

Genetic variability of the earth lens (*Macrotyloma geocarpum* (HARMS)) in Burkina Faso

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Abstract

Ground bean (*Macrotyloma geocarpum* (HARMS)) is an underground fruiting legume from West Africa. It is confined to tropical climates in Africa. *M. geocarpum* has particular importance in human consumption, animal feed, cultural practices and traditional medicinal treatment. However, the species is going through genetic extinction due to the low cultivation of the species. To prevent this genetic extinction, adequate measures should be taken. Genetic variability study is one of the preliminary studies for gene pool preservation. The objective of this study was to assess the genetic variability between some landraces of ground bean in Burkina Faso. Hence, 20 landraces collected from western regions of the country were evaluated in randomized complete block design at Kamboinsé research station under research field conditions. Both qualitative and quantitative data were collected and subjected to statistical analyses. The results revealed genetic variability amongst the landraces for some characters such as date to maturity, seed length, seed width and hundred seeds weight. Sixty percent of this genetic variability was explained by variables seed length, seed width, number of leaves, plant height, date to 50% flowering, and date to 50% maturity. Strong positive correlations were observed between the date of onset of the first flowering of each landrace and date to 50% maturity, the plant height and number of leaves, seed length and seed width, seed length and hundred seed weight as well as seed width and hundred seed weight. In this study, three classes of landraces were distinguished: a group of short-cycle landraces with medium seed weight, a group of long cycle landraces with low seed weight and a group of landraces with intermediate cycle and seeds weight. The landraces in class 3 (E₁₆₋₁, E₆, E₇, and E_{8.2}) can be considered as high yielding. This can help to set up an improvement program for this species.

Keywords: *Macrotyloma geocarpum*, ground bean, genetic variability, genetic.

Variabilité génétique de la lentille de terre (*Macrotyloma geocarpum* (HARMS)) au Burkina Faso

Résumé

La lentille de terre (*Macrotyloma geocarpum*) est une légumineuse africaine à fructification souterraine. Elle est confinée dans les climats tropicaux. *M. geocarpum* a une importance particulière en nutrition humaine, animale, pour rituelles coutumières et dans la pharmacopée traditionnelle. Cependant, cette espèce est de moins en moins cultivée d'où un risque d'érosion génétique. Des mesures adéquates doivent être entreprises pour éviter cette extinction génétique. Aussi, la présente étude de la variabilité génétique de

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M. geocarpum constitue l'une des étapes préliminaires pour la conservation du pool de gènes. L'objectif de l'étude était d'évaluer la variabilité génétique au sein de quelques écotypes de la lentille de terre au Burkina Faso. Ainsi, 20 écotypes collectés dans les régions de l'ouest du pays ont été évalués selon un dispositif en blocs de Fisher à la station de recherche de Kamboinsé en conditions de champ expérimental. Des données quantitatives et qualitatives ont été collectées et analysées. Les résultats ont révélé l'existence d'une différence significative entre les écotypes pour certains paramètres tels que la date de maturité, la longueur et la largeur des graines et le poids de 100 graines. La plus grande partie (60 %) de cette variabilité a été exprimé à travers la longueur et la largeur des graines, le nombre de feuilles la hauteur des plants la date à 50 % floraison et 50 % maturité. De fortes corrélations positives ont été observées entre les dates à 50 % floraison et 50 % maturité, la longueur des plants et le nombre de feuilles, la longueur et la largeur de graines, la longueur des graines et le poids de 100 graines ainsi que entre la largeur des graines et le poids de 100 graines. L'étude a permis de distinguer trois classes d'écotypes à savoir : les écotypes à cycle court dont le poids de 100 graines est moyen, les écotypes à long cycle avec un faible poids de 100 graines et les écotypes dont le cycle et le poids de 100 graines sont intermédiaires. Les écotypes de la class 3 (E₁₆₋₁, E₆, E₇, and E₈₋₂) peuvent être considérées comme des écotypes à haut rendement. Ces résultats pourront être utiles dans la mise en place d'un programme d'amélioration de l'espèce.

Mots-clés : *Macrotyloma geocarpum*, lentille de terre, variabilité génétique, érosion génétique.

