Journal of Agricultural Science; Vol. 12, No. 3; 2020
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Impact of Seed Size on the Seedling Vigour, Dry Matter Yield and Oil Content of Jatropha (*Jatropha curcas* L.)

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Received: December 7, 2019 Accepted: January 13, 2020 Online Published: February 15, 2020

doi:10.5539/jas.v12n3p197 URL: https://doi.org/10.5539/jas.v12n3p197

Abstract

Seed size is a trait of the plant that affects seed germination and seedling survival. This study aims to assess the growth response of *J. curcas* to different seed sizes. A pot experiment was conducted to evaluate the effects of *J. curcas* seed sizes on the seedling vigour and seed component. The seeds were fractioned into three sizes visually into: large, medium and small and by 1000 seeds weight (SW). Seedling vigour was assessed by: germination % (G%), seedling length cm (SL), seedling vigour index, SVI, seedling growth rate, SGR, and speed of germination, SOG as well as proportion of cake, shell and oil content (OC) expressed as% of the seed. Results obtained shows that G% and the SOG were not affected by seed sizes but by other factors within the seed. However, seedling vigour expressed as SL, SVI and SGR increased significantly ($P \leq 0.05$) with increase in seed sizes. Proportion of cake, shell and oil component of *J. curcas* seeds increased with increasing seed sizes while 60% of the seed is made up of the cake from where the oil is extracted. Dry matter yield, DMY significantly ($P \leq 0.05$) increased with increase in seed size from 6.41 g/plant in large seeds to 2.61 g/plant in small seeds. There is positive and strong significant correlation between, SW and DMY ($r = 0.91^{**}$), yield increase ($r = 0.82^{**}$), OC ($r = 0.85^{**}$), % cake ($r = 0.94^{**}$). Findings revealed that larger seed had higher potential of producing vigorous plants with eventual high crop yield and higher OC.

Keywords: seed size, seedling vigour, Jatropha, yield, oil content

1. Introduction

Jatropha curcas L. is a perennial shrub or tree belonging to the family Euphorbiaceae which in the last decades has received considerable attention from researchers and several stakeholders due to, among many uses, its potential as a feedstock, for renewable biofuel production and the ability to grow in marginal lands with less water and nutrients (Namasivayam et al., 2007; Wang et al., 2011). Nowadays, *J. curcas* grows in tropical and sub-tropical regions in a wide range of climatic conditions from semi-arid to humid (Achten et al., 2010).

J. curcas seeds contain about 25-35% of oil, which can be easily extracted and used both for biodiesel production, a renewable energy source alternative to conventional petrol diesel, and as cooking/lighting fuel, medicine, bio-pesticide, and for soap making. Additionally, the seed cake, an oil extraction by-product, can be used as organic fertilizer, combustible fuel, for biogas production (IFAD-FAO, 2010) and also feedstuff after detoxification (Wang et al., 2011). Besides the economic value attainable from *J. curcas* oil and its derivatives, its potential to adapt to low-nutrient soils and drier soils under arid and semi-arid conditions, minimize *J. curcas* competition against food crops. Furthermore, the plant offers an ecological advantage to mitigate soil degradation and to restore marginal land or abandoned farmlands (Reubens et al., 2011). Despite these potentials, *J. curcas* is still a semi-wild or wild undomesticated plant and has not received enough research attention to be able to understand its basic agronomic needs to improve its growing and management practices in many ecological areas.

Germination of seed indicates its power to reproduce a new plant. It is conditioned by a regular embryo development and the amount of available food reserves. These two components are necessary pre-requisites for the development of a normal embryo, a vigorous seedling and a well-developed plant (Adebisi et al., 2013). Therefore, the use of high-quality seeds is essential for a successful crop production and food security. Crop yield and resource use efficiency depend on the successful plant establishment in the field, and seed vigor is what defines the ability to germinate and establish seedlings rapidly, uniformly and robustly, across diverse environmental conditions (Finch-Savage & Bassel, 2016). Seed size is an important physical indicator of seed quality that affects the emergence, plant growth and performance of the crop in the field (Adebisi et al., 2013). Indeed, the sowing of mixed seeds of a species may result in a non-uniform stand establishment, what may lead to heterogeneity in the plant vigor and size (Mishra et al., 2010). Distinct seed sizes have different levels of starch and other energy reserves which may be an important factor to improve the expression of germination and initial growth of seedlings (Shahi et al., 2015). Germination depends on the ability of the seed to use reserves more efficiently (Bewley et al., 2013), by mobilization of seed reserves for the germination traits (Sikder et al., 2009). However, these results vary widely between the crop species and the germination and growth environment. In general, large seeds have a higher seedling survival rate, higher growth and better field performance than small seeds, under non-stressful environments (Ambika et al., 2014).

