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MORPHO-GENETIC VARIABILITY POTENTIAL OF *CENCHRUS CILIARIS* L., FROM CHOLISTAN DESERT, PAKISTAN

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Abstract

Twenty accessions of perennial range grass *Cenchrus ciliaris* L., collected from different habitats of Cholistan desert were evaluated on the basis of morphological characters. Wide range of variation was recorded among these accessions. Data recorded on morphological characters were analysed by using principal component analysis and all the accessions gathered into five groups. The biggest and smallest groups were represented by eleven and two accessions, respectively. The germplasm collected from different sites of Cholistan desert, though grouped into the same group, exhibited morphological variation. Keeping in view the prominent characters associated with PC2 and PC1 the accession number 14 collected from "Shaheeda Wala Toba", accession number 8 from "Cheepan Wala Toba", accession number 5 from desert area of 43/D.B (Yazman) and accession number 2 & 4 collected from Lal Suhanra appeared as the best accessions according to days taken to earing, number of tillers per plant, number of internodes on main tiller, number of leaves on main tiller, fresh weight of the plant, total number of branches per plant, height of the plant, leaf area, number of leaves on main tiller, part of internode covered by leaf sheath, total number of branches per plant and number of reproductive branches per plant. It is emphasized that the germplasm of *Cenchrus ciliaris* L. adapted in hot and punishing climate of Cholistan desert has a lot of potential for its further evaluation against multiple stresses such as drought, salinity and high temperature to sort out the best genotypes, which ultimately will be helpful in greening the degraded rangelands of Cholistan desert.

Introduction

Cholistan desert spreading over an area of 26000 km^2 in the southern part of Punjab province, Pakistan is confronted with arid and semi-arid climate. It is a hot and sandy desert with a mean annual rainfall of 100 to 250 mm usually falling during the monsoon season (July through September) and in winter and spring (January through March) (Akbar *et al*., 1996; Akbar & Arshad, 2000). The mean minimum temperature of the winter is 6.6^{o}C (December and January) and the mean minimum of the summer is 46.5^{o}C, soaring up to 51^{o}C (Mughal, 1997; Arshad *et al*., 2006). Aridity is the most striking feature of this desert with wet and dry years occurring in clusters. The soils of Cholistan desert are generally poor, lacking organic matter, saline alkaline, gypsiferous and often duned. The dune reaches up to an average height of 100-150 m (Rao *et al*., 1989; Akbar *et al*., 1996; Akhter & Arshad 2006). Rainwater harvested in low-lying areas or dug-out ponds (Tobas) is used by the humans and their livestock. Underground water is mostly brackish containing salt 9000 - 24000 mg/l (Anon., 1993; Akhter & Arshad 2006).

Unpredictable rainfalls support only leafless and spiny scrub jungle with stunted and half nibbled shrubs with a few trees. These plant species, though very slow growing, respond very well to the favourable climatic conditions and provide ample biomass for consumption by livestock and wildlife. Important genera of perennial grasses and sedges include *Lasiurus, Cenchrus, Panicum, Ochthochloa, Sporobolus, Aeluropus, Cymbopogon* and *Cyperus.* Forage shrubs include *Calligonum, Haloxylon, Salsola, Suaeda, Acacia, Leptadenia* and *Capparis. Prosopis, Tamarix, Acacia* and *Zizyphus* are notable forage tree species of the area (Rao & Arshad, 1991; Akbar & Arshad, 2000; Arshad *et al*., 2006). These plant species are very site specific, based on availability of soil moisture, salinity and plant characteristics (Arshad & Rao, 1994; Arshad *et al*., 1999)

