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Variability of morpho-metric traits and oleaginous biofuel potential of *Jatropha curcas* L. (*Euphorbiaceae*) seeds in Burkina Faso

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In the recent decades, *Jatropha curcas* has received attention as a potential source of bio fuel production in many West African countries. To detect performant accessions for improvement and breeding programmes, the degree of variability of morphological traits and oil content of seeds in a large range of accessions were assessed in this study. The morphological traits and oil content of seed of 40 accessions of *J. curcas* in Burkina and their genetic values and correlation was calculated. The results show a high variability of morphological traits and oil content of seed. The accession has a significant effect on the morphological traits and oil content of seed whereas, phytogeographic zone has no significant effect. The results permitted identification of accessions with interesting morpho-metric parameters and oil content of seed. The results also show positive and significant correlations between seed width and all the morphological traits and the value of genetic parameters indicate that the high variability in seed traits and oil content can be explain by genetic factors. Also, the highest value of genetic gain was observed for the oil content. As a result, there are good opportunities for selection and improvement of traits and seed oil production through selection.

Key words: *Jatropha curcas*, Burkina, diversity, oil content, seed traits, heritability.

INTRODUCTION

Jatropha curcas is a shrub of *Euphorbiaceae* family and native to Central America and Mexico (Heller, 1996; Agnieszka et al., 2013; Sawadogo et al., 2015). It is well-known by African people, who use it for delimiting farms and concessions. In recent years, because of its biofuel potentials, the species is considered as a solution to deal with climate change, energy insecurity and to fight against poverty in rural areas by generating income especially for women (Terren et al., 2012; Guittet and Massimiliano, 2015).

In Burkina Faso, *J. curcas* plantations are widespread through out the country's phytogeographic zones (Bazongo et al., 2015); Tiendrebeogo et al., 2016a). However, the seed yields and seed oil content are variable and generally weak, reducing its economic potential and making its culture a risk company (Singh et al., 2010; Kumar and Singh, 2014). These constraints justify the need of a varietal improvement which require the identification of high oil content in local ecotypes in order to optimize profitability of the species and to boost the *J.curcas* sector (Guittet and Massimiliano, 2015). Unfortunately, data on the characterization of local varieties in Burkina Faso are limited. Yet, previous works in Burkina Faso (Sama et al., 2013; Tiendrebeogo et al., 2016b) and the world (Rao et al., 2007, 2011; Kaushik et al., 2007) have highlighted a wide range of variability in seed traits and oil content depending on phytogeographic conditions. Therefore, regarding the different phytogeographical areas in Burkina Faso, large variability of seed traits and oil content is expected and some accessions may have better oleaginous potential. Moreover, these studies have shown that there is a positive correlation between *J. curcas* seeds weight and its oil content. In addition, the authors reported that heavy *J. curcas* seeds have better vigor at emergence and the seedlings grown from heavy seeds have better growth. Thus, assessment of the natural variability of seed traits and oil content of the species could help in identifying accessions with better seed trait and would be an important step for improvement programs (Kumar and Singh, 2014; Tiendrebeogo et al., 2016b). In Burkina Faso, the lack of data on morphological variability and seed oil content of *J. curcas* strongly limits such perspectives. In fact, the level of seed oil production of local accessions of *J. curcas* is still poorly understood. Despite the considerable economic potential of the species, limited research has focused on the variability of seed traits and oil content of the *J. curcas* seeds in Burkina Faso. Researches on the species have focused on the species physiology and biology (Tiendrebeogo et al., 2016a). However, information regarding the extent and pattern of genetic variation in *J. curcas* of local accessions is limited barring a few recent studies undertaken by Sama et al. (2013) and Tiendrebeogo et al. (2016b). The present study aims at characterizing the morpho-metric traits and the oleaginous potential of seeds of the accessions of *J. curcas* in Burkina in order to identify the performant accessions. Such accessions would be very capital for improvement and breeding programmes for a durable production of biodiesel containing *J. curcas*.