Introduction

The Africa Kersting's groundnut, *Macrotyloma geocarpum* (HARMS) also known as earth lens is a diploid grain legume with $2n=22$ chromosomes (MARECHAL and BAUDET, 1977b). It is an herbaceous self-pollinated crop of 5 to 9 cm height with pubescent or glabrous stems (MERGEAI, 1993). *M. geocarpum* is typically a West African originated plant mainly produced in coastal countries (MERGEAI, 1993). It has either a bunched or prostrate growth habit (AMUTI, 1980; MERGEAI, 1993). Leaflets of trifoliolate leaves are ovate. The plant has small flowers of white to green pale or purple color which appear in pairs (AMUTI, 1980; MERGEAI, 1993). Mature pods are dehiscent (MERGEAI, 1993). The dry seed coat is smooth. The seeds are small, kidney-shaped with a 100 seed weight ranging from 5-15 g. The seed coat varies in color from white, brown, mottled (speckled), to black (AMUTI, 1980; MERGEAI, 1993). The crop is well adapted to sandy loams soils in which it gives better yields, though it tolerates poor sandy soils (MERGEAI, 1993 ; MARECHAL and BAUDET, 1977a ; ACHIGAN *et al.*, 2003). Generally, earth lens is produced on small land areas or sometimes in gardens. It can be cultivated in association with cowpea, yam, and cassava or as mono-cropping (ACHIGAN *et al.*, 2003). Mainly produced for its seeds, *M. geocarpum* is high nutritive. It is a good source of protein, carbohydrate, fiber and mineral salts (ECHENDU *et al.*, 2009). In addition to its dietary importance, the earth lens also has a remarkable importance in ritual practices and therapeutic use in West Africa and particularly in Benin, Ghana and Nigeria (AMUTI, 1980 ; MERGEAI, 1993 ; MARECHAL and BAUDET, 1977a). Moreover, *M. geocarpum* contributes at restoring soil fertility through atmospheric nitrogen fixation (ACHIGAN *et al.*, 2003). However, the earth lens is more and more neglected. Its cultivation has become marginal since the introduction of groundnuts (PORTERS, 1950). Farmers prefer grain legumes such as cowpeas, groundnuts and soybeans to earth lens (KOUÉLO *et al.*, 2012). An investigation done by the DGPV (2008) in Burkina Faso concluded that *M. geocarpum* is one of the seriously endangered species. Since early 1990's MERGEAI (1993) asserted that earth lens still survives thanks to its privileged role in cultural practices. This abandonment is explained by factors such as its small seeds size (5 mm x 4 mm), low yield (200-500 Kg/ha) and the quantity of labor required for harvest. Although the yield can

be improved up a ton per hectare (967 kg/ha) if proper soil fertility management strategies are applied (ACHIGAN *et al.*, 2003). *M. geocarpum* production is abandoned to elderly people even though it requires a lot of efforts in soil labor (AMUTI, 1980 ; BEHANZIN, 1986 ; ACHIGAN *et al.*, 2003). Consequently, the production is drastically decreased as a result of small land areas allocated to its production.

The abandonment of some ritual practices, by ignorance or on the benefit of revealed religions, during which earth lens is used is also one of the factors that contributed to its disappearance (TAMINI, 1995 ; 1997). This contributed to a low marketing value of the crop in the 1990's in Burkina Faso where 20 kg were sold for only 4.3 \$US (TAMINI, 1997). This poor market demand do not encourage a wide scale production of the crop. However, the crop is more expensive nowadays as compared to the other grain legumes (KOUÉLO *et al.*, 2012).

In addition to these social, cultural and economic constraints, the abandonment of the cultivation of the earth lens is also related to biotic and abiotic constraints (ACHIGAN *et al.*, 2003 ; BRINK & BELAY, 2006). The production of earth lens is confined to tropical and subtropical (MARECHAL and BAUDET, 1977b) requiring abundant sunlight and temperature between 18 and 34°C. In wet regions important damage related to fungal diseases such rust mold are reported (MARECHAL and BAUDET, 1977b ; ACHIGAN *et al.*, 2003). Non negligible post-harvest insects' attacks have also been reported (BRINK & BELAY, 2006). Weevils (*Piezotrachelus* spp.) and bruchids (*Bruchidae*) are the most import storage insects (ACHIGAN *et al.*, 2003).

The consequence of the high pressure of these constraints is the loss of genetic diversity. This risk of genetic extinction was far earlier mentioned by CHEVALIER (1910). For TAMINI (1995, 1997) beyond its importance as a food, the abandonment of its grain legume crop constitutes a heavy loss in the universal heritage. In addition, no known genetic study has been reported on this crop diversity in Burkina Faso. Therefore, it is necessary to preserve the existing genetic diversity for future improvement to prevent a genetic erosion of the species. The first step towards this goal is the characterization of the genetic variability which is done through this study.

I. Material and methods

1.1. Germplasm collection

The plant material used in this study composed of 20 *Macrotyloma geocarpum* landraces collected from farmers in the provinces of Kéné Dougou and Tuy located in the Hauts-Bassins Region and Léraba province in the Cascades region in Burkina Faso. These regions have been identified as the only earth lens production zones by TAMINI (1995, 1997).

