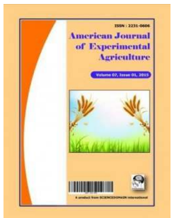

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Climate Change Effect on Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] Genetic Variability in Burkina Faso

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Authors' contributions

This work was carried out in collaboration between all authors. Author LAB wrote the protocol, wrote the first draft of the manuscript and performed the statistical analysis. Author MHO reviewed the experimental design and all drafts of the manuscript. Author NS managed the analyses of the study. Authors MS and LAB identified the plants, designed the study, read and approved the final manuscript.

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ABSTRACT

Aims: To compare pearl millet genetic variability in the different agro-climatic zones in Burkina Faso.

Methodology: The experiments were conducted by Technology and Science Department and bio-sciences laboratory, Pr Joseph Ki-Zerbo University Ouaga 1, between July and October 2015. The test was carried out in rain condition according to a block of Fisher with three replications. Seventy-two (72) accessions were collected in five northern latitudes degrees in Burkina Faso. Nineteen (19) quantitative characters were noted including, eight (8) phenologic traits evaluated on eight (8) feet and eleven (11) agro-morphological characters measured on three (3) plants in each accession.

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Results: The results analyzing showed the difference between the accessions in the five (05) northern latitudes degrees depends more of the phenologic traits than on the agro-morphological characters. The cycle 50% flowering and the plants harvest cycle varied respectively between the five (05) northern latitudes degrees: from 90 to 64 and from 110 to 80 days after sowing. Indeed, the genetic variability higher of the pearl millet was the 10° and 11° northern latitudes and the lowest genetic variability was indicated by the 14° no rthern latitude. This study shows that the rural farmers majority pearl millet selection was early variety cycle.
Conclusion: Climate change effect reduced the genetic base of the pearl millet traditional varieties in the weak rain zones.

Keywords: Climate change; pearl millet; latitude; variability; Burkina Faso.

1. INTRODUCTION

Pearl millet is a plastic crop plant. It stills, one of cereals the most exploited of production systems and of the diets in Sahelian countries [1,2], where majority of inhabitants prefer it than sorghum as culinary ends. It is Burkina Faso second basic commodity the most cultivated, with a national production estimated on 2012 at a little more than one million tons [3]. This pearl millet average consumption per day in Burkina Faso is approximately 70 grams, and is growing since 40 year's [3]. In spite of, this general upward tendency, outputs knew great annual fluctuations since 20 years in the country [3]. This production is mainly assured by the local ecotypes resulting from farmer's selection methods [4]. However, rainfall variability higher within and between the north and the south divides the country in three distinct agro-climatic zones [5]. This Burkina Faso rains variability as the others soudano-sahelian areas of West Africa, is one of the most significant in the world [6]. Nowadays, the rural farmers had modified their cultural methods and their seeds selection modes for because of the climatic variation factors [4]. The country south annual rainfalls are currently three times higher than the north ones [7]. Indeed, the isohyets moving from north to south, explain climate draining around 13° and 14° latitudes [7]. Several authors [8,9] showed the impact which could traduce these climatic variations on agricultural genetic diversity loss. Some studies evoke species cultivated distribution an upheaval possibility like their phenologic traits and their life cycles [10,11,12] on weak rain zones. Thus, it was established the Burkina Faso climatic conditions constitute a threat for its genetic diversity [5]. Others studies reported agricultural species whose vegetative 90 days higher cycle will be threatened to disappearance for climate change reasons [13]. That could undoubtedly provoke a negative impact on outputs, varietal distribution, plants growth and development [14,15] and reduce agricultural species genetic variability under the farming conditions. In order to contribute to the best conservation of pearl millet cultivated local genetic resources on climate change conditions, it is necessary to know the traditional pearl millets genetic variability currently cultivated in Burkina Faso. This study aims to know differences agro climatic level effect of the country and rural farmer's selection modes on pearl millet diversity structuring for a better safeguarding of this resource.