Genetic variability in forage range grasses is mostly scattered in arid and semi-arid areas of Pakistan, especially in Cholistan desert. *Cenchrus ciliaris* L., is an important perennial range grass species of Cholistan desert. Because of heavy grazing pressure and prolonged droughts of many years this grass is going to be rare in the rangelands of this desert. It is one of the highly palatable and nutritious perennial grasses of the area. It is very well distributed in sandy and sandy loam areas of this desert (Rao & Arshad, 1991; Arshad *et al*., 1999). Inherent genetic variability present in perennial grass *Cymbopogon jwarancusa* (Arshad *et al*., 1995b) and *Sporobolus ioclados* (Arshad *et al*., 2000) collected from different habitats of Cholistan desert were evaluated and high amount of genetic variations were recorded among the accessions. Noor (1991) determined the comparative performance of 10 ecotypes of *Cenchrus ciliaris* under rainfed conditions and recorded a high amount of ecotypic variation. Rai *et al*., (1982) observed significance variation in forage yield of 8 strains of *Cenchrus ciliaris.* Agarwal *et al*., (1999) evaluated 55 accessions of perennial range grass *Dicanthium annulatum* L., (Stapf) on the basis of agro-morphological attributes and observed a wide diversity among the accessions.

Cenchrus ciliaris L., has sufficient variability in the form of different agro-ecotypes. This vast genetic resources adapted in multiple stress environment of Cholistan desert could be utilized for higher productivity potential. The present investigation is an attempt to evaluate the morpho-genetic variations among the accessions of *Cenchrus ciliaris* L., collected from different habitats of Cholistan desert, Pakistan and to identify some useful accessions for future studies.

Materials and Methods

Desert grass germplasm collecting expeditions were executed in 2004 and 2005 in different habitats of Cholistan desert by the Cholistan Institute of Desert Studies (CIDS), Islamia University, Bahawalpur, Pakistan and different accessions of *Cenchrus ciliaris* L., were collected from a range of sites. Because of the overgrazing and severe/prolonged droughts the seeds of this grass was not available, consequently the plantlets were uprooted for their multiplication at the grass germplasm nursery of CIDS. Twenty accessions of this grass having contrasting characteristics were selected for present study (Table 1).

The plant samples of each accession were further sub-divided into 8 equal sized plantlets and propagated under randomized complete block design. The study was replicated three times. Plant to plant and line to line distance was maintained one meter. Data on yield and morphological characters were recorded. For statistical analysis means of all variables over an entire season were used and the data were analyzed using multivariate analysis (Anon., 1987).

Table 1. Collection numbers and site names.

Accession number	Collection number	Name of the site	Accession number	Collection number	Name of the site
1	LS2/8	Lal Suhanra	11	BW1/4	Bhuddi Wali Khui
2	LS3/2	Lal Suhanra	12	KW3/2	Khaitran Wala Toba
3	LS310	Lal Suhanra	13	SH2/3	Shaheedan Wala Toba
4	LS3/8	Lal Suhanra	14	SH2/4	Shaheedan Wala Toba
5	YZ1/1	Desert of 43/D.B (Yazman)	15	QP3/3	Qaimpur desert
6	DG1/3	Din Garh Fort	16	QP3/6	Qaimpur desert
7	KWT1/3	Khiwtal Wala Toba	17	ASR1/2	Asarani desert
8	CWT1/3	Cheepan Wala Toba	18	BC1/1	Islamia University, Bahawalpur
9	CWT2/4	Cheepan Wala Toba	19	BC2/2	Islamia University, Bahawalpur
10	BGD1/4	Bagrrown Wala Dahar	20	BC3/5	Islamia University, Bahawalpur

Table 2. Mean values and range of the variables recorded in various accessions of *Cenchrus ciliaris* L., from Cholistan desert.

