ESJ Natural/Life/Medical Sciences

Estimates of Genetic Variability in a Collection of Amaranths (*Amaranthus ssp*) Cultivated in Burkina Faso

Ouedraogo Jacques
Kiebre Zakaria
Université Joseph KI-ZERBO, Ecole Doctorale Sciences et Technologies, Equipe de Génétique et Amélioration des Plantes, Ouagadougou, Burkina Faso
Sawadogo Pingawinde
Université Thomas SANKARA, Centre Universitaire de Tenkodogo, Burkina Faso
Kabre Vonogo Nikodeme
Centre Universitaire de Manga, Université Norbert ZONGO, Equipe de Génétique et Amélioration des Plantes, Koudougou, Burkina Faso
Kiebre Mariam
Bationo Kando Pauline
Université Joseph KI-ZERBO, Ecole Doctorale Sciences et Technologies, Equipe de Génétique et Amélioration des Plantes, Ouagadougou, Burkina Faso

Doi:10.19044/esj.2022.v18n27p165

Submitted: 21 February 2022
Accepted: 11 August 2022
Published: 31 August 2022

Cite As:
Ouedrango J., Kiebre Z., Sawadogo P., Nikodeme K.V., Mariam K. & Bationo Kando P. (2022) *Estimates of Genetic Variability in a Collection of Amaranths (Amaranthus ssp) Cultivated in Burkina Faso.* European Scientific Journal, ESJ, 18 (27), 165. https://doi.org/10.19044/esj.2022.v18n27p165

Abstract

In Burkina Faso, little information is available on morphological variability of amaranth and the association of different genetic traits. This has been a constraint to its genetic improvement for yield potential, whereby the necessity of this study which aimed at assessing 80 accessions of amaranth collected in the three agro-climatic zones of Burkina Faso. The study was conducted in 2019 during the rainy season. The experimental design was a Randomized complete block design (RCBD) with three replicates. A total of 12 quantitative descriptors related to the vegetative system, flowering cycle,

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

and leaf and seed yield were assessed. The level of variation of each descriptor, their correlations, and their importance in the structure of agro-morphological variability of amaranths was studied. Significant morphological variability was observed among the accessions. The most discriminating and heritable traits were leaf blade length, number of primary branches bearing an inflorescence, number of leaves per plant, and fresh leaf weight. Late maturing accessions with many branches and long leaves were the best accessions for leaf biomass production. Early maturing accessions with fewer primary branches had better seed production. Two accessions, namely BOB4 and BOB5 of *Amaranthus hypochondriacus* were identified as the best seed yielding. Breeding programs to facilitate parental selection and increase genetic diversity in breeding populations can use these data.

Keywords: Leaf biomass, Variability, Heritability, *Amaranthus*, Burkina Faso

Introduction

Leafy vegetables play an important role in diets across the world, particularly in Africa, Asia, and Oceania, where they provide a significant proportion of nutritional and medicinal needs (Kahane *et al*., 2005, Andini *et al*., 2013; Dinssa *et al.*, 2016). Among these leafy vegetables, amaranth is very rich in ß-carotene, iron, calcium, vitamin C, and folic acid (Varalakshmi, 2004). In Africa, more than 15 species of amaranth are described (Das, 2016). In Burkina Faso three of these species are cultivated. They are *Amaranthus cruentus, Amaranthus hypochondriacus* and *Amaranthus dibius* (Somtore *et al*., 2019). *Amaranthus cruentus* is widely cultivated by a high number of urban and peri-urban market gardeners and is much appreciated and consumed by the population in Burkina Faso (Hama-Ba *et al*., 2017; Somtore *et al*., 2019). In many countries across the world, amaranth production (seed and/or leaf) is booming thanks to its high nutritional value, and its great capacity to adapt to different agro-climatic conditions (Katiyar *et al.*, 2000; Shukla *et al*., 2000; Snezana *et al.*, 2012). As C4 plants, amaranths have a carbon sequestration capacity, which allows them to have high dry matter and protein production per unit area (Caburet *et al.*, 2002). Leaf biomass yield in China can reach 90000 to 180000 kg/ha and 2200 to 5,500 kg/ha for grain yield (Corke *et al*., 2016) and is highly related not only to genotype but often to agronomic practices and environmental conditions (Rita *et al.*, 2008; Joshua, 2017; Dinssa, 2018).

In Burkina Faso, few studies have been done on the morphological variability of amaranth species. Nevertheless, an ethnobotanical study and the genetic diversity of 54 accessions collected in two climatic zones of Burkina Faso were reported by Somtore *et al.* (2019) and Ouedraogo *et al.* (2019), respectively.

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

A better knowledge of the morphological variables of the different production zones and the association of the different quantitative variables will allow the development of conservation strategies and selection programs for these resources. The objective of this study is to characterize a collection of accessions of amaranth (*Amaranthus ssp*) grown in Burkina Faso. The specific objectives were to (i) assess the morphological variability of cultivated amaranths using quantitative descriptors, and (ii) establish the structure of this variability of the accessions studied.

