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Assessment of Distinctiveness, Uniformity and Stability of Finger Millet (*Eleusine coracana*) Varieties

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Characterization of 12 finger millet varieties was carried out over two seasons using morphological descriptors given by the Bioversity International, 1985. Data was recorded on 28 morphological characters (13 visual and 15 measurable). Among thirteen visually assessed characters five were monomorphic, six were dimorphic and two were polymorphic in nature. No intra-varietal variation was observed for any of the visual characteristics and expression of characters in different varieties remained same for the two consecutive years confirming the uniformity and stability of varieties. COYD (combined over years distinctiveness) analysis with respect to 15 measurable traits indicated that all the varieties were absolutely distinct from each other. COYD analysis was supported with MJRA (Modified Joint Regression Analysis) in which the slope of the MJRA curve and regression probability was calculated, which indicated that characteristics under study were not completely independent but interacting with each other as well as with the environment. COYU (combined over years uniformity) analysis revealed that all the varieties were more or less uniform for measurable characteristics.

Key Words: Combined over years distinctiveness, Combined over years uniformity, DUS, Finger millet

Introduction

Eleusine coracana commonly known as finger millet or *ragi* is an alloteraploid cereal **(**2n= 4X=36, genome composition = AABB), that includes two distinct subspecies: subsp. *coracana* (finger millet) and subsp. *africana* (wild finger millet). It is an important staple food in semi-arid regions of East Africa and Southern India. India has enormous diversity of millets in both cultivated and wild species. Obviously there is a need of consolidated system in the country to protect such vast variability present in the species and proper sharing of benefits derived out of them. In order to achieve this goal, India ratified the agreement on Trade Related aspects of Intellectual Property Rights agreement (TRIPs) in 1994. Under the Article 27.3(b) of the TRIPs agreement, member countries are required to grant protection to plant varieties either by a patent or by an effective system of *sui generis* protection, or a combination of these two. In this context, Government of India has chosen a *sui generis* system and passed an Act in 2001, named as Protection of Plant Varieties and Farmers' Rights Act (PPV&FR). The PPV&FR Act, 2001 encourage public/ private investment in research and development of new plant varieties by giving protection to different categories of plant varieties against unauthorized multiplication of seeds or propagating materials for a specific period (Anonymous 2001). The plant varieties must fulfill the distinctiveness, uniformity and stability (DUS) criteria for protection under the Act. Hence there is a need to characterize finger millet varieties especially farmers' varieties on the basis of DUS criteria and to register them with PPV&FR Authority on behalf of the farmers otherwise valuable germplasm which is being conserved by the farmers could be lost or misused without giving any beneficial advantage to the farmer. However, DUS descriptors for finger millet were not developed at the time of conducting the experiment. Hence, this is the first report taken up with the objective to develop DUS descriptors for characterisation and identification of finger millet varieties.

Materials and Methods

The experimental material consisted of 12 genotypes of finger millet varieties comprising 10 released varieties and two farmer's varieties. The trials were conducted during *kharif* season of 2012 and 2013 in randomized block design with three replications. Each variety was accommodated in a plot of two rows of 3 m length spaced at 25 cm row to row and 15 cm plant to plant

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distance. The observations were recorded at different growth stages as per the descriptors for finger millet (The International Board for Plant Genetic Resources, 1985) from 30 plants or parts of 30 plants, which were divided among 3 replications (10 plants per replication). Finger millet varieties were distinguished by recording observations on 28 morphological characteristics which included 13 visually assessed characteristics and 15 measurable characteristics.

For determining distinctiveness in case of visually assessed characters, differences between two varieties were considered clear if the expression of one or more characteristics fell into two different states. Analysis of measurable characteristics was carried out with the help of DUSNT software (Watson *et al.*, 1998) comprising of COY-D (combined over years distinctiveness) for analysis of distinctiveness (Anonymous 2008a) and COY-U (combined over years uniformity) for analysis of uniformity (Anonymous 2008b). F_1 and F_2 ratios were calculated for COY-D analysis of 15 measurable characteristics which were variety MS by variety × year MS and variety × year MS by variety × replication MS, respectively. Modified Joint Regression Analysis (MJRA) was also used as a part of COY-D analysis. This MJRA model took account of systematic annual increases or decreases in character expression across all varieties by fitting extra terms, one for each year, in the analysis of variance. Each term represented the linear regression of the observations for the year against the variety means over all years, as described by Digby (1979).

