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Pearl millet [*Pennisetum glaucum* (L.) R. Br] landraces from south Algeria: variability, yield components, grain and panicle quality

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ABSTRACT

The millet is one of the most important cereals for food and feed in the world. Through this study, the behavior of 15 autochthonous cultivars of pearl millet in presence of one Nigerian control was done in Mitidja's conditions (sub-humid region in Algeria) to assess the variability using pheno-agro-morphological traits, grain and panicle quality. Analysis of variance showed the existence of a large variability between landraces, revealed by very highly significant differences among the following characters: plant height, panicle length, panicle thickness, 1000 grain weight and crude fiber content of panicles. Differences were significant for stem diameter and panicle weight and high significant for dry matter content of panicles. Principal component analysis showed that four components explained 81.03 % of variation. The greatest variability was explained by the following traits: panicle weight, panicle length, panicle thickness, 1000 grain weight and crude fiber content of panicles. Significant correlations existed between many traits studied which are promising for breeding works.

Keywords:
Autochthonous cultivars; Nutritional quality; Performance; variability

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Introduction

Pearl millet *Pennisetum glaucum* L. is the fourth most important grain next to rice, wheat and sorghum. It is becoming increasingly important forage crop in many regions of the world (Zerbini and Thomas, 2003). It is a hardy cereal crop, grown mostly in marginal environments in the arid and semi-arid tropical regions of Asia and Africa (Vadez et al., 2012). It is the most tolerant cereal drought (Bezançon et al., 1997). Pearl millet has been detected as a promising new forage crop of excellent quality and productivity since 1985 (Park et al., 1988).

Pearl millet is used by livestock producers for grazing, silage, hay and green chop (Newman et al., 2010). The crop residue/straw of dual-purpose pearl millet is an important source of fodder, accounting for 40-50 % of dry matter intake year round, and the only source of feed in the dry months (Vadez et al., 2012).

In the oases of Algeria, especially in the extreme south, pearl millet held for a long time an important place among other cereals both for human and animal feed (Rahal-Bouziane et al., 2003, Rahal-Bouziane et al., 2010). Following a modernization not well planned in these rural areas, great genetic erosion threatens pearl millet resources and other species (Rahal-Bouziane, 2011).

In the country, the fodder deficit is among the major constraints hampering the development of animal production (Rahal-Bouziane et al., 2015). With climate change, Algeria will face increasing scarcity of water and hence the development of resilient crops like pearl millet and barley becomes strategic and necessary.

According to Hassan et al. (2014), it is essential to supply adequate and nutrition forage on regular basis for production and development of livestock. On their side, Chohan et al. (2006) indicate that it is the dire need to develop such pearl millet cultivars which have the higher yield potential so that the growing demand of forage for livestock can be achieved.

Being drought-tolerant, higher protein concentration and protein quality compared to other cereals, scientists hope to increase use of pearl millet as feed grain for both humans and animals alike (Govindaraj et al., 2011). However, the nutritive value of this crop has not received extensive attention and as a result the data available are limited (Hulse et al., 1980). In general, in pearl millet program, a strong emphasis is placed on selection for evident quality characters (Govindaraj et al., 2009).

Landraces are considered as storehouses of valuable genetic diversity (Bashir et al., 2015). Thus, assessment of genetic diversity in pearl millet germplasm and determination of their phenotypic and biochemical activities would help to know the breeding potential of a particular variety (Kiprotich et al., 2015). The foremost important consideration in any crop breeding program for its improvement is the detailed study on genetic variability (Vidyadhar et al., 2007).

Before placing strong emphasis on breeding for nutritional quality characters, the knowledge on the association between yield and yield attributes and also interaction between yield and nutritional quality traits will enable the breeder for simultaneous improvement of yield with nutritional traits (Govindaraj et al., 2009). Dry matter, pH, crude protein, available protein, amoniacal nitrogen, fiber contents and ash are the recommended tests for determining forage quality (Fulgueira et al., 2007). Among many options to overcome the shortage of forage the best one is introduction of high yielding crop varieties (Bilal et al., 2001). Genetic resources of pearl millet are untapped that need attempt to improve protein content in harvested varieties for significant yield improvements (Rai et al., 1999). The extent of association between yield and yield attributes can be known through correlation studies (Vidyadhar et al., 2007).

