International Journal of Agriculture and Biological Sciences- ISSN (2522-6584) Jan & Feb 2021

February 28, 2021

Morphological and Yield Characteristics of Six (6) Varieties of *Jatropha Curcas* L. Collected From Different Locations in South-West Nigeria

Author's Details:

Banjoko, K. T.[1], Feyisola, R. T.[1] and Oyekale, K. O.[2]

[1]Department of Plant Science, Faculty of Science, Olabisi Onabanjo University, Ago-Iwoye, Ogun State.

[2]Department of Agriculture and Industrial Technology, School of Science and Technology, Babcock University, Ilishan-Remo, Ogun State, Nigeria.

Corresponding e-mail: oyekalek@babcock.edu.ng

Received Date: 31-Dec-2020 Accepted Date: 30-Jan-2021 Published Date: 28-Feb-2021

Abstract

The world's crude oil is fast depleting, hence the need to look inwards for other energy sources. Biodiesel is a renewable fuel that has received considerable attention recently because it is non-polluting and biofuels from plants represent the most abundant source of renewable fuels. Jatropha curcas L, a multipurpose perennial plant has gained lots of importance for the use of its non-edible seeds in the production of biodiesel. This study is aimed at assessing performance of selected Morphological and yield parameters of wild collections of the crop comparing their variability for future improvement breeding programmes. Seeds of Jatropha curcas LA01JC, OG01JC, OG02JC, OS01JC, OY01JC and OY02JC were collected from Lagos, Ogun, Oyo and Osun States and nursed in loam soil. The seedlings were then transplanted on the field using Randomized Complete Block Design (RCBD) with three replications. Data collection (Plant height, Stem length, Petiole length, Collar diameter, Canopy spread, Leaf length, Leaf width, Number of branches, Number of leaves; Days to flowering Number of fruits per tree, Number of inflorescences, Number of fruits per inflorescence, Fruit length, Fruit weight, Fresh fruit weight) commenced four weeks after transplanting. The data collected were subjected to analysis of variance and mean separated using Duncan's Multiple Range Tests; while Pearson correlation and Principal component analysis were used to study relationships and variability of the collections and the characters. The result showed significant differences between the collections with respect to the morphological and yield variables measured. OY01JC had the highest plant height (107.217cm), OS01JC flowered earliest (254 days) and produced more fruits per stand (23). Morphological and Yield variables had significant ($p \leq 0.01$) and positive correlation with one another. Correlation between days to flowering is negatively highly significant with number of fruits per inflorescence (-0.615), number of inflorescence (-0.571), number of fruits per tree (0.869), fruit length (-0.724), fruit width (-0.714) and fresh fruit weight (-0.729). Consequently, this study demonstrates that collections investigated were highly variable for all parameters evaluated and harbours obvious potentials for improvement. Hence OS01JC, OY01JC and OY02JC could serve as a good starting point for further improvements.

***Keywords**: Jatropha curcas, Morphology, Nigeria, Variability, Yield*

Introduction

The sustenance of infrastructure necessary for the current and future development of the world is dependent on a steady and continuous supply of energy. Majority of our current energy supply is derived from burning of fossil fuels and, even considering the discovery of new reserves, it is expected that fossil fuel supplies will be severely depleted over the next century with an increase in energy demand (Sawin and Sverrisson, 2014). This effect on climate change, depletion of natural resource, and scarcity of fossil fuel has triggered a sense of urgency among researchers and industrialist to find sustainable and viable solutions in biofuels (Chakroborty *et al*., 2012). Biofuels from plants represent the most abundant source of renewable fuels, offering the manufacture of ethanol and butanol and long-chain hydrocarbons from starch, cellulose, hemicellulose, and oils. The source of the energy captured by plants is the sun, which will be a constant source of energy for the next few billion years. The carbon released from the burning of biofuels is continually cycled rather than being released from ancient fixed carbon sources, as is the case for fossil

