

Original Research Article

Title: Variability of fruit and seed characters and oil content of 35 accessions of *Jatropha curcas* L. grown in a semi-arid site in Senegal

Abstract

Aim: This study has evaluated variations in seed and fruits traits as well as the oil content of 35 accessions of *Jatropha curcas* grown in the same soil and agroclimatic conditions in Senegal.

Methodology: The study was conducted ~~on~~ using 35 accessions of *J. curcas* planted at the research station of Ecole Nationale Supérieure d'Agriculture ([National Advanced School of Agriculture](#)) located in Thies, Senegal. Fruits were collected from 1-4 year-old plantations. ~~Then,~~ For each accession, 30 dry fruits were randomly selected and ~~were~~ subjected to measurements of the ~~size parameters~~ (length, diameter,) and weight using ~~respectively~~ an electronic caliper and an electronic balance, respectively. Fruits were peeled and ~~the~~ shells weighed. A sample of 20 seeds per accession was selected with ~~3~~ three replications for ~~seed~~ ~~trait~~ size measurements (length, width and thickness) and ~~seed~~ oil content determination by Soxhlet method.

Results: The results showed significant differences ($p < .001$) in seed and fruit traits as well as the oil content between accessions. Oil content, weight of kernel / weight of seed coat ratio and 100-seed weight ~~are~~ were highly correlated quantitative characters ~~which have also, with~~ high heritability in the broad sense (92.51%, 100% and 87.14%, respectively) and genetic advance values (39.32%, 36.44% and 28.77%, respectively). ~~Also,~~ This study has also highlighted

[detected](#) four local accessions (Keur Samba Gueye, Notto 3, Ndary and Soutra) with high oil content (> 55%).

Conclusion:

There is high genetic variability of *Jatropha curcas* in Senegal in terms of seed [and](#), fruit [sizes](#) and oil [traits content](#). The quantitative characters such as oil content and 100-seed weight might be used for early selection of promising accessions. ~~The~~ [Some of the](#) local *J. curcas* plant [materiel materials isare](#) interesting enough to perform breeding programs and support national sustainable production of biofuel.

Key words: *Jatropha curcas*, seeds, [fruit, oil content](#), variability, ~~oil content~~, Senegal, ~~West~~ [Africa](#)

35 1. Introduction [c1]

36 The energy issue is widely discussed in the world, because of the widening gap between
 37 decreasing supply and an increasing demand. This imbalance leads to a global crisis that affects
 38 the countries' economy. ~~None African oil producers-producing~~ countries like Senegal are more
 39 affected by this crisis. [c2] For example, in 2006, almost 140 billion CFA francs were spent to
 40 subsidize the energy sector. ~~Also,~~ Senegal's oil bill rose from 185 billion FCFA in 2000 to 384
 41 ~~,000,000,000billion~~ FCFA in 2006 and to 623 billion FCFA in 2008, ~~;~~ an increase of over 40% in
 42 two years. ~~Also~~ Moreover, over 46% of export revenue are mobilized to meet this invoice [1].
 43 This energy shortage has created a renewed interest in renewable energy. Senegal, like some
 44 African countries embarked on biofuel production by opting for the promotion of *Jatropha*
 45 (*Jatropha curcas* L.).

46 The choice of this plant is justified by the fact that its seeds contain oil of high energy value
 47 whose properties are comparable to those of diesel. In addition, this plant is little exigent. It
 48 provides various products [c3] and benefits that promote an integrated rural development [2].

49 However, there are many agronomic challenges to overcome for a sustainable development of
 50 *Jatropha* biofuel value chain. Among them, the increase in seed yield ~~or~~ and in oil content is
 51 probably the most emergent for producers. This might involves identifying a more productive
 52 plant material and the development of suitable cropping systems.