MATERIALS AND METHODS

The study involved a total of 40 accessions of *J. curcas* L. collected in different sites of Burkina Faso. The characteristics of accessions are presented in Table 1. The collection was carried out based on a climatic gradient with a rainfall ranging from 500 to 1200 mm. The collection sites belong to southern Sudan, northern Sudan, sub-Sahelian and Sahelian zones (Figure 1). In each site, fruits were collected in plantations or hedges of *J. curcas* at least 5 years older, between July and September 2016. In each plantation or hedge, ripe fruits of ten (10) plants distant at least 10 m were randomly selected. All the fruits collected in the same plantation or hedge were gathered to form an accession. Afterward, fruits were dried under ventilation in the laboratory, decorticated manually and bagged in kraft envelopes without any pretreatment and stored at room temperature.

Characterization of traits variability and seed oil content

Variability of seed traits

For each accession, five batches of ten (10) seeds were randomly selected for the measurement of their morphological parameters (length, width and thickness) using an electronic Vernier caliper (precision of 0.01 mm) and ten seeds weight using an electronic balance (precision 0.01 g).

Oil content of the seeds

The seed oil content was determinate according AOAC 960.39 method described by Turinayo et al. (2015). Oil in seeds was extracted in with Soxhlet apparatus for 6 h, using petroleum ether (boiling point of 40 - 60°C) as an extraction solvent. The extracted oil is recovered by solvent evaporation using a rotavapor apparatus to remove the majority of the solvent by rotatory evaporation at 40°C under reduced pressure. The extracted seed oil was weighed. For each accession, the oil content of three samples was determined in triplicate tests in order to enhance accurate statistical inference. The amount of oil in seeds was calculated and expressed as percentage (%) by following formula:

$$\text{Oil content (\%)} = \frac{\text{Oil weight}}{\text{Sample weight}} \times 100$$

Statistical analysis

The investigated parameters were subjected to one-way analysis of variance at the 5% level. The effect of climatic zones was the first to be evaluated. The Sahelian zone was excluded from this analysis because of the small number of accessions; only two accessions belong to this zone. When there were no significant differences between climatic zones, the traits of the accessions were subjected to a one-way ANOVA. When the ANOVA test showed significant differences in seed traits, the Tukey test (at the 5% threshold) was performed for the ranking of averages. The Pearson test was performed at the 5% threshold to assess the correlation between seed traits. All these statistical analysis were carried out in the R. software. Ward's aggregation method was used to group the accessions. According to Vachon et al. (2005), it is a method of entities partitioning into classes according to their similarity traits. In this classification, each class is a group of entities in which the variance between members is relatively small. The ANOVA results were also used to calculate genetic parameters (variance and coefficient of genotypic and phenotypic variability, heritability of traits studied and expected genetic gain) according to Gbemavo et al. (2015).

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Table 1. Geographical coordinates of *J. curcas* plantations and hedges based on phytogeographic zones and age.