petroleum and natural gas. Biodiesel derived from surplus edible oils like soybean, sunflower and rapeseed oils is already being used in USA and Europe to reduce air pollution (Berchmans and Hirata, 2008).*Jatropha curcas* L, belonging to Euphorbiaceae family widely occurring in Africa, India, South America, West Indies, Central America, and the Caribbean (Leal and Agra, 2005) is a multipurpose, drought resistant, perennial plant that has gained lots of importance for the use of its non-edible seeds in the production of biodiesel (Kumar and Sharma, 2008). Common names include Barbados Nut, Purging Nut and Physic Nut. In Nigeria, it is known as "lapalapa" and "binidazugu" in Yoruba and hausa languages respectively (Warra, 2012). It can grow to about 3-6m in height and may be evergreen or deciduous depending on climate. It has a short tap root, stout branches and leaves are palmate with 5-7 shallow hollow lobes arranged alternately in spiral phyllotaxis. Leaf length, leaf width and petiole length vary between 16-21, 14-18 and 12-19cm long respectively. Flowers usually pollinated by moths and bees are monoecious with terminal inflorescence having light green oblong petals and quinquepartite sepals. Fruits can be 2.5cm-3.5cm long and 2 to 2.5cm wide while the seeds are black oblong and are not more than 3 to 4 in a fruit (Kumar and Tewari, 2015).

In India, studies have revealed high level variations among accessions using morphological parameters such as Plant height, leaf growth, fresh and dry weight of leaves, petiole and root length of the plant from seed propagated crop (Nahar and Hoque, 2013). Basu*et al*., (2017) in their morphological trait-based analysis revealed large variation of quantitative traits among the *Jatrophacurcas*populations. A high variation was observed in the floral sex ratio M:F (% coefficient of variation = 23.19) while canopy spread appeared as the least variable trait (% coefficient of variation = 1.67).

In Nigeria, despite the biofuel producing potential of the crop, there are little or no studies on the crop as there are few germplasm, seed banks where elite accessions can be assessed. However, Morphological variation has been found to occur amongst *Jatropha curcas* accessions from the Northern part of the country. This is revealed in the study of Abubakar *et al*., (2014) that accessions that are close in terms of geographical locations ensures easy pollen exchange at the reproductive life phase. They arrived at this conclusion because the higher values of seedling height, leaf length and leaf width (15.851, 9.315 and 7.747cm respectively) were shown by KDKNO4, KGKNO8 and RNGJ13 respectively and incidentally the accessions were from Kano state. In the study of Saadaoui *et al*., (2015), it was reported that plants from all the accessions studied shed their leaves from December to April and the first flowers appeared in May. They also observed that Positive correlation was found between plant height and canopy circumference ($r2 = 0.87$), total yield and yield of last harvest (August 2013; $r2 = 0.76$), plant height and seed yield in winter (0.56), and canopy circumference and seed yield in summer (0.51) and in winter (0.62). Furthermore, Analysis of variance revealed high morphological variability with a significant ($p < 0.05$) effect of accession for all five characters under study (FS, LL, LW, PL, NN). Significant ($p < 0.05$) positive correlations were found between all leaf magnitudes (leaf surface (FS), leaf length (LL), leaf width (LW) and petiole length (PL).

Wani *et al*., (2012) reported that Plant height had a significant correlation with all characters evaluated in their study except leaf width. They suggested that the number of branches/plants, plant spread and plant height are the important factors to which further improvement could be made. Significant variation was observed in plant height of 23 wild accessions of *Jatropha curcas* in the study of Gawali *et al*., (2016). The Maximum plant height of 176.75 cm was observed in RJ-87 followed by RJ-130 which recorded 172.25 cm. The lowest plant height was observed in the RJ-133 which 129.0 cm. The study also reported significant variation with regards to collar diameter highest found in R- 3 (5.33 cm) and lowest in RJ- (4.23 cm). The collar diameter, number of primary branches, number of secondary branches, number of fruits per plant, number of seeds per fruits , fruits diameter at both longitudinal and equatorial, 100 seed Test weight and seed yield per plant traits were positive and significant correlation with plant height where these were negatively and non-significantly associated with oil content and shelling percentage. Sulaiman *et al*., (2016) Aranisola *et al*., (2015) Phurpa *et al*., (2015) have all successfully produced biofuel from Jatropha using hand driven expeller in acid-base catalysed trans esterification and base trans esterification respectively.