Material and Methods

Plant material

The plant material used in this study consisted of 80 amaranth accessions collected in 2017 from market gardeners in the three agro-climatic zones of Burkina Faso (Table 1). The accessions were collected from ten provinces where amaranth cultivation is widely practiced.

Table 1. Distribution of accessions number and their collection locations in agro-climatic zones

Agro-climatic zones	Province	Number of accessions
Sahelian zone	Yatenga	14
	Bam	06
	Seno	03
Sudano-sahelian zone	Kadiogo	12
	Sanguié	19
	Oubritenga	11
	Gourma	01
	Bazèga	03
	Kouritenga	04
sudanian zone	Houet	06

Experimental site

The trial was conducted in the experimental site at the "Institute of Development Rural" (IDR) at Gampèla. The "Institute of Development Rural" (IDR) site is 20 km far from Ouagadougou, geographical coordinates are 12°15' North latitude and 1°12' West longitude. The climate is of the Sudano-Sahelian type with rainfall that varies greatly from month to month throughout the year. The average rainfall and temperature for the two years are presented in Table 2.

Table 2. Temperature and rainfall data for 2019

Month	Temperatures (°C)	Rainfall (mm)
January	25.6	0
February	27.7	0
March	31.6	8.9
April	34.7	33.5

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

May	33.5	71.6
July	28	215.5
August	27.4	335.3
September	29	111.7
October	29.2	3

Methods

Experimental design and cultural practices

The experimental design was a Randomized Complete Block Design (RCBD) with three replicates. The blocks were 2 m apart. Each accession constituted an experimental plot composed of 07 rows of 5.25 m long. Spacing between and within lines was 0.75 m.

Before sowing, the seeds of each accession collected were wrapped in a cotton cloth and soaked in hot water (100°C) for five (5) seconds to break seed dormancy. The seeds were then nursed in pots and transplanted 30 days later to the experimental plot. Before transplanting, the soil was deeply ploughed and levelled. Organic fertilizer at the dose of 20 t/ ha was applied before transplanting. NPK fertilizer (15-15-15) was applied (100 kg/ha) two weeks after transplanting.

Data Collection

Measurements and observations were done on 12 quantitative variables. Except for the number of days to 50 % heading and the number of days to 50 % flowering, all the parameters were measured at 120 days after sowing on three (3) plants per row and per accession for a total of 21 plants per plot. The days to 50 % flowering were determined as the ratio of the number of flowering plants over the total number of plants on the plot. The other variables measured were:

-variables measured on the stem: plant height at maturity (PH), stem height (SH) measured from the collar to the last leaf, stem diameter (SD) between 3rd and 4th nodes (at the end of flowering), number of primary racemes (NPR);

-leaf variables (03 adult leaves per plant per row): petiole length (PL) at the heading stage, leaf blade length (LBL) at the heading stage, leaf blade width (LBW) at the heading stage, number of leaves per plant at maturity (NLP);

-yield components: total fresh leaf weight per plant averaging three plants per accession (FLW) and 1000 seed weight per accession (1000SDW);

-inflorescence variables: length of inflorescence (LI), number of days to 50 % heading (HEAD50), and number of days to 50 % flowering (FLO50).

Data Analysis

Statistical analyses were performed to estimate the variability among accessions. An analysis of variance (ANOVA) was performed using GenStat v4.10.3 software (VSN International, 2011) to determine the traits that

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

discriminate between accessions. Mean separation at a 5 % threshold was done using the Newman-Keuls test for both variables and genetic groups derived from cluster analysis.

For each discriminating character, genotypic variance (GV), phenotypic variance (PV), and, the error variance was determined. In addition, the genotypic coefficient of variation (GCV), the phenotypic coefficient of variation (PCV), and the broad heritability (H^2) were calculated. The expected genetic gain with respect to the trait mean (GA) was also calculated. Coefficients of variation were calculated using the formula of Bruton (1952). PCV and GCV values less than 15 % (<15 %) were considered as low. Moderate PCV and GCV values ranged between 15 and 20 % (15-20 %), and high PCV and GCV were greater than 20 % (>20 %).

Broad sense heritability was calculated using the formulas by Lush (1940). It was classified into three categories: low (<50 %), moderate (50-70 %) and high (>70 %).

The expected genetic gain was estimated according to Johnson *et al.* (1955). The different classes of genetic gain are as below:
<25 % = low genetic advance,
25-40 % = moderate genetic advance,
>40 % = high genetic advance.

The Xlstat Pro 7.1 software was used to determine the relationships between variables using the Pearson total correlation matrix. A principal component analysis (PCA) was also performed with this software and the coordinates of the individuals were used to group the accessions through cluster analysis.