This study was done with objectives to evaluate diversity among the landraces and to investigate the relationship among phenology, yield components, nutritional quality and morphological traits under sub-humid conditions.

Material and methods

The germplasm studied on pearl millet consisted of sixteen genotypes coming from Saharan regions of Algeria. The collection sites were divided into western and central regions of Algerian Southern. Autochthonous genotypes were collected by researchers of INRAA within the following regions: Ain Salah (1, 2, 3 and 4), Hoggar (5, 6, 7, 8, 9 and 10), the control (11) is from Niger and was collected at Hoggar. Five genotypes were from different locations in Adrar (12, 13, 14, 15 and 16).

Ain Salah and Hoggar are situated in Tamanrasset which is located in the Central Sahara. Adrar is lo-

Table 1. ANOVAs of agronomic traits in pearl millet genotypes (with six replications per trait)

	Minimum value	Maximum value	Mean	SEM	LSD	CV (%)	Prob.
LTI	182.9	274.8	229.7	17.49	34.8	13.2	‹ 0.001
LOC	122.6	172.8	143.7	9.8	19.5	11.8	‹ 0.001
GRC	25.4	45.8	33.21	3.63	7.23	18.9	‹ 0.001
GRT	9.5	13.5	10.9	1.41	2.8	22.4	0.048
TAT	5.3	12.5	9.82	2.01	4	35.4	0.11
TAP	2.5	8.2	4.97	1.61	3.2	56	0.091
LOF	55.5	69	61.94	5.04	10	14.1	0.32
PMG	9	15.6	11.2	1.27	2.52	16.7	‹ 0.001
PAP	18.16	57.53	25.31	5.16	10.3	35.3	0.013
DEX	6.17	15.17	10.71	2.92	5.82	47.3	0.187

SEM: Standard Error of Means; LSD: Least significant difference; CV: Coefficient of Variance; Significant at P ‹ 0.05; Highly Significant at P ‹ 0.01; Very highly significant at P ‹ 0.001

Table 2. ANOVAs of quality traits in pearl millet genotypes (with two replications per trait)

	Minimum value	Maximum value	Mean	SEM	LSD	CV (%)	Prob.
GPR	11.7	14.4	13.23	1.11	2.36	8.4	0.386
PRP	10.3	13.2	11.97	0.9	1.91	7.5	0.25
DMG	91.9	93.9	93.2	0.51	1.08	0.5	0.038
DMP	88.8	91.9	91.01	0.57	1.22	0.6	0.009
CFP	6	31.6	11.2	3.14	6.7	28.1	‹ 0.001

SEM: Standard Error of Means; LSD: Least significant difference; CV: Coefficient of Variance; Significant at P ‹ 0.05; Highly Significant at P ‹ 0.01; Very highly significant at P ‹ 0.001

Table 3. Correlation matrix of 16 pearl millet genotypes based on seventeen traits

