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EFFECTS OF FERTILIZER APPLICATION ON GROWTH CAPACITY OF CASTOR (RICINUS COMMUNIS) SHRUB

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Abstract

Previous attempt to seek substitute locally available raw materials for sunflower oil, an imported raw material for surface coating manufacture has remained a challenge. The aim of this study is to evaluate the effect of organic fertilizer on the growth capacity of castor shrub since its oil has been found to be a close substitute to sunflower oil. This effort will drive backward integration in order to ensure sustained supply chain as required by local content policy of the Federal Government of Nigeria that will lead to developing local initiative for innovative technology. Data was obtained by measuring the progressive lateral growth parameters of the castor seed plant namely; plant height, stem diameter, leaf width, leaf length, petiole length and petiole diameter until maturity. A standard statistical package Minitab version 16.0 program was used to generate various plots which graphically depict and summarize the data while descriptive statistics of the data was solved using SPSS version 16.0 Software. The result showed that fertilizer type employed affects growth and development rate differently. In particular, poultry manure was found to be the most potent. The results also showed that the seed, upon sowing, sprouts in 7 days, and grows to maturity in about 146 days. It also suggest a growth capacity of 81.53 cm/kg which imports that in every 1 kg of soil considered, there is likely going to be available 1.51g of nitrogen. It is believed that this threshold amount of nitrogen would provide seemly quantity of nutrient that would sustain the growth.

Keywords: Growth capacity, castor seed, logistic model, drying oils, ogive

1. Introduction

Some concern had been expressed by pundits over the limited availability of castor seed oil, a seed oil discovered to be a close substitute to sunflower oil that is currently being used for wood surface coating. In recent years, castor oil is largely used in the specialty chemical industry worldwide, and the growth of its consumption is limited by insufficient and unreliable feedstock supply rather than by the industry demand [1]. With the shift of emphasis to seek alternative natural resources, the need therefore to ensure steady cultivation of castor shrub and subsequent sustainable production of its oil to meet the ever growing demand of the product for industrial uses has become imperative. If for instance nations in Sub Sahara Africa are to improve their economy through manufacturing of surface coatings, polymers, lubricants for aircrafts, cosmetics, food seasoning, perfumery products, ointments, waxes, pharmaceuticals, printing inks, hair dressings, nylon, enamels, electrical insulations and disinfectants. This growing demand calls for refocus on backward integration in order to ensure sustained supply chain. Previous researchers had devoted huge attention to the effect of various fertilizer applications on plants. Mohapatra and Panda [2] analyzed the effects of fertilizer application on growth and yield of Jatropha curcas L. in an Aeric Tropaquept of Eastern India. Ludwig et al. [3] Studied the effects of fertilization and soil management on crop yields and carbon stabilization in soils while Jamil et al. [4] described the impact of sowing techniques and nitrogen fertilization on castor bean yield in salt affected soils. Stefano et al. [5] reported that inorganic fertilizer applications exerted a strong influence on growth, development and grain yield of maize. Amali and Namo [6] investigated the growth and yield responses of four varieties of maize to time of fertilizer application in Jos-Plateau Environment. The study revealed that the yield of maize could be enhanced by the early application of fertilizer at two weeks after planting. Salamatbakhsh et al. [7] studied the effects of foliar application of micronutrients on yield and yield components of castor bean varieties in West Azerbaijan climate. Kareem et al. [8] determined the optimum level of complete fertilizer needed for better production of cowpea, the application of nitrogen, potassium and nitrogen (NPK) in ratio 16:16:16 fertilizer on the growth and yield of the crop was also investigated. The result showed that NPK fertilizer at the rate of 200 kg/ha improved pod production, weight of 100 seeds, pod weight and final grain yield per hectare. Razaq et al [9] investigated the effects of fertilization on the growth and root morphology of Acer mono four-year-old seedlings in the field. The results indicated that both N and P application significantly affect plant height, root collar diameter, chlorophyll content, and root morphology. Dong et al. [10] said that appropriate fertilizer application is an important management practice to improve soil fertility and quality in the red soil. The authors examined the effects of five fertilization treatments [these were: no fertilizer (CK), rice straw return (SR), chemical fertilizer (NPK), organic manure (OM) and green manure (GM)] on soil pH, soil organic carbon (SOC), total nitrogen (TN), C/N ratio and available nutrients (AN, AP and AK) contents in the plowed layer (0–20 cm) of paddy soil from 1998 to 2009 in Jiangxi Province, southern China. Results showed that the soil pH was the lowest with an average of 5.33 units in CK and was significantly higher in NPK (5.89 units) and OM (5.63 units) treatments (P, 0.05). It has been considered by previous researches that the concentrations of soil nutrients (e.g., organic C, N, P, and K) are good indicators of soil quality and productivity because of their favorable effects on the physical, chemical, and biological properties of soil [11]. Han et al [12] investigated the effects of organic manure and chemical fertilizer treatments on growth perfo g/m2; fused superphosphate, 70 g/m2; potassium chloride, 15 g/m2), and organic manure plus NPK chemical fertilizer. Adegbidi et al. [13] reported that fertilization costs accounted for 20-30% of the total production costs in biomass production. However, the effects of the mixed use of chemical fertilizer and organic manure on the growth of trees and soil fertility vary substantially according to the fertilizer amounts and the organic manure characteristics. Awodun [14] investigated the effect of poultry manure treatments and NPK fertilizer on growth, leaf nutrient content and yield components of Telfaria (Telfaria occidentalis Hook F) grown on Akure soil in the rainforest zone of Nigeria. The treatments

