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Variability Study and DUS Characterization in Kodo Millet (*Paspalum scrobiculatum* L.)

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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

Aims: To study variability and DUS characterization for yield and its attributing traits
Study Design: Randomized Block Design
Place and Duration of Study: 49 genotypes of kodo millet, were evaluated at the Experimental Farm of the Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, during *kharif*, 2021.
Methodology: The experimental material consisted of 49 different kodo millet genotypes procured from Hill Millet Research Station, Muvaliya Farm, Anand Agricultural University, Dahod, Gujarat.

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Results: Qualitative traits offered considerable variability and differentiated the genotypes distinctly, but genotypes did not vary much for characters such *as* internode pigmentation, spike curvature and spike branching. No co-linearity was found between pigmentation at the leaf sheath, leaf juncture, internode or leaf blade, indicating the involvement of different loci for pigmentation at these different plant parts. The genotypic and phenotypic variance were high (>>40) for plant height, followed by fodder yield per plant, total carbohydrate and days to maturity. High GCV and PCV were recorded for total phenol, peduncle length and grain yield per plant, whereas low GCV and PCV were recorded for all other traits including days to 50% flowering. High heritability along with high genetic advance as percent of mean was observed for grain yield per plant, flag leaf blade length, raceme length, peduncle length, total carbohydrate and total phenol. This indicated the involvement of additive genetic control in the expression of those trait; hence, the traits can be continued for selection in segregating generations.

Conclusion: Qualitative characters differentiated the genotypes distinctly except pigmentation at leaf sheath, spike curvature and spike branching because genotypes did not vary much for this characters and estimates of GCV were lower than PCV for all the characters which indicated interaction of genotypes with environments.

Keywords: Kodo millet; DUS; heritability; genetic advance as % of mean; genotypes; Paspalum scrobiculatum L.; ditch millet.

1. INTRODUCTION

Kodo millet *(Paspalum scrobiculatum* L.) is small grained tetraploid (2n=4x=40) species, also known as varagu, kodo, haraka, arakalu, cow grass, rice grass, ditch millet, native paspalum, or Indian crown grass and belonging to the family poaceae (gramineae). The crop originates in tropical Africa, and domesticated in India 3000 years ago [1].

In kodo millet the percentage of open flowers does not exceed (15-20) % and show cleistogamy condition and thereby self-pollination is the rule in kodo millet [2,3].

This crop is ideal for rainfed agriculture due to its ease of cultivation, low risk of pests and diseases, broad adaptability, and resistance to drought. It is an extremely resilient crop that can thrive on marginal soils also [4].

In India Small millets production is highest in Rajasthan followed by Karnataka, Madhya Pradesh, and Uttar Pradesh. In India kodo millet has highest productivity among the small millets. It occupies an area of 9.08 lakh ha with an annual production of 3.11 lakh tones and average productivity of 342kg/ha [5]. It is mainly grown in the states of Madhya Pradesh, Chhattisgarh, Gujarat, Karnataka and parts of Tamil Nadu as a major food source. Madhya Pradesh ranks first in area of kodo millet cultivation with 71.7% share in the country [6]. In Gujarat small millets are mainly grown in hilly and tribal regions.

In post-green revolution era area under millets cultivation have been decline due to dominance of rice and wheat. But nowadays millets cultivation is increasing as millets provide regional food security in the dry and marginal lands, as well as nutritional superiority as compared to the major cereals [7]. United Nation (UN) designated 2023 as “International Year of Millets” and intention behind this is to create awareness among peoples and increasing production and productivity of small millets.

The genetic and heritable components are expressed by the relative magnitude of the genotypic coefficient of variation (GCV), whereas the environmental and genetic influences on a character are expressed by the phenotypic coefficient of variation (PCV). Heritability estimates by themselves are not very useful for selection based on phenotypic performance. Genotypic coefficient of variation (GCV) along with heritability estimates provides a better understanding of the genetic gain to be expected by phenotypic selection. Moreover, heritability along with genetic advance as percent of mean are more useful in predicting gain under selection. Genetic advance refers to enhancement in mean genotypic value of selected individuals over parental population and understanding the type of gene action involved in polygenic traits expression [8].

Assessment of genetic variability are necessary for any crop improvement programme and because hybridization is restricted as in self-pollinated crop so highly variable germplasm offer much scope for improvement.

Testing of experimental material for distinctness, uniformity and stability (DUS) is useful for identification and classification of varieties as well as for registration. Descriptors for different species have been specified by Protection of Plant Varieties and Farmers' Rights Authority in India.

