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Research article

EVALUATION OF MORPHO-METRIC CHARACTERISTICS OF FRUITS AND OIL CONTENT OF SEEDS OF *Jatropha curcas* L. IN BURKINA FASO

Fidèle Kouka TIENDREBEOGO; Nerbéwendé SAWADOGO; Romaric Kiswendsida NANEMA; Ernest Renan TRAORE ; Pauline BATIONO-KANDO; Mahamadi Hamed OUEDRAOGO and Mahamadou SAWADOGO

Genetics and Plant Breeding Team (EGAP), Biosciences Laboratory, Sciences and Technologies Doctoral School, University Ouaga I Professor Joseph KI-ZERBO, BURKINA FASO 03 BP 7021 Ouagadougou 03

ABSTRACT : *Jatropha curcas* is a perennial oleaginous plant whose seed oil is used in the manufacture of biodiesel and soap. Despite its many potentialities, it remains under exploited in Burkina Faso. The objective of this study is to determine the level of genetic diversity and estimate genetic parameters of the collection in order to contribute to the valorization of plant. Thus, the fruits of 50 accessions of an experimental field located at Gampèla in station of the Institute of Rural Development were collected and evaluated using ten characters which relate to measurements and weight of fruits and seeds and one trait about the oil content of seeds.

Results revealed a significant variability of all characters. Seed weight and oil content showed an important variation than the others characters with average values ranging respectively from 36.9 g to 71.16 g and 49.24% to 72.9%. Accessions S7, S14, S15, S26 and H16 showed the highest weight of 100 seeds while accessions H4, H6, H10, N2 and N107 showed the highest oil content. Characters oil content and weight of 100 seeds showed high broad sense heritability and high expected genetic advance indicating additive effects of genes and an opportunity for improvement of these traits through selection.

The results of this study could be used in *Jatropha curcas* breeding programs in Burkina Faso.

Key words: *Jatropha curcas*, genetic diversity, selection, Burkina Faso.

*Corresponding author: Fidèle Kouka TIENDREBEOGO, Genetics and Plant Breeding Team (EGAP), Biosciences Laboratory, Sciences and Technologies Doctoral School, University Ouaga I Professor Joseph KI-ZERBO, BURKINA FASO 03 BP 7021 Ouagadougou Email: tkfidele@yahoo.fr, (00226)78147118

INTRODUCTION

Jatropha curcas L. is a species native to tropical America and cultivated in tropical areas of Africa and Asia [1]. In Burkina Faso it is found in the different phytogeographical sectors in diverse climatic and soil conditions. *Jatropha curcas* is a perennial oleaginous plant belong to the Euphorbiaceae family. According to Fairless [2], it is an alternative for the production of biodiesel. The crude oil extracted from the seed can be converted into biodiesel by a transesterification process [3]. Many plant parts are also used in cosmetics, in the biopharmaceutical industry and in the manufacture of biopesticides [4]. Due to the high index of saponification, the oil is suitable for soap making [5]. Oil is however inedible [6] because, it contains anti-nutritional factors such as phorbol esters. The residue obtained after extraction of the oil is also unsuitable for animal feed, despite its rich nutritional composition [7,8]. Yet these same authors indicate the existence of non-toxic *Jatropha curcas* varieties encountered in Mexico whose culture could bring oil for biodiesel production and the residue obtained could be used to feed livestock.

Despite its potentialities, the plant remains underexploited and its genetic variability is not well known in Burkina Faso. Yet, the knowledge of the genetic variability of morphological characters and seed oil content is important for breeding programs, particularly the selection of elites phenotypes with high oil content and high yield [9]. Indeed, the existence of genetic variability is important in breeding programs because it allows selection of genotypes to produce hybrids and lines [10].
The study of traits of seeds of oleaginous plant according to Mohapatra *et al.* [11] is often regarded as useful in assessing genetic diversity.
This study aims to know the morphological and biochemical diversity of fruits and seeds of 50 accessions of *Jatropha curcas* from different phytogeographical areas of Burkina Faso in order to select the elites varieties. The specific objectives are to determine the level and structuring of the agromorphological diversity of the collection and to estimate genetic parameters in order to identify the best strategies for improvement and valorization of this genetic resource.

MATERIAL AND METHODS

EXPERIMENTAL SITE

Study was carried out in 2014 in the experimental station of the Institute of Rural Development (IDR) at Gampela, 18 km east of Ouagadougou (1 21' 0.9' West longitude, 12 ° 24' 10.7'' North latitude and 924 m above sea level). The site soils are very heterogeneous, deep and low physico-chemical fertility [12]. The rainfall recorded in the station between 2007 and 2014 are presented in Table 1.

