

ASSESSMENT OF THE DIVERSITY OF PEARL MILLET OF WEST AFRICA AND INDIA BASED ON AGROMORPHOLOGIC TRAITS

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ABSTRACT. Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a basic cereal for many populations living in the arid and semi-arid zones of Africa and India. In Burkina Faso, pearl millet is one of the main cereal crops in the population. However, most of the cultivated varieties are traditional landraces which productivity is always very low. This study goal is to assess and characterize available germplasm of pearl millet of Burkina Faso, India and Togo and to provide the diversity genetic and to identify the traits of interest that could be improved. Estimation of genetic diversity and identification of superior genotypes are essential of any crop improvement program. The trial was carry out during the wet season, 2020-2021 between July and November according to a Fisher block design with three (3) replications. Fourteen (14) quantitative traits were considered. The variability was particularly related, plant height, number of days 50% flowering, time to maturity, panicle length, number of basal tillers, hundred grain weight and overall qualitative trait aspect. An organization of the diversity allowed to classify the accessions into 3 distinct groups. Group 1 individuals had a late cycle, a high plant height, a large number of productive basal tillers and a low 100-grains weight. Accessions of group 2 had a short cycle, high hundred kernel weight and medium plant height. Accessions of group 3 corresponded to accessions with a medium cycle and short plant height. Strong positive correlations were observed between panicle length and plant height, plant height and number of days 50% flowering. The time to 50% flowering, onset to flowering, time to vegetative period, plant height, panicle length and 100-grains weight were less influenced by the environment. Indeed, they showed a heritability in the broad sense greater than to 70%. The variability highlighted in this study could be used to feed the genetic improvement programs of pearl millet in Burkina Faso through the creation of improved varieties.

Keywords: *Pennisetum glaucum*, phenotyping, pre-breeding, Burkina Faso.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* [L.] R. Br.) is the sixth most important cereal world-wide and is the main food source in the poorest regions of India and the African continent. It is a diploid C4 summer grass with 2n=14 chromosomes [1, 2, 3]. About 29 million tons,

or the equivalent of maize production in the United States, is produced in Africa and India [1, 4]. In Sub-Saharan Africa, this species [*Pennisetum glaucum* (L.) R. Br., syn. *Cenchrus americanus* (L.) Morrone] [5, 6] is considered to be the best cereal for millions of people in terms of the contribution of crops to food security. In terms of production amongst African countries, the largest producers are Niger, Sudan, Nigeria, Mali, Burkina Faso, Ethiopia, Chad, and Senegal. Consumers ultimately preferred other cereals with milder taste over millets, which are nutritionally superior but have stronger taste [1]. In Burkina Faso, the genetic variability of cultivated material is mainly managed by small rural farmers in their agricultural field [7, 8]. Its allogamous mode of reproduction depends on the existing genetic variability to ensure a better heterosis effect [9, 10, 11]. Although pearl millet is known for its drought tolerance, a recent review of climate change impact studies indicates that cultivated species are at risk of genetic erosion in their production area [12, 13, 14, 15]. According to [16], the isohyets in Burkina Faso have moved from north to south indicating a drying of the climate around latitudes 13° and 14°. Annual rainfall experiences great variability and has a negative impact on the different morphotypes of pearl millet [17]. However, the endogenous practices of preserving the genetic variability of the species is no longer obvious to increase its production.

Pearl millet yields are much lower in West Africa (WA) than in India. Grain yields in Burkina Faso were on average 1262 kg ha⁻¹ in 2021 [18]. In addition, the adoption of improved open-pollinated varieties (OPVs) was very limited [19, 20] due to the lack of access to improved OPV seed along with their performance that did not always fulfill farmers' preferences [21]. The success in crop improvement programs depends largely on the extent of genetic variability available to the researchers. Genetic breeding programs of plants have had a significant impact on agricultural production.

The present material from the collections of Togo and India should contribute to expanding the genetic variability cultivated in Burkina Faso. To do this, an agromorphological characterization was carried out in order to (i) determine the performance of the agromorphological characters, (ii) identify the relationships between the characters and (iii) structure the accessions on the basis of their characters of interest in the goal of selecting the best genotypes.

MATERIALS AND METHODS

Experimental site

The 72 accessions were evaluated under field conditions in Burkina Faso. The geographic coordinates of site are 1°21' West longitude and 12°24' North latitude. The experiments were arranged in Fisher block designs with three replications. Each accession was sown on 2 m long and spaced 0.75 m apart with an intra-row 0.4 m between hills. The treatment conditions represented the recommendations for pearl millet. The average rainfall of the station varies from 600 mm to 900 mm per year. Maximum temperatures vary between 35 and 40 °C and minimum temperatures between 18 and 19°C. The average rainfall recorded during the rainy season was about 978 mm of water spread over 45 days. The material genetic was measured on morphological and agronomic traits, time to heading, time to 50% flowering, onset to flowering, time to vegetative period, plant height (cm) time to maturity (days), rod diameter (mm), flag sheet length (cm), flag sheet width (cm), total tillers per plant; productive tillers per plant, panicle length, panicle

diameter, panicle weight, 100-grain weight (g). The characters and the measurement stage of plants from pearl millet descriptors.