To achieve success in crop production, the use of good quality seed is very essential which increase the yield by 15-20%. The extent of this increase is directly proportional to the quality of seed that is being sown. The seeds of a seed lot may differ by size, weight and density due to production environment and cultivation practices. Seed size is one of the components of seed quality which affects the performance of crop (Adebisi et al., 2011). Size is a widely accepted measure of seed quality and large seeds have high seeding survival growth and establishment (Jerlin & Vadivelu, 2004). A wide array of different effects of seed size has been reported for seed germination, emergence and related agronomical aspects in many crop species (Kaydan & Yagmur, 2008). However, these results varied widely between species. Generally, large seed has better field performance than small seed.

Bhatt et al. (1989) assessment of the effect of seed size on the nutrient composition and germination of potato seed showed that large seeds contained higher levels (% dry weight) of total proteins, ethanol soluble proteins and alkali soluble proteins than small seeds and they germinated faster and had the highest percentage of germination. Small seeds had the lowest levels of total lipids, phospholipids and water soluble proteins, the longest water saturation time and the lowest germination. In other words, seed size effects on canola emergence, yield or seed quality were not significant (Harker et al., 2015). Meanwhile, increasing seed size had a positive linear association with early canola biomass and 1000-seed weights, whereas, both days to flowering and days to the end of flowering had a negative linear association with seed size. Greater biomass from large seeds increases crop competition with weeds and also hastens flowering. Similarly, Adejare (2010) reported that large seed size of elite maize had higher seed quality and higher seed yield compared to other medium and small sizes.

If seed size influences seed quality and yield, it would be advantageous to sow seeds that give the best seed quality and highest yield. With the dwindling oil prices in the world and its corresponding effects on Nigeria income and economy, the development of research in a non-food crop like *J. curcas* may just be a way out of diversifying Nigeria economy as the cry for green, renewable energy continues because of its minimal contribution to global warming. Since the oil is contained in the seed of *J. curcas*, a better understanding of the seed in relation to oil production among other variables will provide agronomic information to the policy makers, growers and other stakeholders in alternative energy development, enhancing eco-friendly agricultural sustainability. Therefore, the objective of the study is to evaluate the growth response of *J. curcas* to different seeds sizes in a rainforest environment.

2. Materials and Methods

A pot experiment was conducted at the Seed laboratory of the department of Agriculture and Industrial Technology of Babcock University, Ogun State, Nigeria between January and March, 2019 to evaluate the effects of *J. curcas* seed sizes on the seedling vigour and the composition of the seeds.

2.1 Seed and Seed Source

Jatropha seeds used for the experiment were obtained from an already established farm in Oyo town, Nigeria. The seeds were harvested at the same physiological stage of maturity, that is, at yellowish-brown stage. This particular variety is commonly called “Linneaus” which begins to fruit from nine months after planting and can continue for between 20-25 years under good management.

2.2 Seed Size Allotment

The seeds were separated into three sizes visually and this was corroborated with weighing of 1000 seeds per size, using electronic balance (Model XY 1000C, Axion Medical Ltd, U.K) as well as width measurement of the samples using digital micrometer screw gauge. The mean seed weight varies from 717.9 g in large seeds to 652.9 g in medium seed and 505.1 g in small seeds. Similarly, average seed width of large seeds is 6.63 mm, medium seeds is 5.87 mm and 5.04 mm in small seeds. Seed moisture content, MC varies from 3.52% in large seeds to 2.92% in small seeds.

2.3 Potting of the Seeds

Ten kg of sieved top soil was filled into 18 bottom-perforated plastic pots. The soil was saturated with water after which 20 seeds were planted in each pot at 3 cm depth. Subsequent watering was done at three days' interval using 120 ml per pot. Maximum relative humidity of the environment ranges from maximum of 85% to minimum of 67% while maximum temperature is 37 ^{o}C and minimum temperature is 25.5 ^{o}C.

2.4 Experimental Design

The experiment was a completely randomized design comprising of *J. curcas* seeds separated into three seed sizes and replicated six times.

2.5 Seed Viability and Seedling Vigour Assessment

Germination count began 4 days after planting after which germination count was done daily till 8 days after planting when germination peaked. The following parameters were taken to assess seedling vigour: germination % (G%), seedling length cm (SL), seedling vigour index, SVI, seedling growth rate, SGR, and speed of germination, SOG.

