

Effect of the climate change on genetic variability of the Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] in Burkina Faso

ABSTRACT

Aims: To compare pearl millet genetic variability in the different agro-climatic zones in Burkina Faso.
Study design: The test was carried out in rain condition according to a block of Fisher with three replications.
Place and Duration of Study: Department of Technology Science and laboratory of bio-sciences, University of Ouaga1 Pr Joseph Ki-Zerbo, between July and October 2015.
Methodology: Seventy-two (72) accessions were collected in five degrees northern latitudes in Burkina Faso. 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) feet in each accession.
Results: The results analyzing showed the difference between the accessions in the five degrees northern latitudes depends more of the phenologic traits than on the morphological characters. The cycle 50% flowering and the plants harvest cycle varied respectively between the five degrees northern 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 genetic variability lowest was indicated 14° northern latitude. The study shows accessions majority selection by rural farmers was cycle early variety.
Conclusion: The effect of climate change reduced the genetic base of the pearl millet traditional varieties in the weak rain zones.

Keywords: Climate change, Millet, Latitude, 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, and 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 (Figure1). 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.

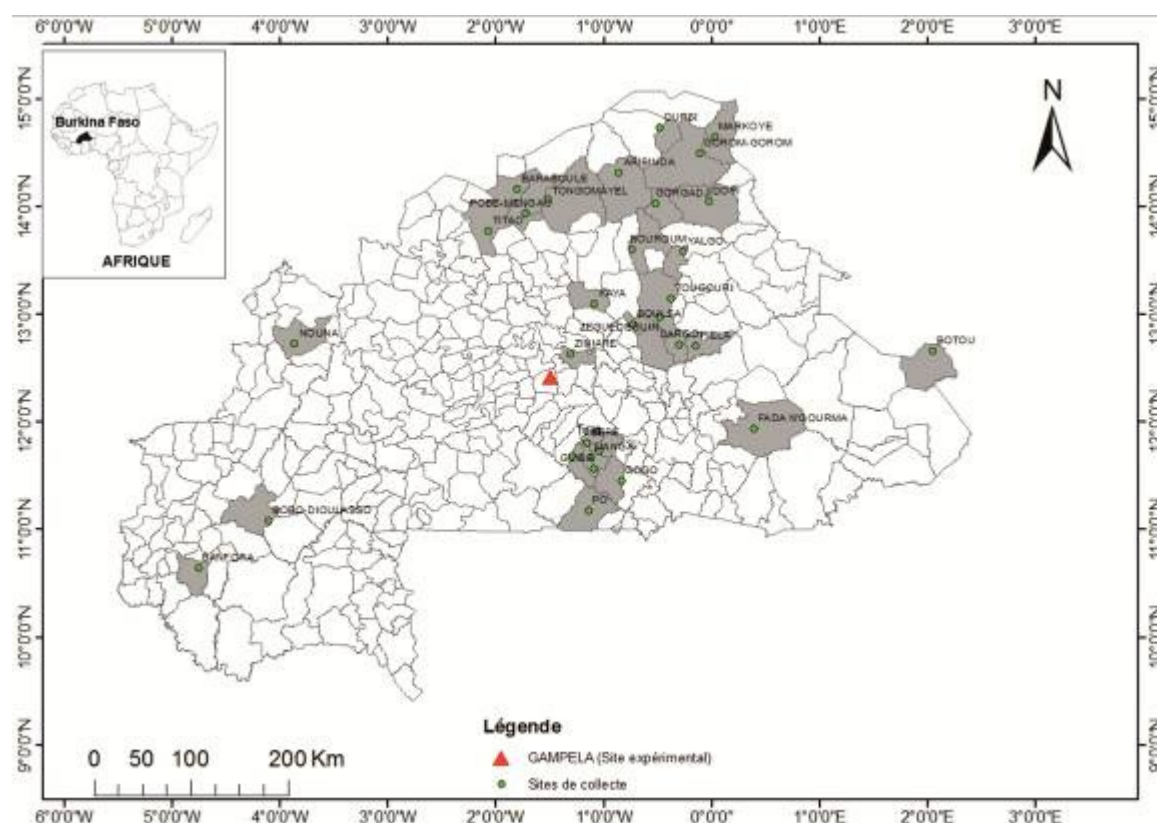


Figure 1: Localization of collection sites of the accessions

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 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) feet and eleven (11) agro-morphological characters measured on three (3) feet in each block. Data were collected on the phenologic traits refer to the sheet flag date appearance (DFD), epiblast date (EPD), flowering beginning date (DDF), flowering 50% cycle (50%CF), vegetative phase (DPV) and reproductive one (DPR) and physiological maturity (DMP) durations and cycle harvest variety (DMC). The agro-morphological characters were the maturity plants height (HPM), diameter between 3^e and 4^e node of the principal stem (DT3-4), leaf flag length (LOFD), leaf flag width (LAFD), panicle length (LOE), panicle diameter (DAE), stalk length (LOP), collected panicle number per plant (RER/P), report/ratio number panicles collected on a basal tillers number (NER/NTB), tillers basal number (NTB) and the weight of 1000 seeds (PMG).