Materials and Method

The genetic material comprised of six (6) *Jatropha curcas* accessions, which were obtained from Six different locations in Southwest of Nigeria; Lagos (LA), Ogun (OG), Osun (OS) and Oyo (OY) states.

Matured fruit samples were collected randomly in polythene bags from 5 parent plants in a population and labelled with accession numbers.

Table 1 Locations of *Jatropha curcas* collections

S/N	Collection number	Locality
1	LA01JC	Epe, Lagos State
2	OG01JC	Ilese, Ijebu Ode, Ogun State
3	OG02JC	Iloti, Ijebu Ode, Ogun State
4	OS01JC	Igbaye, Osun State
5	OY01JC	Moniya, Ibadan, Oyo State
6	OY02JC	Oyo town, Oyo State

Seed Preparation, Nursery, Field Preparation and Planting

Seeds of each of the accessions of *Jatropha curcas* were nursed in loam soil contained in nursery bags on 3rd September, 2018 under a shed at the Department of Plant science, Olabisi Onabanjo University, Ago Iwoye, Ogun state, Nigeria. There was regular daily wetting during nursery except on raining days. The experimental area was manually prepared with use of simple farm tools. Thirty seedlings for each accession were transplanted to the experimental field four weeks after nursery. Wetting was done twice (Morning and Evening) daily.

Experimental Design

The Experiment was carried out using Randomized Complete Block Design (RCBD) with three replications on the field. Each replicate consists of six plots with ten seedlings of each accession. Seedlings were planted at 1m x 1m between rows and 2m and 1.5m spacing between blocks and plots respectively.

Data Collection

Data collection commenced four weeks after transplanting. Data were collected from five tagged plants for each accession in all the replicates, making a total of fifteen plants per accession all through the experiment. Each time, the five tagged for each accession in each plot were sampled and observations were taken on the following morphological parameters.

1. Plant height (cm): The height from the ground level to the tip of the main stem using a measuring tape.
2. Stem length (cm)
3. Petiole length (cm): Petiole length were measured using a measuring tape
4. Collar diameter (cm): this is measured with a measuring tape from the girth measurement of the main stem 5cm above the ground level.
5. Canopy spread: Canopy spread were measured using standard measuring tape.
6. Leaf length (cm): the length of the biggest leaf from the point of detachment from the petiole to the leaf apex was measured with a ruler.
7. Leaf width (cm)
8. Number of branches
9. Number of leaves

Yield parameters include:

1. Days to flowering
2. Number of fruits per tree
3. Number of inflorescences
4. Number of fruits per inflorescence
5. Fruit length
6. Fruit weight

7. Fresh fruit weight.

Statistical Analysis

Data were analysed using Statistical Analysis Software (SAS, 1999) adopting the method of Steel and Torrie (1980). Analysis of variance (ANOVA) was carried out on the parameters evaluated for the treatments. Treatment means from ANOVA were separated using Duncan's Multiple Range Test (DMRT). The relationship among the parameters evaluated for all accessions was also studied using correlation coefficients generated through correlation analysis. The extents of genetic variation percentage similarity within accessions were determined through Principal Component Analysis (PCA). Finally, Eigen-values and factor scores obtained from PCA were used to determine the relative discriminative power of the axes and their associated parameters.

Results and Discussion

Table 2 shows the means of 6 accessions of *Jatropha curcas* for morphological and yield parameters evaluated. The means of plant height, stem length, petiole length, canopy spread of OG02JC, OS01JC, OY01JC, were not significantly different from one another. Similarly, plant height, stem length of OG01JC and OY02JC were also not significantly different from one another. In the same vein, collar diameter and canopy spread of LAO1JC and OYO2JC are not significantly different. The means of number of fruits, number of fruit per inflorescence and number of inflorescence for LAO1JC and OG01JC are not significantly different. The means of days of flowering for OS01JC and OY01JC are not significantly different from one another even through other accession showed significant difference. The means of numbers of inflorescence show that the pairs LAO1JC, OG01JC; OG02JC, OYO2JC; OS01JC, OY01JC respectively are not significantly different from each other, same is observed for the pairs of OG01JC, OG02JC, OY01JC; LAO1JC, OYO2JC for fresh fruit weight. OS01JC however shows significant different from others.

