methods

The experiment was carried out during kharif, 2023 and summer, 2024 in Randomized Block Design with three replications having spacing 30 cm x 10 cm. The gross and net plot size were 3.00 m x 3.00 m and 2.40 m x 3.00 m respectively. The pure seed of Eighteen Barnyard millet genotypes with two checks were obtained from the All-India Co-ordinated Research Project on small millets, ZARS, Kolhapur. The sowing was done on 14th July 2023 (*kharif* season) and 18th January 2024 (*summer* season).

Table 1: Morphological Qualitative (DUS) characters studied in barnyard millet genotype

Sr. No.	Character	State of expression	Score/ Notes	Stage of observation	Type of assessment
1	Plant: Growth habit	Erect	1	15	VG
		Decumbent	5		
		Prostrate	7		
2	Inflorescence: Colour	Green	1	59	VG
		Light purple	5		
		Dark purple	7		
3	Plant: Pigmentation at leaf sheath	Absent	1	59	VG
		Present	9		
4	Inflorescence: Shape	Cylindrical	3	59	VG
		Pyramidical	5		
		Globose - Elliptic	7		
5	Lodging	Absent	1	83	VS
		Present	9		
6	Grain colour	Straw white	2	83	VG
		Light grey	4		
		Grey	5		
7	Panicle: Compactness	Open	3	67	VG
		Intermediate	5		
		Compact	7		

Table 2: Decimal code for the growth stage

Stage code	General Description
15	Two- Four Leaf stage
59	Complete flowering
67	Dough stage
83	Maturity

Table 3: Qualitative characterization of Barnyard millet genotypes as per DUS guidelines during *Kharif* 2023

Sr. no.	Genotypes	Plant growth habit	Plant pigmentation at leaf sheath	Inflorescence: Shape	Inflorescence: Colour	Panicle: Compactness	Lodging	Grain colour
1	KIBMG-22-01	Decumbent (5)	Absent (1)	Pyramidical (5)	Green (1)	Compact (7)	Absent (1)	Light Grey (4)
2	KIBMG-22-02	Erect (1)	Absent (1)	Pyramidical (5)	Green (1)	Compact (7)	Absent (1)	Straw White (2)
3	KIBMG-22-03	Decumbent (5)	Absent (1)	Pyramidical (5)	Green (1)	Compact (7)	Present (9)	Straw White (2)
4	KIBMG-22-04	Erect (1)	Absent (1)	Cylindrical (3)	Green (1)	Open (3)	Absent (1)	Light Grey (4)
5	KIBMG-22-05	Decumbent (5)	Present (9)	Cylindrical (3)	Light purple (5)	Open (3)	Absent (1)	Straw White (2)
6	KIBMG-22-06	Decumbent (5)	Present (9)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
7	KIBMG-22-07	Erect (1)	Present (9)	Pyramidical (5)	Dark purple (7)	Compact (7)	Absent (1)	Straw White (2)
8	KIBMG-22-08	Decumbent (5)	Present (9)	Pyramidical (5)	Green (1)	Compact (7)	Absent (1)	Light Grey (4)
9	KIBMG-22-09	Erect (1)	Absent (1)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
10	KIBMG-22-10	Prostrate (7)	Present (9)	Pyramidical (5)	Green (1)	Intermediate (5)	Present (9)	Straw White (2)
11	KIBMG-22-11	Erect (1)	Present (9)	Pyramidical (5)	Dark purple (7)	Compact (7)	Present (9)	Straw White (2)
12	KIBMG-22-12	Prostrate (7)	Absent (1)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Present (9)	Straw White (2)
13	KIBMG-22-13	Decumbent (5)	Absent (1)	Globose-Elliptic (7)	Green (1)	Open (3)	Absent (1)	Light Grey (4)
14	KIBMG-22-14	Erect (1)	Absent (1)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Absent (1)	Grey (5)
15	KIBMG-22-15	Prostrate (7)	Present (9)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Present (9)	Light Grey (4)
16	KIBMG-22-16	Erect (1)	Absent (1)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
17	Phule Barti-1 (C)	Decumbent (5)	Present (9)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
18	DHBM-93-3 (C)	Erect (1)	Present (9)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Grey (5)

Table 4: Qualitative characterization of Barnyard millet genotypes as per DUS guidelines during *Summer* 2024