Zone climatic zone	Accessions	Age (years)	Geographical coordinates of accessions
Northern Sudan	J4	6	30P0502967 UTM 1416658
	J5	5	30P0510362 UTM 1416428
	J13	6	alt1:105 9 ft N: 12 47'08.5" H 001 41'35.1"
	J14	5	30P049792 UTM 1361549
	J15	5	30P0440077 UTM 1364004
	J16	5	30P044351 UTM 1363920
	J22	5	alt1:220 9 ft N: 12 47'08.5" H 001 41'35.1"
	J25	7	30P0658968 UTM 1488854
	J26	8	30P0447169 UTM 1259930
	J36	6	30P0510362 UTM 1408255
	J38	6	30P0447315 UTM1259885
	J40	7	alt:995ft N: 12 40'43.9 H:001 20'50.3
Sahelian	J17	6	30P067388 UTM 1529367
	J18	7	30P0697161 UTM 1531587
Sub- Sahelian	J6	5	30P075871 UTM 1485040
	J7	7	30 P0645225 UTM 1471332
	J10	8	31P0211417 UTM 1335233
	J11	7	31P0211366 UTM 1335283
	J12	5	31P0211805 UTM 1337988
Southern Sudan	J1	9	30P0338029 UTM 1242633
	J2	7	30P0336843 UTM 1242817
	J3	8	30P0423736 UTM 1286009
	J8	10	30P 0638098 UTM 1248194
	J9	10	30P0330932 UTM 1146119
	J19	10	30P0423736 UTM 1286009
	J20	5	30P0447169 UTM 1259930
	J21	6	30P0447315 UTM 1259885
	J23	6	30P0308695 UTM 1177542
	J24	8	30P0370952 UTM 1220292
	J27	6	30P 0601801 UTM 1232344
	J28	5	30P0699791 UTM 1491388
	J29	10	30P 0638087 UTM 1248075
	J30	8	30P0346283 UTM 1109579
	J31	6	30P 0585113 UTM 1221071
	J32	7	30P0345321 UTM 1116435
	J33	6	30P0347565 UTM 1108143
	J34	8	30P0342087 UTM 1108345
	J35	5	30P0402964 UTM2416446
	J37	7	30P0345762 UTM 1108143
	J39	10	30P 0601744 UTM 1232416

RESULTS

Distribution of accessions through phytogeographic zones of Burkina Faso

In Burkina Faso, *J. curcas* is found in all phytogeographic zones of the country mainly in the form of plantations. *J. curcas* hedgerows, used to delineate plots or to protect fields have also been encountered. However, plantations are more abundant in southern Sudan. In addition, older *J. curcas* plantations (more than ten years) are met in southern Sudan as compared to the other climatic zones

Figure 1. Phytogeographical zones in Burkina Faso (the collection sites represented by white circles).

where plantations are commonly below ten years old.

Morphological traits of seeds in relation to accession and the phytogeographic zone

The results of morphological seed traits showed that accession has a significant effect on seed traits ($P < 0.001$) in opposite to the phytogeographic zone that has no significant effect. Also, the results showed a very great variability of seed morphological traits from one accession to another. Seed length ranged from 17.40 ± 1.14 to 19.30 ± 0.98 mm with an average length of 18.55 mm. The shortest length was recorded in the J4 accession (North Soudan zone) and the highest value in the accession J13 (North Sudan zone). The width varied from 10.86 ± 0.46 mm for accession J4 (North Sudan zone) to 11.86 ± 0.43 mm for accession J31 (Sudanian zone) with an average value of 11.33 mm. The thickness ranged from 7.0 ± 0.17 mm for J18 accession (Sahelian zone) to 9.22 ± 0.22 mm for J35 accession (Sud Sudanian zone), while the weight of 10 seeds ranged from 5.88 ± 0.96 g for accession of J2 (Sudan zone) to 9.60 ± 0.96 g for accession J15 (Sudan North Area). Morphological traits of seeds were subjected to an Ascending Hierarchical Classification (CAH). This classification allowed the distribution of accessions into four classes and characteristics are presented in Table 2. Class IV is represented only by the J18 accession collected in the Sahelian zone, while the other classes include accessions from different phytogeographic zones. The highest values of traits are observed in class I while the lowest is in class IV.

Seed oil content in relation to the accession and the phytogeographical zone

Seed oil contents were expressed as a percentage of kernel dry weight and the corresponding accessions. Seed oil contents of the different accessions ranged from 33.83 ± 1.65 to 57.21 ± 2.44% respectively for J1 accession (South Sudan zone) and J7 (Sub-Sahelian zone). The results also show that accession has a significant effect on the seed oil content ($P < 0.001$), whereas phytogeographic zone has no significant effect. Table 3 shows different ranges of oil content as percentage of mass of dry seeds. The contents are stored in intervals of amplitude 5%.