Table 3 shows the means square from analysis of variance for Morphological and Yield Parameters of *Jatropha curcas* from field evaluation. Accession was highly significant ($p \leq 0.01$) on all the parameters evaluated. Replicate was also highly significant on all parameters with leaf length, leaf width and number of lead per tree significant at $p \leq 0.01$. All other parameters were significant at $p \leq 0.05$ except days to flowering, number of fruit per inflorescence, fruit length, fruit width and fresh fruit weight that were not significant.

Table 4 shows the correlation coefficients from correlation analysis carried out on the morphological parameters of *Jatropha curcas*. All the morphological parameters had significant ($p \leq 0.01$) and positive correlation with one another. Majority of the yield parameters evaluated had significant ($p \leq 0.01$) and positive correlation with one another. Correlation between days to flowering is negative and highly significant with number of fruits per inflorescence (-0.615), number of inflorescence (-0.571), number of fruits per tree (-0.869), fruit length (-0.724), fruit width (-0.714) and fresh fruit weight (-0.729). The result from the table also shows that number of inflorescences was also significant and positively correlated with number of fruits per tree (0.861) and number of fruits per inflorescence (0.640). However, the relationship between number of inflorescences with fruit length (0.146), fruit width (0.128) and fresh fruit weight (0.145) were not significant.

Table 2. Means of 16 Morphological and Yield Variables for 6 Varieties of *Jatropha curcas*

Accessions	pht	Slt	cdm	llt	lwt	plt	css	nlt	nbt	Dfl	nfs	nfl	nii	flt	fwt	ffw
JC01	58.80c	47.512c	22.361d	10.558e	12.420d	13.720c	49.525c	59.858e	0.833d	283.917ba	7.333e	4.000c	4.750c	0.000e	0.000c	0.000d
JC02	70.06b	65.633b	30.117c	13.430c	16.001cb	17.316b	60.058b	82.758c	1.875b	281.733b	7.983e	4.050c	4.333c	32.550d	29.800b	14.226b
JC03	104.942a	97.725a	38.743a	16.698a	19.328a	21.797a	78.025a	119.642a	2.675a	254.067d	23.000a	4.933b	12.066a	33.242c	29.747b	14.883ba
JC04	107.217a	100.708a	38.230a	15.240b	17.331b	20.198a	79.330a	125.358a	2.616a	265.867c	19.466b	5.066b	9.400b	37.260a	31.442a	14.966a
JC05	100.042a	93.675a	34.343b	15.110b	17.086b	19.635a	72.717a	111.008b	2.541a	266.983c	16.550c	5.683a	9.466b	34.588b	30.035b	13.319c
JC06	64.979b	59.979b	25.355d	12.151d	14.811c	15.150cb	51.100c	72.050d	1.275c	285.667a	14.000d	4.666b	11.250a	0.000e	0.000c	0.000d

Key: means with same letter along the column are not significantly different from one another; pht- plant height, slt- stem length, cdm- collar diameter, llt- leaf length, lwt- leaf width, plt- petiole length, css- canopy spread, nlt- number of leaves per tree, nbt- number of branches per tree, dfl-days to flowering, nfs- number of fruit per stand, nfi- number of fruit per inflorescence, nii- number of inflorescence, flt- fruit length, fwt- fruit width, ffw- fresh fruit weight.