2. MATERIALS AND METHODS

2.1 Genotypes Material

The material is constituted for seventy-two (72) accessions of pearl millet, originated from the different parts of Burkina Faso north latitudes degrees (Fig. 1). They were collected between 10° and 14° northern latitudes which constitute the country three agro-climatic zones. These accessions are cultivated on various types of soil by rural farmers with different selection modes.

2.2 Experimental Site

The experiments were conducted on a muddy-cookie soil in July 2015 under rain condition at the research station, i.e., in Gampela where is Ouagadougou Institute for Rural Development and agronomic research center (Latitude: 12°5' N and Longitude: 1°12' W). The site maximum and minimal annual temperatures vary respectively between 35 to 40°C and 18 to 19°C. Water quantity was 836 mm and distributed on July to October period.

2.3 Experimental Design

Design used, was a Fisher block of three replications. In the replication, each accession is sown on a line of 9 meters length corresponding to 15 seed holes. The spacing was 0.6 meter between holes and 0.8 meter between lines. A plant per hole was selected, 14 days after sowing. Two types of mineral contributions such

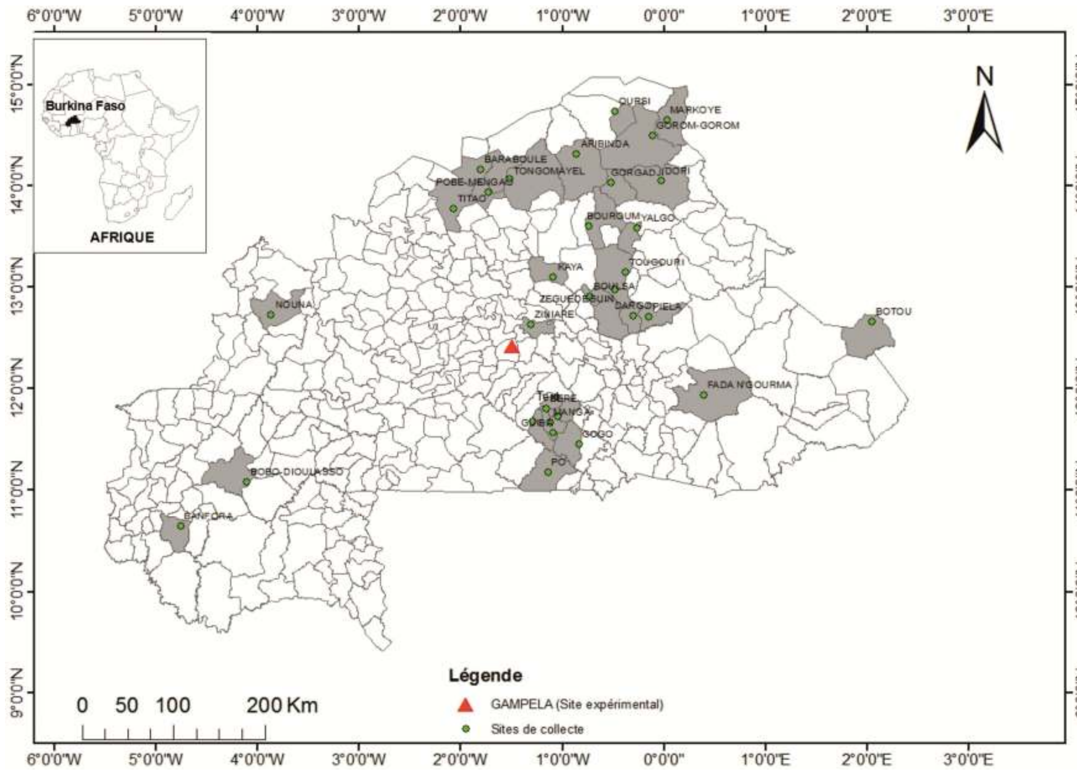

Fig. 1. Localization of collection sites of the accessions

as the NPK (10: 20: 20) and the urea (46% N) were applied respectively during vegetative and reproductive periods of the plants. Two labors were carried out and the last was accompanied of a ridging.