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 (FAD).

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 (Table1). The phenologic traits relating to the epiblast appearance date (EPD), to the flowering 50% of cycle (50%CF), the harvest cycle (DMC) and the vegetative phase period (DPV) and the morphological characters such as the panicle diameter (DAE), leaf flag width (LAFD) and length (LOFD) were significantly different between the latitudes. On the other hand, the variables related plants height of maturity (HPM), the reproductive period duration (DPR) and the weight of 1000 seeds (PMG), 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 (Table2). 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
DAE (mm)	19.74a	19.03b	21.31c	24.48cd	27.52d
DDF	82.60a	74.20b	68.33c	62.19d	57.66d
DEP	76.00a	69.34b	60.66c	55.58d	50.71d
50% CF	90.20a	80.30b	73.74c	69.80c	63.90d
DFD	72.13a	63.91b	56.62c	50.93d	46.09d
DMC	110.66a	106.52a	92.48b	86.03c	79.47c
DMP	98.13a	87.96b	80.11c	74.95c	68.00d
DPR	10.46a	10.28a	11.70a	11.25a	11.57a
DPV	68.13a	59.91b	52.62c	46.93d	42.09d
DT3-4 (mm)	10.18a	9.54b	11.09bc	11.62cd	13.13d
HPM (cm)	308.80ab	317.24ab	308.57ab	307.50ab	281.68b
LAFD (cm)	3.44a	3.47b	3.95c	4.56d	5.22d
LOE (cm)	37.87a	27.89b	48.06b	40.31b	37.10b
LOFD (cm)	39.15a	45.13a	50.91a	50.38b	51.80c
LOP (cm)	35.74a	33.28a	35.89ab	36.41ab	38.06b
NER/NTB	0.25a	0.43a	0.42a	0.47a	0.50b
NER/P	4.33a	6.25ab	5.44b	5.38b	5.28b
NTB	21.40a	14.92b	13.48bc	11.31c	10.85c
PMG (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: DAE: panicle diameter; DDF: flowering beginning date; EPD: epiblast appearance date; 50%CF: semi-flowering cycle; DFD: leaf flag appearance date; DMC: maturity complete cycle; DMP: physiological maturity date; DPR: reproductive period duration; DPV: vegetative period duration; DT3-4: diameter between node 3 and 4; HPM: maturity plants height; LAFD: leaf flag width; LOE: panicle length; LOFD: leaf flag length; LOP: stalk length; NER/NTB: collected panicle numbers report/ratio on a basal tillers number; NER/P: collected panicle number per plant; NTB: basal tillers number; PMG: thousand-seed weight

