Impact of Pedo-Climatic Conditions on *Jatropha curcas* L. Seeds Oil Content

Ouédraogo Razacswendé Fanta[1], Sama Hemayoro[2], Nana Rasmata[1], Kihindo Adama Pascal[1], Kiendrébéogo Fidèle Kouka[3], Badiel Badoua [1], Kaboré Zeya[1], Dondassé Edmond[1], Ouédraogo Makido[1] et Zombré Gérard[1]

[1]Plant Ecophysiology Team, Biosciences Laboratory, Joseph Ki-Zerbo University, 03 BP 7021 Ouagadougou 03, Burkina Faso
[2]Laboratory of Applied Biochemistry and Chemistry, Joseph Ki-Zerbo University, 03 BP 7021 Ouagadougou 03, Burkina Faso
[3]Genetic and Plants Improvement Team, Biosciences Laboratory, Joseph Ki-Zerbo University, 03 BP 7021 Ouagadougou 03, Burkina Faso.
Corresponding Author: Razacswendé Fanta Ouédraogo. Phone number: +226 70 55 70 19. E-mail: fantaroued[at]gmail.com

Abstract: ***Plants, like Jatropha curcas prized for its biofuel production, are subjected to climatic variations. An aim of this study was to highlight the impact of Burkina Faso climate on the quality of Jatropha curcas seeds in terms of lipid accumulation. For this, dried fruits and seeds were harvested from eight (08) years old trees situated at three (03) localities i. e. Mansila (in Sahelian zone), Bobo-Dioulasso (in soudanese zone) and Gampela (in soudano-sahelian zone) of the country. Fruits, seeds and kernels masses were determined for every ecotype and filling rates of fruit with seeds and seed with kernel were deducted. The filling rate of seeds with kernel in terms of surface was also calculated from seed and kernel surfaces. Seed oil content was determined by the soxhlet method. Results of the current study revealed no significant difference for fruits or seeds masses between ecotypes and their filling rates of seed with kernel in terms of mass or surface were similar too. Seeds account for 90% of fruit mass, and kernel for 65% of the seed mass. Similarly, kernel oil contents are also significantly different considering ecotypes and seeds taken from Mansila are rich in oil (59.80 ± 0.28%) compared to those from Bobo-Dioulasso (54.50±0.20%) and Gampela (56.67±0.16%). This difference in oil contents seemed to be linked to climatic factors. In the sahelian zone, the best adaptation strategy for Jatropha curcas plant survival face to the long hot season would involve an important accumulation of lipids within albumen of seed to ensure embryo development and thus, the species survival.***

Keywords: *Jatropha curcas*, filling rate, oil content, climatic zones, Burkina Faso

1. Introduction

Jatropha curcas is a multi-propose perennial shrub basically used in traditional medicine, in soap manufacture, and to fight against soil erosion and desertification (Baumert et al., 2018; Warra, 2012) . Its cultivation became a global interest since the oil shocks in 1973, 1979 and 2008 (Hashimoto et al., 2014; Srinivasnaik et al., 2015) . Since 1985, many studies on the plant oil using in diesel engines have been undertaken in Burkina Faso (Ouedraogo et al., 1991) . After this, various government policies developed for the sustainable use of *J. curcas* in the frame of two major objectives: soils protection/restructuration, and increasing seeds yield for agrofuel production (Bazongo et al., 2015a) . *Jatropha curcas* seed is rich in lipids with 30-45% of seed mass (Jingura et al., 2011) and appears to be ellipsoidal like castor seed (Akintayo, 2004; Annarao et al., 2008) . It produces fruits twice a year but seeds yield highly depends on the environmental conditions and soil quality (Diedhiou et al., 2018) . Indeed, trees grown from seeds bear fruit after 3 years of seed sown. However, those grown from vegetative parts take less than one year to bear fruit but have a weak root system (Joshi et al., 2011; Tamalampudi et al., 2008) . Growing on any waste surface of soil products about 2.25 to 5 tons of seed per hectare and from 125 to 250 liters of oil per kilometer of hedge (Parawira, 2010) . Two kilograms of seeds can be harvested per tree on an arable soil corresponding to the double of the yield on poor soil (Joshi et al., 2011; Tamalampudi et al., 2008) .