53 Therefore, many studies have been conducted in Asia [3, 4, 5, 6] as well in West Africa [7, 8, 9]
 54 on agromorphological, biochemical and genetic characterization of *Jatropha*'s germplasm. ~~These~~
 55 ~~studies~~ They have shown a high variability in seed traits and oil content between accessions. ~~This~~

suggests that the accessions analyzed are different ecotypes well adapted to different local conditions.[c4] However, this hypothesis can~~not~~ be validated if and only if, a genetic basis of variation is established and phenotypic plasticity responses due to environmental differences can be excluded.[c5]

Unfortunately, this is not the case for the studies carried out in West Africa [7, 8, 9]; these works have compared different accessions using seeds harvested on their sites of origin.

In this context, the objective of this work is to analyze variability in seeds and fruits traits as well as in oil content of 35 accessions of *J. curcas* collected from different agroclimatic zones of Senegal but which have been planted on the same site.

2. MATERIAL AND METHODS

2.1 Study area

The present study was conducted at the research station of “Ecole Nationale Supérieure d’Agriculture (ENSA)” located in Thies city, Senegal (latitude 14° 42'52" N; longitude 16° 28'64" O). The climate is tropical semi-arid with an annual average rainfall of about 450 mm [10]. However, the total rainfall of the study year recorded by a weather station ~~is~~ was 500.02 mm. The minimum mean annual ambient temperature is 20° C and a maximum mean annual ambient temperature of 33° C. [c6][11]. The soils are poorly developed with a sandy loam texture and a pH of 5.0. Their level of fertility is poor with both the organic carbon and nitrogen, respectively, less than 5%

and 0.3% [12].

The mean annual minimum ambient temperature is 20° C and the mean annual maximum ambient temperature is 36° C, with a marked seasonal variation[13].

2.2 Plant material

The plant material ~~consists~~consisted of 35 accessions of *J. curcas* planted in the research station of ~~“Ecole Nationale Supérieure d’Agriculture”~~ (ENSA). Thirty three ~~are~~were from Senegal while 2 others were introduced from Mozambique (Southern Africa) and Tanzania (East Africa).

2.3 Methods of the survey^[c7]

The fruits were collected between September 9th and December 12th, 2013 from plantations of 1-4 years old. ^[c8]For each accession, harvesting was done on 4-6 trees among the most vigorous. Only ripen fruits of yellow or brown color were collected and then dried in the laboratory at ambient temperature (about 25 °C).

For each source^[c9], 30 fruits were randomly selected. They were pre-dried in an oven at a temperature of 65 °C for 72 hours to obtain a constant weight. Then, each fruit has its length and diameter measured using an electronic caliper^[c10], the weight was also determined with an electronic balance^[c11] (1/1000 g). At the end of these measurements, 30 fruits were peeled ^[c12]and shells were weighed with the same balance as before. To determine seeds ~~trait~~sizes, a sample of 20 seeds per accession was selected with three (3) replications. These seeds were subjected to measurement of

the length (longitudinal axis of the seed ~~with electronic calipers~~), the width (lateral axis of the seed) and the thickness (radial axis) with electronic caliper. The weight of each lot of 20 seeds was measured with an electronic balance (1/1000 g). ~~From the weight of 20 seeds, The~~ 100-seed weight ~~were was~~ calculated from the weight of 20 seeds as follows:-

$$\text{100-seed weight} \text{ ~~Weight of 100 seeds~~ (g) = (W \text{ ~~weight of 20 seeds~~ / 20) x 100}$$

For each accession, the three lots of 20 seeds ~~that were~~ used to determine seed traits were reused ~~also,~~ to measure the average seed oil content by Soxhlet method [3]. ~~To do this~~ Therefore, the kernel was separated from husks, ~~and~~ placed in an incubator at 65 °C for 48 hours and. ~~Then,~~ ~~they were~~ crushed using a mortar and pestle. Thereafter, ~~it was taken~~ 2 g of crushed kernel ~~(sample)~~ were used for Soxhlet extraction with 3 replications per accession. The oil content of the kernel was determined by the following formula:

$$\% \text{ Oil } (\%) = (\text{oil mass} / \text{mass of sample}) * 100$$

2.4 Data analysis Method

Analysis of variance was performed using the software called Statistix to ~~highlight~~ look for the influence of the accession factor over the seed and fruit-shape variables as well as the oil content. Comparison of mean values of seed and fruit sizes and oil content was performed using Tukey's test at 5%.