The COY-U analysis involves ranking references and candidate varieties by the mean value of the characteristics. Standard deviation (SD) of each variety is taken and the mean SD of the most similar varieties is subtracted. A candidate variety will be considered to be sufficiently uniform, if using a COYU analysis the standard deviation for each characteristic is not greater than the mean standard deviation for the same characteristic in comparable varieties at 1% probability level. COYU test compared within-plot standard deviations between varieties, hence, if there is no variation within-plot, this test cannot be performed.

Phenotypic coefficient of variation (PCV), genotype coefficient of variation (GCV), heritability and genetic advance were calculated from the pooled data of the measurable characters over two years and compared for the analysis of stability.

Result and Discussion

Out of thirteen visually assessed characteristics five were monomorphic, six were found to be dimorphic and two were polymorphic (Table 2). These visually assessed characteristics did not show any variation in their states of expression over two years of study. Further, no off type plants were observed hence, these characters were considered to be uniform. Expression of each characteristic was found to be stable in both the two years for the respective varieties, thus confirming their consistency and stability. The stability of visually assessed characteristics can be attributed to a low genotype × environment interaction in their expression. This is due to the fact that most of the visually assessed characters are controlled by single or two genes with simple dominant or recessive relationship.

Data recorded on 15 measurable characteristics were subjected to COY-D statistical method at 0.1 percent level of significance. Each variety at a time was considered to be a candidate variety and compared to rest of the varieties as reference varieties to obtain a pair-wise distinctiveness matrix using COYD analysis (Table 3). Analysis revealed that all the varieties showed distinctiveness with respect to each other.

Table 1. Details of finger millet varieties studied with their pedigree and source

S.No.	Genotype	Parentage	Year of release	Released from
1	VL 149	VL 204 × IE - 882	1991	Vivekananda Parvatiya Krishi Anusandhan Shala, Almora
2	GE 149	Germplasm	–	Champawat, Lauhaghat
3	HR 911	UAS-1 × IE 927	1986	U.A.S. Bangalore
4	VR 708	VMEC-36	1998	Agril Res. Station, Vizianagaram (AP)
5	Indaf 8	Hullu bele × IE 929	1988	U.A.S. Bangalore
6	PES 110	Selection from IC germplasm	1985	G.B.P.U.A.T. Pantnagar
7	PRM-1	Pureline selection from Ekeshwar local	2006	G.B.P.U.A.T. Pantnagar
8	PRM-2	Selection from Tehri local	2010	G.B.P.U.A.T. Pantnagar
9	PES 400	Selection from IC germplasm	1986	G.B. .U.A.T. Pantnagar
10	PR202	Sarada × EC 158	1976	U.A.S. Bangalore
11	Parvati	Farmer's Variety	–	Kanalchhin, Gundoli Gaon, Pithoragarh
12	Gausari	Farmer's Variety	–	Dabri Tholdar block, Tehri Garhwal

Table 2. Morphological characterization of visually assessed characteristics in finger millet genotypes