2.4 Phenology Traits and Agro-morphological Characters Measures

The Measurements were carried out to select plants in a random way in each block. Nineteen (19) quantitative characters were noted including, eight (8) phenologic traits evaluated on eight (8) plants and eleven (11) agro-morphological characters measured on three (3) plants in each block. Data were collected on the phenologic traits refer to the leaf flag date appearance (LFD), epiblast date (EPD), flowering beginning date (Fr BD), semi-flowering cycle (50%FrC), vegetative phase (VPD) and reproductive one (RPD) and physiological maturity (PMD) durations and cycle harvest variety (HCV). The agro-morphological characters were the maturity plants height (MPH), diameter between node 3 and 4 of the principal stem (DP3-4), leaf flag length (LFL), leaf flag width (LFW), panicle length (PL), panicle diameter (PD), stalk length (SL), collected panicle number per plant (PN/P), tillers basal number (TBN), report/ratio panicles number collected on a basal tillers number (PN/TBN) and the weight of thousand seeds (1000-WS).

2.5 Statistic Analyses

Data were analyzed with the software R version 3.2.1 in order to compare genetic variability between pearl millet cultures latitudes degrees various. According to Ward's, aggregation method is used for Ascending Hierarchical Clustering (AHC). Accessions discrimination of variables was done by Tukey row multiple tests with *P=.05*. Variation coefficient with *P=.05* is used to evaluate accessions variability level inside each latitude degree. Thus, Levene test by variance homogeneity test with *P= .001* is used to compare the intra-accessions variability within the same latitude degree. As for software XLSTAT pro.2015, it was used to establish the association relationship between the various variables by Principal Components Analysis (PCA) and the group's characterization by a Discriminating Factorial Analysis (DFA).

3. RESULTS

3.1 Phenotypic Structure of Accessions in the Five Northern Latitudes Degrees

The results analyzing emphasizes a significant difference between the two type's latitudes variables (Table 1). The phenologic traits relating to the epiblast appearance date (EPD), to the semi-flowering cycle (50%FrC), the harvest cycle (HCV) and the vegetative phase duration (VPD) and the morphological characters such as the panicle diameter (PD), leaf flag width (LFW) and length (LFL) were significantly different between the latitudes. On the other hand, the variables related plants height of maturity (MPH), the reproductive phase duration (RPD) and the weight of 1000 seeds (1000-SW), the difference was not significant between the latitudes. The comparison analyzing per pair of latitudes indicates a significant difference for related variables majority of the phenologic traits between the 13° and 14° of northern latitudes. Between the 10° and 11° northern latitudes, the difference was not significant inside the major parts of the variables related on morphological characters. However, reproductive period duration is similar between the latitudes. Phenologic traits appearance dates decrease South to North between 10° and 14° latitudes.

The variables variability extent estimated by variation coefficient shows the variability intra-accessions also differ between these latitudes (Table 2). Indeed, the majority of the phenologic traits of 10° latitude having variation coefficient was raised, on the other hand, the phenologic traits on 13° to 14° latitudes were less low (Table 2). The variables related to the morphological characters, the variation coefficient was average for all the latitudes excepted maturity plants height, leaf flag length and width whose variation coefficient was low between 11° and 14° latitudes. This variation coefficients analyzing indicates the variations between the accessions on 10° latitude are higher than the other degrees on the phenologic traits.