	LOC	TAP	TAT	GRT	LTI	GRC	PMG	DEP	DC	LOF	GPR	PRP	DMG	DMP	CFP	PPA
TAP	0.22															
TAT	0.32	0.53														
GRT	0.29	-0.27	-0.09													
LTI	0.07	0.15	0.45	-0.22												
GRC	0.67*	0.06	-0.17	0.51	-0.45											
PMG	0.45	0.23	0.08	0.1	-0.36	0.53										
DEP	0.2	-0.43	-0.05	0.26	-0.05	0.13	-0.2									
DC	0.34	-0.11	0.14	0.22	-0.17	0.09	0.13	0.69*								
LOF	0.48	-0.18	0.36	0.34	0.6*	0.12	-0.04	0.1	-0.03							
GPR	0.57*	0.00	0.43	0.39	0.13	0.35	0.2	-0.04	-0.1	0.48						
PRP	0.48	0.3	0.39	0.09	0.22	0.33	0.1	-0.27	-0.38	0.26	0.73**					
DMG	-0.51	-0.19	0.14	0.19	0.34	-0.49	-0.56*	-0.09	-0.46	0.23	0.18	0.14				
DMP	-0.12	0.16	-0.27	-0.37	-0.11	-0.12	-0.04	-0.4	-0.35	-0.24	-0.19	0.12	-0.12			
CFP	0.4	0.14	0.06	-0.06	-0.29	0.45	0.79**	-0.03	0.15	0.06	0.19	0.11	-0.42	0.04		
PPA	0.79**	0.17	-0.06	0.28	-0.24	0.81***	0.58*	-0.1	0.05	0.17	0.51	0.47	-0.56*	-0.09	0.43	
DEX	-0.19	0.22	-0.03	-0.35	0.38	-0.32	-0.12	0.11	0.28	-0.23	-0.56*	-0.35	-0.23	-0.27	-0.14	-0.21

* P ‹ 0.05 ; ** P ‹ 0.01 ; *** P ‹ 0.001

cated in Southwest of it. The study was conducted at the Institute of Algerian Agricultural Research of Baraki (Algiers) situated in the plain of Mitidja (with an average rainfall exceeding 500 mm). Planting occurred on 23 June in 2011. The protocol was in total randomization. Each genotype was represented by three lines with a length of 6.30 m each, spaced out by 70 cm. For every quantitative character studied, a random sampling of six plants was considered in the middle line. With 09 seeds by line, the distance between plants was 70 cm. The test was led with two irrigations per week at the beginning of cycle and one irrigation per week at the end of cycle. NPK fertilization was done with 50 kg/ha before sowing. The texture of the soil was a sandy clay loam texture.

The traits studied at the dough stage were: plant height (LTI) (cm), panicle length (LOC) (mm), panicle thickness or panicle width (GRC) (mm), stem diameter (GRT) (mm), total number of tillers (TAT), number of productive tillers (TAP) and ear exsertion distance (DEX) (cm). Leaf length (LOF) (cm) was taken at head emergence. At harvest, characters studied were: 1000 grain weight (PMG) (g), panicle weight (PPA), protein content of grain or crude protein of grain (GPR) (%), protein content of panicles (without grains) (PRP), fiber content of panicles or crude fiber content (without grains) (CFP) (%), dry matter content of grain (DMG) (%) and dry matter content of panicles (without grains) (DMP) (%). Also, days to heading (DEP) and days to maturity (DC) were considered.

The studied characters were in their majority those described by IBPGR/ICRISAT (1993).

One-way analysis of variance (ANOVA) was made by the software GENSTAT Discovery version 3, on ten quantitative characters with six replications for each (LTI, LOC, GRC, GRT, TAT, TAP, LOF, PPA, DEX and PMG) (table 1). Another analysis of variance was done on the following traits with two repetitions for each of them: GPR, PRP, CFP, DMG and DMP (table 2). Comparison of means was done by the Fisher's least significant test (LSD) at 0.05 probability level. Correlations (table 3) and principal component analysis (table 4), were obtained by STATISTICA version 6. Correlations were performed based on seventeen quantitative characters (LTI, LOC, GRC, GRT, TAT, TAP, LOF, PMG, GPR, PRP, CFP, DMG, DMP, PPA, DEX, DEP and DC) using Spearman correlation. Principal component analysis was taken on thirteen traits: LTI, LOC, GRC, LOF, PMG, GPR, PRP, CFP, DMG, PPA, DEX, DEP and DC.

The grain protein content was determined from the nitrogen content, tested by Kjeldahl method (AFNOR, 1985). It is expressed in percentage by weight referred to dry matter. The crude fiber (CF) content (%) was determined by the Weende method (AFNOR, 1985).