Table 3. Formulas used to estimate genetic parameters

Parameters	Formulas
Phenotypic Variance (PV)	PV $= VG + \frac{MSE}{r} = \frac{MSG}{r}$
Genotypic Variance (GV)	GV $= \frac{MSG - MSE}{r}$
Heritability (Broad sense) (H^2)	$H^2(\%) = \frac{VG}{VP} * 100$
Phenotypic Coefficient of variability (PCV)	PCV (%) $= \frac{\sqrt{VC}}{X} * 100$
Genotypic Coefficient of variability (GCV)	GCV (%) $= \frac{\sqrt{VG}}{X} * 100$
Genetic Advance (GA)	GA$= H^2 x \sqrt{VP} * I$
Genetic advance expected over the GA mean	GA (% mean variable) $= \frac{GA}{X} * 100$

Legend: *MSG: mean square of genotypes; MSE: mean square of error; r: number of replications; I: constant, with a selection coefficient of 5 %, I is 2.06; X: mean of the character; √GV: standard deviation of genotypic variance; √PV: standard deviation of phenotypic variance*

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

Results

Genetic variability within accessions of *Amaranthus* in Burkina Faso

Results of the analysis of variance of the quantitative variables are presented in Table 4. This analysis revealed a highly significant difference between mean squares of genotypes for all variables. This indicates the existence of a large variability among the studied material.

The analysis of variance showed that all the characters significantly discriminate the accessions at the 1 % threshold. The diameter of the plants varied from 19.00 to 67.67 cm with an average of 39.51 cm. Plant height ranged from 113.33 to 346.7 cm with a mean of 216.97 cm. The number of branches bearing an inflorescence ranged from 7.67 to 85. The fresh weight of the leaves ranged from 77.00 g to 678 g with an average of 330.34 g. The coefficient of variation for the different variables shows a variation ranging from the lowest 11.3% to the highest 34.6%. The highest variations above 25% were observed for number of leaves per plant (R^2 = 30.7%), stem diameter (R^2 = 25.9%), blade width (R^2 = 25.4%), number of primary branches bearing an inflorescence (31%) and fresh leaf weight (R^2 = 34.6%). The smallest variations, less than 15%, were observed for the number of days to 50% flowering (R^2 = 11.3%), the number of days to inflorescence onset (R^2 = 12.2%) and 1000 seed weight (R^2 = 12.2%). Moderate variations between 15% and 25% were observed on plant height at maturity (R^2 = 21.7%), petiole length (R^2 = 21.7%), blade length (R^2 = 16.9%), and Length of inflorescence (R^2 = 18.5%)

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

Table 4. Analysis of variance of *Amaranthus ssp* accessions grown in Burkina Faso

Variable	Mini-Maxi	Mean sum of squares: Blocs	Climate	Genotypes	Error	CV %	R^2
(df)		(2)	(2)	(72)	(144)	(	
Number of days to 50% heading	41 - 75	55.51	552.87**	127.95**	20.15	12.2	0.76
Number of days to 50% flowering	51 - 87	39.00	579.21**	146.44**	23.10	11.3	0.76
Number of leaves per plant	80 - 756	41215.53	412383.8**	41178.16**	6682.73	30.7	0.75
plant height at maturity	113.33 - 346.7	1496.12	12731.37*	4500.9**	1060.71	21.7	0.68
Stem diameter	19- 67.7	249.69	511.07*	162.46**	74.60	25.9	0.52
Number of primary racemes	7.67 - 85	18.21	1720.92**	363.7**	60.72	31	0.75
Blade width	5.63 - 17.82	18.21	51.44*	16.94**	3.37	25.4	0.71
Blade length	14.12- 33.50	52.14	169**	33.46**	9.91	16.9	0.62
Petiole length	8 - 22.10	235.32	48.22*	14.26	10.39	21.7	0.40
Length of inflorescence	30.67- 84.50	105.21	784.74*	173.61**	72.60	18.5	0.54
Fresh leaves weight per plant	77 - 678	40933.52	172524.21**	26971.4**	5968.89	34.6	0.69
1000 seed weight	0.25 - 0.8	0.02	0.08**	0.02**	0.00	12.2	0.92

*Legend: *: significant at the 0.05 threshold, **: significant at the 0.001 threshold*
Muni: Minimum, Maxi: Maximum, CV: coefficient of variation, R^2: Coefficient of Determination, df: degree of freedom

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

Estimation of genetic variability of cultivated amaranth accessions

The results showed higher coefficients of phenotypic variation than genotypic variation for all variables (Table 5). The coefficient of phenotypic variation ranged from 9.89% for the trait (FLO50) to 28.7% for the variable (FLW). As for the genotypic coefficient of variation, it ranged from 7.25% for the (PL) variable to 25.34% for the (FLW) variable. Low values (<15%) were registered by cycle-related traits such as the number of days to 50% flowering (FLO) and a number of days to 50% heading (HEAD50), Leaf blade length (LBL) and length Petiole (LP).

Estimated 1000 seed weight per accession, plant height at maturity, and Stem diameter have been a relatively moderate influence on genetic variability. The variables showed high phenotypic and genotypic coefficients of variation above 20% for the number of leaves per plant (26.6%- 24.35%), the number of primary racemes (26.75% - 24.41%) and the fresh leaves weight per plant (28.7% - 25.34%).