Genetic parameters were estimated to identify the genetic variability between accessions and determine the effects of the genotype and environment on various studied traits [13]. These genetic and phenotypic variances ~~s-components~~, coefficients of variation, heritability in the broad sense and genetic gain were calculated by adjusting the formula suggested by Allard [14] and Singh and Chaudhary [15]:

116 σ^2g = (genotypic variance) = (MSG - MSE) / r

117 MSG = inter accession variance;

118 σ^2E = MSE = environmental variance;

119 r = number of replications;

120 σ^2p = (phenotypic variance) = (σ^2g + σ^2E)

121 PCV (phenotypic coefficient of variation) = ($\sqrt{\sigma^2p}$) / X * 100

122 | X = ~~mean of~~ Traits mean;

123 GCV (genotypic coefficient of variation) = ($\sqrt{\sigma^2g}$) / X * 100

124 h^2B = (broad sense heritability) = σ^2E / σ^2p [C14]

125 | = GA (genetic gain) = K * ($\sqrt{\sigma^2p}$) / X * 100 * h^2B

126 K = constant = 2.06

127 | The XLSTAT 2010 software (reference to the developer) [C15] was used for testing significance of
128 Pearson correlation coefficients and thus assesses the relationships between the different
129 variables studied.

130 | A hierarchical clustering has been performed using PAST software [C16] based on the calculation
131 of the Euclidean distances between the accessions ~~has been performed using the software PAST.~~
132 It generated a dendrogram that grouped the accessions according to the similarity of their
133 behavior, growth and fruit production performances ~~for~~ the ~~studied~~ variables studied.

134 | 3. RESULTS

135 | 3.1 Variability in fruits, seeds and oil content traits [C17]

The results of the analysis of variance (Table 1) show that the accession-factor has a significant influence on all morphological parameters of fruits and seeds and the oil content ($p < .0001$).

The coefficients of variation are highest for fruits traits with values of 23.92% for weight, 8.98% for diameter and 7.69% [c18] for length. For seeds, the highest coefficients of variation were obtained with Kernel weight/Seed coat weight (K/SC) ratio (7.60%), 100-seed weight (5.78%) and oil content (5.65%). [c19]

The average values of seed traits are: 18.25 mm for length, 11.04 mm for width, 8.70 mm for thickness, 60.25 g for 100-seed weight, 44.68% for oil content and 1.26 for K/SC ratio. For fruits, the average values of the measured parameters are 25.68 mm for length, 20.19 mm for diameter and 2.34 g for weight. [c20]

For the different studied parameters, the accessions that obtained the highest values are:

- 17 (19.16 mm), 19 (19.11 mm) and 7 (19.03 mm) for seed length;
- 9 (11.41 mm), 20 (11.35 mm) and 30 (11.32 mm) for seed width;
- 7 (9.22 mm), 13 (9.09 mm) and 17 (9.06 mm) for seed thickness;
- 24 (72.65 g), 31 (72.65 g) and 13 (71.00 g) for 100-seed weight;
- 24 (57.16%), 31 (56.50%) and 13 (55.33%) for oil content;
- 24 (1.65), 31 (1.63) and 26 (1.58) for K/SC ratio;
- 19 (27.29 mm), 6 (27.16 mm) and 8 (26.99 mm) for fruit length;
- 27 (21, 64 mm), 6 (21.54 mm) and 17 (21.45 mm) for fruit diameter;
- 31 (2.91 g), 35 (2.82 g) and 27 (2.77 g) for fruit weight.