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

Degree	10°	11°	12°	13°	14°
DAE (mm)	18.55	14.84	12.16	16.65	14.43
DDF	23.65	08.89	08.31	05.30	06.33
DEP	26.76	09.61	09.57	06.29	06.42
50% CF	19.54	08.75	08.00	05.40	05.72
DFD	28.27	10.23	09.83	07.37	07.15
DMC	18.46	09.95	09.81	04.91	06.49
DMP	20.74	08.87	08.42	06.86	06.92
DPR	48.16	28.77	14.57	25.58	16.97
DPV	29.93	10.91	10.58	08.00	07.83
DT3-4 (mm)	24.67	12.63	15.05	11.18	14.77
HPM (cm)	10.18	09.65	08.79	09.67	08.82
LAFD (cm)	35.29	12.02	09.99	10.40	09.02
LOE (cm)	45.82	13.65	32.67	22.99	17.44
LOFD (cm)	43.56	10.41	08.44	09.06	08.05
LOP (cm)	33.12	16.72	13.90	16.81	12.24
NER/NTB	58.16	32.30	46.18	22.77	27.05
NER/P	33.40	29.68	39.89	25.51	25.48
NTB	44.88	23.10	18.67	17.58	24.06
PMG (g)	08.99	28.53	22.35	34.15	22.26

Key: DAE: panicle diameter; DDF: flowering beginning date; EPD: epiblast appearance date; 50%CF: semi-flowering cycle; DFD: leaf flag appearance date; DMC: maturity complete cycle; DMP: physiological maturity date; DPR: reproductive period duration; DPV: vegetative period duration; DT3-4: diameter between node 3 and 4; HPM: maturity plants height; LAFD: leaf flag width; LOE: panicle length; LOFD:

leaf flag length; LOP: stalk length; NER/NTB: collected panicle numbers report/ratio on a basal tillers number; NER/P: collected panicle number per plant; NTB: basal tillers number; PMG: thousand-seed weight

The variance of homogeneity test indicates differ significantly the intra-accessions variance among the five degrees northern latitudes (Table3). Variance significant appeared for the phenologic traits related to the variables semi-flowering cycle (50%CF), maturity complete cycle (DMC) in all the latitudes except on 14° latitude. The variables majority It is noted that the majority on 14° latitude has a low variability with $P=.05$ (Table 2). The variance reveals accessions differences depends on the phenologic traits and no morphological characters.

Table3: Value P of data per variance of analysis

Degree	10°	11°	12°	13°	14°
DAE (mm)	0.02 *	0.06	0.26	4.026e-06 ***	0.44
DDF	0.11	4.668e-06 ***	0.001 **	0.006**	0.11
DEP	0.51	0.001 **	0.02 *	0.01 *	0.16
DF50%	0.04 *	7.31e-05 ***	0.008 **	0.02 *	0.06
DFD	0.32	0.01 *	0.05	0.004 **	0.31
DMC	0.04 *	0.01 *	0.07	0.03 *	0.16
DMP	0.05	0.006 **	0.14	0.007 **	0.18
DPR	0.01 *	0.005 **	0.02 *	0.001 **	0.06
DPV	0.32	0.01 *	0.05	0.004 **	0.31
DT3-4(mm)	0.16	0.0003 ***	0.07	0.004 **	0.23
HPM (cm)	0.15	0.005 **	0.01 *	0.01 *	0.43
LAFD (cm)	0.07	0.03 *	0.02 *	0.12	0.76
LOE (cm)	0.04 *	0.005 **	0.37	0.001 **	0.48
LOFD (cm)	0.26	0.2865	0.14	0.43	0.08
LOP (cm)	0.07	0.002 **	0.14	0.08	0.51
NER/NTB	0.13	0.0007 ***	0.12	0.0005 ***	0.11
NER/P	0.35	0.03 *	0.30	0.006**	0.70
NTB	0.12	0.001 **	0.70	0.01 *	0.01 *
PMG (g)	0.24	0.003 **	0.013 *	0.0001 ***	0.02 *

Key:****: significant difference at 0; ' ** ' significantly different at with the threshold of .001; ' * ' significantly different at .01, ' ' significantly different at .05; DAE: panicle diameter; DDF: flowering

146 *beginning date; EPD: epiblast appearance date; 50%CF: semi-flowering cycle; DFD: leaf flag appearance*
 147 *date; DMC: maturity complete cycle; DMP: physiological maturity date; DPR: reproductive period*
 148 *duration; DPV: vegetative period duration; DT3-4: diameter between node 3 and 4; HPM: maturity plants*
 149 *height; LAFD: leaf flag width; LOE: panicle length; LOFD: leaf flag length; LOP: stalk length; NER/NTB:*
 150 *collected panicle numbers report/ratio on a basal tillers number; NER/P: collected panicle number per*
 151 *plant; NTB: basal tillers number; PMG: thousand-seed weight*