2.5.1 Germination %

Germination % was calculated based on the normal seedling evaluated on the 8th day and it was expressed in % (ISTA, 1999). Percent seed germination was then expressed as number of seed germinated over total no of seed planted (expressed in percentage).

2.5.2 Seedling Length

This was obtained with the aid of a ruler; by measuring the length (in cm) of the seedling from the base of the plant above the substrate to the apex of the last leaf on the 8th day.

2.5.3 Seedling Vigour Index

Seedling vigour index (SVI) was computed using the following formula suggested by Abdul-Baki and Anderson (1973), *i.e.*, SVI = Germination (%) × Seedling length (cm).

2.5.4 Speed of Germination

SOG was determined by dividing the number of first seedling emergence with day at emergence till the final count which are added together to give SOG according to AOSA (1983). *i.e.*, No of seeds at 1st count/day of 1st count + … No of seeds at final count/day of final count.

2.5.5 Seedling Growth Rate

SGR is the change in plant weight divided by the period of such change (www.wikihow.com) developed by Timothy Paine (2012).

2.6 Seed Component Determination

Proportion of cake and shell in the seed were also determined by their expression as a percentage of seed components while oil content of the seeds was determined in the laboratory using a Soxhlet extractor. Oil Content (OC) expressed in %: The oil content was determined gravimetrically after extraction using petroleum ether (n-hexane), in a Soxhlet instrument, technique 920.85 (AOAC, 1990), expressed in dry matter %. Air oven method recommended by ISTA (1985) was used to determine the moisture content, where the crushed seeds were oven-dried at 105 ^{o}C for 6 hours. Weight of a Thousand Seeds (WTS), expressed in grams/1000.

2.7 Dry Matter Yield

Dry matter yield was also determined by oven-drying the plant samples at 65 ^{o}C till constant weight was obtained and was expressed as g/plant.

2.8 Statistical Analysis

The data collected from the experiment were analyzed using SAS (Statistical Analysis Software) version 9.1 (SAS, 1999). Analysis of variance (ANOVA) was carried out on each variable and the Duncan Multiple Range Test (DMRT) was used for means separation ($P \leq 0.05$). Correlation analysis was also carried out on the parameters evaluated to ascertain the kind(s) of relationships that exist among the variables.

3. Results and Discussion

Growth response of *J. curcas* to different seed sizes was shown in Table 1. It was observed that the number of seedling emergence and the rate of such emergence from a seed lot was not determined by the size of the seeds but by other factors within and outside the seed. A glimpse of those factors were observed by (Shahi et al., 2015) where seeds of different sizes were found to have different levels of starch and other energy reserves which may be an important factor to facilitate germination and initial growth of seedlings. Hence, growers will have to look beyond seed size in selecting their seeds but also the genetic quality of such seeds. Also, ability of the seed to use reserves more efficiently (Bewley et al., 2013) could be a reason as well as heterogeneity in the plant vigor and size (Mishra et al., 2010). Expectedly, seedling vigour expressed as seedling length, seedling vigour index and seedling growth rate increased significantly ($P \leq 0.05$) with increase in seed sizes. Hence, seed size was found to be an important physical indicator of seed quality that affects the emergence, plant growth and performance of the crop in the field (Adebisi et al., 2013). This is because large seeds will be able to mobilize more seed reserves for the germination traits (Sikder et al., 2009).

Table 1. Effect of Seed size on the indices of Seedling vigour of *J. curcas*

Treatment (Seed size)	Germination % (G%)	Seedling length (cm)	Seedling Vigour Index (SVI)	Seedling Growth Rate (SGR)	Speed of Germination (SOG)
Large	39.17	25.00a	976.08a	1.59a	4.41
Medium	34.17	22.57b	790.67ab	0.80b	3.93
Small	27.50	22.43b	616.83b	0.59b	3.18
	Ns				Ns

Note. Means with same letter(s) in a column are not significantly different at 5% level of probability according to DMRT.