2. MATERIALS AND METHODS

A total of 49 different genotypes of kodo millet were collected from Hill millet research station, Anand Agricultural University, Dahod (Table 1).

The material was planted in randomized complete block design with three replications at the Experimental Farm of Department of Genetics & Plant Breeding,

B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during *kharif*, 2021 with a spacing of 30 × 10 cm. All the recommended package of practices was followed to raise a good crop.

A total of 16 different quantitative parameters, namely, number of basal tillers per plant, days to 50% flowering, flag leaf blade length (cm), flag leaf blade width (cm), peduncle length (cm), number of productive tillers per plant, panicle length (cm), plant height (cm), days to maturity, 1000 seed weight (g), grain yield per plant (g), fodder yield per plant (g), harvest index (%) including three biochemical parameters, *viz.*, crude protein content (%), total carbohydrate content (%), total phenol content (%).

Analysis of variance (ANOVA) was carried out following Panse and Sukhatme [9], Genotypic (σ^2g), phenotypic (σ^2p) and environmental variance (σ^2e) were calculated as per the formulae suggested by Johnson et al. [10]. GCV and PCV were computed according to the method suggested by Burton [11]. Heritability in broad sense (H^2b) and genetic advance (as % of mean) was calculated according to Allard et al. [12] and Johnson et al. [10], respectively. Traits were classified as having high, moderate or low genetic advance as per the method suggested by Johnson et al. [10].

3. RESULTS AND DISCUSSION

Estimates of variance components are presented in Table 2. Genotypic variances (σ^2g) and estimates of GCV were found lower than phenotypic variances (σ^2p) and PCV respectively, for all the traits indicating an influence of environment in the expression of the traits (Table 2).

High GCV and PCV (>>20.0) were recorded for total phenol, peduncle length and grain yield per plant. Similar results were observed by Thakur [13] and Sreeja et al. [14] in kodo millet.

Moderate GCV and PCV (10.1 - 20.0) were recorded for fodder yield per plant, culm branching, flag leaf blade length, harvest index, total carbohydrate content, raceme length, panicle length, plant height and crude protein content.

Table 1. List of genotypes used in the present study

Sr. No	Genotypes	Sr. No	Genotypes	Sr. No	Genotypes
1	ERP-78	18	RPS-811	35	RPS-697
2	RPS-712	19	RPS-824	36	RPS-925
3	RPS-754	20	RPS-648	37	ELB-80
4	RPS-589	21	RPS-882	38	GK-4
5	RPS-745	22	RPS-974	39	RPS-861
6	ERP-49	23	RPS-727	40	RPS-510
7	RPS-560	24	ERP-77	41	GAK-3
8	RPS-903	25	RPS-689	42	RPS-533
9	RPS-685	26	RPS-866	43	ERP-55
10	RPS-1004	27	ELB-56	44	ELB-103
11	RPS-981	28	RPS-310	45	ELB-76
12	ELB-77	29	RPS-771	46	ELB-109
13	RPS-623	30	RPS-802	47	RPS-784
14	RPS-661	31	RPS-794	48	RPS-599
15	RPS-584	32	ELSB-77	49	ELSG-22
16	ELB-61	33	RPS-612		
17	ELB-89	34	RPS-877		

Table 2. Estimates of genetic parameters

Sr. No.	Characters	σ^2g	σ^2p	GCV %	PCV %	Heritability (%)	GA as % mean
1	Number of basal tillers per plant	0.490	0.848	5.129	6.745	57.83	8.036
2	Days to 50% flowering	12.183	14.978	4.902	5.435	81.34	9.108
3	Flag leaf blade length (cm)	18.850	19.103	17.384	17.500	98.67	35.573
4	Flag leaf blade width (cm)	0.007	0.008	8.821	9.765	81.61	16.415
5	Peduncle length (cm)	2.889	2.929	25.834	26.013	98.63	52.852
6	Number of productive tiller per plant	0.405	0.539	8.425	9.717	75.17	15.047
7	Culm branching	0.298	0.462	16.554	20.608	64.53	27.393
8	Panicle length (cm)	0.844	0.886	13.489	13.820	95.26	27.121
9	Raceme length (cm)	1.011	1.051	15.847	16.159	96.18	32.014
10	Number of raceme per tiller	0.105	0.134	9.121	10.399	78.28	16.624
11	Plant height (cm)	75.148	76.980	12.288	12.437	97.62	25.011
12	Days to maturity	44.307	48.588	5.993	6.276	91.19	11.790
13	1000 seed weight (g)	0.264	0.269	10.945	11.056	98.00	22.320
14	Grain yield per plant (g)	18.912	19.787	24.257	24.812	95.58	48.852
15	Fodder yield per plant (g)	60.422	72.075	17.447	19.055	83.84	32.910
16	Harvest index (%)	22.176	25.720	16.391	17.652	86.22	31.353
17	Total carbohydrate (%)	62.693	64.028	16.124	16.295	97.91	32.868
18	Crude protein (%)	1.726	1.823	11.767	12.096	94.63	23.581
19	Total Phenol (%)	0.002	0.002	40.470	40.470	99.10	83.369