In Burkina Faso, improved varieties leading to a yield potential of 2 to 2.5 kg of seeds per year for five-year-old plantations against 500 g per tree with local varieties. The country is threatened by desertification and *J. curcas* is cultivated in all the phytogeographic zones, often with contrasting soil and climatic conditions (Bazongo et al., 2015b; Ouédraogo et al., 2013) . However, many studies around the world on various plant species have revealed that soil and climatic conditions have an impact on their productivity, yield, morphological traits and seed chemical composition (Mendelsohn, 2009; Pugnaire et al., 2019; Wen et al., 2012) . Climatic and edaphic conditions have remarkable effect of the plant growth and provide either a suitable environment for its needs or an adverse environment that greatly disturbs its metabolism (Ma et al., 2015; Sapeta et al., 2013; Sehgal et al., 2018; Singer et al., 2016) . Biotic or abiotic stress negatively affects seed oil content and quality and significantly reduces their economic values. Indeed, although *J. curcas* is considered tolerant to drought, several studies (Ma et al., 2015; Maes et al., 2009) showed that availability of the water has a significant effect on its productivity, seeds yield and seeds morphology. However, knowledge on the relationship between the seed oil content or the seeds quality of *J. curcas* with climate and soil conditions can improve the economic potential of the Jatropha sector (Ouattara et al., 2014) . Unfortunately, few scientific research reports the adaptation of *J. curcas* shrubs to adapt to climatic changes able to harm yields and seeds oil quality (Ouédraogo et al., 2013; Tiendrebeogo et al., 2019). Even if variations in productivity and morphology of *J. curcas* seeds according to climatic zones seems to be documented in Asia and in some African countries, there is little information on seed oil content and oil quality in relation with pedo-climatic conditions. Our study aims at displaying the impacts of climate and soil on *Jatropha curcas* plants according to the filling rate of seeds and the seeds oil.

2. Material and Methods

2.1. Vegetal material and climatic characteristics of localities

Fruit and seeds were collected from three distinct climatic zones of Burkina Faso Mansila in sahelian zone (SAZ), Bobo-Dioulasso in sudanese zone (SUZ) and Gampela in sudano-sahelian zone (SSZ) (Figure 1). The climatic characteristics of these 3 zones are given in the figure 1.

2.2. Fruit and seeds mass

One hundred (100) dried fruits from each location, total three hundred (300) seeds (each fruit with three seeds) were collected from the selected locality (Mansila, Gampela, Bobo-Dioulasso). An electronic precision-scale with calibration weight gave the mass of a fruit, the mass of its 3 seeds and the mass of each kernel. The filling rate of a fruit with its seeds in term of mass (M^s/M^f) is given by the formula (1). The filling rate in mass of the seed with kernel (M^a/M^s) is determined by the formula (2).

(1) $$\mathbf{M^s/M^f\ (\%)} = \frac{mass\ of\ the\ 3\ seeds\ (g)}{mass\ of\ fruit\ (g)} \times \mathbf{100}$$

(2) $$\mathbf{M^a/M^s\ (\%)} = \frac{mass\ of\ kernel\ (g)}{mass\ of seed (g)} \times \mathbf{100}$$

M^s: masse of seed; M^f: masse of fruit; M^a: masse of kernel; %: percentage; g: gram

2.3. Biometrics parameters of seeds

Three hundred (300) seeds per locality (Mansila, Gampela, Bobo-Dioulasso) also served for the determination of biometrics parameters. The sizes of each seed have been obtained by measuring by the big diameter (D) and the small one (d) according to (Dranski et al., 2010) (Figure 2).

The kernel has been measured after weighing and peeling the seed. For each specimen seed or kernel was measured three times. Because of the ellipsoidal form of *J. curcas* seed, the ellipsoidal surface of the seed and that one of the kernel has been deducted with the following formula (3).

(3) $$\mathbf{S^s\ or\ S^k\ (cm^2)} = \pi \times \frac{D}{2} \times \frac{d}{2}$$

S^s: surface of seed; S^a: surface of kernel; D: big diameter (of seed or kernel); d: small diameter (of seed or kernel).

The filling rate of seed with kernel in terms of surface S^a/S^k is given by the formula (4).