Plant material

A set of 72 accessions of pearl millet from Burkina Faso, India and Togo were used in this study (Fig.1). We sampled the accessions from world collections assembled by ICRISAT and Burkina Faso germplasm (Table 1).

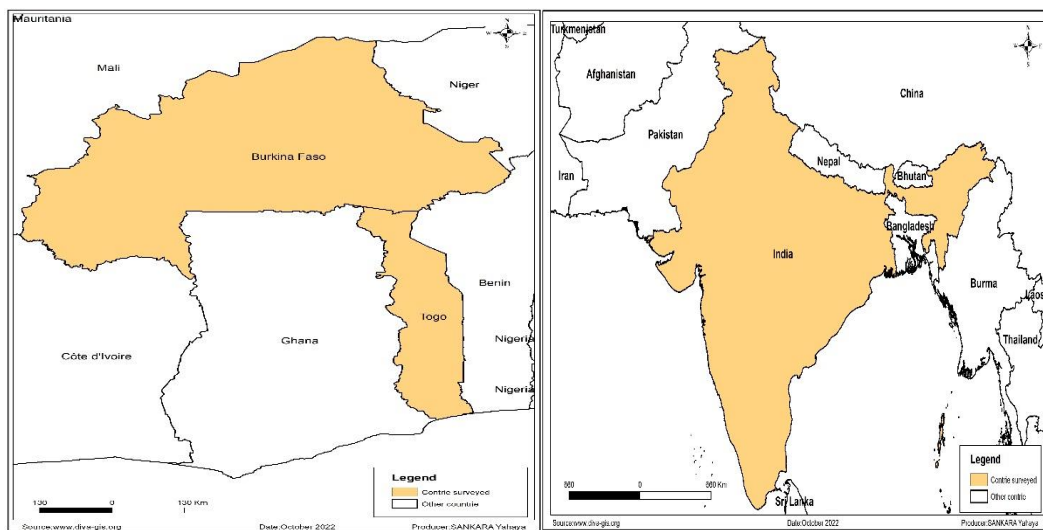


Fig.1. Geographical locations of sample collection site collected from Africa (Burkina Faso and Togo and India)

Table 1. List of material and countries provided

Origin	Membership Code	Number of accessions
Burkina Faso	MC13-5, MC13-13, MC13-14, MCN2, MCN-20, ME12-1, MN13-12, MN13-15, MN13-17, MO10-3, MO12-1, MOg1-U, MS11-7, MS11-14, MS11-20, MS14-1, MS14-3 MS14-5, MS14-6, MS14-7, MS14-12, MS14-15, MS14-24, MS14-31.	24
India	ISP 1577, ISP 1751, ISP 1580, ISP 1816, ISP 1819, ISP 1822, ISP 1894, ISP 1906, ISP 1909, ISP 1911, ISP 1915, ISP 1956, ISP 1977, ISP 1980, ISP 1981, ISP 7, 1985 1995, ISP 1992, ISP 1995, ISP 1998, ISP 1999, ISP 2000, ISP 2002, ISP 2023.	24
Togo	ISP 173, ISP 177, ISP 178, ISP 179, ISP 183, ISP 190, ISP 199, ISP 203, ISP 205, ISP 206, ISP 220, ISP 229, ISP241, ISP 278, ISP 281, ISP 285, ISP 286, ISP 291, ISP 311, ISP 313, ISP 319, ISP 321, ISP 353, ISP 386.	24

Data analysis

One-way ANOVA and followed by Newman-Keuls procedure was carried out with XLSTAT software. Three variance components are calculated: (i) entire population variance, (ii) between sub-population variance, (iii) within sub-population variance.

Genetic correlations between traits are calculated with Pearson correlation matrix. This analysis allows to know traits which can be genetically correlated positive or negative because of pleiotropy (same genes/QTLs affecting different traits) or linkage (genes/QTLs close to each other)

Genetic correlation between traits x and y: $r_g = \sigma_{xy} / \sqrt{(\sigma^2_x * \sigma^2_y)}$

Where

σ_{xy} = covariance between x and y

σ^2_x and σ^2_y the variances of traits x and y

The simple ratio between genetic and phenotypic variance gives estimates of h^2 at the plot level with [22]: $h^2 = \sigma^2_g / (\sigma^2_g + \sigma^2_e)$.