applied were 0, 2, 4 6 t ha-1 poultry manure and 250 kg ha-1 NPK 15-15-15 fertilizer. Growth and yield parameters such as number of leaves and branches, stem girth, length of internodes were increased by poultry manure treatments. Poultry manure contains high percentage of nitrogen and phosphorus for the healthy growth of plants [15]. Liu et al [16] studied the effect of organic manure and chemical fertilizer on growth and development of Stevia rebaudiana Bertoni in experimental plots in Qingdao Agricultural University. The results showed that organic manure cultivation promoted root activity in 40 days after transplanting compared with the chemical fertilizer cultivation, and the dry weight of the above-ground has exceeded chemical fertilizer cultivation in 60 days after transplanting. Adekiya and Agbede [17] carried out field experiment to obtain maximum economic value of plant nutrients in poultry manure and increase in tomato yield, at Owo, southwest Nigeria, during 2012 and 2013 early cropping seasons to study the effect of two methods (broadcasting on the soil surface and the incorporated) and four times (3 weeks before transplanting (3 WBTP), 0 week at transplanting (0 WATP), 3 weeks after transplanting (3 WATP), and 6 weeks after transplanting (6 WATP) of poultry manure (PM) applications on soil chemical properties, leaf nutrient concentrations, growth and yield of tomato.
Organic material such as poultry manure is identified as a suitable organic fertilizer. Poultry manure, if properly handled is the most valuable of all animal manures. The use of poultry manure for soil fertility maintenance, growth and yield of tomato had been reported [18, 19, 20].
Oyedeji et al. [21] compared the growth, yield, and proximate composition of Amaranthus hybridus, Amaranthus cruentus, and Amaranthus deflexus, grown with poultry manure and NPK in relation to the unfertilized soil of Ilorin, Nigeria. Viable seeds of the Amaranths raised in nursery for two weeks were transplanted (one plant per pot) into unfertilized soil (control) and soils fertilized with either NPK or poultry manure (PM) at 30 Kg ha−1 rate arranged in randomized complete block design with four replicates. The result shows that NPK grown Amaranthus species had the highest protein while PM-grown vegetables had the highest ash content. Crude fibre in Amaranthus cruentus grown with PM was significantly higher than NPK and the control. The NPK treatment of Amaranthus hybridus and Amaranthus deflexus had the highest crude fibre content. NPK and PM favoured growth and yield of the Amaranthus species but influenced proximate composition differently.

Poultry manure, sometimes called chicken manure, is an excellent soil amendment that provides nutrients for growing crops and also improves soil quality when applied wisely, because it has high organic matter content combined with available nutrients for plant growth [22]. The chemical composition of poultry manure varies with factors such as source of manure, feed of the birds, age and condition of the birds, storage, handling of manure, and litter used [23]. Poultry waste consists of droppings, wasted feed, broken eggs, feathers, and sometimes sawdust from poultry floor. It also includes the dead birds and hatchery waste, all of which are high in protein and contain substantial amount of calcium and phosphorus due to high level of mineral supplement in their diet. Poultry manure has been reported to contain more plant nutrients than all other organic manures [24].