σ2g = Genotypic variance σ2p = Phenotypic variance GCV= Genotypic coefficients of variation PCV= Phenotypic coefficients of variation (H2b) % = Broad sense heritability % G.A as % of mean = Genetic advance as % of mean

Low GCV and PCV were recorded for other characters including days to 50% flowering, days to maturity, number of basal tillers per plant and number of productive tillers per plant indicating narrow range of existing variation for these traits. Similar findings in kodo millet were reported by Sao et al. [15].

The highest magnitude of heritability was observed for total phenol followed by flag leaf blade length, peduncle length, 1000 seed weight and total carbohydrate content indicating that these characters are least affected by environment. The result is supported by similar findings from Thakur [13] and Anuradha et al. [16].

Low heritability was observed for number of racemes per tiller (78.28%), number of productive tillers per plant, culm branching and least was observed for number of basal tillers per plant.

High heritability (H^2b) along with high genetic advance as percent of mean (GA as % of mean) was observed for grain yield per plant, flag leaf blade length, peduncle length, raceme length, total carbohydrate and total phenol, which indicated involvement of additive gene action in control of those traits, hence for selection of genotype based on the traits can be carried out. Similar results were observed by Sreeja et al. [14], Sao et al. [15], Nirubana et al. [17], Thakur [13] and Anuradha et al. [16] in kodo millet.

3.1 DUS Characterization

The performance of 49 genotypes for different 18 qualitative and 11 quantitative characters as per DUS guidelines are summarized in Table 3.

No co-linearity was found between pigmentation at leaf sheath, leaf juncture, internode or leaf blade, indicating involvement of different loci for pigmentation at these different plant parts. Much variation was observed for genotype performance for the characters viz., plant growth habit, leaf attitude, leaf juncture pigmentation, internode pigmentation, leaf blade pigmentation, panicle appearance, panicle exertion, spikelet arrangement on rachis, intensity of irregular rows in spikelet, spikelet density, appearance of glumes nerves, lodging, seed shattering, grain colour and grain shape, while, genotypes did not vary much for characters viz., internode pigmentation, spike curvature and spike branching

Table 3. DUS characterization

Sl. no.	Characteristics	States	Example Varieties	Stage of observations	Type of assessment
1 (+)	Plant: Growth habit	Erect	2, 3, 5, 6, 7, 8, 12, 14, 15, 16, 17, 18, 19, 21, 23, 26, 27, 32, 35, 36, 38,40, 41, 42, 43, 44, 45, 47	15	VG
		Decumbent	9,10, 29, 33, 37		
		Prostrate	1, 4, 11, 13, 20, 22, 24, 25, 28, 30, 31, 34, 39, 46, 48, 49		
2	Basal tillers: Number	Very low (<10)	-	26	MS
		Low (10-20)	1-49		
		Medium (20.1-30.0)	-		
		High (>30)	-		
3 (*) (+)	Leaf : Attitude	Erect	1 to 10,12, 14, 15, 16, 17, 18, 20 to 25, 27, 28, 29, 30, 32, 33, 34, 36 to 41, 43, 45, 46, 48	26	VG
		Droopy	11, 13, 19, 26, 31, 35, 42, 44, 47, 49		
4 (*) (+)	Days to 50%flowering	Early (<65)	14, 38	51	MG
		Medium (65-75)	1 to 13, 16 to 27, 29 to 34, 36, 37, 39, 41 to 46, 48		
		Late(75-85)	7, 15, 28, 35, 40, 47, 49		
		Very late (>85)	-		
5 (*)	Leaf Sheath: Pigmentation	Absent	3, 6, 7, 8, 9, 12, 16, 17, 18, 20, 22, 23, 25, 26, 27, 28, 29, 35, 38, 39, 40, 41, 42, 48, 49	54	VS
		Present	1, 2, 4, 5, 10, 11, 13, 14, 15, 19, 21, 24, 30, 31, 32, 33, 34, 36, 37, 43, 44, 45, 46, 47		
6 (*)	Leaf juncture: Pigmentation	Absent	1, 3, 6, 10, 14, 5, 16, 17, 18, 21, 22, 23, 24, 26, 27, 28, 29, 35, 37, 38, 39, 41, 43, 44, 45, 47, 48, 49	54	VS
		Present	2, 4, 5, 7, 8, 9, 11, 12, 13, 19, 20, 25, 30, 31, 32, 33, 34, 36, 40, 42, 46		
7 (*)	Internode: Pigmentation	Absent	-	54	VS
		Present	1 to 49		
8	Leaf blade: Pigmentation	Absent	3, 4, 6 to 19, 21, 22, 24 to 30, 32, 34, 35, 36, 39, 40, 42, 43 to 47, 49	54	VG
		Present	1, 2, 5, 20, 23, 31, 33, 37, 38, 41, 48		
9	Flag leaf blade: Length	Short (<20.0)	4, 6, 12, 13, 15, 19, 22, 30	54	MS