A principal component analysis using R version 4.1.2 software was performed to identify the discriminant traits.

Heterotic groups of landraces were realized with subjected to hierarchical cluster algorithm of Ward with XLSTAT software.

RESULTS AND DISCUSSION

Variation of quantitative characteristics

Table 2 presents the mean values, the standard deviations, the variance, the coefficient of variation and the intervals of variation (minimum and maximum) of the traits studied. The standard deviation of each of the variables studied revealed a significant dispersion around their mean. Higher variability was observed between plant height (*CV:40%*) and panicle weight (*CV:47%*). The variables time to heading, plant height, total tillers per plant, productive tillers per plant, panicle length, panicle weight and 100-grains weight showed a coefficient of variation greater than 30%. The lowest value of the coefficient of variation is obtained with the width variable of the flag sheet. All these variations indicate the presence of significant variability within and between the collection for the agromorphological traits studied.

Table 2. Average performances of the accessions studied for the quantitative traits

Traits	Minimum	Maximum	Mean	standard deviation	CV (%)	Pr (>F)
DUE	5.00	31.00	15.67	5.16	33	3, 07e-10 ***
NJF	33.00	88.00	53.08	11.53	22	<2e-16 ***
DFL	31.00	83.00	48.96	11.76	24	<2e-16 ***
PDS	22.00	81.00	46.14	11.97	26	<2e-16 ***
HTTP (cm)	0.89	503.67	222.90	88.51	40	<2e-16 ***
DIT (mm)	7.70	47.27	13.62	3.39	25	9.57e-06 ***
LOFD (cm)	25.67	74.00	46.68	9.63	21	5.45e-08 ***
LAFD (cm)	2.57	6.70	4.49	0.81	18	7.33e-09 ***
NTB	2.33	16.00	6.97	2.42	35	0.0043 **
NTBP	0.00	10.33	3.94	1.50	38	9.61e-05 ***
LOE (cm)	13.67	81.00	30.41	11.08	36	<2e-16 ***
DIAE (mm)	5.41	37.56	23.23	6.58	28	0.0186 *
PDE (g)	2.67	88.67	38.06	17.83	47	8.74e-14 ***
PCG (g)	0.30	1.80	1.00	0.32	32	<2e-16 ***

Legend: CV% = coefficient of variation; DUE: time to heading; NJF: time to 50% flowering; DFL: onset to flowering; DPV: time to vegetative period; HTTP: plant height; DIT: rod to diameter; LOFD: length to flag sheet; LAFD: width to flag sheet; NTB: total tillers per plant; NTBP: productive tillers per plant; LOE: panicle length; DIAE: panicle diameter; PDE: panicle weight; PCG: 100-grains weight

Structuring of the phenotypic variation of accessions

The variance was different between the different groups of populations constituted according to the variable considered (Fig. 2). For a given population, the high variability depends of trait considered. The variables were better diversified within sup-population than between the sup-population and total population. It is noted that only the variation of trait productive tillers was low between accessions (pop-total), between countries (inter-pop) and within of country (intra-pop).

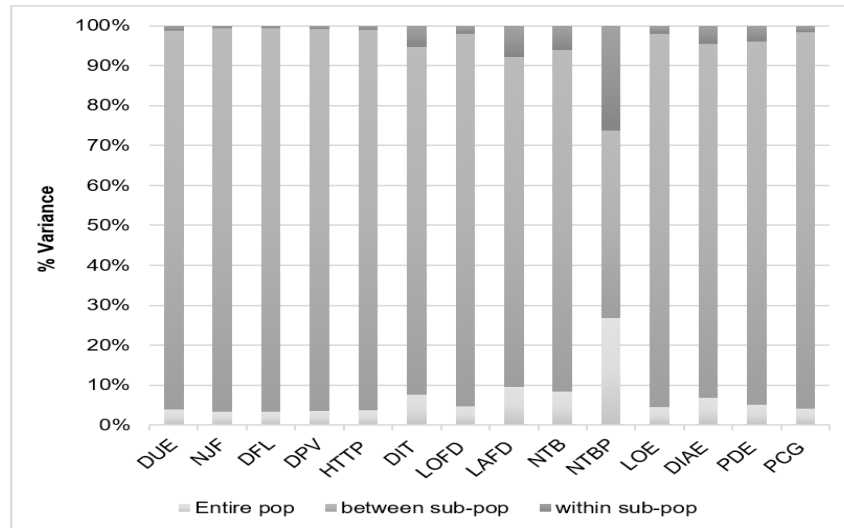


Fig.2. Phenotypic variation of accessions by population group

Inter-population variation of accessions

The Newman Keuls means comparison test of means shows a significant difference between the measured variables of the three countries (Table 3). The date of heading indicates that accessions from Togo (20.09a) have a heading about twice as high as those from Burkina Faso (11.87c). However, the flowering date of accessions from Burkina Faso showed a variance of 15 days to 24 days respectively between accessions from India and Togo. Accessions from Burkina Faso showed very contrasting height and length of panicle with accessions from India and Togo. There is a significant difference between the weight of the seeds to Togo and those to Burkina Faso and to India. The variation is weakly marked between the accessions for the variables number of basal tillers and number of productive tillers per plant.