1.2. Field management and data collection

The trial was implemented at Kamboinsé research station of the Institut de l'Environnement et de Recherches Agricoles (INERA) in Burkina Faso. This center is located in the Sudanian savannah zone between 12 ° 28 'north latitude and 1 ° 33' west longitude at 300 m above sea level, with a North-Sudanian type of climate. The trial was planted in a randomized complete block design with three replications. The experimental units were composed of two rows of 4 m each. The land preparation consisted of plowing and leveling. A single seed was planted per hill with a planting space of 0.3 m between and within rows.

NPK fertilizer (14-23-14) was applied, two weeks after planting, during the first weeding at a dose of 100 kg/ha. Insect pests spray was done using DECIS (deltametrin) at flowering stage at the dose of 2 cc/l.

Data were collected on ten randomly selected plants for each experimental unit. The quantitative data collected include days to first flowering, days to 50% flowering, days to 50% senescence, and days to 50% maturity. In addition, plant height, the number of leaves and the number of branches per plant were determined. Post-harvest data were pod size, seed size, hundred seed weight and yield. The yield estimate was done using the formula as follows:

$$Yield = (Total\ seed\ weight * 10\ 000) / (Plot\ area)$$

For qualitative data, flowers color, seeds color and leaflet shape were determined through visual assessment.

I.3. Data analysis

Analysis of Variance (ANOVA) was performed with the quantitative data collected using the GenStat 12th Edition. The relationships between the different parameters were determined through correlation analysis using Person's model. Principal component analysis (PCA) was run to determine the main parameters contributing to the genetic variability between the landraces. Cluster analysis was also done based on the pod length (GL) and width (GW), hundred seed weight (HSW), and the crop cycle (50% Mat).

II. Results

2.1. Morphological characters

The variation in both flowers and seed coat color observed among the different genotypes are presented in Table I. Three different flower and seeds colors were observed. Fifty percent (50%) of the tested genotypes had white flowers. The two other colors observed were violet (35%) and purple (15%). Plants having white and violet flowers produced exclusively white and black seeds respectively. However, genotype with purple flower produced both black and brown seed. The proportions of seed coat color observed were as follows: white (50%), black (35%), and brown (15%). Figure 1 presents samples of earth lens seeds.

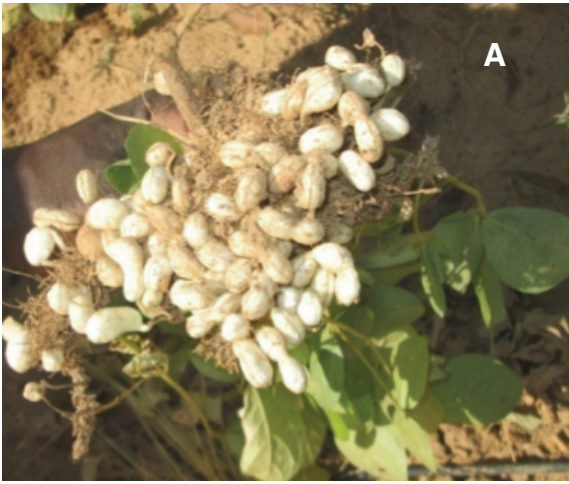


Figure 1 : Photo of pods and seeds of the earth lens. A: fresh pods, B: dry pods; C: seed

Table I: Observed flower colour and seed colour per ecotype.

Ecotype	Flower colour	Seed colour
E1-3	V	B
E1-4	V	B
E10	W	W
E11-1	W	W
E12-1	W	W
E13	W	W
E14	W	W
E15	W	W
E16-1	P	B ; Br
E16-2	P	B ; Br
E16-3	P	B ; Br
E18	V	B
E2	W	W
E3	W	W
E4	W	W
E5	W	W
E6	V	B
E7	V	B
E8-2	V	B
E9	V	B

V: violet, W: white, P: purple, B: black, Br: brown

The results of the statistical analysis showed that there was not significant differences (P-value > 0.05) between the landraces for morphologic characters such as plant height number of leaves per plant, the leaflet length and width, and number of branches (table II). The average number of leaves per plant was 41 leaves and leaf number ranged from 30 leaves (ecotype E16-3) to 60 leaves (ecotype E4). The leaflet length and width varied between 6.48 cm to 7.21 cm and from 4.35 cm to 4.77 cm respectively. The mean value of leaf length was 6.82 cm while the average leaf width was 4.55 cm. The minimum number of branches per ecotype was 4 and the maximum was 8 with an average of 6 branches. The shortest landraces measured 27.56 cm and the tallest 34.16 cm. Mean height was 30.57 cm.

Table II: Means and standard errors of morphologic characters for the 20 ecotypes.