[c21]

Table 1. Variability of Seed and fruit sizes and weights, and oil content traits variability in *Jatropha curcas*

Accession N°	Locality	Seed						Fruit		
		Length (mm)	Width (mm)	Thickness (mm)	100 seed weight (g)	Kernel/Seed coat ratio	Oil content (%)	Length (mm)	Diameter (mm)	Fruit weight (g)
1	Karang	18,37	11,02	8,78	64,65	1,40	47,00	25,38	20,36	2,45
2	Darou mousty	17,44	11,31	8,30	52,00	1,05	36,66	25,10	19,23	2,10
3	Dianamalary	18,74	11,04	8,86	62,30	1,19	46,33	26,55	21,10	2,48
4	Diassime Mandina	18,06	10,65	8,62	56,65	1,15	42,33	25,96	20,33	2,20
5	Diouroup	18,88	11,08	8,96	67,30	1,25	53,00	26,51	20,56	2,44
6	Fimela	18,65	11,09	8,74	65,65	1,32	52,66	27,16	21,54	2,67
7	Fois 1	19,03	11,24	9,22	67,00	1,23	51,83	25,35	20,18	2,16
8	Gandiaye	18,17	10,99	8,65	64,65	1,29	48,83	26,99	20,59	2,7
9	Ngoule	17,25	11,41	8,23	43,75	0,77	30,16	24,41	18,61	1,89
10	Gourel Bowe	17,39	10,81	8,39	48,00	0,92	30,33	24,66	18,62	1,90
11	Kagnobon	16,93	10,32	7,84	31,30	0,74	23,00	21,48	17,14	1,30
12	Kamonghone	16,89	10,87	8,16	56,30	1,37	43,00	23,23	19,07	1,94
13	Keur Samba Gueye	18,93	11,21	9,09	71,00	1,46	55,33	26,96	21,22	2,49
14	Koumbal	18,31	10,75	8,11	48,65	1,06	32,16	25,63	20,43	2,19
15	Linguere	18,66	10,93	8,73	58,00	1,11	42,66	26,34	20,35	2,26
16	Lompoul	17,17	11,28	8,25	52,30	1,23	35,33	24,61	19,24	2,15
17	Madiop Boye	19,16	11,30	9,06	68,00	1,41	54,00	26,71	21,45	2,70
18	Maleme Hoddar	18,43	10,96	8,82	67,00	1,48	50,16	26,08	19,83	2,32
19	Maleme Niani	19,11	11,26	8,73	57,65	1,06	42,33	27,29	20,20	2,30
20	Medina Sabakh	17,76	11,35	8,88	63,30	1,32	46,33	25,23	19,07	2,23
21	Mozambique	18,13	10,84	8,75	61,65	1,36	44,00	25,64	20,56	2,28
22	Mpack	18,07	10,53	8,52	62,30	1,40	44,50	26,39	20,37	2,70
23	Ndande	18,09	11,00	8,47	56,00	1,11	40,83	25,96	20,41	2,35
24	Ndary	19,00	11,15	8,89	72,65	1,65	57,16	26,04	20,54	2,69
25	Nguekokh	17,88	10,67	8,64	56,00	1,23	39,83	25,13	20,08	2,16
26	Notto 3	18,78	11,04	8,71	70,65	1,58	55,16	25,44	20,69	2,70
27	Ouassadou	18,63	11,10	8,92	69,30	1,43	54,50	26,71	21,00	2,77
28	Porokhane	18,11	11,28	9,01	62,00	1,20	44,66	25,02	18,86	2,06
29	Sangalkham	18,32	11,09	8,53	54,65	1,13	36,33	25,60	20,13	2,24
30	Sare Diatta	18,30	11,32	8,67	48,65	0,87	30,83	26,69	20,82	2,03

The broad sense heritability is high for all of the studied characters except the fruit diameter for which the average value is (43.21%). However, the values are highest in K/SC ratio (100%), oil content (92.51%), seed-length (90.40%), seed-thickness (89.65%) and 100-seed weight (87.14%).