Table 3. Results of the Newman Keuls Means Comparison Test by Country

Traits	Burkina Faso	India	Togo
DUE	11.87 ^c	15.02 ^b	20.09 ^a
NJF	66.06 ^a	51.01 ^b	42.16 ^c
DFL	62.61 ^a	46.48 ^b	37.79 ^c
PDS	59.62 ^a	43.18 ^b	35.62 ^c
HTTP (cm)	319.08 ^a	150.30 ^c	199.29 ^b
DIT (mm)	15.51 ^a	13.23 ^b	12.11 ^b
LOFD (cm)	53.86 ^a	45.79 ^b	40.38 ^c
LAFD (cm)	4.92 ^a	4.29 ^b	4.24 ^b
NTB	8.13 ^a	6.72 ^b	6.05 ^b
NTBP	4.20 ^a	3.97 ^a	3.62 ^a
LOE (cm)	40.52 ^a	29.53 ^b	21.16 ^c
DIAE (mm)	22.10 ^b	20.79 ^b	26.79 ^a
PDE(g)	52.52 ^a	28.97 ^b	32.67 ^b
PCG (g)	0.9 ^b	0.76 ^c	1.30 ^a

Legend: CV%=coefficient of variation; **DUE:** time to heading; **NJF:** time to 50% flowering; **DFL:** onset to flowering; **DPV:** time to vegetative period; **HTTP:** plant height; **DIT:** rod to diameter; **LOFD:** length to flag sheet; **LAFD:** width to flag sheet; **NTB:** total tillers per plant; **NTBP:** productive tillers per plant; **LOE:** panicle length; **DIAE:** panicle diameter; **PDE:** panicle weight; **PCG:** 100-grains weight

Relationships between characters

The Pearson correlation matrix (Table 4) revealed numerous correlations at the 1% threshold. Indeed, the number of 50% flowering days is strongly negatively correlated with the duration of heading ($r=-0.65$) while the time to 50% flowering days is positively correlated ($r=0.38$) with the panicle weight. As for the panicle diameter, it is negatively correlated with the number of days 50% flowering. Strong correlations were also observed between the start of flowering and the time to 50% flowering days ($r=0.9$), between the plant height at maturity and the time to 50% flowering ($r=0.63$). In addition, the number of productive basal tillers has a strong positive correlation ($r=0.69$) with the number of basal tillers. 100-grains weight ($r=0.18$) was weakly correlated with stem diameter and basal tillers number ($r=0.69$).

Genotypic and phenotypic variances of the different quantitative characters and their coefficients of variation

The phenotypic variation coefficients are higher than the genotypic variation coefficients for all of the 14 traits studied (Table 5). The phenotypic coefficients of variation ranged from 18% to 47% for flag leaf width and panicle weight, respectively. The flag leaf width with a phenotypic variation coefficient of 18% and a genotypic variation coefficient to 11% presents the lowest values.

Furthermore, the number of basal tillers with a phenotypic variation coefficient of 38% and a genotypic variation coefficient of 20%, the plant height with a phenotypic variation coefficient equal to 40% and a genotypic variation coefficient equal to 36% and the panicle weight whose phenotypic variation coefficient is 47% and the genotypic variation coefficient is 34% have high values. The results of the estimation of the genotypic and phenotypic variances of the different traits and their coefficients of variation are given in table 5.

Table 5. Estimation of the genotypic and phenotypic variances of the different traits and their coefficients of variation

Traits	genotypic Variance	Phenotypic Variance	genotypic CV%	phenotypic CV%
DUE	11.84	26.78	22	33
NJF	119.87	133.97	21	22
DFL	131.30	139.60	23	24
PDS	130.57	144.57	25	26
HTTP (cm)	6,420.00	7,894.00	36	40
DIT (g)	3.54	11.54	14	25
LOFD (cm)	35.50	93.16	13	21
LAFD (cm)	0.26	0.65	11	18
NTB	1.09	5.85	15	35
NTBP	0.61	2.27	20	38
LOE (cm)	103.93	123.73	34	37
DIAE (mm)	6.34	43.33	11	28
PDE (g)	166.40	319.60	34	47
PCG (g)	0.07	0.10	27	32