Ecotype	HP	NL	LL	LW	NBr
E1-3	27.7±0.66	30.7±4.84	6.51±0.01	4.43±0.06	7.33±1.65
E1-4	28.2±3.50	35.7±8.96	6.80±0.40	4.64 ±0.39	4.67±0.33
E10	30.5±0.55	39.3±5.66	6.99±0.24	4.69±0.19	7.67±0.88
E11-1	33.1±3.13	44.0±4.50	6.74±0.12	4.35±0.02	6.00±0.57
E12-1	31.8±1.84	45.0±3.60	6.91±0.20	4.52±0.13	8.33±0.33
E13	29.2±3.27	44.7±4.80	7.17±0.09	4.53±0.11	8.33±1.20
E14	32.6±1.24	44.3±7.21	6.75±0.39	4.38±0.31	6.67±0.66
E15	28.4±0.61	35.7±6.88	7.22±0.27	4.71±0.19	6.67±1.76
E16-1	30.9±1.12	35.3±3.38	6.56±0.27	4.53±0.08	6.33±0.33
E16-2	32.1±1.91	38.0±4.16	6.79±0.26	4.53±0.16	6.00±0.00
E16-3	30.2±1.76	30.0±7.00	6.48±0.12	4.42±0.10	4.33±0.33
E18	32.4±1.96	41.7±7.31	6.71±0.12	4.64±0.16	6.67±0.33
E2	27.6±2.09	32.3±3.64	6.80±0.40	4.62±0.40	5.67±0.66
E3	29.5±2.71	44.3±2.33	6.92±0.15	4.42±0.10	6.00±0.00
E4	31.5±2.21	60.3±16.12	7.07±0.63	4.77±0.52	8.00±1.15
E5	34.2±4.02	43.0±8.18	7.14±0.06	4.53±0.03	6.33±0.88
E6	31.0±4.36	44.3±8.95	6.84±0.09	4.59±0.07	6.33±0.88
E7	29.0±1.63	41.7±4.17	6.82±0.25	4.61±0.15	5.00±0.57
E8-2	31.8±1.18	46.0±6.80	6.51±0.18	4.55±0.12	6.67±0.33
E9	29.7±0.75	45.7±6.17	6.68±0.31	4.67±0.24	6.67±0.88
Mean	30.6	41.1	6.82	4.56	6.48
CV	12.8	24.5	7	8.3	23
P-value (5%)	0.795 ^{ns}	0.181 ^{ns}	0.853 ^{ns}	0.998 ^{ns}	0.099 ^{ns}

ns: not significant; HP: plant height; NL: number of leaves; LL: leaflet length; LW: Leaflet width; NBr: number of branches; CV: coefficient of variation;

2.2. Agronomic traits

The results of the analysis of variance for days to first flowering, days to 50% flowering, days to 50% senescence, and days to 50% maturity are presented in Table III. There was no statistical differences between the genotypes for all these parameters except days to 50% maturity. All the tested landraces set their first flower within the 46th day after planting (DAP) and the 48th DAP. The number of days to 50% flowering ranged from 46 days to 54 days with an average of 51 days. Leaf senescence of different landraces occurred between 82 days after planting and 84 days; the average was 83 days. The number of days to 50% maturity of different landraces ranged from 92 days to 95 days with an average of 93 days. The analysis of variance for this trait was highly significant ($P < 0.001$).

Table III: Means and standard errors of the 20 ecotypes for flowering and maturity parameters.

Ecotype	DAPF	50% Flo	50% Sen	50% Mat
E1-3	47.00±0.00	51.67±0.88	83.00±0.00	92.00±0.00
E1-4	46.67±0.33	52.67±2.18	83.00±0.00	92.00±0.00
E10	47.33±0.33	51.67±1.20	83.67±0.33	94.33±0.33
E11-1	47.00±0.00	51.67±1.20	83.00±1.00	92.00±0.00
E12-1	47.33±0.88	54.00±1.68	83.33±1.02	94.67±0.66
E13	47.33±0.33	51.33±1.52	83.33±0.66	93.33±0.66
E14	46.67±0.66	50.33±1.20	84.00±1.15	93.00±0.57
E15	48.33±1.20	51.33±0.66	84.00±0.00	93.67±0.88
E16-1	47.33±0.33	52.00±2.08	84.00±0.57	94.33±0.33
E16-2	46.67±0.33	52.33±1.85	82.33±0.33	92.67±0.33
E16-3	48.33±0.88	53.67±1.85	83.33±0.33	95.33±0.33
E18	47.67±0.33	50.67±0.66	82.33±0.88	92.33±0.33
E2	47.33±0.33	52.33±1.20	84.00±0.57	93.67±0.33
E3	46.67±0.33	52.33±2.60	84.00±0.66	93.00±0.57
E4	48.00±1.15.	51.67±1.66	83.33±0.66	94.33±0.33
E5	47.33±0.33	51.67±0.88	83.33±0.66	93.00±0.00
E6	47.67±0.33	50.33±0.33	83.00±1.15	93.67±0.33
E7	47.33±0.33	49.67±0.88	82.33±0.33	92.66±0.33
E8-2	46.33±0.33	52.33±1.85	82.67±1.20	93.67±0.33
E9	47.33±0.57	50.33±0.66	82.67±0.33	92.67±0.33
Mean	47.28	51.7	83.22	93.317
CV	2.1	4	1.5	0.8
P-value (5%)	0.590 ns	0.637 ns	0.705 ns	<.001**
LSD (5%)				1.2317