Table 3. Means Square from Analysis of Variance of Morphological and Yield Characters of 6 Varieties of *Jatropha curcas*

SOV	pht	slt	cdm	llt	lwt	plt	css	nlt	nbt	dfl	nfs	nfl	nii	flt	fwt	ffw
acce	1657.056**	1533.841**	137.415**	15.317**	16.86**	23.991**	534.934**	2217.917**	1.815**	480.861**	116.941**	1.237**	32.063**	955.040**	733.494**	165.757**
rep	32.333*	38.117*	13.505*	6.428**	6.027**	7.537*	31.787*	220.887**	0.032*	1.435ns	1.073**	0.037ns	1.150**	0.053ns	0.049ns	0.290ns
error	10															
total	17															

Key: ns: non-significant; **significant at 1% level of probability; * significant at 5% level of probability; pht- plant height, slt- stem length, cdm- collar diameter, llt- leaf length, lwt- leaf width, plt- petiole length, css- canopy spread, nlt- number of leaves per tree, nbt- number of branches per tree dfl-days to flowering, nfs- number of fruit per stand, nfi- number of fruit per inflorescence, nii- number of inflorescence, flt- fruit length, fwt- fruit width, ffw- fresh fruit weight.

Table 4: Relationships among Morphological and Yield Characters of 6 Varieties of *Jatropha curcas*

	pht	slt	cdm	llt	lwt	plt	Css	nlt	nbt	dfl	nfs	nfl	nii	flt	fwt	ffw
pht		0.998**	0.963**	0.897**	0.867**	0.916**	0.974**	0.985**	0.955**	-0.893**	0.867**	0731**	0.587*	0.825**	0.803**	0.808**
slt			0.966**	0.896**	0.869**	0.913**	0.973**	0.984**	0.960**	-0.879**	0.861**	0.733**	0.576**	0.830**	0.809**	0.813**
cdm				0.943**	0.929**	0.956**	0.981**	0.976**	0.953**	-0.860**	0.807**	0.565**	0.491*	0.856**	0.842**	0.862**
llt					0.982**	0.983**	0.910**	0.919**	0.888**	-0.824**	0.781**	0.530*	0.537*	0.785**	0.779**	0.802**
lwt						0.959**	0.875**	0.891**	0.884**	-0.799**	0.786**	0.515*	0.578*	0.759**	0.756**	0.784**
plt							0.935**	0.933**	0.893**	-0.846**	0.756**	0.516*	0.485*	0.815**	0.805**	0.828**
css								0.981**	0.951**	-0.889**	0.808**	0.612**	0.474*	0.858**	0.841**	0.852**
nlt									0.956**	-0.871**	0.842**	0.664**	0.544**	0.839**	0.818**	0.827**
nbt										-0.857**	0.793**	0.692**	0.483**	0.907**	0.895**	0.894**
dfl											-0.869**	-0.615**	-0.571*	-0.725**	-0.714**	-0.729**
nfs												0.708**	0.862**	0.526*	0.507*	0.524*
nfl													0.641**	0.482*	0.453ns	0.419ns
nii														0.146ns	0.128ns	0.146ns
flt															0.998**	0.994**
fwt																0.995**
ffw																

Key: ns: non-significant; **significant at 1% level of probability; * significant at 5% level of probability; pht- plant height, slt- stem length, cdm- collar diameter, llt- leaf length, lwt- leaf width, plt- petiole length, css- canopy spread, nlt- number of leaves per tree, nbt- number of branches per tree dfl-days to flowering, nfs- number of fruit per stand, nfi- number of fruit per inflorescence, nii- number of inflorescence, flt- fruit length, fwt- fruit width, ffw- fresh fruit weight.

Jatropha curcas has been characterized based on their morphological differences. The study has been able to show that morphological differences exist between the six (6) collections. This corroborates the results of earlier studies (Nahar and Hoque 2013; Abubakar *et al*., 2014; Naresh *et al*., 2015; Ahmed *et al*., 2016 and Basu *et al*., 2017;).

After planting, the seeds began to sprout on the 7th day an indication of higher seed viability across the collections. The findings of Abubakar *et al*., (2014) substantiate this observation. After field planting, it was also observed that the leaves of all the collections began to shed between the months of December and April and this is validated by the findings of Saadaoui *et al*., (2015) who reported shedding of leaves between the months of December and May.