Heritability and Genetic Advance

Broad sense heritability was very high for all variables. It ranged from 27.10 % for Petiole length to 95.66 % for 1000 seed weight (Table 5). The expected genetic gain compared to the observed mean was low for the number of days to 50 % flowering (17.16 %) and the number of days to 50 % heading (18.53 %). As for 1000 seeds' weight, plant height and leaf blade width; the expected genetic gain compared to the average was moderate (35%, 28.11% and 35.67% respectively). The number of primary branches, Number of leaves per plant, and fresh leaf weight showed genetic gains of 45.90%, 45.90%, and 46.04% respectively. When combining expected genetic gain and broad sense heritability, the variables with a highly significant share of genotypic variance were a number of primary branches, leaf blade width, fresh leaf weight and a number of leaves per plant.

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

Table 5. Genetic parameters of cultivated amaranth accessions from Burkina Faso

Variables	PV	GV	PCV %	GCV %	H² %	GA%
Number of days to 50 % heading	35.94	42.65	10.66	9.8	84.25	18.53
Number of days to 50% flowering	41.12	48.82	9.89	9.08	84.23	17.16
Number of leaves per plant	11498.48	13726.05	26.60	24.35	83.77	45.90
Plant height	1146.73	1500.30	17.85	15.61	76.43	28.11
Stem diameter	29.29	54.15	18.63	137	54.08	20.75
Number of primary racemes	100.99	121.23	26.75	24.41	83.30	45.90
Leaf blade width	4.52	5.65	21.62	19.35	80.09	35.67
Leaf blade length	7.85	11.16	13.36	11.21	70.38	19.37
Petiole length	1.29	4.75	13.92	7.25	27.10	7.77
Length of inflorescence	33.67	57.87	13.61	10.38	58.18	16.32
Fresh leaves weight per plant	7000.84	8990.47	28.70	25.34	77.87	46.04
1000 seeds weight	0.00	0.01	17.76	17.37	95.66	35

Legend: *GV: Genotypic Variance, PV: Phenotypic Variance, GCV: Genotypic Coefficient of variance, PCV: Phenotypic Coefficient of Variance,* H^2*: Heritability in the broad sense, GA %: Expected genetic advance over the mean*

Relationship between the quantitative characters studied

Table 6 shows the correlations obtained between the different variables studied. These results showed many significant correlations at 1 % threshold. Maturity cycle was strongly and positively correlated with number of leave per plant. Plant height and number of primary racemes. The number of days to 50 % flowering was significantly correlated with fresh leaf weight (r = 0.57). Number of primary racemes (r = 0.59), number of leaves per plant (r = 0.5). Stem height was highly significantly and positively correlated with the number of leaves per plant (r= 0.80), the number of primary branching (r= 0.86) and the fresh leaves weight per plant (r= 0.93).

Fresh leaves weight per plant was significantly and positively correlated with the number of leaves per plant (r = 0.92), plant height (r = 0.73) and number of primary racemes (r = 0.86). The variables measured on the leaf were strongly and positively correlated with each other. The 1000 seed weight per plant showed very low correlations, most of its correlations were negative except for the variables measured on the leaf.

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

Table 6. Pearson correlation matrix between the characters of the studied accessions at the 1% threshold

Variables	HEAD50	FLO50	NPL	PH	SD	NRP	LBW	LBL	PL	LI	FLW	1000SDW
HEAD50	**1**											
FLO50	**0.99****	**1**										
NPL	**0.51****	**0.50****	**1**									
PH	0.27	0.25	**0.70****	**1**								
SD	0.09	0.09	**0.58****	**0.68****	**1**							
NRP	**0.60****	**0.59****	**0.85****	**0.78****	**0.62****	**1**						
LBW	-0.04	-0.09	0.18	**0.58****	0.30	0.27	**1**					
LBL	0.29	0.25	0.41	**0.63****	**0.54****	**0.62****	**0.58****	**1**				
PL	-0.02	-0.02	0.22	0.49	**0.57****	0.34	**0.64****	**0.68****	**1**			
LI	-0.07	-0.07	**0.54****	**0.71****	**0.54****	0.47	0.30	0.23	0.28	**1**		
FLW	**0.50****	0.49	**0.92****	**0.73****	**0.51****	**0.86****	0.28	0.49	0.26	**0.51****	**1**	
1000SDW	-0.096	-0.09	-0.23	-0.03	-0.06	-0.10	0.19	0.26	0.11	-0.18	-0.16	**1**

*Legend: **: significant at the 0.001 threshold*

HEAD50 : Number of days at 50 % heading, FLO50 : Number of days at 50 % flowering, NPL: Number of leaves per plant, PH : Plant height; SD : Stem diameter, NRP : Number of primary racemes, PL : Petiole length; LBL : Leaf blade length; LBW : Leaf blade width; LI : Length

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

Association between the quantitative traits studied

The three axes of the principal component analysis (PCA) explain 79.68% of the total variability.