S. #	Variables	Mean + SE	Standard deviation	Range
1.	Days taken to sprouting of stubbles	16.25+0.691	5.35	6.28 - 29.66
2.	Days taken to earing	32.18+0.533	4.13	23.75 - 42.00
3.	Days taken to maturity	59.04+0.426	3.30	50.50 - 65.00
4.	Number of tillers per plant	4.24+0.265	2.05	1.00 - 10.50
5.	Height of the plant (cm)	55.75+1.46	11.27	23.00 - 79.00
6.	Leaf area (cm^2)	2.66+0.125	0.96	1.17 - 6.18
7.	Length of the inflorescence (cm)	7.78+0.135	1.04	5.64 - 10.58
8.	Total number of branches on main tiller	3.62+0.155	1.19	1.00 - 6.67
9.	Number of internodes on main tiller	7.14+0.075	0.58	5.00 - 8.66
10.	Number of leaves on main tiller	54.06+2.48	19.22	28.50 - 117.66
11.	Part of internode covered by leaf sheath (cm)	7.40+0.158	1.22	4.80 - 11.50
12.	Part of internode not covered by leaf sheath (cm)	3.44+0.137	1.05	0.90 - 5.10
13.	Length of last internode (cm)	10.79+0.173	1.33	6.10 - 13.25
14.	Thickness of the basal internode. (mm)	1.54+0.049	0.38	1.00 - 2.50
15.	Fresh weight of the plant (g)	44.98+4.73	33.85	7.50 - 123.75
16.	Total number of branches per plant	14.58+0.729	5.65	6.00 - 37.66
17.	Number of reproductive branches per plant	11.95+0.583	4.51	5.00 - 28.66
18.	Ratio between covered and un-covered part of internode by leaf sheath.	3.99+0.672	5.20	5.86 - 24.83

Results and Discussion

Mean values, standard deviations and range of variations for 18 distinct morphological variables of *Cenchrus ciliaris* L., showed considerable variations (Table 2). High morphological variation was observed for fresh weight of the plant, number of leaves on main tiller, height of the plant, total number of branches per plant and days taken to sprouting of stubbles. Medium variation was recorded for leaf area, days taken to earing, length of inflorescence, number of reproductive branches per plant and ratio between covered and un-covered part of internode by leaf sheath and low morphological variation were noted for days taken to maturity, total number of branches on main tiller, number of internodes on main tiller, part of internode covered by leaf sheath, part of internode not covered by leaf sheath, length of last internode and thickness of the basal internode.

The large number of observations raised the test power, giving significance to most of the correlations (Table 3). Only values above 0.6 are discussed. Number of tillers per plant showed highly significant correlation with fresh weight of the plant. Height of the plant was associated with the number of leaves per plant and leaf area associated with the length of the inflorescence and part of the internode covered by leaf sheath. Length of the inflorescence showed its association with part of the internode covered by leaf sheath.

Table 3. Correlation coefficients for morphological traits measured in twenty accessions of *Cenchrus ciliaris*.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	C11	V12	V13	V14	V15	V16	V17
V2	0.345**																
V3	0.092	0.482**															
V4	-0.470	-0.418	-0.240														
V5	-0.547	-0.368	-0.199	0.436**													
V6	-0.263	-0.223	-0.146	0.577**	0.557**												
V7	-0.344	-0.163	-0.052	0.398**	0.581**	0.635**											
V8	-0.201	-0.124	-0.141	0.120	0.311*	0.337**	0.109										
V9	-0.058	-0.032	-0.182	0.160	0.527**	0.496**	0.380**	0.120									
V10	-0.296	-0.072	-0.230	0.232	0.608**	0.581**	0.295*	0.463**	0.689**								
V11	-0.306	-0.137	-0.048	0.429**	0.580**	0.743**	0.623**	0.272*	0.637**	0.597**							
V12	0.047	-0.096	-0.037	-0.059	-0.077	-0.198	-0.228	0.081	-0.442	-0.216	-0.450						
V13	-0.319	-0.202	-0.067	0.388**	0.516**	0.574**	0.453**	0.372**	0.281*	0.439**	0.631**	0.373					
V14	-0.315	-0.269	-0.141	0.301*	0.585**	0.426**	0.511**	0.275*	0.521**	0.403**	0.694**	-0.321	0.424**				
V15	-0.575	-0.605	-0.270	0.689**	0.430**	0.424**	0.304*	0.152	0.050	0.143	0.381**	-0.014	0.368**	0.370**			
V16	-0.361	-0.141	-0.220	0.197	0.544**	0.451**	0.159	0.402	0.545**	0.927**	0.445**	-0.137	0.346**	0.339**	0.157		
V17	-0.339	-0.159	-0.265	0.237	0.543**	0.487**	0.179	0.459	0.500**	0.877**	0.453**	-0.119	0.364**	0.365**	0.184	0.952**	
V18	-0.136	-0.128	-0.244	0.182	0.197	0.310*	0.189	0.065	0.218	0.252*	0.368**	-0.362	0.089	0.192	0.183	0.185	0.205