Effect of seed sizes on the dry matter yield of *J. curcas* and the attributes of seed was shown in Table 2. Results showed that cake, shell and oil component of *J. curcas* seeds increased with increasing seed sizes. A proportion (60%) of the seed is made up of cake from where the oil is extracted while the remaining 40% is the shell which can be compounded as manure and as input in biogas production (IFAD-FAO, 2010). Similarly, Bhatt et al. (1989) assessment of the effect of seed size on the nutrient composition and germination of potato seed showed that large seeds contained higher levels (% dry weight) of total proteins, ethanol soluble proteins and alkali soluble proteins than small seeds. Smaller seeds of harvested Canola offered lower seed attributes of lowest levels of total lipids, phospholipids and water soluble proteins (Harker et al., 2015). Growers can therefore focus on raising and selecting bigger seeds to ensure higher yield. Meanwhile, dry matter yield is yield component in plants showing their ability to produce and mobilize assimilates for the proper growth of the plant. Therefore, with increased dry matter yield, the plant will be able to grow vigorously, utilize resources for growth better and resist the pest interference better and thus enhance its productivity. With the observed increase in dry matter yield with increasing seed sizes, bigger seed will tend to produce better than plant raised from smaller seeds (Adejare, 2010; Harker et al., 2015).

Table 2. Effect of seed size on the seed components of *J. curcas* and dry matter yield (g/plant)

Treatment (Seed size)	% Cake	% Shell	% Oil content	Dry Matter Yield (DMY) (g/plant)
Large	60.42a	44.90a	59.93a	6.41a
Medium	58.97b	41.03b	57.87b	3.73b
Small	55.10c	39.58c	54.13c	2.61c

Means with same letter (s) in a column are not significantly different at 5% level of probability according to DMRT.

As shown in Table 3, positive and highly significant correlation was found between seed weight, SW and dry matter yield, DMY ($r = 0.91^{**}$), yield increase, YI ($r = 0.82^{**}$), oil content ($r = 0.85^{**}$), % cake ($r = 0.94^{**}$). These results shows that larger seed had higher potential of producing vigorous plants as described by (Zareian et al., 2013) where it is obvious that increase in biological yield by increasing seed size was related to higher seedling weight and weight of 100 plants were produced by larger seed sizes in wheat., increasing seed size had a positive linear association with early canola biomass and 1000-seed weights, (Harker et al., 2015). In the same vein, positive association exists between seed size and oil content in soybean (Marega et al., 2001). However, there is positive and weak correlation between the seed weight and seedling length, SL (r = 0.51*) and seedling vigour index, SVI (r = 0.51*) showing that the rate of plant growth can be inferred from the plant seed weight. The was no correlation between the seed weight and germination percent as well as speed of germination which showed that other factors within the seed like availability of nutrient reserves, maturity of the seeds among other factors would affect rate of seedling growth other than the size of the seeds (Shahi et al., 2015). This is contrary to the general belief that, heavier seeds have a higher seedling survival rate, higher growth and better field performance than small seeds, under non-stressful environments (Ambika et al., 2014).

Table 3. Correlations among the eleven seed related variables in *J. curcas* (n = 18)

	SW	G%	SL	SVI	DMY	YI	SGR	SOG	% Oil	% Cake	% Shell
SW	1	.458	.499*	.514*	.909**	.862**	.858**	.369	.847**	.938**	-.938**
G%	.	1	.392	.983**	.361	.349	.347	.869**	.426	.459	-.459
SL	.	.	1	.552*	.580*	.577*	.578*	.416	.463	.411	-.411
SVI	.		.	1	.440	.428	.426	.872**	.472*	.491*	-.491*
DMY		.		.	1	.988**	.988**	.322	.789**	.819**	-.819**
YI	.		.	.	.	1	1.000**	.312	.726**	.767**	-.767**
SGR	.		.	.			1	.310	.721**	.761**	-.761**
SOG		.		.	.	.	.	1	.398	.409	-.409
% Oil	.		.					.	1	.879**	-.879**
% Cake		.			.				.	1	-1.000**
% Shell											1

Note. * Correlation is significant at the 0.05 level (2-tailed). SW = Seed Weight.

** Correlation is significant at the 0.01 level (2-tailed). YI = Yield Increase.

4. Conclusions

Seed size of *J. curcas* did not affect seedling emergence and rate of germination but significantly affect all the other seedling vigour indices, indicating early establishment and growth of crops raised from bigger seeds. Similarly, with increasing dry matter yield with increase in seed sizes, more vigorous growth against field interference and better utilization of resources is expected in larger seeds. Therefore, to ensure better survival of *J. curcas* on marginal land, bigger seeds should be selected to improve on its survival rate on the field. Since, seed size is directly proportional to oil content in *J. curcas,* therefore, in large scale oil production; bigger seeds should be used for better productivity and higher income while smaller seeds may be used for other industrial or domestic uses.

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