The high significant differences ($p \leq 0.01$) amongst the six collections for all morphological variables evaluated revealed by analysis of variance are an indication that a good number of genetic variability exist in the collections. These variations could even be wider because these collections were sourced from different natural environments which might have been affected by natural selection. This indicates that significant improvement could be achieved through selection for the traits of interest. Hence, these observed variations therefore present us with a raw material for breeding at a very early stage from seed material that could be of use in improvement programmes. The significant difference in plant height among the collections may result from adjustment of the populations to their specific environmental condition via natural selection

An effective selection is a function of correlation among traits (Reis *et al*., 2017). The correlation studies revealed that plant height had significant correlation with all other characters. The study of Wani *et al*., (2012) corroborates this observation even though their study showed that correlation of plant height and leaf width was not significant. Furthermore, the correlation of plant height with all other morphological parameters was observed to be positive. This result can be validated by the positive and significant correlation of plant height with other parameters in the study of Gawali *et al*., (2016). The positive correlation that exists between the number of leaves and yield variables (number of fruits; fruit length; fruit width and fruit weight) is an indication that leaf traits are also responsible for yield in fruits. This is so because of the role of photosynthesis in the development of fruits of some vegetables.

The high fruit yield of OS01JC is as a result the highly significant correlation between number of branches with number of inflorescence as well as with number of fruit per inflorescence indicating that plants with good branching habit tend to develop more number of fruits. This is in agreement with the work of Rao *et al*., (2008) who found a significant correlation between seed yield and number of branches and plant height. Furthermore, Mohapatra and Panda, (2010) also agree with and was of the opinion that poor branching is considered a limitation to high fruit yield.

Conclusion

The mean of the morphological and yield traits evaluated in the study were highly significant on all the six collections of *Jatropha curcas*. This study demonstrates that the collections investigated were highly variable for all the morphological traits evaluated and they harbour obvious potentials for improvement in *Jatropha curcas* at $p \leq 0.05$ and $p \leq 0.01$ respectively. The mean of all parameters evaluated have moderate significance difference. However it should be noted that collections OS01JC, OY01JC and OY02JC behaved closely to each other on all parameters evaluated despite not being from the same collection source. Hence, they could serve as a good starting point for further improvements. The *Jatropha curcas* collections evaluated in this research were grown in only one location. Since interactions between genes and the environment can affect performance, similar experiments can be carried out in several other geographical and ecological areas to really ascertain their level of performance. However, collections with promising morphological and yield traits could be used for further breeding works. Furthermore, studies at both chromosomal and molecular level should be carried out to ascertain genetic variability not captured in the morphological level.

References

i. *Abubakar, B.Y., Dangora, D.B., Adamu, A.K., Iortsum, D.N., Abdul-hadi, B.D., Saidu, M.A., Saminu, S.A and Abubakar, S.U (2014).“Morphological characterization of some accession of Jatropha*

curcas L for biofuel production".International journal of phytofuels and allied sciences 3(1):147-155.

ii. *Ahmed D. M. M., Mahfouze HA., Ali E. A. M and Abdelrahman, H. H. (2016). "Morphological, Biochemical and Molecular Studies on Jatropha curcas Seedlings".International Journal of ChemTech Research 9(7):37-45.*

iii. *Aransiola, E.F Daramola, M.O, Ojumu T.V., Aremu M.O, Layokun S.K., Stephen and Solomon B.O (2012). "Nigerian Jatropha Curcas Oil Seeds: Prospect for Biodiesel Production in Nigeria". International Journal of Renewable Energy Research 2(2):317-325.*

iv. *Basu, A., Gunupuru, L.R and Sahoo, L (2017)."Morphometric characterization of Jatropha curcas germplasm of NorthEast India".African Journal of Biotechnology 16(13):648-656.*

v. *Berchmans, H.J and Hirata, S (2008)."Biodiesel production from crude Jatropha curcas L. seed oil with a high content of free fatty acids.Bioresource Technology 99: 1716-1721.*

vi. *Chakraborty, S., Aggarwal, V., Mukherjee, D., and Andras, K. (2012). "Biomass to Biofuel: A Review on Production Technology". Asia-Pacific Journal of Chemical Engineering, 7(S3), S254-S262*

vii. *Dias, L.A.S, Missio, R.F and Dias, D.S.F.S (2012)."Antiquity, botany, origin and domestication of Jatropha curcas(Euphorbiaceae), a plant species with potential for biodiesel production".Genetics and Molecular Research 11(3):2719-2728.*