* and ** indicate statistical significance at P = 0.05 and P = 0.01, respectively

V1 = Days taken to sprouting, **V2** = Days taken to earing, **V3** = Days taken to maturity, **V4** = Number of tillers per plant, **V5** = Height of the plant, **V6** = Leaf area, **V7** = length of the inflorescence, **V8** = Total number of branches on main tiller, **V9** = Number of internodes on main tiller, **V10** = Number of leaves on main tiller, **V11** = Part of internode covered by leaf sheath, **V12** = Part of internode not covered by leaf sheath, **V13** = Length of last internode, **V14** = Thickness of the basal internode, **V15** = Fresh weight of the plant, **V16** = Total number of branches per plant, **V17** = Number of reproductive branches per plant, **V18** = Ratio between covered and uncovered part of leaf sheath

Table 4. Latent roots, percentage of the variance explained by the each component and accumulative variance.

Principal components	Latent roots	Percentage variance	Accumulative variance
PC1	69.59	38.70	38.70
PC2	23.23	12.90	51.60
PC3	18.44	10.20	61.81
PC4	14.63	8.10	69.90
PC5	9.71	5.40	75.30

Table 5. Relationship of principal components with different variables.

S. #	Variables	PC1	PC2	PC3	PC4	PC5
1.	Days taken to sprouting of stubbles	0.205	-0.258	-0.082	-0.012	**-0.609**
2.	Days taken to earing	0.146	**-0.402**	-0.128	**-0.317**	0.126
3.	Days taken to maturity	0.115	-0.140	-0.198	**-0.510**	**0.482**
4.	Number of tillers per plant	-0.221	**0.351**	-0.078	0.037	0.080
5.	Height of the plant (cm)	**-0.309**	0.058	0.030	-0.080	0.097
6.	Leaf area (cm^2)	**-0.300**	0.024	0.145	-0.130	-0.195
7.	Length of the inflorescence (cm)	-0.236	0.099	**-0.323**	-0.246	-0.087
8.	Total number of branches on main tiller	-0.165	-0.067	**0.339**	-0.117	-0.025
9.	Number of internodes on main tiller	-0.249	**-0.310**	-0.161	0.063	-0.172
10.	Number of leaves on main tiller	**-0.304**	**-0.305**	**0.305**	0.041	0.033
11.	Part of internode covered by leaf sheath (cm)	**-0.315**	-0.076	**-0.276**	-0.145	-0.088
12.	Part of internode not covered by leaf sheath (cm)	0.094	0.252	**0.438**	**-0.351**	**-0.284**
13	Length of last internode (cm)	-0.244	0.132	0.136	**-0.457**	**-0.302**
14	Thickness of the basal internode. (mm)	-0.262	0.003	-0.199	-0.060	-0.024
15	Fresh weight of the plant (g)	-0.206	**0.444**	-0.019	0.117	0.170
16	Total number of branches per plant	**-0.275**	**-0.275**	**0.316**	0.110	0.182
17	Number of reproductive branches per plant	**-0.280**	-0.245	**0.322**	0.111	0.129
18	Ratio between covered and un-covered part of internode by leaf sheath.	-0.138	-0.040	-0.217	**0.373**	-0.169

Number of internodes on main tiller as expected showed very close association with the number of leaves on main tiller and the part of the internode covered by leaf sheath. Number of leaves on main tiller correlated with the number of branches per plant and number of reproductive branches per plant. Part of the internode covered by leaf sheath highly significantly correlated with the length of the last internode and the thickness of the basal internode. Total number of reproductive branches showed their association with the number of branches per plant. These results are in conformity with the findings of Tefera *et al*., (1992) in calculating genetic correlation among twelve characters of *Eragrostis tef (zuec)* and Brandolini & Brandolini (2001) in evaluating the correlation among the germplasm of Italian maize.