Legend: *DUE*: time to heading; *NJF*: time to 50% flowering; *DFL*: onset to flowering; *DPV*: time to vegetative period; *HTTP*: plant height; *DIT*: rod to diameter; *LOFD*: length to flag sheet; *LAFD*: width to flag sheet; *NTB*: total tillers per plant; *NTBP*: productive tillers per plant; *LOE*: panicle length; *DIAE*: panicle diameter; *PDE*: panicle weight; *PCG*: 100-grains weight

Table 4. Correlation matrix between the different variables studied

Traits	DUE	NJF	DFL	DPV	HTTP	DIT	LOFD	LAFD	NTB	NTBP	LOE	DIAE	PDE
DUE	1												
NJF	0.65**	1											
DFL	0.72**	0.96**	1										
DPV	0.71**	0.94**	0.97**	1									
HTTP	0.34**	0.63**	0.64**	0.64**	1								
DIT	0.22**	0.41**	0.40**	0.39**	0.29**	1							
LOFD	0.38**	0.51**	0.51**	0.48**	0.38**	0.30**	1						
LAFD	0.19**	0.31**	0.30**	0.30**	0.32**	0.31**	0.59**	1					
NTB	0.21**	0.30**	0.35**	0.34**	0.31**	0.03	0.11	0.18**	1				
NTBP	-0.06	0.11	0.16*	0.15*	0.10	-0.11	-0.00	-0.01	0.69**	1			
LOE	0.53**	0.61**	0.61**	0.59**	0.46**	0.37**	0.57**	0.44**	0.19*	-0.07	1		
DIAE	0.18**	0.18**	0.19**	0.19**	0.03	-0.03	-0.04	0.06	-0.24*	-0.09	0.27**	1	
PDE	0.26**	0.38**	0.39**	0.39**	0.59**	0.40**	0.43**	0.44**	0.18*	-0.08	0.63**	0.05	1
PCG	0.47**	0.36**	0.37**	0.33**	0.11	-0.18*	-0.17*	-0.12	-0.15*	-0.09	0.33**	0.34**	0.04

Legend: *: Significant at the 0.05 level; **: Significant at the 0.001 level. DUE: time to heading; NJF: time to 50% flowering; DFL: onset to flowering; DPV: time to vegetative period; HTTP: plant height; DIT: rod to diameter; LOFD: length to flag sheet; LAFD: width to flag sheet; NTB: total tillers per plant; NTBP: productive tillers per plant; LOE: panicle length; DIAE: panicle diameter; PDE: panicle weight; PCG: 100-grains weight

Heritability in the broad sense and genetic progress expected from accessions

Broad-sense heritability ranged from 15 to 94% for panicle diameter and onset of flowering, respectively. The time to 50% flowering (89%), the start of flowering (94%), the length of the vegetative period (90%), the height of the plant (81%) and the panicle length (84%) have heritability values greater than 80% (Table 6). The expected genetic progress compared to the average of the character varies from 8% for the panicle diameter to 66% for the plant height. The highest values of expected genetic progress are observed for the plant height at maturity, while the lowest are obtained for the 100-grains weight, the flag leaf width and the number of productive basal tillers. Onset of heading, stem diameter, flag leaf length, flag leaf width, number of basal tillers, number of productive basal tillers and panicle diameter are expected genetic advances compared to the average moderate, that is to say less than 30%.

Table 6. Heritability, expected genetic progress and expected genetic progress as a percentage of the mean

Traits	Broad sense (h^2)	Expected genetic progress	Expected genetic progress as % of mean
DUE	44	4.69	29
NJF	89	21.22	39
DFL	94	22.88	46
PDS	90	22.29	48
HTTP (cm)	81	148.25	66
DIT (mm)	31	2.17	15
LOFD (cm)	38	7.56	16
LAFD (cm)	41	0.68	15
NTB	19	0.95	13
NTBP	27	0.84	21
LOE (cm)	84	19.25	63
DIAE (mm)	15	2.03	8
PDE(g)	52	19.15	50
PCG (g)	71	0.47	45

Legend: CV% = coefficient of variation. **DUE:** time to heading; **NJF:** time to 50% flowering; **DFL:** onset to flowering; **DPV:** time to vegetative period; **HTTP:** plant height; **DIT:** rod to diameter; **LOFD:** length to flag sheet; **LAFD:** width to flag sheet; **NTB:** total tillers per plant; **NTBP:** productive tillers per plant; **LOE:** panicle length; **DIAE:** panicle diameter; **PDE:** panicle weight; **PCG:** 100-grains weight

Association of quantitative traits

The principal component results (PCA) show the contribution of each variable to the formation of the axes. The cumulative values of the variance of the first two factors (Dim 1 and Dim 1) for the fourteen quantitative variables were 51.09% (Fig. 3). The F1 component (Dim 1) explains 40% of the total variability. F1 associates characters such as: the start to flowering, the time to 50% flowering, the time to vegetative period, the panicle length, the flag leaf length, the plant height and time to heading. Factor F2 (Dim2) contributes 11.9% of the total variability and combines the traits number of basal productive tillers, panicle weight, panicle diameter, 100-grains weight and the number of basal tillers.