Table 2. Classes of morphological traits of *J. curcas* seeds based on Ascending Hierarchical Classification (CAH) in relation to the accession and phytogeographic zone.

Classes	Climatic zone	Accession	Morphological traits of seeds			
			Length (mm)	Width (mm)	Thickness (mm)	Weight of 10 seeds (g)
I	Northern Sudan	J4, J13, J14, J26	19.100	11.640	9.020	8.32
	Southern Sudan	J1, J2, J7, J8, J9, J27, J28, J29, J32				
II	Northern Sudan	J15, J16, J22, J25, J36, J38, J40	18.400	11.240	8.800	7.36
	Sub-Sahelian	J5, J6, J10, J11,				
	Southern Sudan	J2, J19, J20, J21, J30, J31, J33, J34, J35, J37, J39				
	Sahelian	J17				
III	Northern Sudan	J3	17.740	10.920	8.600	6.10
	Sub-Sahelian	J12				
	Southern Sudan	J23, J24				
IV	Sahelian	J18	18.000	10.600	7.000	6.33

Table 3. Seed oil content in relation to the accession and phytogeographic zone.

Range of oil content percentage of mass of dry seeds (%)	Climatic zone	Accessions
[30; 35]	Northern Sudan	J16, J25
	Sub-Sahelian	J5
	Southern Sudan	J2
[35; 40]	Northern Sudan	J26, J40, J22, J15
	Sub-Sahelian	J11, J6,
	Southern Sudan	J9, J21, J39, J34,
[40; 45]	Northern Sudan	J3, J4, J14
	Sub-Sahelian	J19
	Southern Sudan	J31, J37
	Sahelian	J17
[45; 50]	Northern Sudan	J38
	Sub-Sahelian	J10, J12
	Southern Sudan	J1, J8, J23, J28, J30, J33, J35,
[50; 55]	Northern Sudan	J13, J36
	Southern Sudan	J20, J27, J29, J32
	Sahelian	J18
[55; 60]	Sahelian	J7

Genetic parameters

The genetic parameters have been calculated and results of calculate of genetic variables are reported in Table 4.

The highest values of phenotypic variation coefficient (CVP) (95.20%) and genotypic variation coefficient (CVG) (77.80%) were recorded for seed oil content. The lowest values of CVP (7.30%) and CGV (5.50%) were observed

Table 4. Genetic variables of seed traits of *J. curcas* accessions.

Seed source	Variance		Coefficient of variation		Heritability broad sense (H2B)	GA as % mean
	Phenotypic	Genotypic	Phenotypic	Genotypic		
Seed weight (g)	0.006	0.004	0.084	0.070	0.692	14.165
Length (mm)	0.191	0.087	0.101	0.069	0.464	2.249
Breadth (mm)	0.052	0.061	0.085	0.073	0.737	3.847
Thickness (mm)	0.048	0.027	0.073	0.055	0.560	2.856
Oil content (%)	39.162	26.108	0.952	0.778	0.667	19.929

Table 5. Pearson correlation coefficients between traits of *J. curcas* seeds.

Variables	Length	Width	Thickness	Weight
Length	**1**			
Width	0.453			
Thickness	0.424	**0.672**		
Weight	**0.652**	**0.642**	**0.539**	
Oil content	0.130	-0.001	-0.220	0.128

In bold, significant correlation.

with seed length. The lowest value of heritability in the broad sense (46.40%) was recorded in seed length while the other traits of the seeds showed heritability between 56.00 and 73.70%. The genetic gain ranged from 2.24 to 19.93% for the length and seed oil content, respectively.

Correlation between seed traits

The correlation matrix based on the Pearson coefficient correlation is presented in Table 5. These correlations are positive and significant between the thickness and the width and between the weight and the other morphological traits of the seeds. However, there is no correlation between seed oil content and seed traits.