The first five principal components gave eigenvalues greater than 9.0 and altogether explained 75% of the accumulated variation (Table 4). The first principal component (PC1) explained 38.70% of the variation and was associated prominently with height of the plant, leaf area, number of leaves on main tiller, part of internode covered by leaf sheath, total number of branches per plant and number of reproductive branches per plant. The second principal component (PC2) explained 12.90% of the variation and was associated prominently with days taken to earing, number of tillers per plant, number of internodes on main tiller, number of leaves on main tiller, fresh weight of the plant and

total number of branches per plant. The third principal component (PC3) explained 10.20% of the variation and was mainly associated prominently with length of inflorescence, total number of branches on main tiller, number of leaves on main tiller, part of internode covered by leaf sheath and total number of branches per plant.

The fourth principal component (PC4) explained 8.10% of the variation and associated prominently with days taken to earing, days taken to maturity, part of internode covered by leaf sheath, length of last internode and ratio between covered and un-covered part of internode by leaf sheath. The fifth principal component (PC5) explained 5.40% of the variation and was associated prominently with days taken to sprouting of stubbles, days taken to maturity, part of internode covered by of leaf sheath and length of the last internode.

The plot of the accessions drawn against PC2 (12.90) and PC1 (38.70) grouped all the 20 accessions into five cohesive groups containing 1-9 accessions (Fig. 1) and indicated a high amount of genetic variation among the accessions based on the morphogenetic characters of the collected accessions of *Cenchrus ciliaris* L. Even the accessions collected from the same location/habitat showed considerable differences. Except accession 6 collected from National Park Lalsuhanra and 18 and 19 collected from Baghda-ul-Jadeed campus, Islamia University Bahawalpur all the other accessions were scattered very well in the diagram.

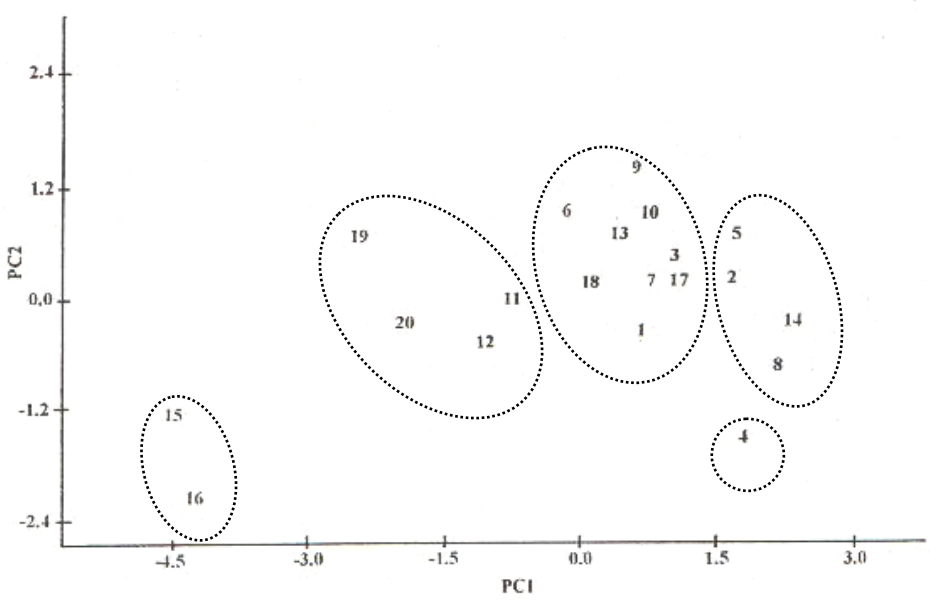

Fig. 1. Plot of principal components 2 and 1 for different accessions of *Cenchrus ciliaris* collected from Cholistan desert