(4) $$\mathbf{S^k/\ S^s(\%)} = \frac{surface\ of\ kernel\ (cm^2)}{surface\ of\ seed\ (cm^2)} \times \mathbf{100}$$

2.4. Seeds content in oil

A sample of five grams (5g) of kernel powder were used for a modified method of oil extraction by Soxhlet (Ouédraogo, 2000; Shivani et al., 2011). The method required a high degree of temperature (60°C) consisting of an extraction of lipids molecules in the kernel powder with hexane as solvent, and needed a soxhlet linked to a cooling column (on the upper part) and to a balloon of recuperation (on the lower part). To determine the sample content in oil, it was necessary to note the mass of the empty balloon ($M_{balloon}$) before adding 200ml of solvent and putting the kernel powder into the soxhlet. After four (4) hours of heating the balloon containing the resulting oil is dried under 105°C in a heat chamber to eliminate the residual solvent and to recover the extracted oil. Then, the mass of the balloon containing oil $M_{balloon\ +oil}$ is noted and the content in oil (CO) is determined according to the following formula (5)

(5) $$\mathbf{CO\ (\%)} = \frac{\mathbf{Mballoon+oil(g)-Mballoon(g)}}{\mathbf{Malmond\ sample\ (g)}} \times \mathbf{100}$$

Statistical Analysis

GenStat Discovery software Edition 4-VSN International was used for data analysis. An ANOVA test was used to compare the variance between averages and when at least one average was significantly different from the others, the Student Newman-Keuls test was applied. It then compares average in pairs. P value less than to 0.05, for each variable, was considered as significant.

2.5. Filling rate in terms of mass

The mass means of fruit, seed and kernel are presented in the table 2 do not show any statistical difference between the three ecotypes (P> 0.05). The filling rates of fruit with seeds M^s/M^f or seed with kernel M^k/M^s deducted from masses were also similar between ecotypes. Indeed M^s/M^f is around 90±4% (P=0.726) and M^k/M^s is around 65±4% (P=0.791).

2.6. Biometrics parameters and filling rate in terms of the surface

The big diameter, small diameter and ellipsoidal surface of seed or kernel as well as the filling rate of seed with kernel in terms of surface did not show significantly differences considering ecotype (P>0.05; table 3). This filling rate is close to 66 ± 3% (P=0.746).

2.7. Oil content

From one ecotype to another, the content in extracted oil from kernel has changed significantly (p<0.001; Figure 3). Kernel from Mansila seeds had the richest oil content with 59.80 ± 0.28% while the lowest lipid content was reported from the Bobo-Dioulasso ecotype (54.24±0.20%) whereas Gampela ecotype exhibited a middle value of 56.67±0.16%. Taking account of the whole seeds values became weaker than those relative to the oil content in kernel and following the same trend: 41.24 %, 36.51 % and 34.50 % (P<0.001) for Mansila, Gampela and Bobo-Dioulasso seeds respectively.

3. Results

3.1. Filling rate in terms of mass

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4. Discussion and conclusion

4.1. Filling rate of seed and kernel

The study revealed a similarity between the 3 ecotypes for mass, dimensions and filling rate of seeds and comparable values to those given by the previous authors: mass of dry seeds between 0.56 g and 0.63 g, big diameter between 1.87 cm and 1.90 cm and small diameter between 0.85 cm and 1.3 cm (Dranski et al., 2010; Müller et al., 2015) . The filling rate of the seed with kernel in term of mass $M^{k/}M^s$, (65%), can explain an important loss of water during seed dehydratation (about 35%). The higher filling rate (90%) in terms of dry mass of the fruit with seeds M^s/M^f indicated that water content of the fresh fruit is higher than 10% and containing water may be most concentrate in the endocarp and the kernel. Dranski et al. (2010) obtained 14.48% as water content in *J. curcas* seed in fruit at the last maturation stage. Whereas the same authors showed an important decreasing of water content from stage 1 to stage 6 due to the function of fruit dehiscence. The filling rate of seed in kernel considering surface S^k/S^s (66%) confirms the loss of water in the seed and mainly in the kernel during seed desiccation.

4.2. Seed and kernel oil contents

The study revealed significant differences in seeds oil content considering ecotypes. The difference in oil content observed between seeds of the three ecotypes seems to be due to the climatic and edaphic factors. In plants, lipid biosynthesis is also influenced to environmental factors such as temperature, drought, light availability and soil nutrients (Singer et al., 2016).