Results

Results of analysis of variance showed very highly significant differences among the following characters: plant height, panicle length, panicle thickness, 1000 grain weight (table 1) and crude fiber content of panicles (table 2). Differences were significant for stem diameter and panicle weight (table 1) and high significant for dry matter content of panicles (table 2). Differences were no significant for the following traits: number of productive tillers, total number of tillers, leaf length, ear exsertion distance (table 1), dry matter content of grain, grain protein content and protein content of panicles (table 2).

Correlations (table 3) showed that grain protein content and protein content of panicles were positively and highly correlated. The grain protein content was negatively correlated with ear exsertion distance. The 1000 grain weight was positively and significantly correlated with panicle weight and highly correlated with crude fiber content of panicles but negatively and significantly correlated with dry matter content of grain. The panicle length was positively correlated with panicle thickness and grain protein content and also positively but highly correlated with panicle weight. The panicle thickness was positively and very highly correlated with panicle weight. The plant height was positively correlated with the length of leaf. Days to heading was highly correlated with days to maturity.

Principal component analysis (table 4) showed that four components explained 81.03 % of variation. The first three components absorbing the greatest percent of variance (71.08 %) were explained by the following traits: panicle weight, panicle length, panicle thickness, 1000 grain weight, crude fiber content of panicles (correlated to the first component with 34.19 % of total variation), protein content of panicles, dry matter content of grain, grain protein content, leaf length (correlated to the second component with 21, 98 % of total variation), days to heading, days to maturity and plant height (correlated to the third component with 14.91

of total variation). The fourth component absorbing 9.95 % of total variation was explained by the ear exsertion distance.

The Nigerian control presented the highest mean value on dry matter of grain (93.9 %) but the lowest mean value of panicle dry matter content (88.8 %). The control also had the greatest length of leaf (68.8 cm) after the genotype 8 (69 cm) and the lowest value of productive tillers (3.3) before the genotype 7 (2.5). It gave the highest mean value of total tillers (12) after the landrace 6 (12.5). It presented the greatest stem diameter (12.9 mm) after the genotype 15 (13.5 mm) (table 5).

Six autochthonous genotypes (13, 1, 15, 12, 2 and 8) gave the highest mean values of 1000 grain weight (15.6 g, 12.9 g, 12 g, 11.8 g, 11.7 g, 11,3 g respectively) exceeding the control (11.3 g). Panicle weight varied between a minimum of 18.17 g (genotype 7) and a maximum of 57.53 g (genotype 12). Thirteen genotypes gave better panicle weights (ranging from 57.53 g and 21.12g) than the control (20.46 g).

For the plant height, the greatest mean values were those concerning three cultivars 5, 8 and 9 (274.8 cm, 271.2 cm and 268.5 cm, respectively) followed by the control with 266.5 cm. The lowest value was 182.9 cm and concerned the genotype 16. All autochthonous cultivars, except the genotype 7, gave more productive tillers than the control with a maximum of 8.2 (genotype 6) and a minimum of 3.5 (genotype 16) productive tillers per plant (the control and the genotype 7 gave 3.3 and 2.5 productive tillers, respectively).

Nine genotypes presented longer and wider panicles than the control. The ear exsertion distance varied between a maximum of 15.17 cm (genotype 2) and a minimum of 6.17 cm (genotype 14). The control had a mean value of 13.25 cm.

The crude protein of grain varied between 11.7 % and 14.4 %. Four genotypes (14, 9, 15 and 13) are distinguished by the highest mean values in grain protein content (14.4 %, 14 %, 14% and 13.9 %, respectively). Four genotypes (1, 4, 5 and 8) gave the same mean value of grain protein content as the control (13.7 %). The highest crude fiber content of panicles concerned the genotypes 13, 1 and 2 (31.3 %, 15.2 % and 12.5 %, respectively), followed by the control (with 12 %). The lowest value concerned the genotype 10 (6 %). Concerning the protein content of panicles, twelve genotypes (5, 15, 9, 2, 13, 1, 4, 14, 3, 6, 8 and 10) gave the highest values which varied between a maximum of 13.2 % and a minimum of 11.5 %, exceeding the control with 11.4 %.