Keeping in view the prominent characters associated with PC2 and PC1 the accession number 14 collected from Shaheeda Wala Toba, accession number 8 from Cheepan Wala Toba, accession number 5 from desert area of 43/D.B (Yazman) and accession number 2 and 4 collected from Lal Suhanra appeared as the best accessions according to days taken to earing, number of tillers per plant, number of internodes on main tiller, number of leaves on main tiller, fresh weight of the plant, total number of

branches per plant, height of the plant, leaf area, number of leaves on main tiller, part of internode covered by leaf sheath, total number of branches per plant and number of reproductive branches per plant. These results are same as reported by Arshad *et al*., (1995) and Arshad *et al*., (2000) on exploring the germplasm of *Cymbopogon jwarancusa* and *Sporobolus iocladus* from different habitats of Cholistan desert. Brandolini & Brandolini (2001) also recorded similar type of the results while evaluating the 562 Italian Maize accessions and grouped them into 65 agroecotypes. These results are also in conformity with the findings of the Puri & Paliwal (1976); Rai *et al*., (1980); Rai *et al*., (1982); Yadav & Mal (1988); But *et al*., (1990); Noor (1991); Agarwal *et al*., (1999); Ojeda *et al*., (2001); Manzano *et al*., (2001) and Frese *et al*., (2001).

Expansion of variability in fresh weight of the plant, number of leaves on main tiller, height of the plant, total number of branches per plant and days taken to sprouting of tillers, days taken to sprouting of stubbles resulted in an appearance of a sufficient quantity of more productive forms. The low variability for the traits revealed a need to explore more genetic resources of this grass. It is emphasized that the germplasm of *Cenchrus ciliaris* L. adapted in hot and punishing climate of Cholistan desert has a lot of potential for its further evaluation against multiple stresses such as drought, salinity and high temperature to sort out the best ecotypes, which ultimately will be helpful in greening the degraded rangelands of Cholistan desert. It is hoped that these efforts will prove a land-mark in the history of this desert in increasing the population of this highly palatable perennial grass. Positive and highly significant correlation among the important/useful morphological characters also supported to conclude that these accessions may eventually prove highly potential for the increase of per unit biomass production of grasslands in Cholistan desert.

References

Agarwal, D.K., S. Gupta, A.K. Roy and S.R. Gupta. 1999. Study on agromorphological variation *vis-à-vis* geographical distribution in marvel grass {*Dichanthium annulatum* L. (Stapf)}. *Plant Genetic Resources Newsletters*, 118: 27-29.

Akbar G., T.N. Khan and M. Arshad. 1996. Cholistan desert, Pakistan. *Rangelands*, 18: 124-128.

Akbar, G. and M. Arshad. 2000. Developing sustainable sterategies for Cholistan desert: opportunities and perspectives. *Science Vision*, 5: 77-85.

Akhter R. and M. Arshad. 2006. Arid rangelands in Cholistan desert (Pakistan). *Secheresse*, 17: 1-8.

Anonymous. 1987. SAS User's Guide: Statistics, Ver. 6, Edn. Cary, North Carolina.

Anonymous. 1993. *Pakistan – Cholistan Area Development Project*. Report No. 59/53 ADB-PAK 58 (Final version). Food and Agriculture Organization of the United Nations, Rome.

Arshad, M. and A.R. Rao. 1994. Flora of Cholistan desert (Systematic list of trees, shrubs and herbs). *J. Econ. Tax. Bot*., 18(3): 615-625.

Arshad, M., A.R. Rao, G. Akbar and M.A. Khan. 1999. Floral wealth and its adaptations in Cholistan Desert, Pakistan. Pages 195-199. In: *Desertification and Soil Degradation*. (Eds.): G.V. Dobrovolkskiy, G.S. Kust. Proceedings of the International Scientific Conference. Institute of Soil Science, Moscow State University, Moscow.

Arshad, M., M. Ashraf and N. Arif. 2006. Morphological variability of *Prosopis cineraria* (L.) Druce, from the Cholistan desert, Pakistan. *Genetic Resources and Crop Evolution*. 53: 1589-1596.