Our results are in agreement with those of (Maes et al., 2009) and (Wen et al., 2012) who reported that the climate factors or ecological conditions (temperature, precipitation, sunshine etc.) could have a significant effect on *Jatropha* distribution, productivity, seed yield and oil content. The Mansila ecotype recorded better lipid accumulation compared to ecotypes from other localities. These results could be justified by the adaptation mechanism of the species to the harsher environmental conditions of the zone of Mansila (Sahelian zone). Plants in their growing environment settings are subjected to pedoclimatic conditions (excessive sunlight, insufficient water intake, very high temperatures, air and soil pollutions, pathogens attacks, etc.). Ouédraogo et al. (2016) which, can be suitable or adverse to them (Jumrani and Bhatia, 2018; Sehgal et al., 2018). In order to compensate for drastic or hostile environmental conditions (temperature, pollution, acidity, pressure), for plant cells, changes in the membrane composition can allow the organism to adapt resulting in changes in seed oil accumulation and fatty acid composition (Denich et al., 2003) . Within its natural biotope, the ecotype from the Mansila area is subject to some harsher environmental conditions than those of the two others ecotypes. Sahelian zone is characterized by a long hot season with an important lack of water and a very long and harsh sunny period. Face to these hard environmental conditions, plants have to be adapted (Sehgal et al., 2018) . So, *J. curcas* trees found in Mansila area would adapt their ecosystem by improving the quantity of oil in the kernel. This lipids reserve concentrated in the cotyledons is a potential source of energy for future plant and thus saving the species (Liang et al., 2019).

In some moderated climate conditions such as in the Gampela and Bobo-Dioulasso areas, seeds would accumulate a less quantity of lipid in kernel. The seeds lipid mobilization would be a characteristic proper to the ecotype and its environment. The hypothesis of a modification according to the synthesis of the lipids under environmental strains must naturally be taken into account.

Conflict of interest

No potential conflict of interest was reported by the authors.

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Table 1: Characteristics of Burkina Faso zones (Ben Yahmed, 2005; Thiombiano and Kammpman, 2010)

Climatic zone	Sahelian zone (SAZ)	Sudano-sahelian zone (SSZ)	Sudanese zone (SUZ)
Average of the rainy system	Less than 600 mn	600 to 900 mn	900 to 1300 mn
Rainy season length	2 to 3 months	4 to 5 months	5 to 6 months
Average annual temperature	Up to 30°C	20 to 30°C	20-25°C
Temperature range	11°C	8°C	5°C
Sunshine range per day	6 to 10h	6 to 10h	6 to 10h
Vegetation	Wooded savannah dated with clear forest relics, trees and shrubs of protected species	Wooded and shrubby savannah (thorny trees and shrubs, stunted)	Savannah and agro-forestry parks.
Soils	Sodium and less evolved sols	Maw mineral soils, ferritic, brownish and undeveloped	Maw mineral soils, ferritic brownish, and undeveloped

SAZ: Sahelian zone; SSZ: Sudano-sahelian zone; SUZ: Sudanese zone; mn: millimeter of water; °C: degree Celcius; Sudano-sahelian zone; SUZ: Sudanese zone.

Table 2: Mass and rate filling of the fruit and the seed of the 3 ecotypes

Parameters		Ecotype			*P*
		Mansila (SAZ)	Gampela (SSZ)	Bobo-Dioulasso (SUZ)	
Dry mass (g)	M^f	2.06 ± 0.07 ^{a}	1.94 ± 0.08 ^{a}	1.97 ± 0.06 ^{a}	*0.781*
	M^s	0.63 ± 0.06 ^{a}	0.59 ± 0.05 ^{a}	0.58 ± 0.05 ^{a}	*0.769*
	M^k	0.40 ± 0.03 ^{a}	0.38 ± 0.04 ^{a}	0.40 ± 0.06 ^{a}	*0.875*
Filling rate (%)	M^s/M^f	92 ± 4 ^{a}	91 ± 3 ^{a}	88 ± 4 ^{a}	*0.726*
	M^k/M^s	63 ± 3 ^{a}	64 ± 3 ^{a}	69 ± 5 ^{a}	*0.791*

Means within lines followed by the same letter are not significantly different at 5% by the Student Newman-Keuls test. g: gram; M^s: seed mass; M^f: fruit mass; M^k: kernel mass; SAZ: Sahelian zone; SSZ: Sudano-sahelian zone; SUZ: Sudanese zone; P: probability.