It is evident from the foregoing sample review, that there appears to be dearth of research work on furnishing information concerning the effect of organic fertilizer on the growth capacity of castor seed plant. The aim of this study is to assess the effect of organic fertilizer on the growth capacity of castor plant that will drive backward integration in order to ensure sustained supply chain as required by local content policy of the Federal Government of Nigeria that will lead to developing local initiative for innovative technology.

2. Materials and method

2.1 Materials

The castor oil bean seeds (Ricinus Communis) big seeded varieties and small seeded varieties used in this study was purchased from a commercial source in Ikokogbe, Omhen in Ewossa Community, Igueben Local Government Area of Edo State, Nigeria. The types of fertilizers were obtained from different sources. NPK 15:15:15 was purchased from a commercial source in Benin City, Edo State, Nigeria while Cow dung and Poultry manure were supplied from UNIBEN farm project, University of Benin, Benin City, Edo State, Nigeria.

2.2 Method

The experiments were carried out with about ninety six (96) castor seed planted at soil science Departmental project farm, Faculty of Agriculture, University of Benin, Nigeria. The seeds were sown in plots having a size of 3x4 m, 1 m between plants and 1 m between rows. Four treatments considered include: Cow Dung, Control (Plain), Poultry Manure, and NPK 15:15:15. The project farm has altogether 8 plots, 2 plots for Control (Plain), 2 plots for Cow Dung, 2 plots for Poultry Manure and 2 plots for NPK 15:15:15 in two (2) replications. Data was obtained by measuring the daily growth parameters of the castor shrub such as: plant height, stem diameter, leaf width, leaf length, petiole length and the petiole diameter for both the big seeded varieties and the small seeded varieties. The data span from the day the shrub sprouted up until the seed matured. The observed data were recorded in Table 1 and analyzed statistically using logistic growth model. A standard statistical package Minitab version 16.0 program was also used to analyze the data that generate various plots which graphically depict and summarize the data while the descriptive statistics of the data was carried out using SPSS version 16.0 software.

3. Model development

According to Pommerening and Muszta [25], the relative rate of growth of castor seed plant, which is a constant, is given by

$$r = \frac{S'(t)}{S(t)}$$

where, $S'(t) = rS(t)$

A population with no restrictions on environment or resources can often be model as having exponential growth. However, when such restrictions exist, it is reasonable to assume there is a largest population k supportable by the environment (called the carrying capacity) and that at any time t, the relative rate of population growth is proportional to the potential population

K - S(t); that is

$$\frac{S'(t)}{S(t)} = r(k - S(t))$$

where, r is as positive constant. This relationship leads to the differential equation

$$\frac{\delta S}{\delta t} = rS(k - S) \tag{1}$$

This is called the logistic equation and the corresponding model of restricted population growth is known as the logistic model.

The logistic equation can also be written as

$$\frac{\delta S}{\delta t} = R(S)$$

where the population rate $R(S) = rS(k - S)$ is a quadratic function in Q, since r > 0.

where S = Size,
r = Malthusian Parameter (Rate of Maximum Population Growth)

k = Carrying Capacity (i.e the Maximum Sustainable Population)

divide both sides of equation 1 by k and defining

$$x = \frac{S}{k} \tag{2}$$

then give the differential equation

$$\frac{\delta S}{\delta t} = rx(1 - x) \tag{3}$$

where, r > 0 is the constant of proportionality. This then follows that equation (3) is a separable differential equation whose solution is

$$\int \frac{\delta x}{x(1-x)} = \int r\,\delta t$$

$$\frac{1}{1}\ln\left|\frac{x}{1-x}\right| = rt + c$$

Integrate $\ln\left|\frac{x}{1-x}\right|$ using $\int \frac{\delta u}{u(a+bu)} = \ln\left|\frac{u}{a+bu}\right| + c$

With $u = x$, a $= 1$ and b = -1

Since x > 0 and 1 > x, we can remove the absolute value bars from the solution and write

$$\ln\left(\frac{x}{1-x}\right) = rt + c$$

$$\ln\left(\frac{x}{1-x}\right) = 1rt + 1c$$

$$\frac{x}{1-x} = \ell^{rt+c} = \ell^{rt}\ell^{c} = x_0\ell^{rt} \quad \text{where } \mathrm{x}_0 = \ell^{c}$$