Discussion

Through the analysis of variance, a great variability was found among pearl millet cultivars for many characters studied which is very important for breeding works. As indicated by Danjuma and Mohammed (2014), genetic diversification of pearl millet cultivars has been a high priority area in pearl millet improvement research.

Differences among genotypes were very highly significant for plant height, panicle length, panicle thickness, 1000 grain weight and crude fiber content of panicles, significant for stem diameter and high significant for dry matter content of panicles. According to Bhattacharjee et al. (2007), cultivated pearl millet displays tremendous phenotypic variability for traits such as flowering time, panicle length, grain and Stover characteristics, tolerance to drought, pests and diseases as well as nutritional value. A high variability was found among pearl millet genotypes studied by Sumathi et al. (2010) for plant height, ear head length, ear head breadth and others traits. Also, Hassan et al. (2014) found variability among pearl millet varieties for plant height, stem diameter, dry matter yield, crude fiber percentage and other traits.

Differences were no significant for number of productive tillers, total number of tillers, leaf length and ear exsertion distance. Also, no significant difference was detected among populations selected for high and low performance in the number of productive panicles by Haryanto et al. (1998). Leaf area which is the product of leaf length and breadth was significantly different in all forage pearl millet varieties studied by Hassan et al. (2014).

Principal component analysis showed that four components absorbed 81.03 % of variation. The first three components with 71.08 % of total variation were explained by panicle weight, panicle length, panicle thickness, 1000 grain weight, crude fiber content of panicles, protein content of panicles, dry matter content of grain, grain protein content, leaf length, days to maturity, days to heading and plant height. Ear distance exsertion was correlated to the fourth component explaining 9.95 % of total variation. On that same species, Akanvou et al. (2012) found almost similar results with 70.25 % of variation represented by three components were panicle length, panicle

Table 4. Principal component analysis (PC) of 16 pearl millet genotypes based on 13 traits

Parameter	PC 1	PC 2	PC 3	PC 4
Eigen values	4.44	2.86	1.94	1.29
% of variance	34.19	21.98	14.91	9.95
Cumulative %	34.19	56.17	71.08	81.03
Characters		Eigenvector		
LOC	-0.857	0.085	-0.429	0.084
LTI	0.291	0.544	-0.547	0.545
GRC	-0.849	-0.119	0.058	-0.173
PMG	-0.728	-0.308	0.279	0.271
DEP	-0.006	-0.353	-0.71	-0.497
DC	-0.159	-0.629	-0.631	-0.199
LOF	-0.257	0.582	-0.559	0.097
GPR	-0.596	0.646	-0.123	-0.214
PRP	-0.491	0.683	0.076	0.075
DMG	0.547	0.668	0.049	-0.282
CFP	-0.655	-0.258	0.166	0.173
PPA	-0.9	0.014	0.037	0.126
DEX	0.382	-0.436	-0.324	0.643

Table 5. Mean values of pheno-agro-morphological and nutritional traits for 16 pearl millet genotypes