Table 3: Biometric parameters and filling rate in terms of surface of the 3 ecotypes seeds

Parameters		Ecotype			*P*
		Mansila (SAZ)	Gampela (SSZ)	Bobo-Diou lasso (SUZ)	
Big diameter D (cm)	D^s	1.84 ± 0, 04 ^{a}	1.77 ± 0, 03 ^{a}	1.82 ± 0, 03 ^{a}	*0.808*
	D^k	1.45 ± 0, 04 ^{a}	1.41 ± 0, 04 ^{a}	1.50 ± 0, 05 ^{a}	*0.882*
Small diameter d (cm)	d^s	0.85 ± 0, 02 ^{a}	0.86 ± 0, 04 ^{a}	0.88 ± 0, 02 ^{a}	*0.828*
	d^k	0.71 ± 0, 02 ^{a}	0.70 ± 0, 03 ^{a}	0.72 ± 0, 03 ^{a}	*0.831*
Ellipsoidal surface (cm^2)	S^s	1.23 ± 0, 02 ^{a}	1.19 ± 0, 02 ^{a}	1.26 ± 0, 03 ^{a}	*0.737*
	S^k	0.81 ± 0, 03 ^{a}	0.77 ± 0, 03 ^{a}	0.85 ± 0, 02 ^{a}	*0.868*
Filling rate (%)	S^k/S^s	66 ± 3 ^{a}	65 ± 2 ^{a}	67 ± 3 ^{a}	*0.746*

Means within columns followed by the same letter are not significantly different at 5% by the Student Newman-Keuls test. g: gram; S^k: kernel surface; S^s: seed surface; cm: centimeter; cm^2: square centimeter;; SAZ: Sahelian zone; SSZ: Sudano-sahelian zone; SUZ: Sudanese zone; P: probability.

Figure 1: Climatic zones of Burkina Faso
(Ben Yahmed, 2005; Thiombiano and Kammpman, 2010)

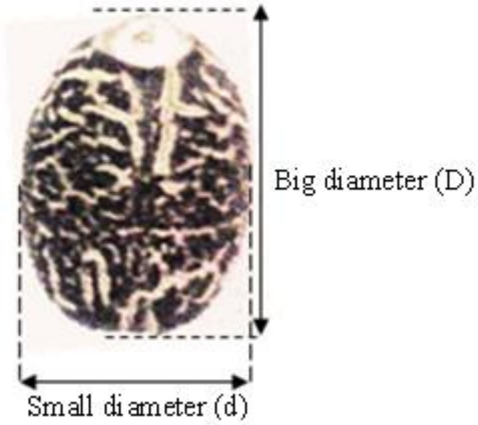

Figure 2: Biometrics parameters of seed

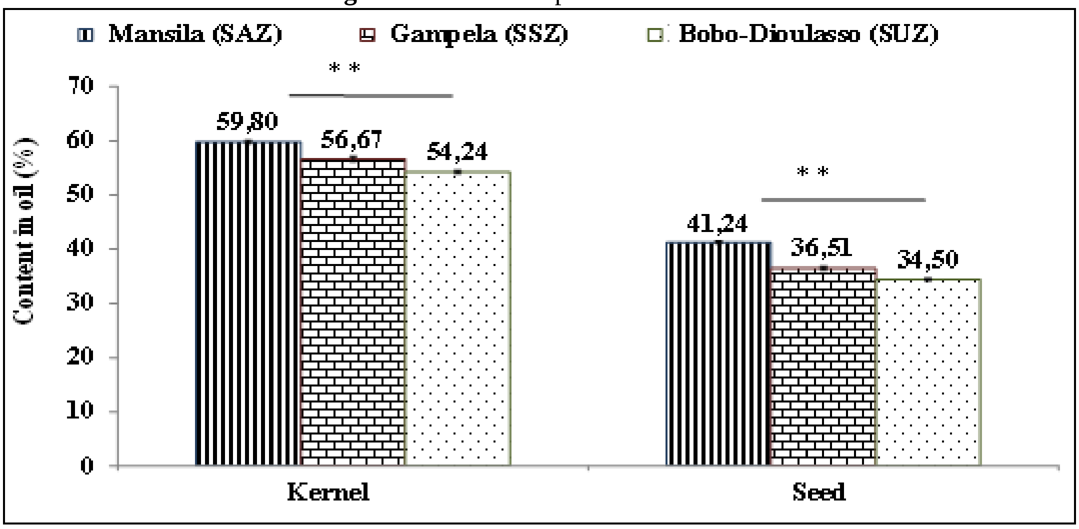

Figure 3: Content in oil of kernel and seed from the 3 ecotypes

The averages of 3 successive histograms marked by different letters are different at 5% by the Student Newman Keuls test; **: P<0.001; ZSA: Sahelian zone; ZSS: Sudano– Sahelian zone; ZSO: Sudanese zone; %: percentage.