In the ½ plane (Figure 1), axis 1 with 47.09% of the total inertia, was positively associated with plant height, number of primary branches, number of leaves per plant, fresh leaf weight, and inflorescence length.

Axis 2, which accounted for 20.09% of the total variance, was positively correlated several days to 50% heading and a few days to 50% flowering and negatively correlated with petiole length and leaf blade width. Axes 1 and 2 explained most of the traits related to biomass production.

In the 1/3 axis 3 with 12.59% of the total inertia, was positively associated 1000 seed weight. Leaf blade width was associated with axis 2 only. In addition to axis 1, petiole length was negatively associated with axis 2. The length of the inflorescence was negatively correlated with axis 3.

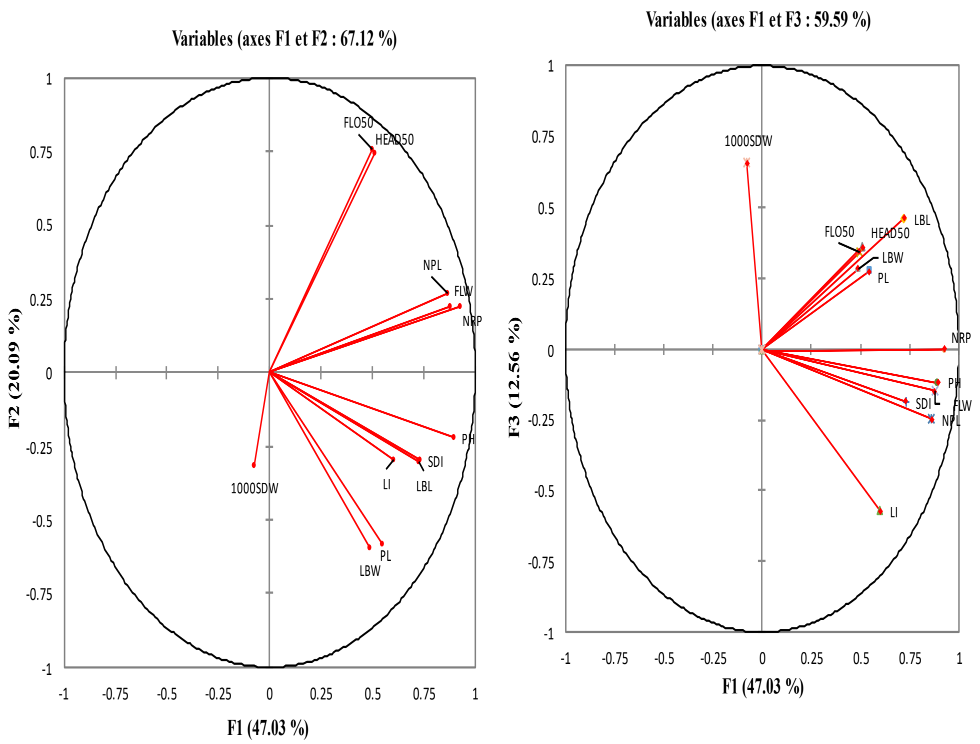

Figure 1. Projection of the discriminant variables in the plane formed by two axes

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

Structure of the genetic variability within accessions based on quantitative variables

The dendrogram resulting from the cluster analysis shows a structuring of the 73 accessions into four groups independently of the morphotypes and species identified (Figure 2). Group 1, comprising of 35 accessions presented the best agronomic performances except for 1000 seeds weight and leaf blade. Group 2 composed of only two accessions from the Sudanian zone, characterized by their short maturing cycle (47.97 days), and seedlings' short height (164.48 cm). The accessions of this group presented the widest (14.36 cm) leaves. They recorded a very low number of primary racemes. These accessions were the best seed yielding (0.79 g per 1000 seeds) conversely their leaf biomass yield was very low (89.5 g). Group 3 is heterogeneous in terms of the geographical distribution of accessions. This group consisting of 36 accessions, showed average agronomic performance.

Except petiole length, the other variables significantly discriminate the three groups at the 1% threshold. The values of the coefficient of determination R^2 showed that only the variables such as number of leaves (R^2 =57%), number of primary branches (R^2= 39.5%), fresh weight of leaves (R^2= 46.6%) and weight of 1000 seeds (R^2=75.8%) would better explain the intergroup variability (Table 7).