Multiplying both sides of the last equation by $(1-x)$ and solving for x, we get

$$x = (1-x)x_0\ell^{rt} = (x_0 - xx_0)\ell^{rt}$$

$$x\ell^{-rt} = x_0 - xx_0$$

Multiply both sides by ℓ^{-rt}

$$x\left(x_0 + \ell^{-rt}\right) = x_0 \text{ add } xx_0 \text{ to both sides}$$

$$x = \frac{1x_0}{x_0 + \ell^{-rt}} \text{ divide all terms on the right by } x_0$$

$$x = \frac{1}{1 + \frac{1}{x_0}\ell^{-rt}}$$

Finally, we see that x has the logistic form

$$x(t) = \frac{1}{1 + \left(\frac{1}{x_0} - 1\right)\ell^{-rt}} \tag{4}$$

where, x is the Growth Capacity.

Growth Capacity x (t) is defined as the amount of nutrient in the soil that can supports the size of the castor seed plant overtime.

4. Results and discussion

The data obtained during the experimental runs by measuring the daily growth parameters of the castor shrub were arranged in tabular form shown in Table 1. These data covered a period of 146 days from the date of sprouting of the shrub up till when the seed matured. Table 1 showed the abridged daily growth data of the Castor shrub.

Table 1. Castor Seed Plant Daily Growth Measurement

Days / Parameters	8	9	10	11	12	13	14	15	-	-	-	144	145	146
Plant Height (cm)	2.15	2.25	2.75	3.00	3.20	3.40	3.60	3.90	-	-	-	160.50	160.35	160.55
Stem Diameter (cm)	0.30	0.30	0.40	0.45	0.60	0.65	0.80	0.85	-	-	-	11.40	11.45	11.50
Leaf Width (cm)	1.55	1.70	1.80	1.90	2.25	2.40	2.85	3.00	-	-	-	23.75	23.85	23.95
Leaf Length (cm)	2.45	2.80	3.00	3.35	4.10	4.30	4.45	5.15	-	-	-	49.15	49.25	49.35
Petiole Length (cm)	0.45	0.65	0.80	0.90	1.00	1.10	1.20	1.30	-	-	-	54.70	54.85	55.00
Petiole Diameter (cm)	0.25	0.35	0.45	0.55	0.70	0.80	0.90	0.95	-	-	-	8.05	8.05	8.15

Note: The Castor Seed Sprouted after 7 days

Figure 1 depicts the Ogive of castor seed growth rate. The graph was developed using the plant height data of row 1 of Table 1. The Ogives for stem diameter, leaf width, leaf length, petiole length and petiole diameter show similar pattern and hence were omitted.

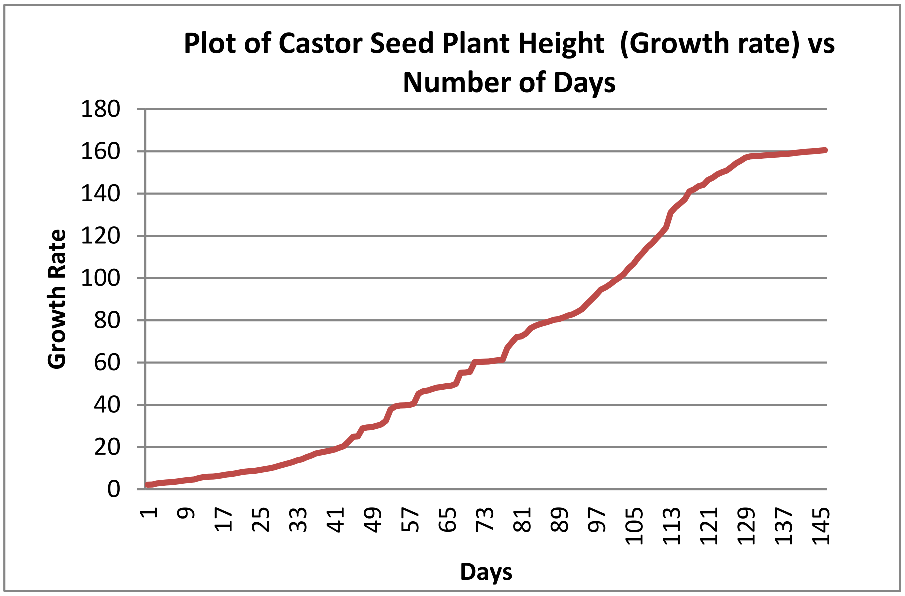

Figure 1. The Ogive of Castor Seed Growth Rate

4.1 Results of descriptive statistics (Box and Whisker's)

Figure 2 represents the Box and Whisker's plot for big seed plant height of the castor plant