Table 1: Rainfall in Gampela Experimental Station from 2007 to 2014

Year	2007	2008	2009	2010	2011	2012	2013	2014
Rainfall (mm)	741.8	865.9	853.6	843	728	984.8	748.9	901.9

Experimental Design

The experimental field consists of 50 elementary plots 8 m x 8 m. Each elementary plot contains 9 plants arranged in three lines of length 8 m. The distance was 4 m. The walk ways between plots were also 4m.

Plant Material

This study was performed using a collection of 50 accessions of *Jatropha curcas* collected between 2006 and 2008 in different phytogeographical areas of Burkina Faso. An accession is all seeds resulting from natural pollination collected on the same tree during the prospection. There seeds of fruits were stored at laboratory temperature without any chemical treatment. The collection covered 33 departments in 21 provinces. The geographical coordinates of the various sites of collection are presented in table 2.

TRAITS MEASURED

Eleven (11) quantitative characters composed of ten (10) morphological traits and one (1) biochemical trait were selected to this study according to many authors [1, 4,13,14].
The morphological characters were measured on fruits and seeds in a ripe and dry state collected on three plants sampled by accession. A preliminary statistical test inspired of the methodology used by Bationo-Kando *et al.* [15] made it possible to retain ten fruits and ten seeds per tree for measurements. The characters measured on the fruits are: capsule length (CL), capsule diameter (CD), capsule weight (CW), pulp weight (PW) and the average number of seeds/capsule (NS). The characters measured on the seed related to the seed length (SL), seed width (SW), seed thickness (ST) and 100 seeds weight (SW100). The seeds capsules proportion (SC) expressed in percentage was determined according to the formula:

$$SC = \left(\frac{seeds\ weight\ of\ 10\ capsules}{10\ capsules\ weight}\right) * 100$$

The biochemical trait, oil content (OIL) was determined according to the soxhlet extraction method by using hexane like solvent [16].

Tableau 2: Geographical coordinates of the various sites of accessions of *Jatropha curcas*

Accessions Codes	Localities	Departments	Provinces	Phytogeographicals Sectors	Coordinates (UTM) Longitude	Latitude
S15	Loumbila	Loumbila	Oubritenga	Nord soudanien	677110,0000	1384613,000
S14	Sokoura	Barani	Kossi	Nord soudanien	392550,0000	1457217,000
S17	Sokoura	Barani	Kossi	Nord soudanien	392550,0000	1457217,000
S22	Tchériba	Tchériba	Mouhoun	Nord soudanien	491123,0000	1355640,000
S16	Tchériba	Tchériba	Mouhoun	Nord soudanien	491123,0000	1355640,000
S7	Dembo	Nouna	Kossi	Nord soudanien	394672,0000	1415451,000
S5	Faramana	Faramana	Houet	Sud soudanien	318396,0000	1332542,000
S26	Loumbila	Loumbila	Oubritenga	Nord soudanien	677110,0000	1384613,000
S12	Sapouy	Sapouy	Ziro	Sud soudanien	633682,0000	1276833,000
S2	Dembo	Nouna	Kossi	Nord soudanien	394672,0000	1415451,000
S1	Tchériba	Tchériba	Mouhoun	Nord soudanien	491123,0000	1355640,000
H16	Mansila	Mansila	Yagha	Sub sahélien	896691,7500	1458325,630
H28	Mantougou	Kantchari	Tapoa	Nord soudanien	978280,1880	1380384,250
H10	Mantougou	Kantchari	Tapoa	Nord soudanien	978280,1880	1380384,250
H3	Cassou	Cassou	Ziro	Sud soudanien	603715,0000	1279740,000
H4	Cassou	Cassou	Ziro	Sud soudanien	603715,0000	1279740,000
H2	Mani	Mani	Gnagna	Sub sahélien	802370,0000	1467398,000
H6	Naponé	Cassou	Ziro	Sud soudanien	603715,0000	1279740,000
H25	Diapangou	Diapangou	Gourma	Nord soudanien	848909,1250	1342144,880
H1	Mansila	Mansila	Yagha	Sub sahélien	896691,7500	1458325,630
N28	Meguet	Meguet	Ganzourgou	Nord soudanien	748323,2500	1374023,130
N52	Sadaba	Ziniaré	Oubritenga	Nord soudanien	685046,0000	1391354,000
N10	Mansila	Mansila	Yagha	Sub sahélien	896691,7500	1458325,630
N65	Lékui	Dédougou	Mouhoun	Nord soudanien	425839,0000	1365639,000
N90	Réo	Réo	Sanguié	Nord soudanien	557601,0000	1361775,000
N108	Yegueresso	Bobo Dsso	Houet	Sud soudanien	373417,0000	1233854,000
N61	Takaledougou	Banfora	Comoé	Sud soudanien	307085,1880	1176861,630
N23	Faramana	Faramana	Houet	Sud soudanien	318396,0000	1332542,000
N62	Toma	Toma	Nayala	Nord soudanien	511253,0000	1410522,000
N83	Bidega	Tenkodogo	Boulgou	Nord soudanien	776271,0000	1305985,000
N88	Séguénéga	Séguénéga	Yatenga	Sub sahélien	611233,0000	1485795,000
N75	Kadio	Pouytenga	Kouritenga	Nord soudanien	779554,0000	1355420,000
N105	Lohkodi	Gaoua	Poni	Sud soudanien	479827,0000	1141623,000
N107	Boni	Boni	Tuy	Sud soudanien	456537,1560	1278061,380
N82	Gbankoran	Kampti	Poni	Sud soudanien	449759,0000	1120914,000
N68	Midebdo	Midebdo	Noumbiel	Sud soudanien	483765,0000	1104022,000
N56	Biba	Yaba	Nayala	Nord soudanien	503174,0000	1415662,000
N69	Pousghin	Boudry	Ganzourgou	Nord soudanien	745909,0630	1338401,750
N2	Péyiri	Koudougou	Boulkiemde	Nord soudanien	569140,0000	1354315,000
N8	Diapangou	Diapangou	Gourma	Nord soudanien	848909,1250	1342144,880
N6	Naponé	Cassou	Ziro	Sud soudanien	603715,0000	1279740,000
N67	Legmoin	Legmoin	Noumbiel	Sud soudanien	510351,0000	1121670,000
N30	Bahala	Kantchari	Tapoa	Nord soudanien	995636,4375	1380338,375
N111	Péyiri	Koudougou	Boulkiemdé	Nord soudanien	569140,0000	1354315,000
N106	Loropéni	Loropéni	Poni	Sud soudanien	441832,0000	1138354,000
N17	Naponé	Cassou	Ziro	Sud soudanien	603715,0000	1279740,000
N80	Founyabou	Logobou	Tapoa	Sud soudanien	1010114,5600	1283526,630
N70	Dargo	Dargo	Namentenga	Sub sahélien	794690,2500	1407387,130
N117	Gbankoran	Kampti	Poni	Sud soudanien	449759,0000	1120914,000
N60	Pousghin	Boudry	Ganzourgou	Nord soudanien	745909,0630	1338401,750