** : highly significant; ns: not significant; DAPF: days to first flowering; 50% Flo: days to fifty percent flowering; 50% Sen: days to fifty percent senescence; 50% Mat: days to fifty percent maturity; CV: coefficient of variation; LSD: least significant difference.

2.3. Yield and yield components

The variation in yield and yield components of the 20 ecotypes are shown in table IV.

Variables like pod length and width and grain yield did not show any significant differences between landraces (P-value > 0.05). Measurements of pod length varied from 0.91 cm to 1.03 cm with an average of 0.98 cm. The ecotype E5 had the shortest pod length while the longest length was obtained with the ecotypes E3, E6 and E9. The width of the pod varied from 0.66 cm (E16-3) to 0.78 cm (E7 and E8-2) with an average of 0.72 cm. Yield ranged from 196.82 Kg/ha (E16-3) to 298.95 Kg/ha (E16-1) with an average of 234.81 Kg/ha.

In contrast to the above three parameters, seed length and width, and hundred seed weight revealed highly significant differences between the landraces (P-value < 0.05). The average seed length was 0.73 cm with a minimum and maximum of 0.64 cm (E15) and 0.81 cm (E9) respectively (table 1). The ecotype E15 also recorded the smallest seed width ranged (0.42 cm). Ecotypes E1-3, E8-2 and E16-1 had the largest seed width (0.55 cm). The average seed width was 0.51 cm.

as for seed length and seed width, the smallest hundred seeds weight was obtained with ecotype E15 (7.32 g). The maximum hundred seed weight was 13.12 g (E9) and the average was 11.12 g.

Table IV: Means and standard errors of yield and yield components.

Ecotype	PL	PW	GL	GW	HSW	Yield
E1-3	0.93±0.05	0.77±0.04	0.79±0.01	0.55±0.00	13.00±0.11	228.35±20.94
E1-4	1.00±0.00	0.73±0.01	0.75±0.01	0.54±0.02	9.95±0.65	217.29±18.92
E10	1.02±0.01	0.76±0.03	0.68±0.00	0.51±0.01	10.20±0.46	223.40±18.92
E11-1	0.97±0.02	0.67±0.02	0.70±0.01	0.50±0.02	10.82±1.15	224.79±18.92
E12-1	0.96±0.02	0.69±0.00	0.69±0.03	0.46±0.01	8.08±0.53	249.33±19.55
E13	1.02±0.04	0.74±0.03	0.74±0.02	0.50±0.02	11.17±0.72	242.97±18.96
E14	0.95±0.07	0.72±0.04	0.69±0.04	0.48±0.03	10.53±0.74	218.70±19.61
E15	0.99±0.02	0.74±0.07	0.64±0.00	0.42±0.00	7.32±0.76	213.16±18.96
E16-1	1.01±0.01	0.75±0.02	0.78±0.02	0.55±0.01	13.07±0.46	298.95±20.75
E16-2	0.95±0.03	0.73±0.02	0.75±0.01	0.52±0.00	12.07±0.17	230,22±19.56
E16-3	0.95±0.01	0.66±0.02	0.73±0.02	0.51±0.01	10.68±0.38	196.82±19.59
E18	1.01±0.02	0.70±0.03	0.75±0.01	0.54±0.00	11.73±1.00	239.50±19.55
E2	0.95±0.08	0.70±0.00	0.72±0.02	0.51±0.00	10.37±2.10	211.06±19.49
E3	1.03±0.04	0.73±0.03	0.72±0.03	0.51±0.02	12.27±1.04	216.05±18.94
E4	1.03±0.04	0.76±0.03	0.74±0.01	0.51±0.01	9.70±0.47	233.89±18.92
E5	0.91±0.01	0.69±0.01	0.68±0.02	0.45±0.01	11.03±0.18	229.08±20.74
E6	1.03±0.00	0.76±0.02	0.78±0.02	0.52±0.01	12.57±0.34	270.59±18.94
E7	0.99±0.01	0.78±0.02	0.76±0.03	0.56±0.02	12.38±1.31	258.29±19.61
E8-2	1.00±0.01	0.78±0.02	0.77±0.02	0.55±0.03	12.47±1.71	269.82±19.61
E9	1.03±0.00	0.73±0.01	0.81±0.00	0.53±0.01	13.12±0.44	224.02±18.96
Mean	0.99	0.73	0.73	0.51	11.13	234.81
CV	6.4	7	5.4	6.7	14.3	13.7
P-value (5%)	0.461 ns	0.160 ns	<.001**	<.001**	0.002*	0.1028 ns
LSD (5%)			0.066	0.056	2.637	

PL: Pod length; PW: Pod width; GL: grain length; GW: grain width; HSW: hundred seeds weight.