N°	LOC	GRC	TAP	TAT	LTI	GRT	PMG	LOF	GPR	PRP	DMG	DMP	CFP	DEX	PAP	DEP	DC
1	129.7	28.39	6.17	11	204.9	10.11	12.9	55.5	13.7	12.3	93.6	91.3	15.2	9.5	21.27	83	97
2	149.9	34.25	5.5	8.67	261.6	10.09	11.67	62.25	13	12.6	92.9	90.5	12.5	15.17	32.25	83	97
3	128	25.4	4.3	10.5	227.2	8.19	10.45	60.08	12.8	12	93.5	91	11.2	9.42	21.12	91	97
4	128.9	28.35	4	8.83	222.3	10.81	9.43	61.67	13.7	12.3	93.7	92	9.6	8.33	24.14	84	97
5	150.2	36.37	6.17	10	274.8	11.3	11.03	64.58	13.7	13.2	93.7	91.6	8.2	9.67	27.57	89	91
6	140.8	29.23	8.17	12.5	244.2	10.61	9.63	61.5	12.2	11.9	93.5	91.3	9	12.17	18.67	89	104
7	129.9	32.04	2.5	7	211.8	10.62	10.97	59	11.7	11.3	92.8	91.8	11.7	12	18.17	97	105
8	165.2	28.68	4.17	10.67	271.2	10.88	11.25	69.11	13.7	11.7	93	91.6	10	9.33	26.21	91	105
9	144.8	33.47	4.83	11	268.5	9.9	9.12	66	14	12.7	93.5	91	7.9	13.67	22.75	89	94
10	133.1	27.49	5.83	9.67	250	10.65	10.53	58.67	12.9	11.5	93	91	6	11.67	22.24	91	105
11	138.7	30.14	3.33	12	266.5	12.9	11.33	68.75	13.7	11.4	94	89	12	13.25	20.46	97	106
12	145.9	34.29	6	10.17	212	9.5	11.8	57.33	12.2	11	92	90.7	7.6	8.67	27.53	91	106
13	172.8	45.8	6.33	10.33	194.2	10.94	15.62	63.83	13.9	12.4	92	91.3	31.3	9.25	36.48	89	104
14	168.1	41.29	4	9.67	196.9	12.71	10.32	60.67	14.4	12.7	93	90.2	10.6	6.17	31.95	105	111
15	150.8	41.16	4.67	9.83	186.5	13.5	12.22	62.92	14	12.8	93.2	90.9	6.4	9.67	31.21	83	97
16	122.6	34.97	3.5	5.33	182.9	11.81	10.43	59.17	12	10.3	93.5	91	10	13.5	22.95	91	97

thickness, plant height, 1000 grain weight, ear distance exsertion and days to maturity were among the traits explaining the greatest variation between pearl millet accessions, beside other traits.

Correlations showed that grain protein content and protein content of panicles were positively and highly correlated. The grain protein content was negatively and significantly correlated with ear exsertion distance. Crude protein is one of the most important quality determinants of forage crops, higher the crude protein contents in forage better will be its palatability and digestibility (Hassan et al., 2014). The 1000 grain weight which is a very important component of yield was positively and highly correlated with crude fiber content of panicles but negatively and significantly correlated with dry matter content of grain. Fiber content is an important measure of forage quality (Kennelly et al., 1995). The ruminants need a minimum amount of fibers to maintain a good function of rumen (Fulgueira et al., 2007). There were no significant correlations between the 1000 grain weight and the protein content of grains and panicles. In a study taken by Govindaraj et al. (2009), no correlation existed between crude protein and grain yield. The 1000 grain weight was positively and significantly correlated with panicle weight. Haryanto et al. (1998) found that panicle weight was higher in the population selected for high grain yield. Panicle length was positively correlated with panicle thickness and grain protein content. A similar result was found by Govindaraj et al. (2009). Vidyadhar et al. (2007) found a positive but not significant correlation between panicle length and panicle width. The panicle thickness was positively and very highly correlated with panicle weight. In a study taken by Vidyadhar et al. (2007), a positive and significant correlation was found between panicle width and grain yield. Haryanto et al. (1998) found that seed weight, panicle weight and number of productive panicles were important characters for the grain yield. The plant height was positively correlated with the leaf length. Vidyadhar et al. (2007) also found a positive and highly significant correlation between these traits. The plant height is a significant growth attribute directly with the productive prospective of plant in terms of forage yield (Hassan et al., 2014). Days to heading were highly and positively correlated with days to maturity. The same result was found by Wolie and Dessalegn (2011) in finger millet. In pearl millet, Vidyadhar et al. (2007) found a positive and significant correlation between days to flowering and days to maturity.

Conclusion

- Resilient species, pearl millet is one of the crops that can raise the challenge of climate change. Used as food and fodder, this species deserves special interest.
- Knowing the genetic diversity of pearl millet genetic resources and their characteristics is essential both for conservation and breeding works.
- Through this study, a great variability was found among the autochthonous genotypes for many characters related to yield components and nutritional quality which is promising for selection.
- Very interesting potentials has characterized some local cultivars for both parameters related to yield than those related to nutritional value.

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