Arshad, M.A.R. Rao, M. Akhter and G. Akbar. 1995. Potential genetic adaptability of *Cymbopogon jwarancusa* (Jones) Schult., from Cholistan, Pakistan. *Sarhad Journal of Agriculture*, 11: 63-69.

Arshad, M.G. Akbar, A.R. Rao and M. Akhter. 2000. Eco-physiological adaptability of *Sporobolus iocladus*, from Cholistan, Pakistan. *Pakistan Journal of Biological Sciences*, 2: 1604-1607.

Brandolini, A. and A. Brandolini. 2001. Classification of Italian maize (*Zea mays* L.) germplasm. *Plant Genetic Resources Newsletter*, 126: 1-11.

But, N.M., N. Muhammad, Sartaj and M.I. Sultani. 1990. Performance of tropical grasses under sub-humid sub-tropical conditions of Pakistan. *Pak. J. of Forestry*, pp. 318-320.

Frese, L., Z. Akbarov, V. I. Burenin, M. N. Arjmand and V. Hajiyev. 2001. Plant exploration in the Talysch Mountains of Azerbaijan and Iran. *Plant Genetic Resources Newsletter*, 126: 1-11.

Manzano, A.R., A.A.R. Nodals, M.I.R. Gutierrez, Z.F. Mayor and L.C. Alfanso. 2001. Morphological and isozyme variability of taro (*Colocasia esculenta* L. Scott) germplasm in Cuba. *Plant Genetic Resources Newsletter*, 126: 1-11.

Mughal, M.R. 1997. *Ancient Cholistan - Archaeology and Architecture*. Ferozsons (Pvt.) Ltd., Lahore. pp. 21.

Noor, M. 1991. Comparative performance of *Cenchrus ciliaris* ecotypes under Barani conditions at Peshawar. *Pak. J. of Forestry*, pp. 183-187.

Ojeda, M., R. Coirini, J. Cosiansi, R. Zapata and Y.J. Zygadlo. 2001. Evaluation of variability in natural populations of peperina (*Minthostachys mollis* (Kunth) Griseb.), an aromatic species from Argentina. *Plant Genetic Resources Newsletter*, 126: 1-11.

Puri, D.N. and M.K. Paliwal. 1976. Selection of promising grass strains of Kota region. 1. *Cenchrus ciliaris* Linn. *Ann. Arid Zone*, 15: 85-88.

Rai, P., B.D. Patil, P.R. Sreenath and K.C. Kanodia. 1980. Studies on the height weight relationship of different cultivars of *Cenchrus ciliaris* Linn., and *Panicum antidotale* Retz. *Ann. Arid Zone*, 19: 29-36.

Rai, P., P.S. Pathak, K.C. Kanodia and G.K. Dwivedi. 1982. Performance of *Cenchrus setigerus* strains under rainfed conditions. *Forage Res*., 8: 133-139.

Rao, A.R. and M. Arshad. 1991. Perennial grasses of Cholistan desert and their distribution. In: *Proceedings of national seminar on 'people's participation in the management of resources in arid lands'* November 11-13, 1991. Islamia University, Bahawalpur, Pakistan. pp. 6-11.

Rao, A.R., M. Arshad and M. Shafiq. 1989. *Perennial grass germplasm of Cholistan desert and their phytosociology*. Cholistan Institute of Desert Studies, Islamia University, Bahawalpur. pp. 84.

Tefera, H., W.E. Peat and G.P. Chapman. 1992. Quantative genetics in t'ef (*Eragrostis tef* (Zucc.) Trotter. Pages 283-296. In: *Desertified Grasslands: Their Biology and Management*. (Ed.): G.D. Chapman. The Linnean Society of London.

Yadav, M.S. and B. Mal. 1988. Genotypic response to defoliation stress and nitrogen on the fodder yield, quality and underground biomass of buffel grass *(Cenchrus ciliaris* Linn.). Rangeland Resource and Management. *Proc. of National Rangeland Symposium, IGFRI, Jhansi, Range Management Society of India*, pp. 203-208.

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