Table 7. Mean performance of the groups from the hierarchical ascending classification

Variable	Group 1	Group 2	Group 3	R^2 %	Pr > F
	35	**02**	**36**		
Number of days to 50 % heading	63.13a	47.97b	60.01a	13.10	< 0.0001
Number of days to 50% flowering	72.71a	56.64b	69.41a	12.90	< 0.0001
Number of leaves per plant	535.75a	97.50c	366.74b	57.00	< 0.0001
Plant height	243.38a	167.48b	194.04b	30.20	< 0.0001
Stem diameter	43.07a	31.33b	36.49ab	12.00	< 0.0001
Number of primary racemes	48.66a	14.36c	35.36b	39.50	< 0.0001
Leaf blade width	11.64b	14.09a	10.19b	10.00	< 0.0001
Leaf blade length	26.25a	25.50a	23.75a	8.70	< 0.0001
Petiole length	16.26a	16.91a	15.01a	3.70	0.018
Length of inflorescence	59.73a	44.64c	52.77b	14.60	< 0.0001
Fresh leaves weight per plant	405.00a	89.50c	271.14b	46.60	< 0.0001
1000 seeds weight	0.41b	0.79a	0.38c	75.80	< 0.0001

Legend: *a, b, and c: classes of values resulting from the comparison by the Newman and Keuls test such that a>b>c., Means followed by the same letter in each class are not significantly different at the 1 % threshold.* R^2*: Coefficient of Determination, Pr > F: Fisher's F*

 ISSN: 1857-7881 (Print) e - ISSN 1857-743

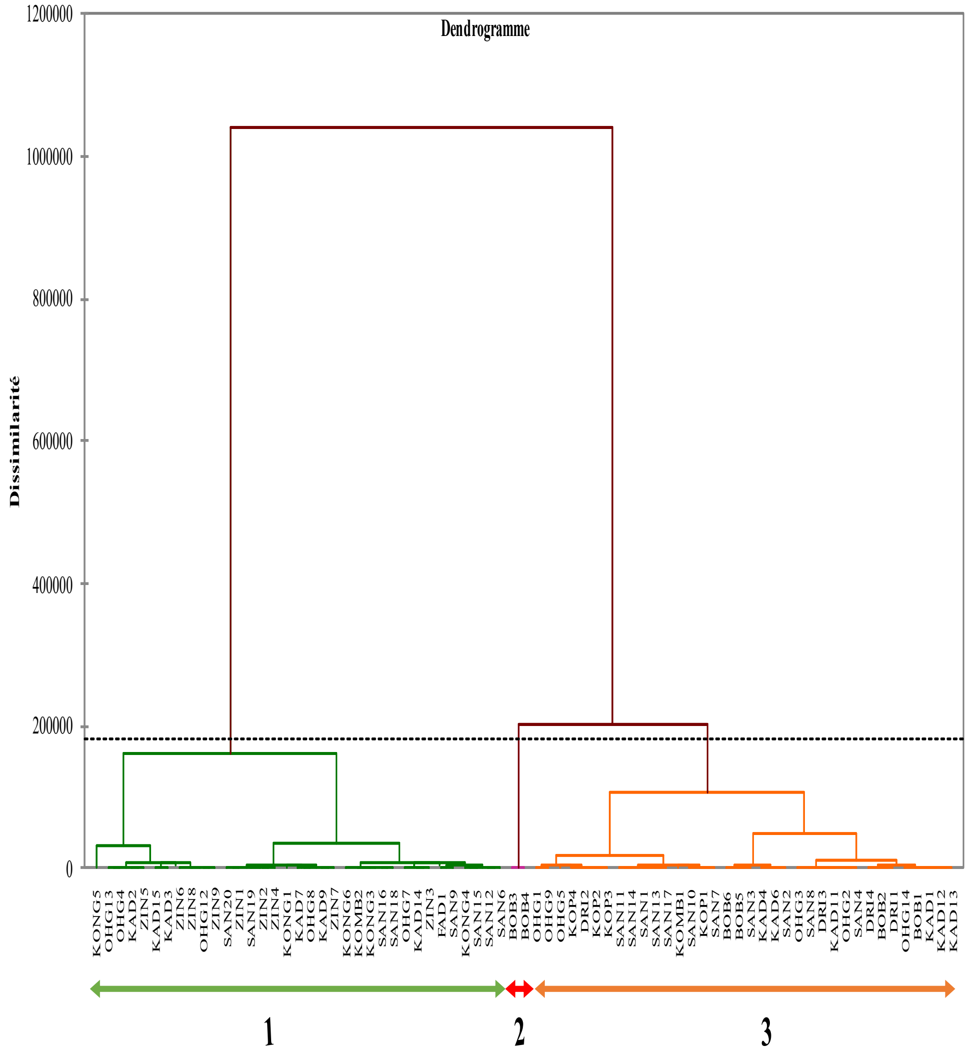

Figure 2. Dendrogram showing the different classes of amaranth accessions grown in Burkina Faso