The oil content has the largest genetic advance (39.32%). It is followed by the K/SC ratio with 36.44%, fruit weight (35.85%) and 100-seedweight with 28.77%.

Table 2. Estimation of genetic variables for seed [and](#), fruit [sizes and weights](#), and oil [content](#) traits in *Jatropha curcas*

Traits	Variance		Coefficient of variation (%)		Heritability broad sense (%)	Genetic advance (%)
	Genotypic	Phenotypic	Genotypic	Phenotypic		
Length (mm)	0,37	0,41	3,36	3,53	90,40	6,58
Width (mm)	0,06	0,07	2,21	2,39	85,71	4,23
Thickness (mm)	0,08	0,09	3,39	3,59	89,65	6,62
100-seed weight (g)	3,25	3,73	14,96	16,03	87,14	28,77
Fruit weight (g)	0,32	0,63	24,40	34,08	51,25	35,87
Fruit diameter (mm)	2,48	5,75	7,80	11,87	43,21	4,50
Fruit length (mm)	4,46	8,34	8,22	11,24	53,52	12,39
Oil content (%)	78,63	84,99	19,84	20,63	92,51	39,32
K/SC*	0,05	0,05	17,74	17,74	100,00	36,44

*K/SC = kernel weight / seed coat weight

3.3. Analysis of Correlation coefficients among 9 morphological traits

Table 3 shows that oil content is significantly correlated to all the studied parameters. However, the correlation is greater for 100-seed weight ($r = 0.98$) followed by K/SC ratio ($r = 0.87$), then fruit weight ($r = 0.85$) and finally seed thickness ($r = 0.80$).

The 100-seed weight was also significantly correlated with all measured parameters. The highest values are obtained with oil content, K/SC ratio ($r = 0.89$) and fruit weight ($r = 0.87$).

The K/SC ratio has a significant correlation with all other parameters except the width.

All parameters are significantly correlated to the length of the seed; however, the correlation is stronger with the fruit diameter ($r = 0.81$) and seeds -thickness ($r = 0.80$).

The width is less correlated with other parameters with non-significant values for its relationship with K/SCratio, fruit diameter and fruit weight.

The thickness is significantly correlated with all other traits fruit and seed traits but with a highest correlation with oil content ($r = 0.80$).

As the thickness, fruit length is significantly related to any other parameter; however, this parameter is more correlated with fruit diameter ($r = 0.83$).

With the exception of the seed length, the fruit diameter is significantly correlated to all the studied parameters.

Finally, the fruit weight is significantly correlated to the set of measured parameters; However, there is a better link with the fruit diameter ($r = 0.84$).

Table 3. Correlation coefficients among 9 morphological traits of *Jatropha curcas*

Variables	Length (mm)	Width (mm)	Thickness (mm)	100- seed weight (g)	K/SC ratio	Oil content (%)	Fruit length (mm)	Fruit diameter (mm)	Fruit weight (g)
Length (mm)									
Width (mm)	0,338*								
Thickness (mm)	0,803*	0,462*							
100-seed weight (g)	0,748*	0,375*	0,834*						
K/SC**	0,508*	0,155	0,571*	0,886*					
Oil content (%)	0,739*	0,340*	0,800*	0,979*	0,869*				
Fruit length (mm)	0,777*	0,385*	0,656*	0,660*	0,360*	0,614*			
Fruit diameter (mm)	0,807*	0,250	0,630*	0,731*	0,578*	0,702*	0,834*		
Fruit weight (g)	0,712*	0,296	0,614*	0,867*	0,755*	0,846*	0,798*	0,844*	

198 **K/SC = kernel weight/seed coat weight; *Correlation is significant at the 0.05 level.