UTM : Universal Transverse Mercator

Data Analysis
Genstat version 410.3 software was used to estimate the statistical descriptive parameters such as averages, minimal and maximum values, coefficients of variation. Analysis of variance (ANOVA) was performed with the same software to determine quantitative traits discriminating the various accessions. For each of these traits, genetics parameters such as genotypic variance (VG), phenotypic variance (VP), genotypic and phenotypic coefficients of variation (GCV and PCV), broad sense heritability (H^2) and expected genetic advance (GA) were calculated according to Hemissi [17] and Shabanimofrad *et al*. [18]. Relationships between these traits were studied through to Pearson correlation tests at 5% and 1% and all accessions were subsequently consolidated from the hierarchical cluster analysis (AHC) using the method of Ward with Statistica version 6 software. The groups were then characterized through the factorial discriminating analysis by the XLSTAT Pro 7.5.2 software.

RESULTS
Variation of Traits
The results of analysis of variance (Table 3) showed that all traits discriminate significantly accessions. The coefficients of variation range from 0.42% for the character oil content and 14.68% for the character capsule weight are relatively low (<30%). However characters seed weight and oil content revealed an important variation compared to the other characters. Moreover characters seed weight and oil content of *Jatropha curcas* are according to Wen *et al*., [19], the two characters whose economic interest is the most important.

Table 3: Performance of accessions of *Jatropha curcas* L.

Variables	Min	Max	Moy	CV (%)	F
CL (mm)	18.70	26.80	23.97	4.36	2.91**
CD (mm)	16.20	22.65	20.87	3.58	2.28**
CW (g)	0.83	3.05	2.22	14.68	3.61**
PW (g)	0.36	1.11	0.75	11.53	3.81**
NS	1.2	3	2.67	11.2	2.35**
SL (mm)	14.5	19.4	17.95	3.18	2.9**
SW (mm)	9.9	11.85	11.06	2.36	3.62**
ST (mm)	7.75	9.5	8.48	2.32	4.46**
SW100 (g)	35.9	72.3	55.88	9.2	5.97**
SC (%)	26.92	76.79	64.99	7.27	4.53**
OIL (%)	48.8	73.02	61.26	0.42	1543.33**