Comparative analysis of accessions

The dendrogram plotted on the basis of the morphological features and the seed oil content using Ward's aggregation method regrouped the 40 accessions into three (03) clusters (I, II and III) (Figure 2) whose composition and average oil contents are shown in Table 6. In this classification, the average oil content of clusters I is 48.81% as compared to clusters II and III that have respectively 32.65 and 39.55%. Class I contains both accessions that have the high values of morphological traits and the highest oil content as compared to those of the other two classes.

DISCUSSION

J. curcas is a widespread species in the different phytogeographic zones of Burkina Faso. This broad distribution in addition to its adoption by the populations could reflect a considerable interest for the species.

The present study, focused on local *J. curcas* accessions in Burkina Faso, showed a high variability of seed traits. This high variability of seed traits constitutes an important input for the species improvement programs. Similar variations were reported by Ouattara et al. (2014) and Tiendrebeogo et al. (2016b) on *J. curcas* and by Govindaraj et al. (2011) and Basavaraj et al. (2017) on *Pennisetum glaucum* (L.) R. Br. Such variability of seed traits have been explained by the genetic diversity, and/or the environment effects or their interactions. Similar results were also reported by Subi and Idris (2013). However, the results show that the phytogeographic zone has no significant effect on morphological seed traits and oil content. This supposes that the variability would be related to the genetic factors. Indeed, Subi and Idris (2013) and Kumar and Singh (2014) reported that the genetic factors are factors influencing the features of seeds. In addition, Gbemavo et al. (2015) and Tiendrebeogo and al. (2016b) reported that cross fecundation (allogamy) of different genotypes in *J. curcas* could be a reason for the variability of seeds traits. Cross fecundation would support a natural genetic mixing leading to an important genetic diversity within the species.

The results showed positive and significant correlations between seed width and all the morphological traits. Such results are very interesting for breeding programs. Indeed, according to Freitas et al. (2011), knowledge of the magnitude of the correlation between characters is important in the choice of improvement methods and the formulation of strategies for the simultaneous selection