Varieties	Characteristics													
	Anthocyanin colouration of first leaf sheath	Node pigmentation	Growth habit	Leaf sheath pubescence	Node pubescence	Spike exertion	Discontinuity of spikelets on finger	Varieties	Anther Colour	Athocyanin pigmentation of glume	Spike shape	Finger branching	Pericarp persistence after threshing	Seed coat colour
VL 149	Absent	Purple	Erect	Absent	Absent	Complete	Absent	VL 149	Purple	Present	Open	Absent	Partial	Brown
GE 149	Absent	Green	Erect	Absent	Absent	Complete	Absent	GE 149	Yellow	Absent	Semi Compact	Absent	Persistent	Brown
HR 911	Absent	Green	Erect	Absent	Absent	Complete	Absent	HR 911	Yellow	Absent	Semi Compact	Absent	Partial	Brown
VR 708	Absent	Green	Erect	Present	Absent	Complete	Absent	VR 708	Yellow	Absent	Semi Compact	Present	Partial	Brown
Indaf 8	Absent	Green	Erect	Absent	Absent	Complete	Absent	Indaf 8	Yellow	Absent	Semi Compact	Present	Partial	Brown
PES 110	Absent	Green	Erect	Present	Absent	Complete	Absent	PES 110	Yellow	Absent	Semi Compact	Absent	Persistent	Brown
PRM-1	Absent	Green	Erect	Present	Absent	Complete	Absent	PRM-1	Yellow	Absent	Compact	Present	Partial	Brown
PRM-2	Absent	Brown	Erect	Absent	Absent	Complete	Absent	PRM-2	Yellow	Present	Compact	Present	Partial	Dark Brown
PES 400	Absent	Purple	Erect	Present	Absent	Complete	Absent	PES 400	Purple	Present	Compact	Absent	Partial	Brown
PR202	Absent	Green	Erect	Present	Absent	Complete	Absent	PR202	Yellow	Absent	Semi Compact	Absent	Persistent	Brown
Parvati	Absent	Green	Erect	Present	Absent	Complete	Absent	Parvati	Yellow	Absent	Compact	Absent	Partial	Brown
Gausari	Absent	Green	Erect	Absent	Absent	Complete	Absent	Gausari	Yellow	Absent	Semi Compact	Present	Partial	Brown
	Monomorphic	Polymorphic	Monomorphic	Dimorphic	Monomorphic	Monomorphic	Monomorphic		Dimorphic	Dimorphic	Polymorphic	Dimorphic	Dimorphic	Dimorphic

COY-D analysis of 15 measurable characters using MJRA model was also carried out (Table 4). The MJRA analysis revealed that the F_1 ratio which takes into account the variety mean square and variety × year mean square was significant for all the measurable characters under the study except for peduncle length, finger number and maturity period at 1% probability. It indicated that there was less role of environment in expression of all the characters except peduncle length, finger number and maturity period. The significant F_2 ratio was observed only for the characters, namely leaf length, head emergence and days to flowering at 1% probability, indicating that the pattern of distinctiveness was inconsistent over the two years of experiment for these characters or in other words environment played a greater role in determining the pattern of distinctiveness among the varieties for these characters thereby, limiting their scope to establish varietal distinctiveness among the present set of varieties. However, the present experimental material with respect to these characters should be tested for one more year or at different locations before arriving at conclusions.

The slope of the MJRA curve and regression probability was calculated for both the years by the DUSNT software which indicated that characteristics under study were not completely independent rather they are interacting with each other as well as with the environment, which emphasize the need for testing the present experimental material in another year and other location.

Measurable characteristics were subjected to COYU analysis for assessment of uniformity using DUSNT software (Table 5) but standard deviation was found to be zero for finger width, days to head emergence, days to flowering, maturity period and 1000 seed weight among all the varieties. Hence, there was no variation within the plot for these characters as a result COYU test could not be performed.

A perusal of Table 5 indicated that out of 12 finger millet varieties, 3 varieties VL 149, HR 911 and PES 110 showed uniformity for all the nine characters followed by GE 149 and VR 708 for eight characters. In addition to this, non-uniformity was observed for majority of the characters but within the acceptable limits of UPOV criteria (Anonymous 2008b). Such non uniformity has been reported earlier in *sorghum* varieties for some characters in local varieties by COYU analysis in maize (Singh *et al.*, 2013), in French bean (Mall and Chawla,

Table 3. Pair-wise distinctness matrix of finger millet varieties obtained from COYD analysis