152 **3.2 Correlation between measured variables**

153 Phenotypic correlation coefficients between all possible relations of phenologic traits and morphological
 154 characters are presented in table 4. Correlation of phenologic traits variables such as leaf flag
 155 appearance date (DFD), maturity complete cycle (DMC), semi-flowering cycle (50%CF) were significant
 156 and positive between them and as the morphological characters, diameter and the length of panicles
 157 (DAE, LOE) and the principal stem diameter (DT3-4). Indeed, leaf flag appearance date was highly and
 158 positivity correlated with semi-flowering cycle (50%CF) and maturity harvest cycle duration and basal
 159 tillers number. Thus, principal stem diameter was correlated and negatively with maturity plants height
 160 whereas correlated and positively with panicle diameter and length. The morphological characters,
 161 panicle diameter (DAE), panicle length (LOE) and principal stem diameter (DT3-4) were correlated and
 162 negatively with the phenologic traits such as leaf flag appearance date (DFD), semi-flowering cycle (50%
 163 CF) and maturity complete cycle (DMC).

164 The principal Components Analysis (PCA) resulting from correlation matrix variables showed the axes
 165 first and second respectively account for 46 and 14% constitute total variance between accessions (Table
 166 4). The axis first with F1=46% associates variables (DFD, 50%CF, NTB, DMC, DT3-4, LOE, DAE) and
 167 the axis second with F2=14% associates variables (NER/P, LOFD, HPM). These variables contribute
 168 better in the construction of the two axes (F1et F2). Indeed, the axis first (F1) determines positivity
 169 variables (DFD, 50%CF, DMC, NTB, DAE) which opposed variables (DT3-4, LOE) and the axis second
 170 (F2) determines positivity the variables (NER/P, HPM, LOFD) related morphological characters.

%
cumulated

46

59,89

3.3 Phenotypic diversity of pearl millet in Burkina Faso

The discriminating factorial analysis reveals three significant groups within the studied collection (Figure 2). This accessions distribution was discriminated by the variables (50% CF, DFD, DMC, DT3-4, LOE, DAE) which showed a significant difference between the different degrees northern latitudes. Indeed, groups 1 and 3, comparing axis F1 (96%) were strongly opposed. Group 1 defines early accessions cycle opposed on same axis group 3 which defines long accessions cycle. Group 2 occupies an intermediate position between groups 1 and 3. The accessions majority of group 2 was near with group 1 and represents semi-early accessions cycle. Ascending Hierarchical Clustering (AHC) on the basis of variable resulting from the Principal Component Analysis shows mainly two groups at 300 as truncation (Figure 3). The variables of the phenologic traits contributed better structuring accessions diversity. The variables principal, leaf flag appearance date, semi-flowering cycle, maturity complete cycle, and vegetative period duration were those which discriminate better the groups. Group 1 defines as early accessions represented (65%) of accessions and group 2 representing by 35% of accessions was long term accessions cycle. These long term accessions cycle from the 10° and 11° northern latitudes. On the other hand, all accessions on 12° to 14° northern latitudes were in group 1, except the 10° and 11° witch accessions were in group 1 and group 2. Indeed, pearl millet structuring agro morphological diversity in Burkina Faso indicates similar accessions between on 10° to 11° northern latitude and between on 12° to 14° northern latitudes.