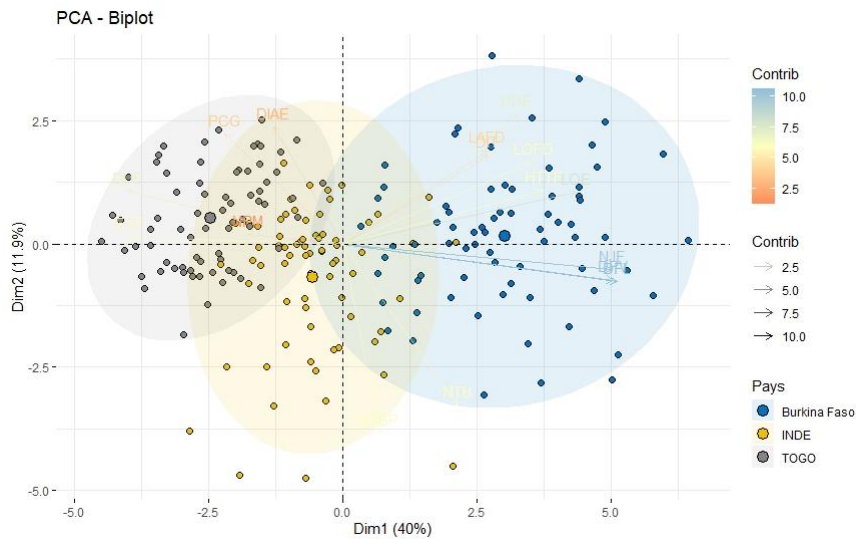


Fig.3. Projection of the variables measured in the plane formed by the first two canonical axes of the principal component analysis

Organization of the phenotypic diversity of pearl millet populations

The dendrogram (Fig. 4) which made it possible to structure the accessions into three groups was made on the basis of variables such as the number of 50% days, the number of basal tillers per plant, the 100-grains weight, the plant height, panicle weight, panicle and stem diameter, panicle length, number of productive basal tillers. The first group consists of 28 accessions including 24 from Burkina Faso, 3 from India and 1 from Togo. The second group is made up of 27 accessions, 22 of which come from Togo and 5 from India. The third group consists of 17 accessions including 16 from India and 1 accession from Togo (Table 7).

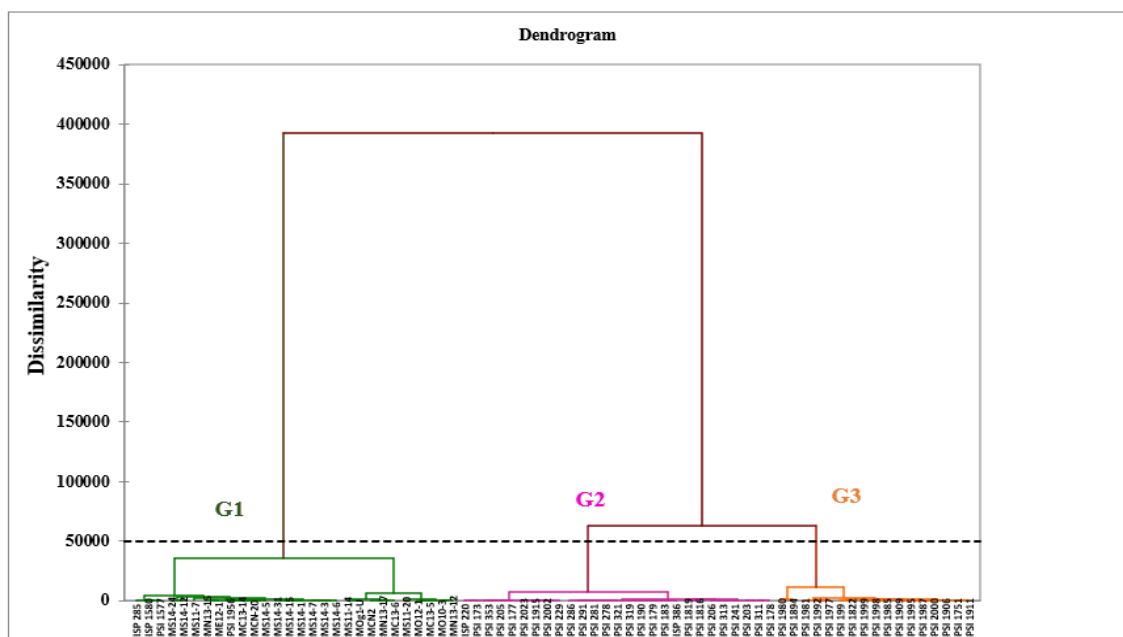


Fig. 4. Dendrogram from the ascending hierarchical classification of our sample

Table 7. *Distribution of accessions in the 3 distribution groups according to ascending hierarchical classification*