2.4. Correlations between characters

Table V presents some parameters which revealed significant correlations between them. Variables DAPF, 50% Flo, 50% Sen and 50% Mat did not show any correlation with other variables. It was observed positive and significant correlations between plant height and leaves number (0.50). Positive and significant correlations were also observed between leaflet length and leaflet width (0.81), pod length and pod width (0.52) and seed length and seed width. Both seed length and seed weight were positively and highly correlated to hundred weight.

Table V: Coefficients of correlation and their significance between the studied parameters

Variables	HP	NL	LL	LW	PL	PW	GL	GW	HSW
HP	1								
NL	0.5036*	1							
LL	0.1923	0.3504	1						
LW	0.2012	0.3594	0.8111**	1					
PL	0.0385	0.1455	0.0417	0.2205	1				
PW	-0.0423	0.0436	0.0651	0.1730	0.5254*	1			
GL	0.0504	0.0725	-0.1883	0.0643	0.4259	0.4418	1		
GW	-0.0080	-0.1174	-0.2768	0.0230	0.3423	0.4231	0.7628**	1	
HSW	0.1527	0.1111	-0.1584	-0.0399	0.2709	0.2784	0.6758**	0.6740**	1

HP: plant height; NL: number of leaves; LL: leaflet length; LW: leaflet width; NBr: number of branches; PL: pod length; PW: pod width; GL: grain length; GW: grain width; HSW: hundred seeds weight.

2.5. Principal component analysis

Principal component analysis was performed to determine the most important parameters determining the genetic variability among the tested genotypes. The results showed that the two first components explained 49.30% of the genetic variability within the landraces (figure 2). PC1 accounted for 30.12% of the observed genetic variability and PC2 contributed for 19.18%. The association between parameters and two axes were also determined. Parameters such as the number of branches, pod length and width and number of leaves contributed more to the genetic variability explained by PC1. The parameters seed length, seed width and hundred seed weight, strongly correlated with the PC1. These results revealed that the relevant parameters of the study are seed length, seed width, number of leaves, plant height, fifty percent flowering and fifty percent maturity.