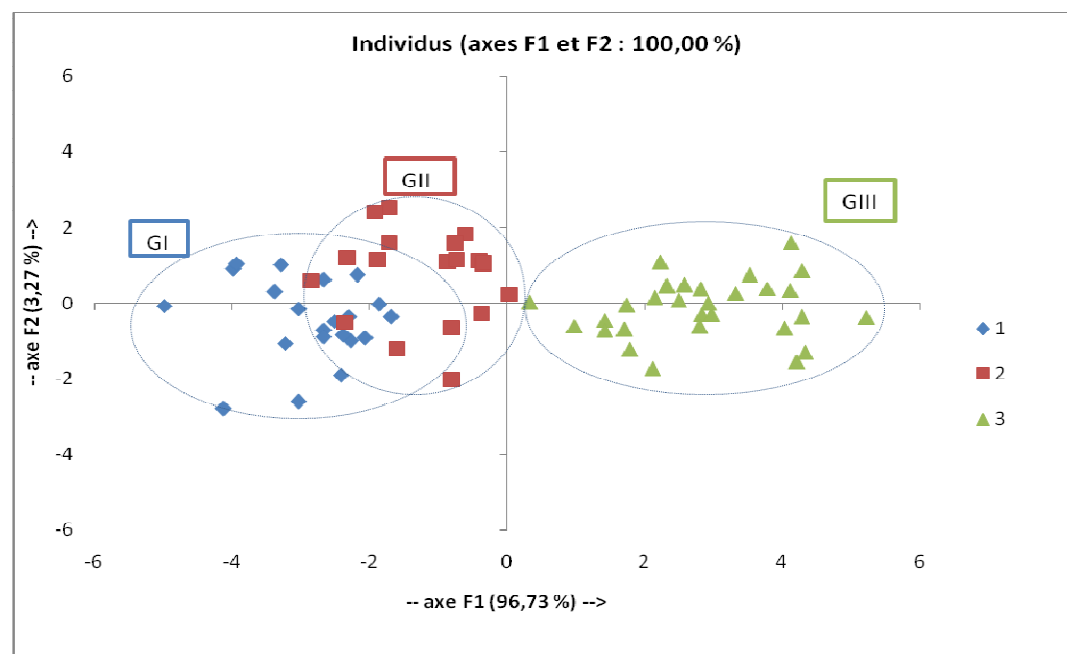


Figure 2: Organization of the accessions by Analysis Factorial Discriminating (AFD)

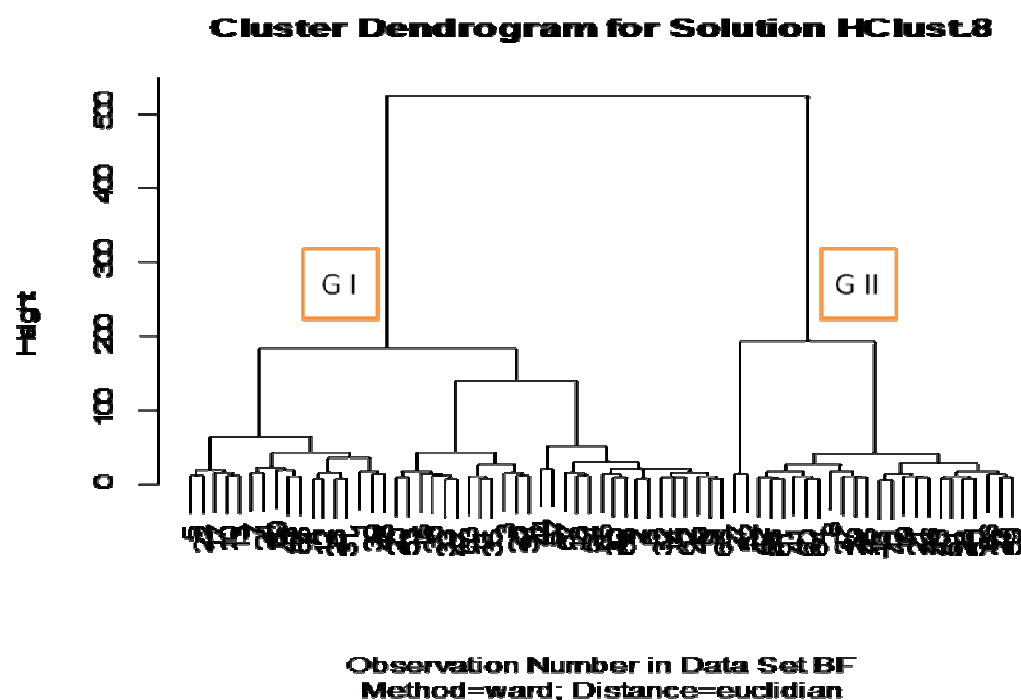


Figure 3: Structuring of the accessions by the Ascending Hierarchical Clustering (AHC)