Table 1. Variables measures comparison by Tukey row test with *P=.05* in the five degrees of northern latitudes

Degrees	10°	11°	12°	13°	14°
	Mean	Mean	Mean	Mean	Mean
PD (mm)	19.74a	19.03b	21.31c	24.48cd	27.52d
FrBD	82.60a	74.20b	68.33c	62.19d	57.66d
EPD	76.00a	69.34b	60.66c	55.58d	50.71d
50%FrC	90.20a	80.30b	73.74c	69.80c	63.90d
LFD	72.13a	63.91b	56.62c	50.93d	46.09d
HCV	110.66a	106.52a	92.48b	86.03c	79.47c
PMD	98.13a	87.96b	80.11c	74.95c	68.00d
RPD	10.46a	10.28a	11.70a	11.25a	11.57a
VPD	68.13a	59.91b	52.62c	46.93d	42.09d
DP3-4 (mm)	10.18a	9.54b	11.09bc	11.62cd	13.13d
MPH (cm)	308.80ab	317.24ab	308.57ab	307.50ab	281.68b
LFW (cm)	3.44a	3.47b	3.95c	4.56d	5.22d
PL (cm)	37.87a	27.89b	48.06b	40.31b	37.10b
LFL (cm)	39.15a	45.13a	50.91a	50.38b	51.80c
SL (cm)	35.74a	33.28a	35.89ab	36.41ab	38.06b
PN/TBN	0.25a	0.43a	0.42a	0.47a	0.50b
PN/P	4.33a	6.25ab	5.44b	5.38b	5.28b
TBN	21.40a	14.92b	13.48bc	11.31c	10.85c
1000-WS (g)	9.72a	9.34a	8.98a	10.64a	10.60a

The averages followed by the same letter are not significantly different with P =.05.
Key: PD: panicle diameter; Fr BD: flowering beginning date; EPD: epiblast appearance date; 50%FrC: semi-flowering cycle; LFD: leaf flag appearance date; HCV: cycle harvest variety; PMD: physiological maturity date; RPD: reproductive phase duration; VPD: vegetative phase duration; DP3-4: diameter between node 3 and 4 of the principal stem; MPH: maturity plants height; LFW: leaf flag width; PL: panicle length; LFL: leaf flag length; SL: stalk length; PN/TBN: collected panicle numbers report/ratio on a basal tillers number; PN/P: collected panicle number per plant; TBN: basal tillers number; 1000-WS: thousand-seed weight

Table 2. Variation coefficient (CV %) intra-accessions among the five degrees northern latitudes

Degree	10°	11°	12°	13°	14°
PD (mm)	18.55	14.84	12.16	16.65	14.43
FrBD	23.65	08.89	08.31	05.30	06.33
EPD	26.76	09.61	09.57	06.29	06.42
50%FrC	19.54	08.75	08.00	05.40	05.72
LFD	28.27	10.23	09.83	07.37	07.15
HCV	18.46	09.95	09.81	04.91	06.49
PMD	20.74	08.87	08.42	06.86	06.92
RPD	48.16	28.77	14.57	25.58	16.97
VPD	29.93	10.91	10.58	08.00	07.83
DP3-4 (mm)	24.67	12.63	15.05	11.18	14.77
MPH (cm)	10.18	09.65	08.79	09.67	08.82
LFW (cm)	35.29	12.02	09.99	10.40	09.02
PL (cm)	45.82	13.65	32.67	22.99	17.44
LFL (cm)	43.56	10.41	08.44	09.06	08.05
SL (cm)	33.12	16.72	13.90	16.81	12.24
PN/TBN	58.16	32.30	46.18	22.77	27.05
PN/P	33.40	29.68	39.89	25.51	25.48
TBN	44.88	23.10	18.67	17.58	24.06
1000-WS (g)	08.99	28.53	22.35	34.15	22.26

Key: PD: panicle diameter; FrBD: flowering beginning date; EPD: epiblast appearance date; 50%FrC: semi-flowering cycle; LFD: leaf flag appearance date; HCV: cycle harvest variety; PMD: physiological maturity date; RPD: reproductive phase duration; VPD: vegetative phase duration; DP3-4: diameter between node 3 and 4 of the principal stem; MPH: maturity plants height; LFW: leaf flag width; PL: panicle length; LFL: leaf flag length; SL: stalk length; PN/TBN: collected panicle numbers report/ratio on a basal tillers number; PN/P: collected panicle number per plant; TBN: basal tillers number; 1000-WS: thousand-seed weight