199 **3.4 Regression equations between oil content and each of 100-seed weight, fruit weight, and**
200 **kernel weight / seed coat weight ratio for estimating oil content**

201 Regression models for estimating oil content are presented in table 4. The values of statistical
202 analysis of parameters such as the coefficient of determination (R^2) and the probability (p)
203 reveals that three equations are significant and can be used to estimate oil content. However,
204 equation 1 appears to be the best; it allows a very good estimate of the oil content.

205 **Table4. Equations between oil content and each of 100-seed weight, fruit weight, and kernel**
206 **weight / seed coat weight ratio for oil content estimation in *Jatropha curcas***

Nº	Equations	R ²	P
1	OC (%) = 0.95 x (P100) – 12.69	0.96	< 0.0001
2	OC (%) = 34.67 x (K/SC) + 0.97	0.75	< 0.0001
3	OC (%) = 19.94 x (FW) – 2.44	0.58	< 0.0001

OC: oil content (%), P100: 100-seed weight (g), FW: fruit weight (g), K/SC: kernel weight / seed
coat weight ratio

3.5Cluster analysis

An hierarchical analysis was realized using data of the nine morphological studied traits of *Jatropha curcas*. The dendrogram obtained revealed five clusters (Figure 1). Cluster 1 (red) includes the maximum accession (12). Clusters 3 (purple) and 4 (green) each have 8 sources. Clusters 2 (blue) and 5 (yellow) respectively 6 and 1 accessions. [c27]

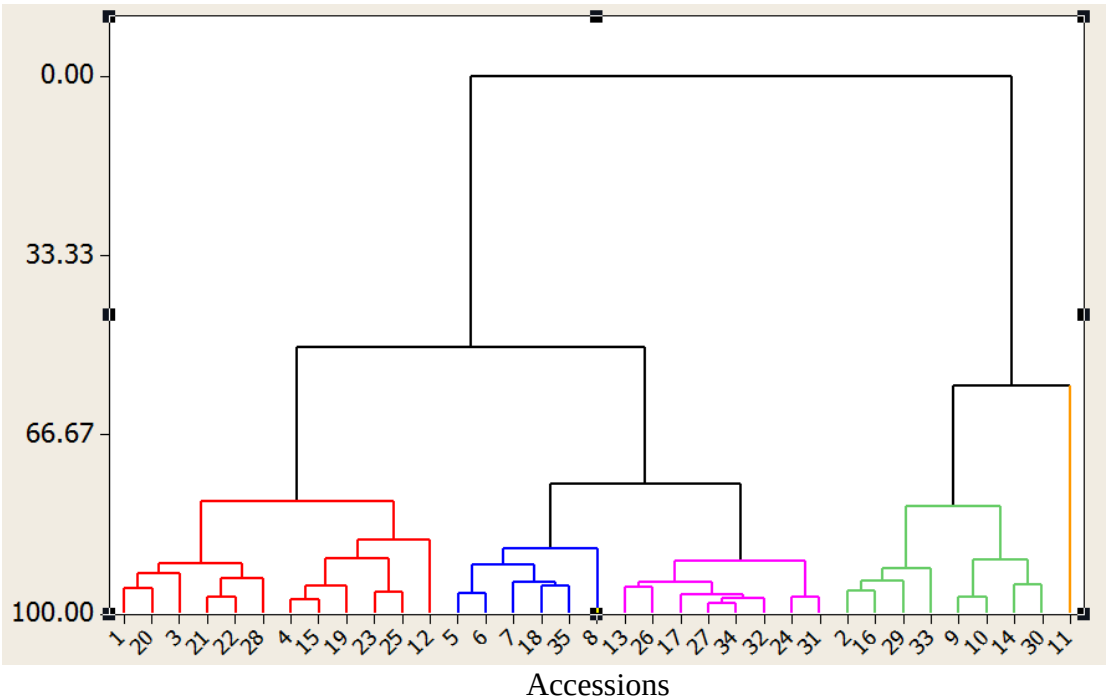


Fig. 1. The dendrogram of 9 morphological traits derived from 35 *Jatropha curcas* accessions constructed using hierarchical analysis method