S.No.	Candidate varieties	1	2	3	4	5	6	7	8	9	10	11	12
1	VL 149	-	D	D	D	D	D	D	D	D	D	D	D
2	GE 149	D	-	D	D	D	D	D	D	D	D	D	D
3	HR 911	D	D	-	D	D	D	D	D	D	D	D	D
4	VR 708	D	D	D	-	D	D	D	D	D	D	D	D
5	Indaf 8	D	D	D	D	-	D	D	D	D	D	D	D
6	PES 110	D	D	D	D	D	-	D	D	D	D	D	D
7	PRM-1	D	D	D	D	D	D	-	D	D	D	D	D
8	PRM-2	D	D	D	D	D	D	D	-	D	D	D	D
9	PES 400	D	D	D	D	D	D	D	D	-	D	D	D
10	PR202	D	D	D	D	D	D	D	D	D	-	D	D
11	Parvati	D	D	D	D	D	D	D	D	D	D	-	
12	Gausari	D	D	D	D	D	D	D	D	D	D	D	-
Overall distinctness		D	D	D	D	D	D	D	D	D	D	D	D

Table 4. Combined over years distinctiveness analysis of 15 measurable characteristics in finger millet varieties using Modified Joint Regression Analysis (MJRA)

	Flag leaf: Length (cm)	Flag leaf: Width (cm)	Leaf: Length (cm)	Leaf: Width (cm)	Leaf sheath length (cm)	Plant height (cm)	Peduncle length (cm)	Spike length (cm)	Finger number	Finger length (cm)	Finger width (cm)	Time of spike emergence (Days)	Time of flowering (Days)	Maturity period (Days)	1000 seed weight (g)
Year MS	2.203	0.003	185.589	0.008	132.031	35.900	2.229	0.312	0.151	4.488	0.003	3.249	3.379	34.032	0.009
Variety MS	91.645	0.146	66.156	0.074	9.828	104.701	6.619	20.029	0.909	15.122	0.035	417.564	415.958	548.564	0.145
Var. year MS	4.786	0.003	10.679	0.003	1.909	17.183	1.727	0.669	0.252	0.505	0.001	21.367	19.946	125.127	0.017
F1 Ratio	19.147	49.907	6.195	25.425	5.149	6.093	3.832	29.955	3.611	29.930	36.711	19.543	20.855	4.384	8.490
Var.Rep MS	1.960	0.001	1.950	0.004	1.582	6.488	1.596	1.187	0.086	0.397	0.001	6.125	6.262	129.871	0.020
F2 Ratio	2.442	2.188	5.476	0.699	1.207	2.648	1.082	0.564	2.913	1.271	0.802	3.489	3.185	0.963	0.861
Between SE	0.893	0.022	1.334	0.022	0.564	1.692	0.537	0.334	0.205	0.290	0.013	1.887	1.823	4.567	0.053
Within SE	0.572	0.015	0.570	0.026	0.513	1.040	0.516	0.445	0.120	0.257	0.014	1.010	1.022	4.652	0.058
MJRA Slope	0.990	1.045	1.212	1.103	1.155	0.819	1.209	0.956	0.891	0.894	1.046	1.011	1.012	0.396	1.044
MJRA Slope	1.010	0.954	0.778	0.897	0.837	1.173	0.774	1.044	1.105	1.106	0.953	0.989	0.988	1.513	0.955
Regr F Val	0.020	1.130	3.503	3.568	1.215	1.988	1.679	0.587	0.313	4.871	0.837	0.024	0.028	13.094	0.152
Regr Prob	89.155	31.273	9.075	8.824	29.622	18.894	22.415	46.116	58.792	5.182	38.183	87.880	87.058	0.470	70.496

$$F_1 \text{ ratio} = \frac{\text{Variety MS}}{\text{Variety} \times \text{Year MS}} \quad F_2 \text{ ratio} = \frac{\text{Variety} \times \text{Year MS}}{\text{Variety} \times \text{replication MS}}$$

2012), and in basmati and aromatic rice varieties (Patra *et al.*, 2010 and Joshi *et al*., 2011).