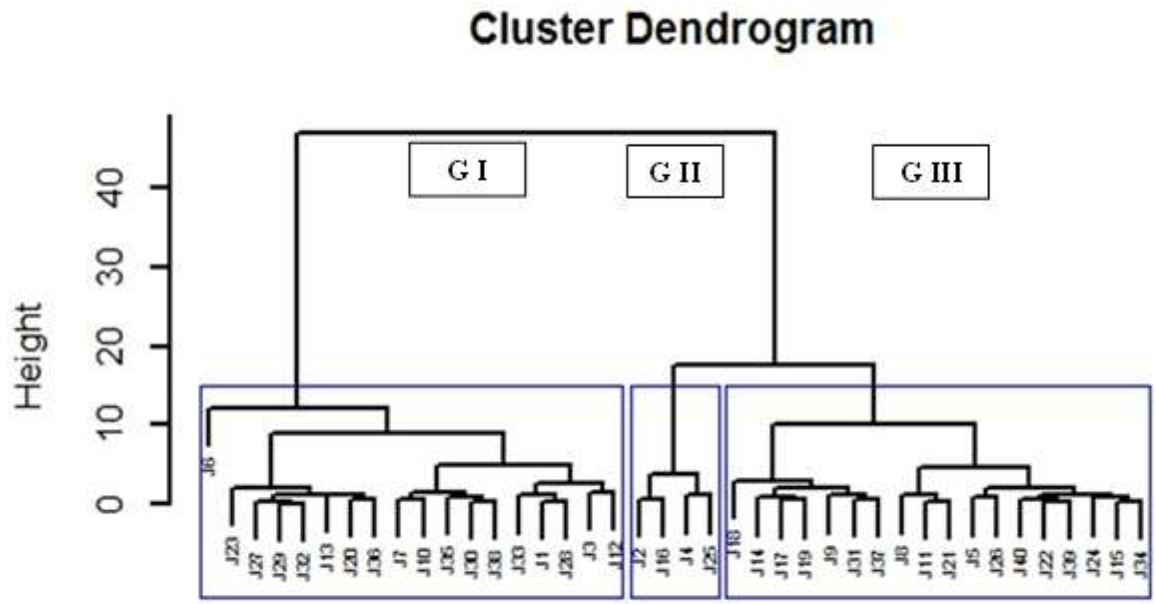

Figure 2. Dendrogram based on morphological traits and seed oil content of 40 Burkina Faso accessions.

Table 6. Composition and average oil content of the groups.

Classes	Accessions	Oil content (%)
I	J1, J3, J6, J7, J10, J12, J13, J20, J23, J27, J28, J29, J30, J32, J33, J35, J36, J38	48.808
II	J2, J4, J16, J25	32.650
III	J5, J8, J9, J11, J14, J15, J17, J18, J19, J21, J22, J24, J26, J31, J34, J37, J39, J40	39.551

for several desired characters.

Hierarchical ascending classification is a powerful tool used to assess the relative contribution of different traits to the total diversity and to quantify the degree of divergence or similarity between accessions. In this study, the Ascending Hierarchical Classification (CAH) based on the oil content and the morphological traits of the seeds showed a breakdown of the forty accessions into three groups. The constitution of groups is independent of the phytogeographic origin of the accessions. Similar results have been reported by Gbemavo et al. (2015) and Tiendrebeogo et al. (2016a). In this study, group I offers a possibility of varietal improvement that could fill the needs of setting up *J. curcas* plantations for biofuel production. Indeed, for the purpose of varietal improvement in order to establish plantations of *J. curcas* for biofuel purpose, accessions belonging to group I present the desired seed traits. Although, this study did not show a significant correlation between oil content and morphological traits of seeds, previous studies have shown that high weight seeds are oil-rich, have higher vigor at emergence, and better seedlings growth (Kaushik et al., 2007; Ouattara, 2013). In addition, these seedlings require little maintenance during the installation phase, which reduces the costs of setting up the plantations.

The genetic parameters presented in Table 4 show a small difference between the phenotypic and genotypic coefficients of variation. Similar results have been reported by Ouattara (2013) and Tiendrebeogo et al. (2016a). According to Basavaraj et al. (2017), a small difference between these two coefficients of variation indicates that the characters are not too influenced by the environment.

Indeed, this results show broad sense heritability values between 56.00 and 73.70%. Except the heritability of seed length, all the traits had high heritability values. According to Miftah (2016), heritability is high when its value is greater than 50%. These high values of heritability in the broad sense confirm the low influence of environmental factors on the expression of these characters. The determination of heritability shows that the observed variability is of genetic origin (Tiendrebeogo et al., 2016a). However, according to Kumar and Singh (2014), heritability and genetic gain must be considered together to predict the resulting effect in an improvement program. Indeed, high heritability (broad sense) may be due to the non-additive action of the gene and will only be reliable when accompanied by a high genetic gain (Kumar and Singh, 2014). The results show, in general, low genetic gain values (values between 2.55 and 19.93). The highest value (19.93) was observed for the oil content. This result suggests large potential for the improvement of seed oil content.

Conclusion

This study showed that plantations and hedgerows of *J. curcas* are widespread throughout the different climatic zones in Burkina Faso. The results show a very high variability of the morphological traits and the oil content of *J. curcas* seeds with certain accessions having good characteristics for these traits. The study also allowed the identification of genotypes of interest for their oleaginous potential that could serve as a basis for selection and breeding programs. The study of the determinism of this variability has revealed that the sources of this variability could be environmental and also genetic. As a result, there are good opportunities for selection and improvement of traits and seed oil production through selection. This study is an introduction of the identification of the best local genotypes with high oil potential.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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