SL : seed length, SW : seed width, ST : seed thickness, SW100 : 100 seeds weight, CL : capsule length, CD : capsule diameter, CW : capsule weight, PW : pulp weight ; NS : average number of seed/capsule , SC : proportion seeds capsules, OIL : oil content, Min : minimum, Max : Maximum, Moy : Mean, CV (%) : coefficient of variation, F : coefficient of Fisher

Results of Table 4 revealed that the accessions S7, S14, S15, S26 and H16 present the highest values of 100 seeds weight (>64 g) while the accessions H4, H6, H10, N2 and N107 have the highest value of oil content (>70%). Also the highest value of oil content was recorded for the accession H4 (72.90 ± 0.12%). Concerning the 100 seeds weight, the highest value was obtained for the accession S14 (71.16 g). Accession N60 has the lowest value for the 100 seeds weight (36.9 g) and oil content (49.24±0.44%).

Correlations Between Characters Studied
Results of table 5 presented many positive and highly significant correlations obtained at $\alpha = 1\%$.The character 100 seeds weight is positively and significantly correlated with the seed length characters (r = 0.59), seed width (r = 0.59) and seed thickness (r = 0.53). However the oil content character is not significantly correlated with any characters studied.

Structure of the Variability of Accessions
The hierarchical clustering (AHC) performed on weighted averages of Euclidean distances (Figure 1) shows, in a truncation of 50 Euclidean distance units, a distribution of 50 accessions into three groups. The structure obtained is not related to the geographic origin of accessions. Indeed, each group contains accessions from the three phytogeographical areas. The results of the analysis of variance (table 6) show highly significant differences at 1% level between groups for all characters except pulp weight and oil content characters.

Furthermore, the characters capsule diameter, capsule weight, 100 seeds weight and seed width are the main factors for discriminating groups. Thus, accessions of group 3 have high 100 seeds weight (63.34 g) and large capsule diameter (21.27 cm) while the group 1 consists of accessions to the weak 100 seeds weight (45.5 g) and weak capsule diameter (20.19 cm). As for group 2, it consists of accessions to the average performance (100SW: 54.67 g ; CD : 20.88 cm).

Table 4: Average values of the 100 seeds weight and oil content of the 50 accessions of *Jatropha curcas* of Burkina Faso

Accession code	SW100 (g)	OIL (%)	Accession code	SW100 (g)	OIL (%)
S15	68.03ABC	58.79±0.14N	N108	61.10ABCDE	54.79±0.18PQ
S14	71.16A	59.48±0.01N	N61	55.60ABCDEF	61.29±0.09LM
S17	54.76ABCDEF	59.49±0.54N	N23	52.90ABCDEF	57.53±0.30O
S22	55.86ABCDEF	57.39±0.27O	N62	53.30ABCDEF	66.38±0.26G
S16	58.70ABCDE	67.72±0.03F	N83	54.93ABCDEF	62.08±0.28JKL
S7	64.40ABCD	67.11±0.10FG	N88	54.45ABCDEF	66.48±0.15G
S5	60.40ABCDE	57.15±0.24O	N75	63.70ABCDE	66.38±0.79G
S26	64.53ABCD	69.54±0.09D	N105	43.85EF	56.63±0.61O
S12	63.00ABCDE	60.55±0.09M	N107	48.50DEF	70.67±0.11C
S2	61.85ABCDE	59.52±0.22N	N82	45.90DEF	54.83±0.40PQ
S1	51.70BCDEF	52.80±0.22S	N68	58.33ABCDE	51.39±0.15T
H16	69.50AB	61.72±0.41KL	N56	55.23ABCDEF	55.26±0.26P
H28	56.50ABCDE	62.96±0.94J	N69	64.30ABCDE	56.85±0.18O
H10	55.96ABCDEF	72.23±0.03AB	N2	59.20ABCDE	71.51±0.21B
H3	43.93EF	55.44±0.37P	N8	63.25ABCDE	60.77±0.15M
H4	52.90ABCDEF	72.90±0.12A	N6	52.45ABCDEF	53.90±0.09QR
H2	54.46ABCDEF	65.16±0.20H	N67	64.00ABCDE	56.81±0.42O
H6	58.10ABCDE	72.33±0.24AB	N30	54.40ABCDEF	57.33±0.08O
H25	46.43DEF	63.73±0.06I	N111	43.30EF	53.33±0.30RS
H1	62.16^{ABCDE}	57.53±0.16^{O}	N106	50.20^{CDEF}	59.57±0.48^{N}
N28	56.10^{ABCDEF}	59.17±0.13^{N}	N17	53.20^{ABCDEF}	64.59±0.55^{H}
N52	47.83^{DEF}	54.53±0.27^{PQ}	N80	51.60^{BCDEF}	67.62±0.28^{F}
N10	63.35^{ABCDE}	62.82±0.19^{J}	N70	43.50^{EF}	55.33±0.43^{P}
N65	62.85^{ABCDE}	60.66±0.20^{M}	N117	47.10^{DEF}	62.21±0.06^{JK}
N90	55.83^{ABCDEF}	68.75±0.58^{E}	N60	36.90^{F}	49.24±0.44^{U}