viii. *Gawali, A.S., Wagh, R.S and Sonawane, C.J (2016)."Genetic Variability in Growth and Seed Traits of Jatropha curcasL. Germplasm for Genetic Tree Improvement".Forest Research 5:171.*

ix. *Kumar, A. and Sharma, S. (2008). An Evaluation of Multipurpose Oil Seed Crop for Industrial Uses (Jatropha curcas L.): A review. Journal of Industrial Crops and Products, 28(1), 1-10.*

x. *Kumar, A. and Tewari, S. K. (2015).Origin, Distribution, Ethnobotany and Pharmacology of Jatropha curcas. Research Journal of Medicinal Plants, 9(2), 48-59.*

xi. *Leal, C.K.A and Agra, M.D.F (2005)."Estudofarmacobotânicocomparativo das folhas de Jatropha molissima (Pohl) Baill".ActaFarmaceuticaBonaerense. 24(1): 5-13.*

xii. *Mohapatra, S., and Panda P. K. (2010).Genetic variability on growth, phonological and seed characteristics of Jatroph acurcas L. NotulaeScientiaBiologicae, 2, 127-132.*

xiii. *Nahar, K and Hoque, S (2013)."A Morphological and Physiological Study of Jatropha curcas Linn. Propagated from Seeds in Bangladesh" Middle-East Journal of Scientific Research 13(8):1115-1118.*

xiv. *Naresh, B., Reddy, SM., Dhanasri, G and Prathibha, D (2015). "Genetic Diversity of Jatropha curcas L. accessions and screening for high Biodiesel production" International Journal of Pure Applied Bioscience 3(1):124-135.*

xv. *Phurpa, D., Kuenzang, T., Yeozer, D., Norbu, Y., Namgay, D and Jambay, J (2015). "Production of Biodiesel from Jatropha curcas L. plants found in Mongar and Tashigang districts, Bhutan. Bhutan Journal of Research and Development. 4:47-53.*

xvi. *Rao, G. R., Korwar, G. R., Shanker, A. K., and Ramakrishna, Y. S. (2008).Genetic associations, variability and diversity in seed characters, growth, reproductive phenology and yield in Jatropha curcas (L.) accessions.Trees-Structure and Function, 22, 697-709*

xvii. *Reis, M. C., Cardoso, D. B. O., Silva Junior, E. G. and Gomes, B. C. (2017).Correlation among traits as criterion of cotton genotypes indirect selection. Genetics and Molecular Research, 16(3), 3-12.*

xviii. *Saadaoui, E., Martín, J.J., Bouazizi, R., Romdhane, C.B., Grira, M., Abdelkabir, S., Khouja, M.L and Cervantes, E (2015). "Phenotypic variability and seed yield of Jatropha curcasl. introduced to Tunisia". ActaBotanica Mexicana 110:119-134.*

xix. *Sawin, J. L. and Sverrisson, F. (2004). Renewables: Global Status Report REN21 Secretariat: Paris, 2004*

xx. *Sarin, R., Sharma, M., Sinharay, S and Malhotra, R.K (2007). "Jatropha-Palm biodiesel blends: An optimum mix for Asia". Fuel 86: 1365-1371.*

xxi. *Steel, R, G., and Torrie, J. H. (1980). Principles and Procedures of Statistics McGraw-Hill Book Co. inc., New York, 481.*

xxii. Sulaiman, Y., Saidat, O. G., Mariam, I., and Abdulwahab, G. (2016). Extraction of Oil from Jatropha Seed Kernels: Optimization and Characterization. International Journal of ChemTech Research, 9(5), 758-770.

xxiii. Warra, A. A. (2012). Cosmetic potentials of physic nut (Jatropha curcas Linn.) seed oil: A review. American Journal of Scientific and Industrial Reseach, 3(6), 358-366.

xxiv. Wani, T.A., Kitchlu, S and Ram, G (2012). "Genetic variability studies for morphological and qualitative attributes among Jatropha curcas L. accessions grown under subtropical conditions of North India". South African Journal of Botany 79:102-10.