Sr. no.	Genotypes	Plant growth habit	Plant pigmentation at leaf sheath	Inflorescence: Shape	Inflorescence: Colour	Panicle: Compactness	Lodging	Grain colour
1	KIBMG-22-01	Decumbent (5)	Absent (1)	Pyramidical (5)	Green (1)	Compact (7)	Present (9)	Light Grey (4)
2	KIBMG-22-02	Erect (1)	Absent (1)	Pyramidical (5)	Green (1)	Compact (7)	Absent (1)	Straw White (2)
3	KIBMG-22-03	Decumbent (5)	Absent (1)	Pyramidical (5)	Green (1)	Compact (7)	Absent (1)	Straw White (2)
4	KIBMG-22-04	Erect (1)	Absent (1)	Cylindrical (3)	Green (1)	Open (3)	Absent (1)	Light Grey (4)
5	KIBMG-22-05	Decumbent (5)	Present (9)	Cylindrical (3)	Light purple (5)	Open (3)	Absent (1)	Straw White (2)
6	KIBMG-22-06	Decumbent (5)	Present (9)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
7	KIBMG-22-07	Erect (1)	Present (9)	Pyramidical (5)	Dark purple (7)	Compact (7)	Absent (1)	Straw White (2)
8	KIBMG-22-08	Decumbent (5)	Present (9)	Pyramidical (5)	Green (1)	Compact (7)	Present (9)	Light Grey (4)
9	KIBMG-22-09	Erect (1)	Absent (1)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
10	KIBMG-22-10	Prostrate (7)	Present (9)	Pyramidical (5)	Green (1)	Intermediate (5)	Present (9)	Straw White (2)
11	KIBMG-22-11	Erect (1)	Present (9)	Pyramidical (5)	Dark purple (7)	Compact (7)	Present (9)	Straw White (2)
12	KIBMG-22-12	Prostrate (7)	Absent (1)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Absent (1)	Straw White (2)
13	KIBMG-22-13	Decumbent (5)	Absent (1)	Globose-Elliptic (7)	Green (1)	Open (3)	Absent (1)	Light Grey (4)
14	KIBMG-22-14	Erect (1)	Absent (1)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Absent (1)	Grey (5)
15	KIBMG-22-15	Prostrate (7)	Present (9)	Globose-Elliptic (7)	Green (1)	Intermediate (5)	Present (9)	Light Grey (4)
16	KIBMG-22-16	Erect (1)	Absent (1)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
17	Phule Barti-1(C)	Decumbent (5)	Present (9)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Light Grey (4)
18	DHBM-93-3(C)	Erect (1)	Present (9)	Pyramidical (5)	Green (1)	Intermediate (5)	Absent (1)	Grey (5)

Type of assessment

MG: Single measurement of a group of plants or parts of plants.

MS: Measurement of a number of individual plants or parts of plants.

VG: Visual assessment by a single observation of a group of plants or plant parts.

VS: Visual assessment by observation of individual plant or parts of plants.

Results and Discussion

A total of eighteen genotypes, including two check varieties, were evaluated for seven key morphological descriptors: plant growth habit, leaf sheath pigmentation, inflorescence shape and colour, panicle compactness, lodging resistance and grain colour. The variation among genotypes across these traits is summarized as follows and details are presented during *Kharif* season in Table 3 and during *summer* season in Table 4.

Plant growth habit

During season *Kharif* 2023, Three distinct plant architectures were recorded that is Erect growth habit was observed in 8 genotypes (e.g., KIBMG-22-02, KIBMG-22-04, KIBMG-22-07, KIBMG-22-09, KIBMG-22-11, KIBMG-22-14, DHBM-93-3) indicating a strong upright growth pattern favourable for mechanical harvesting and high-density planting. Decumbent habit characterized by partially spreading stems was recorded in 7 genotypes (e.g., KIBMG-22-01, KIBMG-22-03, KIBMG-22-05, KIBMG-22-06, KIBMG-22-08, KIBMG-22-13) including the check variety Phule Barti-1. Prostrate growth indicative of completely spreading growth was present in 3 genotypes (KIBMG-22-10, KIBMG-22-12, KIBMG-22-15) suggesting adaptation to ground-cover traits. While during season *summer* 2024 The genotypes showed variability in growth habit, Erect growth habit was observed in 8 genotypes (38.9%) including KIBMG-22-02, KIBMG-22-04, KIBMG-22-07, KIBMG-22-09, KIBMG-22-11, KIBMG-22-14 and DHBM-93-3. Decumbent habit was exhibited by 7 genotypes (33.3%) such as KIBMG-22-01, KIBMG-22-03, KIBMG-22-05, KIBMG-22-06, KIBMG-22-08, KIBMG-22-13 and Phule Barti-1. Prostrate growth habit was present in 3 genotypes (16.7%) including KIBMG-22-10, KIBMG-22-12 and KIBMG-22-15.

Pigmentation at Leaf Sheath

During *Kharif* and *Summer* season same trend was observed. Presence of pigmentation on the leaf sheath was observed in 9 genotypes, including the check varieties. Absence of pigmentation was noted in 9 genotypes. Plant pigmentation at leaf sheath was present in 9 genotypes (50%) including KIBMG-22-05, KIBMG-22-06, KIBMG-22-07, KIBMG-22-08, KIBMG-22-10, KIBMG-22-11, KIBMG-22-15, Phule Barti-1 and DHBM-93-3. The remaining 9 genotypes (50%) showed absence of Plant pigmentation at leaf sheath.