Discussion

The results revealed the existence of a large variability within amaranths from qualitative descriptors. The high rate of open pollination, which is around 33 % in some cases, could explain this diversity (Lanta *et al*., 2003). In addition, these species can adapt to many types of environments across the world (Kumar, 2015; Lavernee *et al*., 2016). The analysis of quantitative descriptors revealed significant variability within Burkina Faso collection. These quantitative variables can often be influenced by the growing environment, but some traits were found to be very interesting for estimating variability within accessions in local or global collections. The findings of this study likewise by Shukla *et al.* (2003) and Khurana *et al*. (2014) revealed large variability for plant height, number of primary branches, leaf blade length, fresh leaf weight, and number of leaves per plant. These variables recorded coefficients of variation values greater than 20 %. Leaf biomass was a complex quantitative trait highly associated with stem height which in turn is associated with the characters number of branches, leaf blade length and stem diameter as reported in previous studies (Akaneme and Anni, 2013; Sarker *et al*., 2014; Kumar, 2015). The positive correlation between the number of days to 50 % flowering and the variables number of primary branches, leaf blade length, plant height and fresh leaf weight shows that the late maturing accessions are those possessing greater height with more branched stems bearing many leaves with large dimensions. Indeed, late maturing accessions have more time for vegetative development in contrast to early maturing ones. Late maturing is a very important parameter in amaranth cultivation, especially in Burkina Faso where it is widely cultivated as a leafy vegetable and consumed in urban and peri-urban areas (Somtore *et al*., 2019). Some early maturing accessions were high yielding and could be subjected to selection in Burkina Faso. In fact, these are cereal amaranths with pale yellow seeds whose starch is reportedly more digestible than other amaranth seeds (Misra *et al.*, 1971).

The agro-morphological variability clustered independently from collection sites, can be explained by farmers' seeds management practices. An ethnobotanical study conducted by (Somtore *et al*., 2019) reported important exchanges of genetic material in the markets or through family ties or during population movements. About clusters obtained, there are opportunities for genetic improvement either the green morphotype of *Amaranthus cruentus* species for leaf biomass production or the light green morphotype of *Amaranthus hypochondriacus* species for seed production.

The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all discriminating variables but with a very small difference. Variables such as number of primary branches bearing inflorescence, number of leaves per plant, fresh weight of leaves and length of leaf blade showed very high PCV and GCV. Shukla *et al*. (2006) and Kumar (2015) also reported very high PCV and GCV for these variables. In fact, the expression of these variables is less influenced by the environment whereby the high values of broad sense heritability and very high expected genetic gain. The high heritability suggests an important additive genes effect for these traits inferring that biomass yield could be indirectly improved through leaf blade length and the number of primary branches.

Conclusion

This study revealed the existence of high genetic variability within *Amaranthus* collection in Burkina Faso. The study revealed significant correlations between several variables such as the vegetative cycle, leaf biomass, and grain yield.

The agro-morphological diversity was clustered into four groups. The population structure is not influenced by the collection area of the accessions. Accessions in group 1 and group 2 showed better agronomic potential and could be used in the extension of amaranth cultivation in Burkina Faso. Group 1 was characterized by individuals with a long flowering cycle and a large number of leaves per plant and could be used in future breeding programs as a leafy vegetable. Group 2 was characterized by short-cycle individuals with high grain yields, which could be used in future breeding programs as a pseudo-cereal.

References:

1. Akaneme FI and Ani GO (2013). Morphological assessment of genetic variability among accessions of *Amaranthus hybridus*. *World Applied Sciences Journal. 28(4): 568-577.*
2. Andini R, Yoshida S and Ohsawa R (2013). Variation in Protein Content and Amino Acids in the Leaves of Grain, Vegetable and Weedy Types of Amaranths. *Agronomy*. 3(2): 391–403. https://doi,org/10,3390/agronomy3020391
3. Caburet A, Daly P Bon H, Huat J, Langlais C, Lyannaz J P and Ryckewaert P (2002). Les legumes in: *MEMENTO de l'Agronome*. CIRAD-GRET/ MFAE, Ed ISBN: 2-86844-129-7, 1023-1050.
4. Corke H, Cai YZ and Wu HX (2016). The legumes and pseudocereals | amaranth: overview. *Module in Food Sciences,* pp. 10. *http://dx.doi.org/10.1016/B978-0-08-100596-5.00032-9*
5. Das S (2016). Taxonomy and phylogeny of grain amaranths. In: *Amaranthus*: A Promising Crop of Future. *Singapore: Springer*, pp. 57–94. doi: 10.1007/978-981-10-1469-7_5.
6. Dinssa FF, Hanson P, Dubois T; Tenkouano A, Stoilova T, Hughes Jd'A and Keatinge JDH (2016). AVRDC - The World Vegetable Center's women-oriented improvement and development strategy for traditional African vegetables in sub-Saharan Africa. *European Journal of Horticultural Science, 81(2): 91-105. Doi: 10.17660/eJHS.2016/81.2.3*
7. Dinssa FF, Yang RC, Ledesma DR, Mbwambo O and Hanson P (2018). Effect of leaf harvest on grain yield and nutrient content of diverse amaranth entries. *Scientia Horticulturae. 236 : 146-157. Doi : 10.1016/j.scienta.2018.03.028*
8. Hama-Ba F, Parkouda C, Kamga R, Tenkouano A and Diawara B (2017). Disponibilité, modes et fréquence de consommation des légumes traditionnels africains dans quatre localités du Burkina Faso a

diverses activités de maraichage : Ouagadougou, Koubri, Loumbila, Kongoussi. *African Journal of Food Agriculture Nutrition and Development 17 (1): 11552-11570*