Groups	1	2	3
Effective	28	27	17
	MO10-3	PSI 319	PSI 1998
	MN13-12	PSI 183	PSI 1995
	MN13-17	PSI 291	PSI 2000
	MO12-1	PSI 190	PSI 1999
	MS14-15	PSI 278	PSI 1981
	MCN2	PSI 179	PSI 1985
	MS14-31	ISP 386	PSI 1992
	MS14-3	PSI 2023	PSI 1909
	MC13-6	PSI 2002	PSI 1977
	MS14-1	PSI 321	PSI 1980
	MC13-5	PSI 281	PSI 1906
	MC13-14	PSI 286	PSI 1751
	MCN-20	PSI 206	PSI 1987
	MS11-20	PSI 1819	PSI 1894
	MN13-15	PSI 229	PSI 199
	MS11-14	PSI 313	PSI 1822
	MS14-7	PSI 353	PSI 1911
	MS14-6	PSI 205	
	MS11-7	PSI 311	
	ME12-1	ISP 220	
	MS14-24	PSI 178	
	MS14-5	PSI 177	
	MS14-12	PSI 203	
	MOg1-U	PSI 1816	
	ISP 285	PSI 1915	
	ISP 1580	PSI 241	
	PSI 1577	PSI 173	
	PSI 1956		

Characterization of the groups resulting from the CAH

Discriminant factor analysis (Fig. 5) shows observations on the first two axes of the three groups based on agromorphological traits. Group 1 is characterized by high values for the variables plant height, time to 50% flowering, stem diameter and number of basal tillers. The 2nd group stands out by low values for the variables time to heading, time to 50% flowering and panicle diameter. Group 3 presents very low values for the variables plant height, 100-grains weight, panicle weight and panicle diameter.

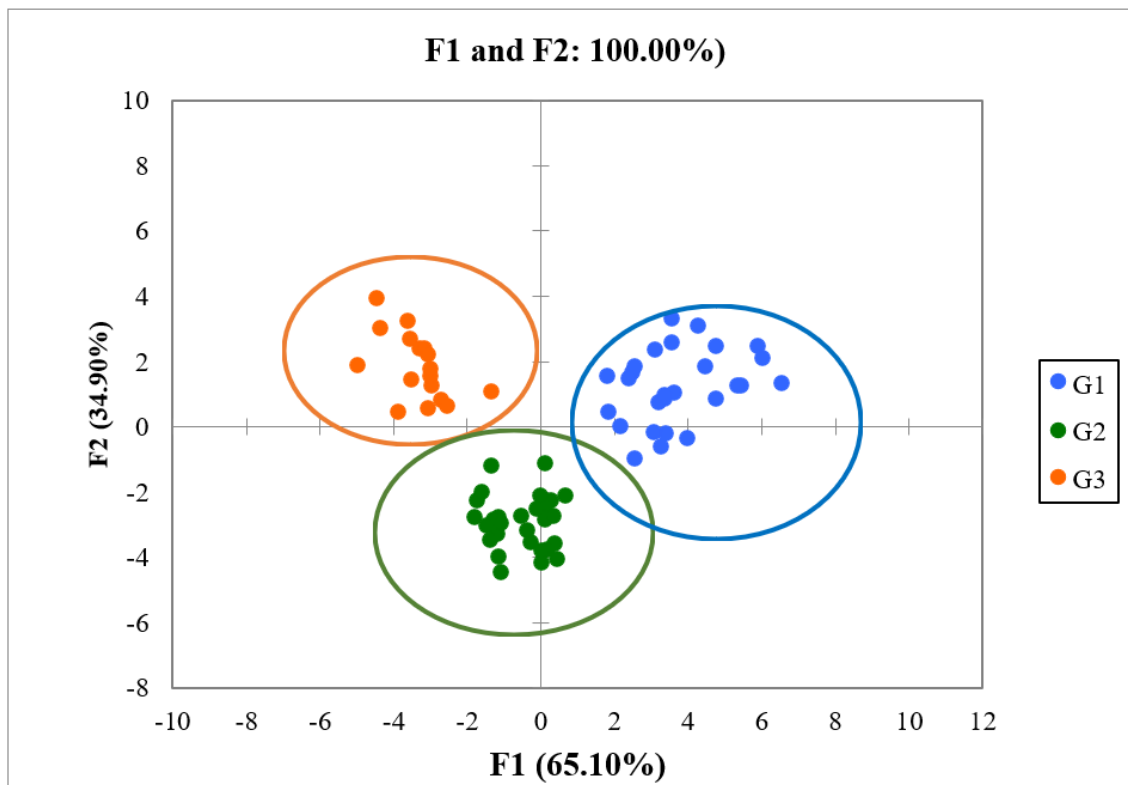


Fig. 5. Projection of the three groups of mil in the plane formed by the first two axes