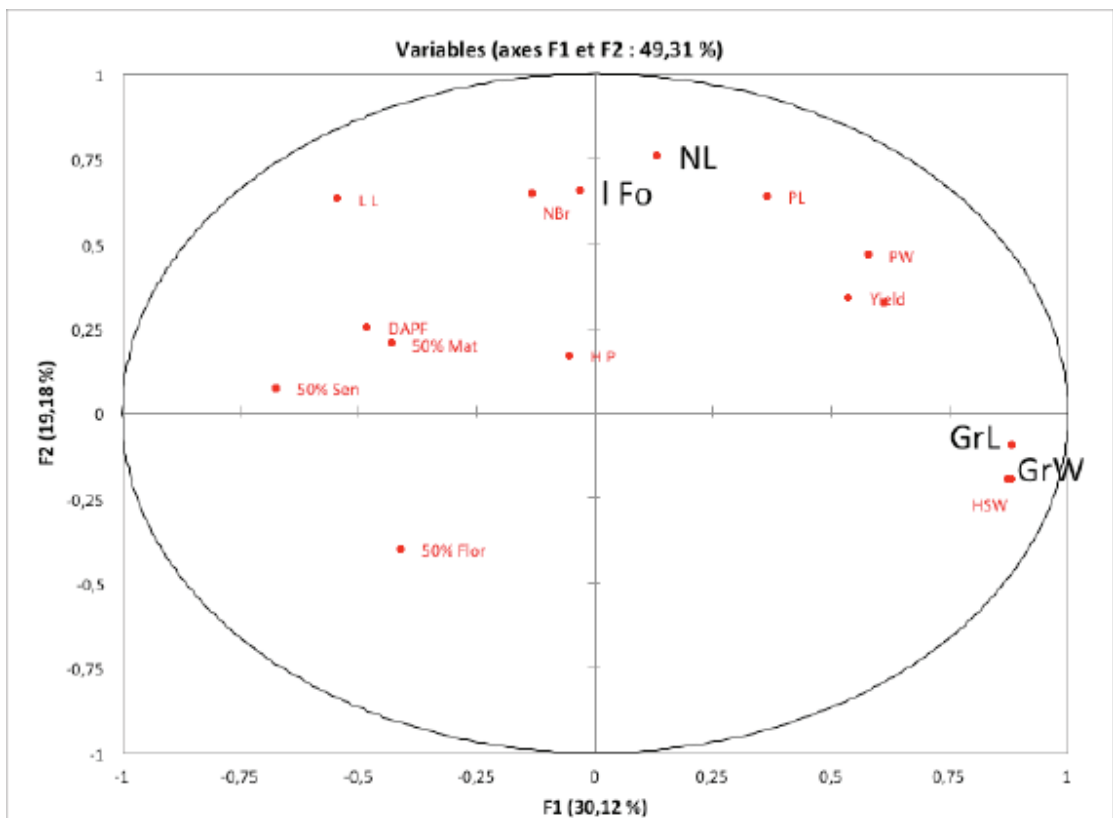


Figure 2: Graph showing the result of the principal components analysis of the parameters studied.

DAPF :date of appearance of the first flower; 50% Flo: fifty percent flowering; 50% Sen): fifty percent senescence; 50% Mat: fifty percent mature; HP: Plant height; NL: number of leaves; LL: length of the leaflet; LW: width of the leaflet; NBr: number of branches; PL: length of the pod; PW: width of the pod; GrL: length of the seed; GrW: width of the seed; HSW: weight of one hundred seeds.

2.6. Grouping by class of different landraces

The hierarchical ascending classification analysis (CAH) revealed three classes with a level of similarity of 0.99 (figure 3) based on the pod length (GL) and width (GW), hundred seed weight (HSW), and the crop cycle (50% Mat) that were highly significant. Class one which is the largest group is composed of 13 ecotypes. Class two and three are made of three and four individuals respectively. The characteristics of each group are presented in table VI.

Class 1 was characterized by ecotypes having short cycle duration and intermediate seed size and hundred seeds weight.

Class 2 was composed of landraces with long-cycle, with small seed size and low hundred seeds weight.

Class 3 comprised mid-cycle duration landraces with large seed size and high seed weight.

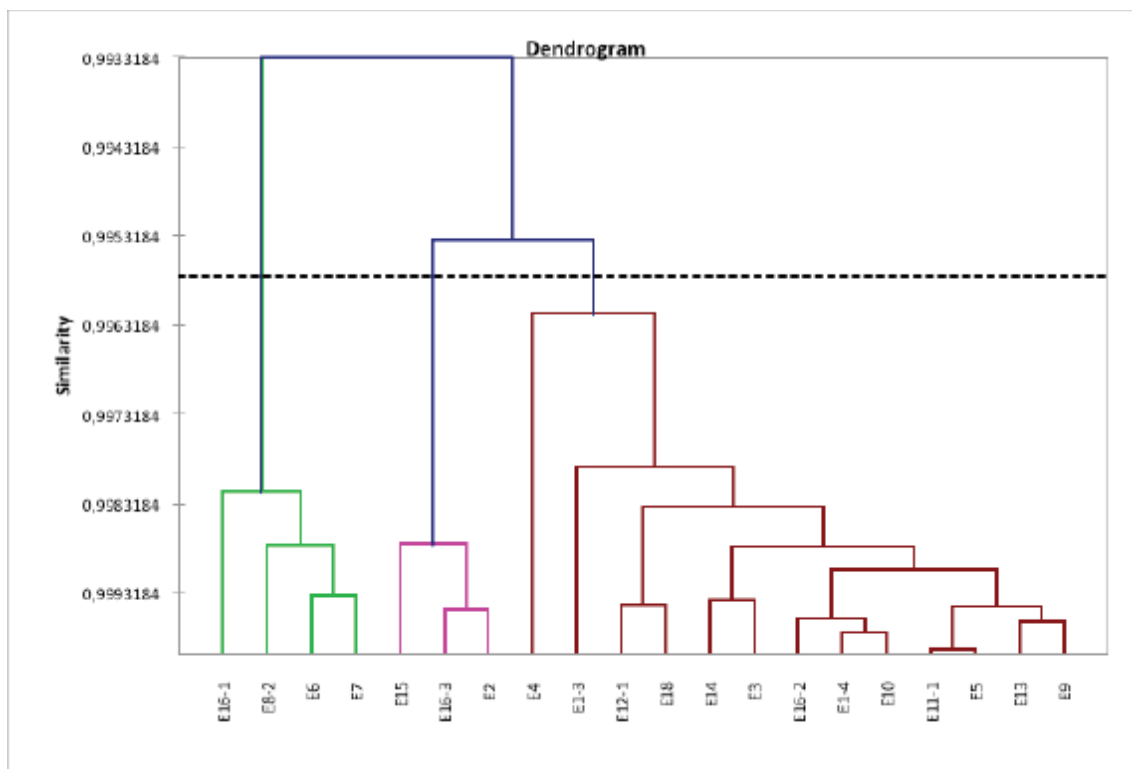


Figure 3: Dendrogramme showing the different classes of landraces of the earth lens.