9. Johnson HW, Robinson HF and Comstock RE (1955). Estimation of genetic and environmental variability in Soybean. *Agronomy Journal,* 47: 314-318.
10. Joshua Omondi Otieno (2017). *Phenotypic variation in morphology, yield and seed quality in selected accessions of leafy amaranths*. Thesis, Department of Applied Plant Sciences, Maseno University, 96 pp.
11. Kahane R, Ludovic T, Brat P and Hubert DB (2005). Les légumes feuilles des pays tropicaux : diversité, Richesse économique et valeur sante dans un Contexte très fragile. Colloque Angers 7-9 septembre 2005-03-14.
12. Katiyar RS, Shukla S and Rai S (2000). Varietal performance of grain amaranth (*A. hypochondriacus*) on sodic soil. *Proceedings of the National Academy of Science*, 70(b) II: 185–187.
13. Khurana DS, Sing J and Kaur B (2013). Genetic variability, correlation and path coefficient analysis in *Amaranthus*. *Vegetable Science,* 40 (2): 238-240.
14. Lanta V, Havranek P and Ondrej V (2003). Morphometry analysis and seed germination of *Amaranthus cruentus*, *A. retroflexus* and their hybrid (*A. x turicensis*). *Plant Soil and Environment* 49: 364–369.
15. Lavernee SG, Teresita B and Constacio DG (2016). Diversity in the morphology of Amaranth (*Amaranthus* sp.) germplasm Collection in the Philippines. *Asian Journal of Agriculture and Food Sciences. 4, 7p. ISSN: 2321 – 1571.*
16. Lush JL (1940). Intro-site correlation and regression of off spring on corn as a method of estimating heritability of characters. *Proceedings Amer Society of Animal Production.* 33: 293-301.
17. Misra PS, Pal M, Mitra CR et al (1971). Chemurgic studies on some diploid and tetraploid grain amaranths. *Proceedings of the Indian Academy of Science,* 74:155–160.
18. Ouédraogo J, Kiébré M, Kiébré Z, Sawadogo B and Bationo-Kando P (2019). Genetic diversity of a collection of amaranth (*Amaranthus spp)* of Burkina Faso using ISSR markers. *American Journal of Innovative Research and Applied Sciences*. 9(3): 257-265.
19. Rita RA, Piergiorgio G, Susanna DM and Salvatore P (2008). Field Evaluation of *Amaranthus* Species for Seed and Biomass Yields in Southern Italy. *Italia Journal of Agronomy / Riv. Agronomy. 3: 225-229.*

20. Sarker U, Islam MT and Oba S (2014). Genotypic variability for nutrient, antioxidant, yield and yield contributing traits in vegetable amaranth. *Journal of Food Agriculture and Environment. 12 (3 and 4): 132-139. https: // www.researchgate.net/ publication /267509472.*
21. Shukla A, Bhargava A, Chatterjee, Srivastava A and Singh SP (2006). Estimates of genetic variability in vegetable amaranth (A. tricolor) over different cuttings. *Horticultural Science (PRAGUE) 3*2 (2): 60-67.
22. Shukla S, Pandey V, Pachauri G, Dixit BS, Banerji R and Singh SP (2003). Nutritional contents of different foliage cuttings of vegetable amaranth. *Plant Foods for Human Nutrition*, 58: 1–8.
23. Shukla S, Singh SP (2000). Studies on genetic parameters in vegetable amaranth*. Journal of Genetics and Breeding,* 54:133–135.
24. Snezana DM, Kostadinovic M, Ristic D, Simic M and Stefanovic L (2012). Assessment of genetic relatedness of the two *Amaranthus retroflexus* populations by protein and random amplified polymorphic DNA (RAPD) markers. *African Journal of Biotechnology,* 11(29): 7331–7337.
25. Somtore H, Sawadogo B, Bationo-Kando P, Kiebre M, Ouedraogo J and Kiebre Z (2019). Ethnobotanical Investigation of Amaranth (*Amaranthus spp*) Cultivated in Burkina. I*nternational Journal of Applied Agricultural Sciences. 2 (5) : 50-55. doi: 10.11648/j.ijaas.20190502.14.*
26. Varalakshmi B (2004). Phenotypic stability for economic traits in vegetable amaranth (*Amaranth tricolor*). *Indian Journal of Agricultural Sciences 73(2): 114– 115*.
27. Yogendra Kumar (2015). *Collection, evaluation and identification of Suitable genotypes of Amaranthus (Amaranthus Spp.) for chhattisgarh plain condition.* Master of Science in Agriculture, Department Of Horticulture College Of Agriculture Faculty Of Agriculture Indira Gandhi Krishi Vishwavidyalaya Raipur (Chhattisgarh). 86p.