SW100: 100 seeds weight, OIL: oil content;

The averages of each class followed by the same letters are not significantly different with the threshold from 1%.

Table 5: Correlation matrix of quantitative traits of fruits and seeds of Jatropha curcas L. collection

	CL	CD	CW	PW	NS	SL	SW	ST	SW100	SC
CD	0.77**									
CW	0.79**	0.73**								
PW	0.55**	0.41**	0.55**							
NS	0.56**	0.51**	0.81**	0.23*						
SL	0.86**	0.81**	0.70**	0.36**	0.53**					
ST	0.46**	0.58**	0.67**	0.31*	0.44**	0.51**				
SW	0.56**	0.74**	0.58**	0.29*	0.24	0.63**	0.75**			
100SW	0.52**	0.62**	0.71**	0.14	0.50**	0.54**	0.59**	0.53**		
SC	0.43**	0.44**	0.63**	-0.28	0.75**	0.51**	0.44**	0.33*	0.64**	
OIL	0.13	0.12	0.19	0.03	0.19	0.24	0.04	0.11	0.25	0.18

*SL : seed length, SW : seed width, ST : seed thickness, SW100 : 100 seed weight, CL : capsule length, CD : capsule diameter, CW : capsule weight, PW : pulp weight ; NS : average number of seed/capsule , SC : proportion seeds capsules, OIL : oil content, * Significantly at 5%, ** : Significantly at 1%,*

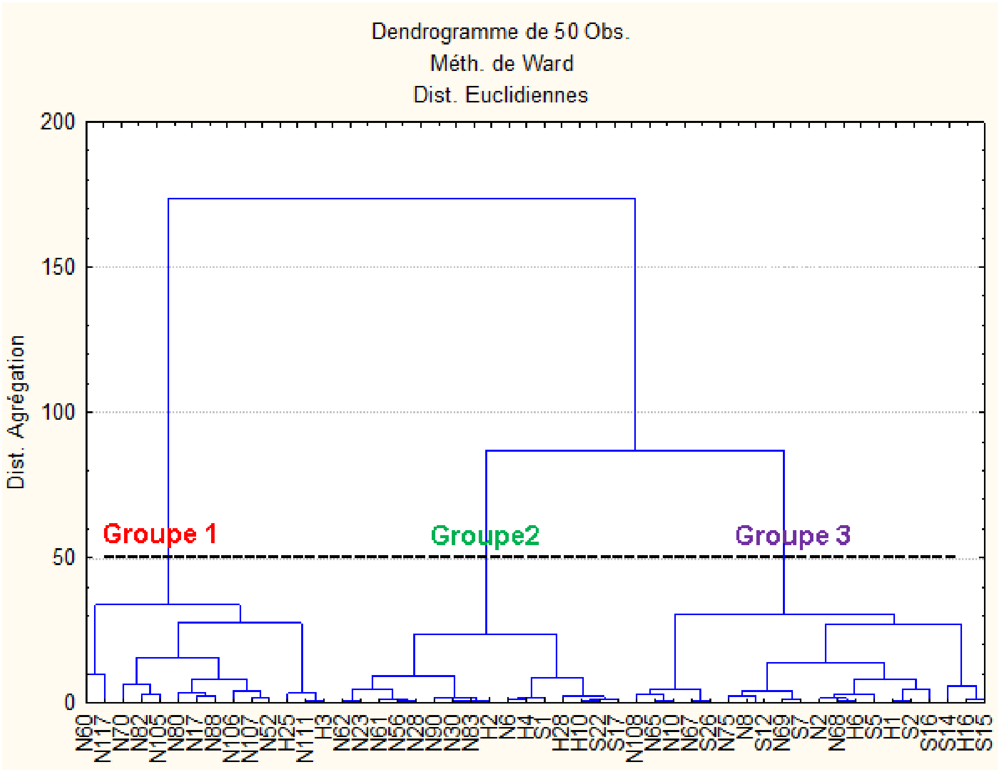

Figure 1: Ascending hierarchical classification of 50 accessions of *Jatropha curcas* L.