Pre-breeding activities are the most important work to identify the traits of interest in a collection. The authors as [23] indicate that it can to both qualitative and quantitative traits and the distinction pre-breeding, introgression and incorporation is not always clear. Quantitative traits are normally controlled by multiple genes with various kinds of genetic effect, and their phenotypes are readily modified by environmental variation. The main objective a pre-breeding is to provide breeders with more genetic material that are easier to use, inbreeding-tolerant forms of out-crossing species for hybrid breeding. The accessions showed, on the one hand, highly heritable characters and, on the other hand, high-performance agronomic characters justifying a material with an important genetic base. This studied pearl millet population can be used in short-term genetic improvement of millet. The three types of populations revealed show a preponderant intra and interspecific variability of the accessions marked by a potentially high inter-population diversity. Overall, the accessions showed three heterotic groups according to their geographical origin, which may be a potential for the development of synthetic populations or composite-crosses of millet. Authors like [24, 25, 26] developed composite-cross varieties respectively on millet, barley and wheat through geographically sourced material different. The use of heterotic groups is the basis of a large proportion of hybrids as in maize confirmed by studies of molecular genetic distances [27, 28, 29]. The existence of subpopulations in the collection reflects a dynamic gene pool. Each subgroup of populations may be promising in a given specific environment or several environments. The differentiation of accessions reflects above all differences in environmental selection pressures showing that landraces from India undergo more improvement than landraces from Burkina Faso and Togo. According to [30] in general,

Indian pearl millet landraces have earliness, high tillering, high harvest index, and local adaptation, whereas African landraces are good sources of high head volume, large seed size, and disease resistance.

Traits with high genetic variance were plant height, grain weight, panicle length and flowering cycle, which are mainly traits involved in yield in pearl millet. These traits could increase the potential for long-term genetic progress. According to [31], selection of F₂ populations reveals higher genetic variance, an increase in the expected genetic gain component of selection. Sometimes, the selection pressures for a character in diversified environments leads to fixing, in part, non-identical alleles for all the loci governing this character [32]. Thus, the genetic variability is all the greater as the selection environments are different. These morpho phenological traits are selection criteria used in pearl millet variety improvement and classification programs [33, 34]. Within the accessions themselves, the inter-population phenotypic variation was well above the intra-population variability. The selection criteria considered vary from country to country. Heritability was high for traits such as plant height, flowering date and 100-seed weight. Research on the subject by [35] revealed higher heritability for traits for flowering date, panicle length and width, and flag leaf width. Strong genetic advances were identified on traits related to plant height and flowering cycle indicating the chance of effective selection for these traits. On the other hand, the number of productive tillers and the weight of 100 grains showed low heritability coupled with weak strong genetic progress inducing genetic effects of the dominance/epistasis type of these characters. Similar results were revealed by [35, 36].

The inter-population heterogeneity within the accessions stands out clearly in the PCA which opposes on its component the highly dispersed accessions of Togo and Burkina Faso. Accessions from India are strongly clustered between the two population groups indicating more frequent interbreeding between populations from India with those from Burkina Faso and Togo. The Iniadi germplasm from the Togo, Ghana, Burkina Faso, Benin regions of western Africa is most commonly used in pearl millet breeding programs worldwide [37]. This variety was released in India as MP 124 in Maharashtra and Andhra Pradesh and as PCB 138 in Punjab, while as Okashana 1 in Namibia and as Nyankhombu [ICMV 88908] in Malawi.

CONCLUSION

This study has shown that there is genetic variability within accessions. Accessions from Burkina Faso showed large size, high basal tiller number and low hundred panicle weight. Accessions from Togo showed characters of interest such as the early start of flowering, an average size and a high 100-grains weight. On the other hand, accessions from India prove to be better in terms of dwarf plant. Within the collection, the most discriminating traits were 50% flowering date, plant height, number of basal tillers, stem diameter, panicle length, panicle weight and the weight of a 100-grains. On the basis of the cycle, we can retain the existence of three distinct groups, namely accessions with an extra-early cycle, a short cycle and a late cycle according to the geographical origin. Hence the importance of directing the selection towards the most productive accessions, with an early cycle and awned panicle in order to best meet consumer expectations. As a perspective, we suggest the continuation of work by making a diallel crossing of accessions with traits of interest in order to generate a population of elite accessions useful for genetic improvement programs.

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