Table VI: Composition and characteristics of classes

Class	Landraces	Characteristics
1	E4, E1-3, E12-1, E18, E14, E3, E16-2, E1-4 , E10, E11-1, E5, E13, E9	- seed length and width (0.73 mm and 0.50 mm) - weight of one hundred seeds medium (11.05 g) - cycle (92 days)
2	E15, E16-3, E2	- length and width of seeds (0.69 mm and 0.48 mm) - low weight of one hundred seeds (9.45 g) - cycle (94 days)
3	E16-1, E8-2, E6, E7	- length and width of seeds (0.77 mm 0.54 mm) - weight of one hundred seeds (12.62 g) - cycle (93 days)

Discussion

The results of the analysis of variance did not reveal any significant differences between the ecotypes of *Macrotyloma geocarpum* for most morphologic characters indicating a lack of genetic diversity among the genotypes. The moderate genetic variability can be explained by the low number of genotypes tested in this study (20) or the loss of the variability due to the genetic

erosion linked the low cultivation of the crop. Nevertheless, mean plant height recorded in this study was higher than reported by (ACHIGAN *et al.*, 2003). This can be related to differences in environmental factors such as soil fertility level, rainfall or the genetic makeup of the tested genotypes. KOUELO *et al.* (2012) reported significant biomass increase when soil fertility is monitored. The only morphological differences observed on flower and seed coat color. Landraces having white and violet flowers produced exclusively white and black color seeds respectively. However, landraces with purple flower produced either black seeds or a mixture of black seeds and brown seeds even though brown seeds are few as compared to black ones. Epistasis gene effect could be involved in the expression of the brown seed color in these genotypes. Previous studies have also reported such correlations between flower and seeds color (DUKE *et al.*, 1977 ; SMART, 1985).

Like morphological characters, no significant differences were observed for some agro-morphological parameters such as days to first flowering, days to 50% flowering, and days to 50% senescence inferring the absence of genetic variability among the ecotypes for these traits. However, their 50% maturity cycle duration were different. The delay between days to flowering and days to maturity observed with some landraces could be explained by their potential of expanding their flowering duration. Days to 50% maturity for all the tested genotypes ranged 92 and 95 days after planting (DAP) meaning that they are all early maturing genotypes, cycle duration of *M. geocarpum* being ranged between 90 and 150 DAP (MARECHAL and BAUDET, 1977a). Medium and late maturing genotypes could have been abandoned due to the gradual shortening of rain seasons.

Statistical analysis revealed significant differences between landraces for seed size (length and width) and grain weight. However, no significant difference was observed between the genotypes for their yield potential and pod size as well. Therefore, seed size and weight are the only yield component variables for which genetic variability is observed in this study. These three variables were also highly correlated to each other meaning that each of these parameters can be measured through the other associated ones. As regards to hundred seed weight, landraces such as ecotype E9 (13.12 g), E1-3 (13 g), E16-1 (13.07 g), and E6 (12.57 g) can be considered as the best. However, all these landraces have black seed coat color which is less preferred to white seeds by women TAMINI (1995 ; 1997). Therefore, these best genotypes possessing both large size seeds with white color and are the ecotype E3 (12.27 g) and E13 (11.17 g). Such characteristics are also preferred by stakeholders for cowpea, the first legume crop produced in Burkina Faso (TIGNEGRE, 2010 ; BATIENO, 2014 ; DIENI, 2017 ; DIENI *et al.*, 2019, ISHIKAWA *et al.*, 2019). Therefore, genetic improvement program on *M. geocarpum* should target these traits for the sake of meeting farmers' preferences.

Genetic improvement is possible if genetic variability is available. The results revealed that 49.36% genetic variability exists within the landraces. This relatively low variability observed could be explained by the self-pollinating nature of the crop and the low number of landraces used in this study. The existing genetic variability could also be the consequence of the loss of genetic variability due to the abandonment of the crop. Therefore, it is urgent to maintain the existing resources and conduct a larger collection in order to reach the entire genetic variability still available at the country level. It is also necessary to create new genetic variability through appropriate methods. The different landraces were grouped into three classes with different characteristics. These classes could serve as basis for selecting genotypes for eventual crosses.

Conclusion

Macrotyloma geocarpum is one of the seriously endangered species in Burkina Faso. The current study revealed a moderate genetic variability still exist within the 20 landraces collected in the country. This variability was expressed through some agro-morphological characters such as cycle duration, seed size and seed weight. Based on these traits, three mains groups were obtained and could serve as basis for genetic improvement. Therefore, urgent measures should be taken for the conservation of the available genetic variability and subsequently improve it by collecting more accession or introduce from other countries.

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