Sl. no.	Characteristics	States	Example Varieties	Stage of observations	Type of assessment
(+)	(cm)	Medium (20.0-30.0)	1, 2, 3, 5, 7 to 11, 14, 16, 18, 20, 21, 23, 24, 25, 26, 27, 28, 29, 31, 32, 34, 36, 37, 40, 41, 42, 43, 45, 46, 47, 48, 49		
		Long (>30.0)	17, 33, 35, 38, 39, 44		
10 (+)	Flag leaf blade: width(cm)	Narrow (<0.5)	-	54	MS
		Medium (0.5-1.0)	1, 3 to 9, 11, 12, 13, 14, 16-19, 22, 23, 25, 27, 30, 31, 32, 36, 37, 39, 41, 42, 43 46, 47, 48, 49		
		Wide (>1.0)	2, 10, 15, 20, 21, 24, 26, 28, 29, 33, 34, 35, 38, 40, 44, 45		
11 (+)	Peduncle: Length (cm)	Short (<5.0)	1, 2, 9, 11, 12, 14, 19, 38, 39	54	MS
		Medium (5.0-10.0)	3, 4, 5, 7, 8, 10, 13, 15, 16, 17, 18, 20 to 34, 36, 37, 40, 41, 42, 43, 44, 46, 47, 49		
		Long (> 10.0)	6, 35, 45, 48		
12 (*) (+)	Panicle: Appearance	Compact	-	54	VG
		Semi compact	1, 14, 19, 22, 28, 30, 40		
		Open	2 to13, 15, 16, 17, 18, 20, 21, 23 to 27, 29, 31 to 39, 41 to 49		
13 (+)	Panicle: Exertion	Partial	4, 5, 6, 7, 9, 10, 11, 15, 16, 19, 20, 21, 26 to 29, 31, 32, 33, 35, 36, 37, 38, 40, 41, 43, 44, 45, 46,48, 49	54	VS
		Complete	1, 2, 3, 8, 12, 13, 14, 17, 18,22, 23, 24, 25, 30, 34, 39, 42, 47		
14 (*) (+)	Spikelet: Arrangement on rachis	Regular	2, 3, 4, 5, 7 to 13, 15, 16, 17, 18, 20, 21, 23 to 27, 29, 31 to 35, 37, 38, 39, 41, 42, 43, 47,48	67	VG
		Irregular	1, 6, 14, 19, 22, 28, 30, 36, 40, 44, 45, 46, 49		
15	Spikelet irregular rows: Intensity	Two-three	14	67	VG
		Two -four	6		
		Lower half	1, 19, 22, 28, 30, 36, 40, 44, 45, 46, 49		
16 (+)	Spike: Branching	Absent	1 to 49	67	VG
		Present	-		
17 (+)	Spike: Curvature	Straight	1 to 6, 8 to 20, 22 to 28, 30 to 39, 41 to 44, 46, 47, 48, 49	67	VG
		Curved	7, 21, 29, 40, 45		