The factorial discriminant analysis (figure 2) shows the position of individuals and gravity centers of groups in the canonical system of axes 1 and 2 with 100% of inertia. The coordinates of the variables show that characters capsule diameter (CD), capsule weight (CW), seed width (SW) and 100 seeds weight (SW100) are strongly and positively correlated with axis 1. Furthermore, the review of the Fisher F statistic indicates that these four characters are the most discriminant with relatively high values of F and a p value <0.0001. These results are confirmed by the test of Newman-Keuls (table 6).

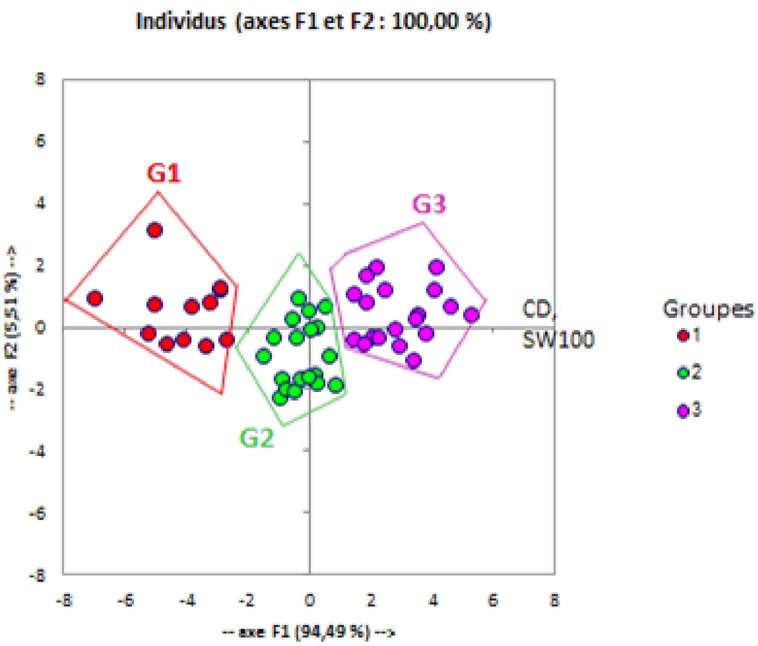

Figure 2: Position of agro morphological groups of *Jatropha curcas* in factorial discriminant analysis

Table 6: Average performance of *Jatropha curcas* groups of Burkina Faso

Characters	Groups			F
	Group 1	Group 2	Group 3	
	Mean	Mean	Mean	
CL (mm)	23.04B	24.18A	24.44A	9.22**
CD (mm)	20.19C	20.88B	21.27A	15.01**
CW (g)	1.82C	2.24B	2.48A	21.96**
PW (g)	0.74A	0.75A	0.78A	0.55ns
NS	2.44B	2.68A	2.80A	9.07**
SL (mm)	17.40B	18.03A	18.23A	11.65**
SW (mm)	10.75C	11.05B	11.26A	18.24**
ST (mm)	8.30B	8.43B	8.64A	10.41**
100SW (g)	45.54C	54.67B	63.34A	128.94**
SC (%)	58.26B	65.97A	68.29A	19.83**
OIL (%)	58.59A	61.42A	62.21A	1.43ns
Number of accessions	12	19	19	

SL : seed length, SW : seed width, ST : seed thickness, SW100 : 100 seeds weight, CL : capsule length, CD : capsule diameter, CW : capsule weight, PW : pulp weight ; NS : average number of seed/capsule, SC : proportion seeds capsules, OIL : oil content, F : coefficient of Fisher, * Significantly at 5%,, ** : Significantly at 1%,.

ESTIMATES OF GENETIC PARAMETERS

Genotypic and phenotypic coefficients of variation

The estimation of genetic parameters (Table 7) shows that for all characters studied, the phenotypic coefficient of variation are higher than the genotypic coefficient of variation. According to Sumathi *et al.* [20], the genotypic and phenotypic coefficients of variation are low below 11%, moderate between 11 and 20% and high beyond 20%. Thus, moderate genotypic and phenotypic coefficients of variation are observed for traits related to the capsule and seeds weight (CW: 13.7% and 16.11%, PW: 11.16 and 12.99%, 100SW: 11.83 % and 12.96%). Characters oil content (OIL), average number of seeds per capsule (NS), proportion seeds capsules (SC) and characters related to the dimensions of capsules and seeds have expressed low genotypic and phenotypic coefficients of variation.