219 The distribution of accessions according to the different groups is indicated in table 5:

220 • 1, 20, 3, 21, 22, 28, 4, 15, 19, 23, 25 and 12 are the cluster I;

221 • 5, 6, 7, 18, 35 and 8 are in the second cluster;

222 • 13, 26, 17, 27, 34, 32, 24 and 31 are the third cluster;

223 • 2, 16, 29, 33, 9, 10, 14 and 30 are the cluster IV:

224 • 11 is the only one of the cluster V. |

225 [c28]Cluster 3 has the highest values for fruit and seed traits except for fruit length (Table 5). For

226 this group, the average values of seed length, 100-seed weight, oil content and fruit diameter are

227 respectively 18.83 mm, 70.20 g, 55.10% and 20.94 mm. The lowest values of these parameters

228 were observed in cluster 5.

229 Considering only the oil content, it appears that the highest values are observed in clusters II and

230 III.

231 Table5. Cluster mean value for fruit, seed and oil traits in *Jatropha curcas* accessions

Cluster	No of accessions	Accessions	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100 seed weight (g)	K/SC	Oil content (%)	Fruit length (mm)	Fruit diameter (mm)	Fruit weight (g)
I	12	1, 20, 3, 21, 22, 28, 4, 15, 19, 23, 25, 12	18,15	10,95	8,67	59,73	1,24	43,65	25,67	20,06	2,28
II	6	13, 26, 17, 27, 34, 32, 24, 31	18,57	11,07	8,84	66,31	1,32	51,3	26,44	20,61	2,51
III	8	31, 24, 26, 32, 34, 27, 17, 13	18,83	11,17	8,9	70,2	1,52	55,1	26,36	20,94	2,69
IV	8	2, 16, 29, 33, 9, 10, 14, 30	17,73	11,1	8,36	50,12	1,04	33,53	24,93	19,59	2,04
V	1	11[C29]	16,93	10,32	7,84	31,3	0,74	23	21,48	17,14	1,3

K/SC = kernel weight / seed coat weight

4. Discussion

This survey was conducted to quantify the variation in morphological characters of seeds and fruits but also the oil content of *J. curcas* [accessions maintained at ENSA](#), which can be attributed to genetic and environmental factors. ~~For this, an experimental approach was adopted; it is based on the analysis of~~ Different characters ~~on~~ of accessions from various geographical origins ~~but which were~~ transplanted in the same site ~~where they were~~ and subjected to the same technical itinerary from sowing to harvesting and seed storage [were assessed](#). The establishment of the accessions in the common experimental field was made from cuttings therefore [assumed](#) perfectly genetically identical ~~material~~ to mother-plants. This is considered by [Montes et al.](#) [16]

as appropriate to reduce environmental impacts and to estimate how much variability ~~due to~~
genotypice in *J. curcas*.

The study of morphological characters of seeds from natural populations or low anthropic of a
species^[c30], is an important step for the study of genetic variability [3]. This work has revealed
that there are significant differences between the 35 ~~studied~~-accessions studied for the seed
length, width and thickness, 100-seed weight, K/SC ratio, fruit length, diameter and weight and
oil content. ^[c31]Previous studies have also reported a high variability of morphological traits [8,
9] and seed oil content [8] of *J. curcas* in Senegal. Similar results were obtained from other
accessions collected in Africa including Nigeria [7] and Mozambique [16], but also in Asia [17,
3, 4, 6]. They can be attributed to the fact that *J. curcas* grows in a wide range of rainfall,
temperatures, and soils [3].