4. DISCUSSION

The accessions resulting from the various agro-climatic zones are quite distinct. Indeed, the structuring of diversity is related mainly to the phenologic traits through the variables cycles of the plant and 50% flowering. The climate factor is a response to the diversity of the crop plants according to [16] was certainly a major element in the seed-bearer management of the rural farmers. The high variability of the phenologic traits compared to the morphological characters between the latitudes shows well that the effect of the climate on the genetic variability of the pearl millet is significant. Similar results had been reported by [17, 18] showing the significant contribution of the environment on the genetic variability of the pearl millet. Indeed, The 10° and 11° of northern latitude with a rainfall ranging between 900mm and 1200mm water per year, could explain the significant variability observed in this climate agro zone. The latitude 10° and 11° contain at the same time the varieties with long term, semi and early cycles. The highest diversity in the south and north is explained by the fact that the climate factor strongly influences the selection of the millet. These results are in accordance with those of [19] which showed that the impact of the climate change contributes to reduce the genetic diversity of the crop plants in sahelian zone. Our results compared to those of [20] reveal the adoption by the rural southern farmers of the early and semi-early varieties following the climate variations. Former studies of [4] had already revealed the presence of varieties to early cycle in the southern zone of Burkina. This genetic variability of the pearl millet in the 10° and 11° of latitudes is especially in connection with the phenologic traits. These variables with a larger variability refer primarily to the cycle 50% flowering (19.54%), to the cycle of the plant (18.46%) and to the duration of the vegetative period (29.93%). The phenologic traits are the variables which discriminate more the accessions of the pearl millet. In the agro-morphological characterization of the pearl millet, the first scission is based on the cycle of the plant attested by the studies of [21] in the genetic structuring of the pearl millet. The adoption of new varieties to cycle in the whole of the country climate agro zones is due to climate change. This idea corresponds to [22] showing the imposition of varieties selection on early cycle as well in the north and the south. The rural farmers explain the reduction of rainfall over the last years to keep their long term varieties. [23] reported a preference to varieties of early cycle in conditions of traditional genetic resources exchange and selection by rural farmers. An inversion of the pearl millet variability following the North-South gradient was noted. These results could be due to the climate change in the conditions of Burkina Faso where long term varieties

disappeared in the zones from north [13]. The movements of the populations from the arid regions north to the south could have also contributed to the increase of the millet diversity in the south of the country. The latitudes 12 ° and 13° reveal that the cultivated ecotypes are mainly semi-early cycles. These ecotypes have a cycle of 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 year's according to [24]. The characters by which, the farmers select are sometimes related to the agronomic ones. Indeed, the rural farmers by selecting the parallel ecotypes to take into account the output and the cycle of the plant. Several studies [25] showed that the good comprehension of the genetic variability of the millet and its components improve the effectiveness and efficiency of plants selection. Lowest genetic variability was observed in the latitude 14 ° whose ecotypes are mainly early. The sub-sahelian zone characterized by a draining of the climate [7] justifies today to the low diversity of the millet related to the cycles of the plants in the latitude 14°. The effect of the climate variations is more dominating in the sub-sahelian zone causing a reduction of plant's cycle. Similar results were observed in Niger whose impact of the climate change on the cycle of plants [26]. The management of the seeds by the rural farmers is largely influenced by the climate in particular the significant rain variations between the various agro-climate zones.

5. CONCLUSION

From this study, it rises a high millet genetic variability in the 10° and 11° of latitudes north in Burkina Faso is linked to phenologic traits. The most restricted variability is in the 14° of northern latitude. The criteria of accessions selection are oriented toward the early varieties in all the degrees of the country latitudes. Thus, the cycle of flowering and the cycle of the plant are the identified variables as criteria of discrimination of the different analyses. The millet of Burkina faso is structured in early and long term varieties. One can retain that the long term varieties are exclusively confined in the 10° and 11° of latitudes. In fact the effect of climate change reduced the genetic base of the millet traditional varieties. Other studies like the molecular characterization of the accessions using markers microsatellites and analyzes it biochemical of the grains could more determine the millet variability in Burkina Faso.

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