High heritability and high genetic advance were observed for flag leaf: blade width (94.57%, 26.50%), spike length (76.59%, 33.30%), finger length (92.01%, 43.62%), time of spike emergence (97.06%, 24.89%) and time of flowering (97%, 23.72%). This implies that, these traits were not much influenced by environmental factors which in turn indicated that these traits are mostly controlled by additive and /or additive × additive gene interactions. High heritability coupled with moderate genetic advance was observed for characters like flag leaf: blade length (83.64%, 19.61%), leaf: blade length (92.18%, 14.50%), leaf: blade width (68.28%, 12.14%), leaf sheath length (61.91%, 15.06%), finger width (75.51%, 11.02%) and maturity period (90.03%, 12.57%). Moderate heritability (36.24%) coupled with low genetic advance (4.8%) was observed for peduncle length. Hence both additive and non-additive gene effects are equally important in the inheritance of these traits. Panse and Kharagonkar (1957) suggested that, if the heritability of a particular character is high in a specific environment coupled with low genetic advance, then it could be mainly due to non-additive gene action. In the present study high

Table 5. Combined over years uniformity analysis of nine measurable characteristics in finger millet varieties

Candidate Variety	Flag leaf: Blade Length (cm)	Flag leaf: Blade Width (cm)	Leaf Blade Length (cm)	Leaf Blade Width (cm)	Leaf sheath length (cm)	Plant height (cm)	Peduncle length (cm)	Spike length	Finger number
VL 149	90	109	102	91	87	82	86	90	105
GE 149	100	114	101	109	110	94	114:1	80	105
HR 911	101	100	92	97	84	100	101	87	112
VR 708	103	94	107	160+1	84	97	109	88	102
Indaf 8	93	103	93	106	135+1	106 1	114:1	108	114
PES 110	98	115	87	92	86	93	99	115	91
PRM-1	114:1	87	116 1	86	98	102	102	116 2	93
PRM-2	96	90	96 1	69	92	96	89	81	117 1
PES 400	95	83	88	104	103	114 1	95	114 1	62
PR202	95	95	119:1	93	107 1	106	93	103	103
Parvati	115:2	107	98	89	113 1	91	96	82	85
Gausari	99	104	101	104	102	118 1	101	136:2	111 1

Symbols :
+ -SD exceeds over-years criterion after 2 years with probability 0.01
: - SD not yet acceptable after 2 years with probability 0.05
1,2,3 - the number of occasions the within-years SD exceeds the UPOV criterion

Table 6. Genetic parameters for measurable characters in finger millet

Characters	Variance			Coefficient of variation			Heritability (h2) %	Genetic advance (%)
	Genotypic variance	Phenotypic variance	Environmental variance	GCV (%)	PCV (%)	ECV (%)		
Flag leaf: Blade length (cm)	13.940	16.691	2.727	10.40	11.38	4.60	83.64	19.61
Flag leaf : Blade width (cm)	0.025	0.026	0.001	13.33	13.71	3.19	94.57	26.50
Leaf: Blade length (cm)	10.697	11.622	0.906	7.32	7.63	2.13	92.18	14.50
Leaf: Blade width (cm)	0.010	0.014	0.004	7.00	8.48	4.78	68.28	12.14
Leaf sheath length (cm)	1.350	2.180	0.830	9.31	11.83	7.30	61.91	15.06
Plant height (cm)	16.201	19.977	3.836	3.35	3.72	1.63	80.75	6.2
Peduncle length (cm)	0.699	1.925	1.231	3.85	6.39	5.11	36.24	4.8
Spike length (cm)	3.040	3.970	0.929	18.49	21.13	10.22	76.59	33.30
Finger number	0.143	0.200	0.057	5.09	6.02	3.21	71.59	8.9
Finger length (cm)	2.483	2.699	0.215	22.10	23.04	6.51	92.01	43.62
Finger width (cm)	0.006	0.007	0.002	6.31	7.27	3.59	75.51	11.02
Time of spike emergence (days)	76.988	79.263	2.342	12.27	12.45	2.14	97.06	24.89
Time of flowering (days)	154.613	74.772	77.093	16.81	11.69	11.87	97	23.72
Maturity period (days)	44.607	49.595	4.941	6.43	6.78	2.14	90.03	12.57
1000 Seed weight (g)	0.023	0.037	0.014	5.34	6.72	4.09	63.03	8.92

heritability coupled with low genetic advance was observed for plant height (80.75%, 6.2%), peduncle length (36.24%, 4.8%) finger number (71.59%, 8.9%) and 1000 seed weight (63.03%, 8.92%) as shown in Table 6. It may be concluded from the present investigation that the morphological descriptors used in this study are sufficient to discriminate the present set of varieties.

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