Table 7: Genetic parameters calculated from the *Jatropha curcas* of Burkina Faso

Variables	X	VG	VP	H^2 (%)	GCV (%)	PCV (%)	GA (%)
CL (mm)	23.97	0.00693667	0.01057333	65.60	3.47	4.28	5.79
CD (mm)	20.87	0.00237667	0.00423867	56.07	2.33	3.11	3.60
CW (g)	2.22	0.09323333	0.12886667	72.34	13.70	16.11	24.01
PW (g)	0.75	0.00717533	0.009727	73.76	11.16	12.99	19.74
NS	2.67	0.04035667	0.07022	57.47	7.51	9.91	11.73
SL (mm)	17.95	0.00206267	0.003147	65.54	2.53	3.12	4.21
SW (mm)	11.06	0.0005952	0.00082213	72.39	2.20	2.59	3.86
ST (mm)	8.48	0.00044733	0.00057643	77.60	2.49	2.83	4.52
100SW (g)	55.88	43.7133333	52.5166667	83.23	11.83	12.96	22.23
SC (%)	64.99	26.2666667	33.7133333	77.91	7.88	8.93	14.33
OIL(%)	61.26	34.0852233	34.1073233	99.93	9.53	9.53	19.62

SL : seed length, SW : seed width, ST : seed thickness, SW100 : 100 seed weight, CL : capsule length, CD : capsule diameter, CW : capsule weight, PW : pulp weight ; NS : average number of seed/capsule , SC : proportion seeds capsules, OIL : oil content, X : mean of character, VG : genotypic variance, VP ; phenotypic variance, H^2 : broad sense heritability, GCV: genotypic coefficient of variation, PCV: phenotypic coefficient of variation, GA: expected genetic advance

Broad sense heritability

The heritability of characters studied ranged from 56.07% for the capsule diameter character to 99.93% for the oil content character. According to Johnson [21] and Stanfield [22], heritability is high at over 50%, low below 20% and average between 20 and 50%. Thus, the broad sense heritability is high for all the characters.

Expected genetic advance

The expected genetic advance ranged from 3.6% for the capsule diameter character to 24.01% for the capsule weight character. The characters related to capsule and seed dimensions recorded the lowest expected genetic advance compared to other characters which express the highest values.

DISCUSSION

The study of morphometric characteristics of fruits and seeds of *Jatropha curcas* has revealed the existence of several discriminatory characters. This variability of morphological characters is due to the mating system of the plant that is the outcrossing [23]. Moreover the accessions studied come from sites where pluviometry, temperature and edaphic characteristics are different. According to Antonovics [24] and Nienstaeädt [25], the wide geographical distribution of plant species usually corresponds to a wide range of anatomical, physiological, morphological and genetic variations that allow it to survive and reproduce in varied environmental conditions. Variability of morphological characters of seeds of *Jatropha curcas* accessions from different sources has also been reported by several previous studies [26,27,28,14]. Similar variations in relation to the habitat have been reported on several plant species [29]. The variation of 100 seeds weight of the accessions studied (35.9 to 72.3 g) is less than that obtained by Halilu *et al.* [30] with accessions of Nigeria (28.56 to 80.05 g) but relatively more important than the results of Ouattara [14] with accessions of Senegal (63.68 to 77.83 g), Rao *et al.* [31] in India (56.98 to 79.09 g). The values of the oil content of the accessions studied (48.8 to 73.02%) were higher than those of Sama *et al.* (2013) who have obtained values between 48.1 and 56% with accessions of six plantations installed in three phytogeographical areas of Burkina Faso, Basha *et al.* [32] with 72 accessions from different countries (45.4 to 64.5%) and Kane [33] in Senegal (42.65 to 58.61%). Several other authors [28,29,31,34,] also showed a wide variability of 100 seeds weight and oil content on *Jatropha curcas* accessions collected in different regions of India. This variability could be explained by the environmental variability of collection sites and by the genetic diversity of *Jatropha curcas*. Indeed, the *Jatropha curcas* accessions were collected in different phytogeographical sectors with varied climatic conditions and different edaphic characteristics. The characteristics of the soil and climate of the collection sites are considered as main factors affecting seed traits [35]. According to Mishra [36], oil content and seed yield of *Jatropha curcas* vary considerably and this variability can be attributed to various factors including genetic factors, rainfall, and soil including soil fertility. The variation of seeds dimensions of accessions studied are higher than those of Sama *et al.* (2013) which are between 15.7 and 18.3 mm for the seeds length, 6.4 and 11.6 mm for the seed width, 6.9 and 11, 2 mm for the seed thickness, and those of Ouattara [14] in Senegal which are ranged of 17.89 and 19.15 mm for the seed length, 10.94 and 11.36 mm for the seed width, and 8.45 to 8.97 mm for the seed thickness. According to Mathur *et al.* [37], variability of seed traits would be an adaptive response to different climatic conditions ranges prevailing in the collection sites. However, environmental conditions cannot be the only factors responsible for the high variability of traits of the seeds observed. Part of the diversity observed may have a genetic determinism. Indeed, of the accessions of *Jatropha curcas* although from the same pytogeographical sector have produced seeds of different sizes. This is supported by the weak difference between the coefficients of genotypic and phenotypic variation. Also high values of broad-sense heritability obtained show that genetic factors would explain an important part of the seed traits diversity. The relative role of heredity and environment in the expression of seed traits was reported by Kaushik *et al.* [29]. All traits related to seeds have presented broad-sense heritability wider than 50%. However the characters 100 seeds weight and oil content showed the highest values of broad-sense heritability (83.23% and 99.93% respectively) and high expected genetic advance. The heritability values of this study are similar to those obtained previously by other authors. Kaushik *et al.* [29] obtained a heritability of 96% for 100 seeds weight character and 99% for the oil content character. Rao *et al.* [31] in turn obtained a heritability of 93% for the 100 seeds weight character and 99% for the oil content character. The high broad-sense heritability values associated with high expected genetic advance indicate that effects of the genes are of additive type for these characters. It exists of the opportunities to improve seed weight character and oil content character through the selection. Plant seeds from different sources having high weight and high oil content can be used in breeding programs [29]. Prior studies have also shown that seeds of a high weight are rich in oil, have a best germination rate, improved seedling vigor and plants derived from its have better growth [26,30,38,39]. According to Wani *et al.* [34], the high seed yield and high 100 seeds weight indicate the possibilities of selecting elites genotypes.