The broad sense heritability is an important parameter in the selection of trees since it provides
an indication of the relative importance of heredity and environment in the expression of many
characters. High values of this parameter indicate that the environment has little influence on the
studied traits. However, the use of broad sense heritability requires coupling it with other genetic
parameters (variances and coefficients of genotypic and phenotypic variation); such an approach
allows selecting characters that are strongly under genetic control and at the same time have a
high genetic variability. Our results show that except for fruit diameter, all studied characters
have high broad sense heritability values (> 45%); therefore we can consider that these
characters are highly heritable. However, oil content, 100-seed weight, K/SC ratio and fruit
weight appear to be the most interesting for breeding programs. These four characters have the
highest values of heritability in broad sense (51.25 to 100%), genotypic variance (0.32 to 78.63)
and coefficient of variation (14.96 to 24.4%). They also have the highest values of genetic

advance (28.77 to 39.32%). Genetic advance is a parameter that provides information on the importance of genetic progress resulting from the selection of the best individuals.

Oil content, 100-seed weight, K/SC ratio and fruit weight are strongly correlated and this suggests that there are opportunities to select these characters together[c32]. The test of different linear regressions between these parameters allowed developing equations for a reliable estimate of the oil content by weight of 100 seeds ($R^2 = 0.96$). The estimation of oil content from the 100-seed weight avoids money expenses and delays associated with oil analysis in laboratory when producers are interested in estimating the oil content of their plantations after harvesting.

The hierarchical analysis performed to classify accessions based on nine (09) studied traits revealed five (5) clusters, including cluster III which contains eight (08) accessions is the most interesting for breeding programs; it has the highest values for all characters. If one refers to [18], we can see that 50% of the accessions of this cluster have high oil content ($> 55\%$); these accessions are 26 (55.16%), 13 (55.33%), 31 (56.15%) and 24 (57.16%). The hierarchical analysis also showed that the maximum distance between groups was observed between groups II and IV. [c33]According to Kaushik et al. [3], this shows a great diversity among the trees of these two groups whose crossing would provide new-high yielding hybrids[c34]. Consequently, trees belonging to these groups should be chosen as parents in *J. curcas* breeding programs in Senegal.

Finally, this study showed that the geographic diversity of accessions does not necessarily reflect their genetic diversity[c35]. Indeed, the groups shown by the hierarchical classification are each of them made up with accessions from three main eco-geographical areas of the country. Our observations are consistent with the results of many studies conducted in Senegal [8, 9] and Asia [3, 6]. [c36]

288 5. Conclusion

289 This study has shown that there is a high variability of seeds and fruits traits as well oil content
290 in *J. curcas* in Senegal^[c37]. Based on the values of calculated genetic parameters, all traits
291 examined, with the exception of fruit diameter, can be considered as heritable charactertraits.
292 However, the oil content, K/SC ratio, the 100-seed weight and fruit weight are the most
293 interesting characters for breeding programs. They have the highest values and genetic
294 parameters are strongly correlated.

295 The hierarchical analysis revealed a cluster of eight (08) promising accessions for biofuel
296 production among them, 7 are local while the eighth is from Tanzania. They have high levels of
297 oil comparable (> 55%) to the best accessions found in Asia. These results show that the local *J.*
298 *curcas* plant material ^{ael} is interesting enough to initiate perform breeding programs and support
299 domestic production of biofuel.

300 This study also showed ~~also~~, that the geographic diversity of accessions does not necessarily
301 reflect their genetic diversity.^[c38]

302 Finally, ~~this study has it has~~ led to developing a simple linear regression for a reliable
303 estimation of the oil content and 100-seedweight without laboratory analyses for ~~;- this equation~~
304 ~~could reduce the money expenses of determining the oil content in the laboratory and~~ easy ily
305 estimate ~~theof~~ oil production of *J. curcas* plantations. ~~of *J. curcas*.~~

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