The Variance homogeneity test indicates that intra-accessions variance among the five northern latitudes degrees differs significantly (Table 3). Significant Variance appeared for the phenologic traits related to the variables semi-flowering cycle (50%FrC), maturity complete cycle (HCV) in all the latitudes degrees excepted the 14° latitude degree. The variables majority showed that on 14° latitude degree had a low variability with *P= .05* (Table 2). The variance reveals accessions difference depends of the phenologic traits but not agro-morphological characters.

3.2 Correlation between Measured Variables

Phenotypic correlation coefficients between all possible relations of phenologic traits and agro-morphological characters are presented in the Table 4. Phenologic traits correlation variables such as leaf flag appearance date (LFD), maturity complete cycle (HCV), semi-flowering cycle (50%FrC) were significant and positive between them as the agro-morphological characters like panicles diameter and their length (PD, PL) and principal stem diameter (DP3-4). Indeed, leaf flag appearance date was highly and positivity correlated with semi-flowering cycle (50%FrC) and maturity harvest cycle and basal tillers number. Thus, the principal stem diameter was negatively correlated with maturity plants height whereas positively correlated with panicle diameter and his length. The agro-morphological characters as panicle diameter (PD), panicle length (PL) and principal stem diameter (DP3-4) were negatively correlated with the phenologic traits such as leaf flag appearance date (LFD), semi-flowering cycle (50%FrC) and complete maturity cycle (HCV).

The principal Components Analysis (PCA) resulting from correlation matrix variables showed the first and second axes respectively account for 46 and 14% of the total variance between accessions (Table 4). The first axe with F1=46% associates LFD, 50% FrC, TBN, HCV, DP3-4, PL, PD and the second one with F2=14% associates PN/P, LFL, MPH. These variables contribute better to the both construction (F1 and F2). Indeed, the first axe (F1) determines

Table 3. Value *P* of data per variance of analysis

Degree	10°	11°	12°	13°	14°
PD (mm)	0.02 *	0.06	0.26	4.026e-06 ***	0.44
FrBD	0.11	4.668e-06 ***	0.001 **	0.006**	0.11
EPD	0.51	0.001 **	0.02 *	0.01 *	0.16
50%FrC	0.04 *	7.31e-05 ***	0.008 **	0.02 *	0.06
LFD	0.32	0.01 *	0.05	0.004 **	0.31
HCV	0.04 *	0.01 *	0.07	0.03 *	0.16
PMD	0.05	0.006 **	0.14	0.007 **	0.18
RPD	0.01 *	0.005 **	0.02 *	0.001 **	0.06
VPD	0.32	0.01 *	0.05	0.004 **	0.31
DP3-4 (mm)	0.16	0.0003 ***	0.07	0.004 **	0.23
MPH (cm)	0.15	0.005 **	0.01 *	0.01 *	0.43
LFW (cm)	0.07	0.03 *	0.02 *	0.12	0.76
PL (cm)	0.04 *	0.005 **	0.37	0.001 **	0.48
LFL (cm)	0.26	0.2865	0.14	0.43	0.08
SL (cm)	0.07	0.002 **	0.14	0.08	0.51
PN/TBN	0.13	0.0007 ***	0.12	0.0005 ***	0.11
PN/P	0.35	0.03 *	0.30	0.006**	0.70
TBN	0.12	0.001 **	0.70	0.01 *	0.01 *
1000-WS (g)	0.24	0.003 **	0.013 *	0.0001 ***	0.02 *