Significant and positive correlations between seeds characters of *Jatropha curcas* reveal possibilities of the simultaneous improvement of these traits through the selection. Thus, in this study, interesting correlations were found between the characters related to the weight and dimensions of the seeds.

The strong positive correlation between seeds characters of the accessions indicates that the responsible genes of these characters are probably linked or have a pleiotropic effect. Similar results were reported by Freitas *et al.* [10] and Shabanimofrad *et al.* [18] between 100 seeds weight and the dimensions of the seed. However, the study found no significant correlation between oil content and other characters studied. Freitas *et al.* [10], Leela *et al.* [4] reported similar results. Kaushik *et al.* [29], Shabanimofrad *et al.* [18] have noted against a positive and significant correlation between seed weight and oil content while Wani *et al.* [34] found a negative correlation between these two characters. According to Leela *et al.* [4], these contrasting results could be explained by the high weight of the seed tegument of some accessions.

The hierarchical clustering reveals that accessions of different geographical areas are found in different groups. This indicates that the geographical diversity does not necessarily represent the genetic diversity among accessions collected. Similar results were obtained by Saini *et al.* [40]. The distribution of plants in the same geographic area in different groups indicates that plants of the same geographical origin may undergo a change for different characters as a result of the selection [29]. According to Latif *et al.* [41], divergent genotypes could be crossed to have better heterosis, Thus, accessions N60 and S15 that have the highest Euclidean distance as well as other genetically distant accessions could be used for crossing. The three morphological groups obtained offer opportunities for choice of sires for breeding new varieties meeting the needs of producers. If the purpose of the selection is the weight of the seed, it could be directed towards accessions of group 3 which present the best seed weight. According to Ouattara [14], the wetter areas of Senegal would be the most favorable areas for the formation of higher seed weight and would probably the most favorable areas for the cultivation of *Jatropha curcas*. This is confirmed by the fact that the nature of the seed weight has low plasticity [42]. Maes *et al.* [43] indicate both that the plantations of *Jatropha curcas* in arid and semi-arid areas could have low productivity and could require a supplementary irrigation and also that natural populations of *Jatropha curcas* are rare in these areas.

CONCLUSION

This study revealed an important morphological diversity within *Jatropha curcas* accessions collected. The high variability in seed traits and highlighting more discriminating characteristics constitute a database for *Jatropha curcas* genetic improvement programs. The improvement potentialities of seed traits exist even if we take into account the sources of variability related to climate and edaphic factors. Particular attention should be paid to accessions whose seeds are large and those whose oil content is high in future breeding programs. Multi-local trials are needed to identify local genotypes which have high yield and determine crop areas suitable for large scale production. Others biochemical study are also needed for identification of non-toxic accessions and to high protein content for the use of oil cakes resulting from the extraction of oil in animal feed.

The results of this study could also be complemented by molecular characterization to better understand the structure of the genetic diversity of the species.

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