Sl. no.	Characteristics	States	Example Varieties	Stage of observations	Type of assessment
18	Spikelet: Density	Lax	2 to 12, 14, 15, 16, 19, 20, 21, 26, 27, 29 to 36, 38, 40, 41, 42, 43, 46, 47, 48,	67	VG
		Dense	1, 13, 17, 18, 22, 23, 24, 25, 28, 37, 39, 44, 45, 49		
19 (+)	Culm: Branching	Low (<3)	2, 9, 12, 18, 19, 21, 25, 26, 30, 32, 38	67	MG
		Medium (3-7)	1, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14, 15, 16, 17, 20, 22, 23, 24, 27, 28, 29, 31, 33, 34, 35, 36, 37, 39, 40, 41 to 49		
		High (>7)	-		
20 (+)	Panicle: Length (cm)	Short (<5.0)	-	77	MS
		Medium (5.1-8.0)	1, 2, 3, 4, 5, 6, 8 to 16, 17, 18-32, 34, 37 to 42, 44 to 48		
		Long (>8.0)	7, 33, 35, 36, 43, 49		
21 (+)	Raceme: Length (cm)	Short (< 5.0)	32, 44	77	MS
		Medium (5.0-10.0)	1 to 31, 33 to 43, 45 to 49		
		Long (10.1-15.0)	-		
		Very long (>15.0)	-		
22 (*)	Raceme: Number (Above thumb)	Low (<2)	-	77	MS
		Medium (2-4)	1 to 27, 29 -32, 34- 43, 45, 47, 48, 49		
		High (4-6)	28, 33, 44, 46		
		Very high (>6)	-		
23 (*) (+)	Glume: Appearance of Nerves	Narrow (7 nerves)	1, 3, 4, 5, 6, 8, 9, 11 to 19, 21, 22, 24, 25, 26, 28, 30 to 34, 36, 37, 39 to 47	77	VG
		Broad (5 nerves)	2, 7, 10, 20, 23, 27, 29, 35, 38, 48, 49		
24 (*) (+)	Plant: Height (cm)	Semi dwarf (<30.0)	-	83	MS
		Dwarf (30-50)	-		
		Medium (50.1-70.0)	1, 2, 5, 7, 8, 9, 10, 20, 21, 24, 27, 28, 30, 31, 32, 35, 36, 37, 39, 43, 44, 48		
		Tall (>70.0)	3, 4, 6, 11 to 19, 22, 23, 25, 26, 29, 33, 34, 38, 40, 41, 42, 45, 46, 47, 49		
25	Lodging	Absent	1, 2, 21, 22, 31, 35, 40, 41, 42, 45	83	VG
		Present	3 to 20, 23 to 30, 32, 33, 34, 36, 37, 38, 39, 43, 44,		

Sl. no.	Characteristics	States	Example Varieties	Stage of observations	Type of assessment
			46, 47, 48, 49		
26	Seed: Shattering	Absent	2, 3, 11, 27, 32, 39, 43, 47	83	VG
		Present	1, 4 to 10, 12 to 26, 28, 29, 30, 31, 33 to 38, 40, 41, 42, 44, 45, 46, 48, 49		
27 (*)	Grain: Colour	Light brown	2, 4, 5, 12, 23, 27, 31, 34, 46,	83	VG
		Brown	1,3, 6, 8, 10, 11, 13 to 22, 24, 26, 28, 29, 30, 32, 33, 36 to 42, 44, 45, 47, 48, 49		
		Dark brown	7, 9, 25, 35, 43		
28	Grain: Shape	Elliptical	1, 2, 6, 8, 9, 10, 12, 14, 16, 18, 21, 23, 26, 27, 33, 36, 38, 41, 45	95	VG
		Oval	3, 4, 5, 7, 11, 13, 15, 17, 19, 20, 22, 24, 25, 28, 29, 30, 31, 32, 34, 35, 37, 39, 40, 42, 43, 44, 46, 47, 48, 49		
29 (*)	1000- grain weight (g)	Low (<5.0)	1, 3 to 21, 23, 26 - 30, 32, 33, 34, 36, 37, 38, 39, 40, 45 - 49	95	MG
		Medium (5.0-6.0)	2, 22, 24, 25, 31, 35, 42, 43, 44		
		High (>6.0)	41		

Similar observation for characters, *viz*., Leaf juncture pigmentation, internode pigmentation, leaf blade pigmentation, spike curvature, panicle appearance, seed shattering, grain colour and grain shape was recorded by Nirubana et al. [18] in kodo millet.

Considering all traits it can be suggested that genotypes, *viz*., RPS-824, RPS- 882, RPS-612 and GK-4 were better performers in terms of yield, its component traits with early to medium flowering.

Table 4. Decimal code for the growth stage

Stage code	General Description
15	2-4 Leaf stage
26	Vegetative
51	50 %Flowering
59	Complete flowering
67	Dough stage
77	Seed filling
83	Maturity
95	After harvest

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

MS: Measurement of several 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.

4. CONCLUSION

Qualitative traits offered considerable variability and differentiated the genotypes distinctly except pigmentation at leaf sheath, spike curvature and spike branching. Magnitudes of phenotypic variances were higher as compared to genotypic variances for all the traits which suggested an influence of environment. Estimates of GCV were lower than PCV for all the characters under study which indicated interaction of genotypes with environments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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