*Key:'***': significant difference at 0; ' ** ' significantly different at .001; ' * ' significantly different at .01,' ' significantly different at .05; PD: panicle diameter; FrBD: flowering beginning date; EPD: epiblast appearance date; 50%FrC: semi-flowering cycle; LFD: leaf flag appearance date;* HCV: cycle harvest variety*; PMD: physiological maturity date; RPD: reproductive phase duration; VPD: vegetative phase duration; DP3-4: diameter between node 3 and 4* of the principal stem*; MPH: maturity plants height; LFW: leaf flag width; PL: panicle length; LFL: leaf flag length; SL: stalk length; PN/TBN: collected panicle numbers report/ratio on a basal tillers number; PN/P: collected panicle number per plant; TBN: basal tillers number; 1000-WS: thousand-seed weight*

positivity LFD, 50%FrC, HCV, TBN, PD which opposed DP3-4, PL and the second axe (F2) determines positivity PN/P, MPH, LFL related agro-morphological characters.

3.3 Phenotypic Diversity of Pearl Millet in Burkina Faso

The discriminating factorial analysis (DFA) reveals three significant groups within the studied collection (Fig. 2).This accessions distribution was discriminated by the following variables: 50%FrC, LFD, HCV, DP3-4, PL, PD which showed a significant difference between the different northern latitudes degrees. Indeed, the groups 1 and 3, comparison in the first axe (F1, 96%) was strongly opposed. Group 1 defines early accessions cycle opposed on same axe to the group 3 which defines long accessions cycle. The Group 2 occupies an intermediate position between the groups 1 and 3. The group 2 majority accessions was near with the group 1 and represent semi-early accessions cycle.

The Ascending Hierarchical Clustering (AHC) on variables basis resulting from the Principal Component Analysis shows mainly two groups at 300 as truncation (Fig. 3). The phenologic traits variables contributed better to the diversity accessions structuring. The principal variables like leaf flag appearance date, semi-flowering cycle, maturity complete cycle, and vegetative period duration discriminating better the groups. The Group 1 defined as the early accessions, represented 65% of accessions and the group 2 represented by 35% of accessions was the long term accessions cycle. These long term accessions cycle come from the 10° and 11° northern latitudes. On the other hand, all accessions on 12° to 14° northern latitudes were in the group 1 excepted the 10° and 11° witch accessions were in the group 1 and the group 2. Indeed, pearl millet agro-morphological diversity structuring in Burkina Faso indicates that accessions were similar between 10° to 11° northern latitude and between 12° to 14° northern latitudes.

Table 4. Correlation coefficients between characters and principal components analysis

Characters	LFD	50%FrC	PN/P	TBN	HCV	1000WS	MPH	DP3-4	LFL	PL	PD	SL	Axes correlation	
													F1	F2
LFD	1												**0,931**	0,015
50%FrC	0,942*	1											**0,932**	0,070
PN/P	-0,009	0,059	1										0,099	**0,681**
TBN	0,702*	0,646*	0,062	1									**0,708**	-0,108
HCV	0,884*	0,887*	0,083	0,603*	1								**0,930**	0,072
1000WS	-0,270	-0,228	0,004	-0,127	-0,234	1							-0,245	-0,218
MPH	0,275	0,316	0,350	0,039	0,265	-0,058	1						0,255	**0,773**
DP3-4	-0,682*	-0,722*	-0,197	-0,457	-0,747*	0,036	-0,308*	1					**-0,824**	-0,121
LFL	-0,578*	-0,536*	0,193	-0,510*	-0,497	-0,035	0,173	0,471	1				-0,650	**0,545**
PL	-0,359	-0,410	-0,198	-0,295	-0,479	-0,185	0,016	0,526*	0,555*	1			**-0,553**	0,232
PD	-0,685*	-0,681*	-0,172	-0,451	-0,742*	0,400	-0,250	0,649*	0,352	0,286	1		**-0,790**	-0,218
SL	-0,402	-0,407	0,174	-0,220	-0,406	0,205	0,097	0,359	0,348	0,274	0,380	1	-0,502	0,353
Component														
Principal value												5,52	1,66	
% variance												46	13,89	
% cumulated												46	59,89	