Inflorescence Shape

During *Kharif* 2023, Pyramidal-shaped panicles were predominant recorded in 11 genotypes indicating a common morphological type among the studied genotypes. Globose to elliptic panicle shape which are round to oval-shaped, were seen in 5 genotypes (e.g., KIBMG-22-06, KIBMG-22-12, KIBMG-22-13, KIBMG-22-14, KIBMG-22-15) representing moderate diversity. Cylindrical-shaped panicles were reported in 2 genotypes (KIBMG-22-04, KIBMG-22-05) a rarer inflorescence structure in the set. While during *Summer* 2024, Three types of inflorescence shapes were recorded: Pyramidical inflorescence was predominant and present in 11 genotypes (55.6%) including KIBMG-22-01, KIBMG-22-02, KIBMG-22-03, KIBMG-22-07, KIBMG-22-08, KIBMG-22-09, KIBMG-22-10, KIBMG-22-11, KIBMG-22-16 and DHBM-93-3. Globose-elliptic shape was noted in 5 genotypes (33.3%) such as KIBMG-22-06, KIBMG-22-12, KIBMG-22-13, KIBMG-22-14, KIBMG-22-15 and Phule Barti-1. Cylindrical shape was the least represented and found in only 2 genotypes (11.1%): KIBMG-22-04 and KIBMG-22-05.

Inflorescence Colour

Green inflorescence colour was the most common, observed in 15 genotypes suggesting the absence of pigmentation during flowering. Light purple panicles were observed in KIBMG-22-05, while dark purple colouration was found in KIBMG-22-07 and KIBMG-22-11 during *kharif* 2023.

Inflorescence colour showed diversity: Green was the most common colour, observed in 15 genotypes (77.8%). Dark purple inflorescences were found in 2 genotypes (KIBMG-22-07 and KIBMG-22-11). Light purple inflorescence was recorded in only 1 genotype (KIBMG-22-05) during *Summer* 2024.

Panicle Compactness

During *Kharif* 2023, Compact panicles were observed in 6 genotypes including elite lines like KIBMG-22-01, KIBMG-22-02, KIBMG-22-03, KIBMG-22-07, KIBMG-22-08, KIBMG-22-11. Intermediate panicle density was found in 9 genotypes including both checks indicating moderately spaced spikelet Open panicle structure with loosely arranged spikelet was seen in 3 genotypes (KIBMG-22-04, KIBMG-22-05, KIBMG-22-13). While during *Summer* 2024, Panicle compactness was classified in three classes and described such as: Compact in 6 genotypes (33.3%)-KIBMG-22-01, KIBMG-22-02, KIBMG-22-03, KIBMG-22-07, KIBMG-22-08 and KIBMG-22-11. Intermediate in 9 genotypes (44.4%) including KIBMG-22-06, KIBMG-22-09, KIBMG-22-10, KIBMG-22-12, KIBMG-22-14, KIBMG-22-15, KIBMG-22-16 and DHBM-93-3. Open panicles were seen in 3 genotypes: KIBMG-22-04, KIBMG-22-05 and KIBMG-22-13.

Lodging

During *Kharif* and *Summer* season same trend was observed. Lodging was absent in 13 genotypes suggesting strong stem strength or favorable plant architecture. Lodging susceptibility was noted in 5 genotypes (KIBMG-22-03, KIBMG-22-10, KIBMG-22-11, KIBMG-22-12, KIBMG-22-15) which could affect yield and harvesting efficiency under adverse weather conditions. Lodging was absent in the majority of the genotypes (13 genotypes, 72.2%) including KIBMG-22-02, KIBMG-22-03, KIBMG-22-04 and others. Lodging was present in 5 genotypes (27.8%)-KIBMG-22-01, KIBMG-22-08, KIBMG-22-10, KIBMG-22-11 and KIBMG-22-15. This indicates that most genotypes are structurally strong and sui Table for mechanical harvesting.

Grain Colour

Light grey grain was recorded in 9 genotypes Straw white grain a common trait for consumer-preferred types, was observed in 7 genotypes. Grey grain colour was found in 2 genotypes (KIBMG-22-14 and DHBM-93-3). Grain colour variation was evident: Straw white grains were most prevalent (50%) -observed in 9 genotypes such as KIBMG-22-02, KIBMG-22-03 and KIBMG-22-11. Light grey grains were seen in 7 genotypes (e.g., KIBMG-22-01, KIBMG-22-06, KIBMG-22-13). Grey grains were found in only 2 genotypes (KIBMG-22-14 and DHBM-93-3) in case of grain colour during *Kharif* and *Summer* season similar trend was observed. Similar results for all seven qualitative characters reported in agreement with Reddy *et al.* (2006), Reddy *et al.* (2007), Reddy *et al.* (2009) and Prakash R. (2015) [12, 13, 14, 9].

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