Key: LFD: leaf flag appearance date; 50%FrC: semi-flowering cycle; PN/P: collected panicle number per plant; TBN: basal tillers number; HCV: cycle harvest variety*; 1000-WS: thousand-seed weight; MPH: maturity plants height; DP3-4: diameter between node 3 and 4* of the principal stem; *LFL: leaf flag length; PL: panicle length; PD: panicle diameter and SL: stalk length*

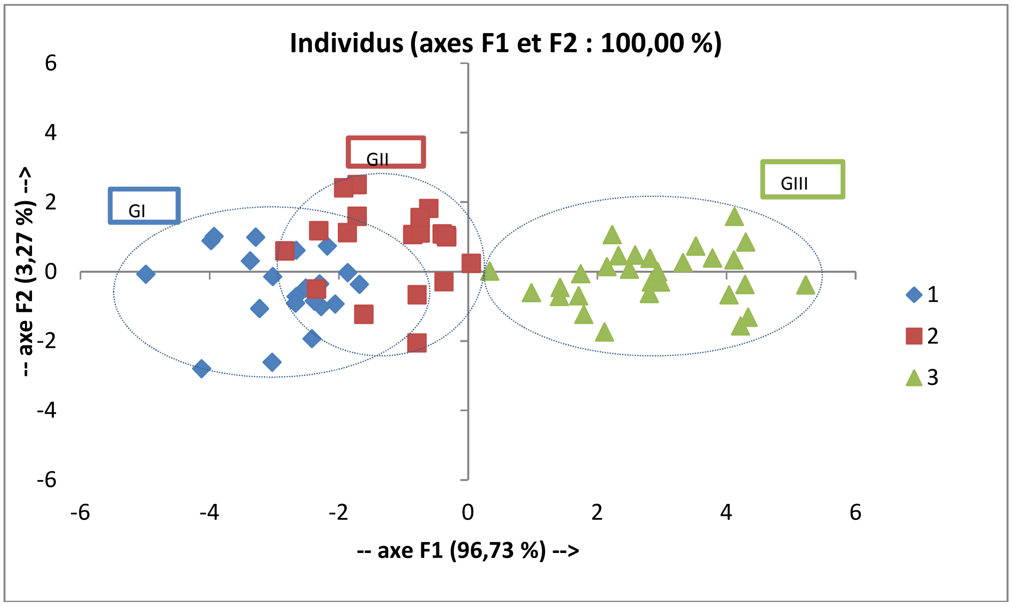

Fig. 2. Accessions organization by Discriminating Factorial Analysis (DFA)

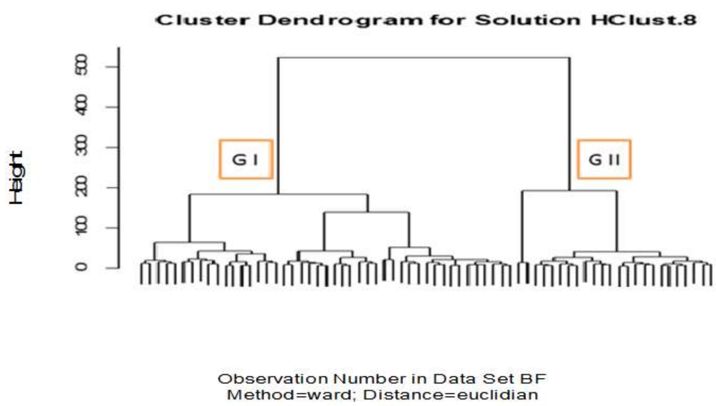

Fig. 3. Accessions structuring by the Ascending Hierarchical Clustering (AHC)

4. DISCUSSION

The accessions resulting from the various agro-climatic zones are quite distinct. Indeed, the diversity structuring is mainly related by phenologic traits through the plant cycles variables with 50% flowering. The climate being the response factor of crop plants diversity according to [16], was certainly a major element in the seed-bearer management of the rural farmers. The phenologic traits high variability compared to the agro-morphological characters between different latitudes shows well that climate effect on the genetic variability of the pearl millet is significant. Similar results had been reported by [17,18] showing the significant impact of environment on the genetic variability of the pearl millet. Indeed, the 10° and 11° northern latitudes with a rainfall ranging between 900 mm and 1200 mm water per year, could explain the significant variability observed in this agro-climatic zones. The latitude 10° and 11° northern latitudes contain long term varieties and semi and early cycles. The highest diversity in the south oppositing to the north is explained by the fact that climatic factor strongly influences the millet selection. These results are in accordance with those of [19] which showed that climate change impact contributes to reduce crop plants genetic diversity in sahelian zone. Our results compared to [20] ones reveal the adoption by the southern rural farmers of the early and semi-early varieties following to the climatic variations. Former studies of [4] had also revealed the early cycle varieties presence in the Burkina southern zone. This pearl millet genetic variability in the 10° and 11° latitudes is particularity in relation with phenologic traits. These variables with a high variability refer primarily to the cycle 50% flowering (19.54%), to the plant cycle (18.46%) and to the vegetative period duration (29.93%). The phenologic traits are the variables which discriminate more pearl millet accessions. In the agro-morphological characterization of the pearl millet, the first scission is based on the plant cycle attested by the studies of [21] in the pearl millet genetic structuring. The early cycle varieties adoption in the country agro-climatic zones whole is due to climate change. This idea corresponds to [22] showing the imposition of the early cycle varieties selection as well as in north and south. The rural farmers explain the rainfall reduction over the last years for keeping their long term varieties. [23] reported a preference of the early cycle varieties in traditional genetic resources exchange and selection conditions by the rural farmers. An inversion of the pearl millet variability following the Northern and Southern gradient was noted. These results could be due to the climate change in Burkina Faso where long term varieties disappeared in the northern zones [13]. The populations movements from the northern arid regions to the south could have also contributed to increase pearl millet diversity in the south of the country. The 12° and 13° latitudes reveal that the cultivated varieties mainly come from semi-early cycles. These varieties cycle where less than 85 days. The northern soudanian zone showed a higher rain variation in comparison to the two other zones of the country during last years ago according to [24].

Others characters by which farmers select are sometimes related to the agronomic ones. Indeed, the rural farmers by selecting the parallel varieties to take into account the output and the plant cycle. Several studies [25] showed that a good comprehension of the pearl millet genetic variability and its components improve the effectiveness and efficiency of plants selection. The lowest genetic variability was observed in the 14° latitude whose varieties are mainly earlies. The sub-sahelian zone characterized by a draining of the climate [7] justifies today the pearl millet lowest diversity related to plants cycles in the 14° latitude. The climatic variations effect is more dominating in the sub-sahelian zone causing a reduction of plants cycle. Similar results were observed in Niger whose impact of climate change on the plants cycle [26]. The seeds management by the rural farmers is largely influenced by the climate in particular the significant rain variations between agro-climate zones various.

5. CONCLUSION

From this study, it rises a high pearl millet genetic variability in the 10° and 11° northern latitudes in Burkina Faso is linked to phenologic traits. The most restricted variability is in the 14° northern latitude. The accessions criteria selection is oriented toward the early varieties in all the degrees latitudes of the country. Thus, the flowering cycle and the plant cycle are the identified variables as criteria of different analyses discrimination. The Burkina Faso pearl millet is structuring in early and long term varieties. We can retain that the long term varieties are exclusively confining in the 10° and 11° latitudes. In fact the climate change effect reduced the genetic base of the pearl millet traditional varieties.

Others studies like the molecular characterization of the accessions using markers microsatellites and the grains biochemical analyzes could more determine the pearl millet variability in Burkina Faso.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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