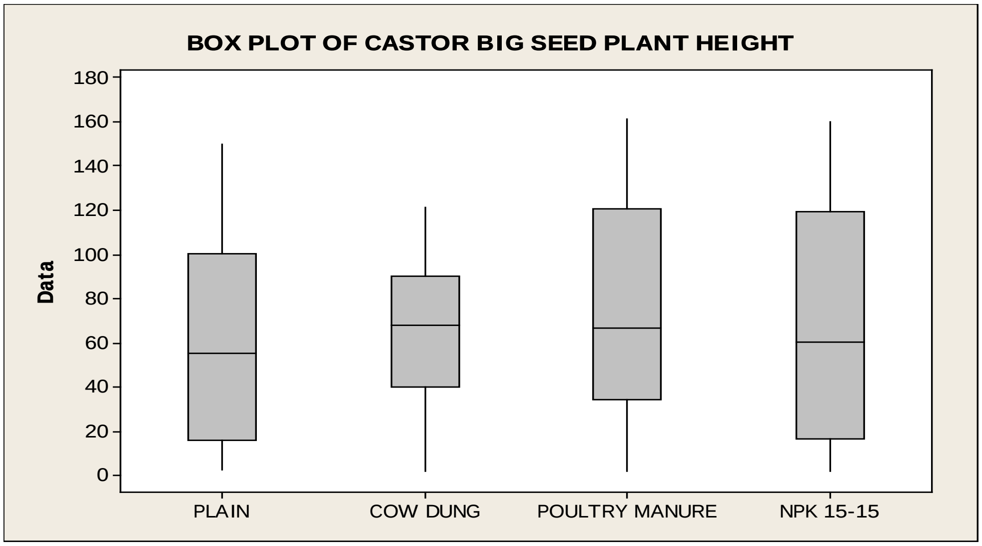

Figure 2. Box Plot of Castor Big Seed Plant Height

Table 2 shows the descriptive statistics of the Box and Whisker's plot for big seed plant height of the castor plant.

Table 2. Box Plot Analysis of Castor Seed Plant Height

	Q_1	Median	Q_3	IQ Range	Whiskers to	N
Plain	16.2625	55.275	100.325	84.0625	2.75, 149.9	146
Cow dung	40.225	40.225	90.1875	49.9625	2.2, 121.6	146
Poultry Manure	34.2125	66.6	121	86.7875	2.25, 161.65	146
NPK 15-15-15	16.6625	60.475	119.525	102.863	2.15, 160.55	146

The box plot for stem diameter, leaf width, leaf length, petiole length and petiole diameter are displayed in figures 3-7 while the descriptive statistics are displayed in Table 3 –7.

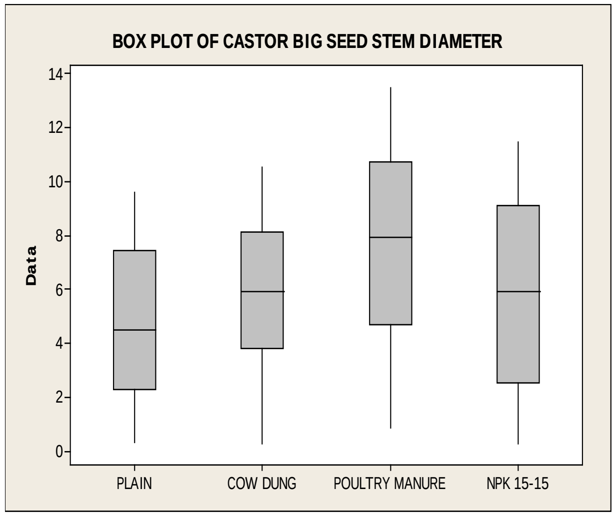

Figure 3. Box Plot of Castor Big Seed Stem Diameter

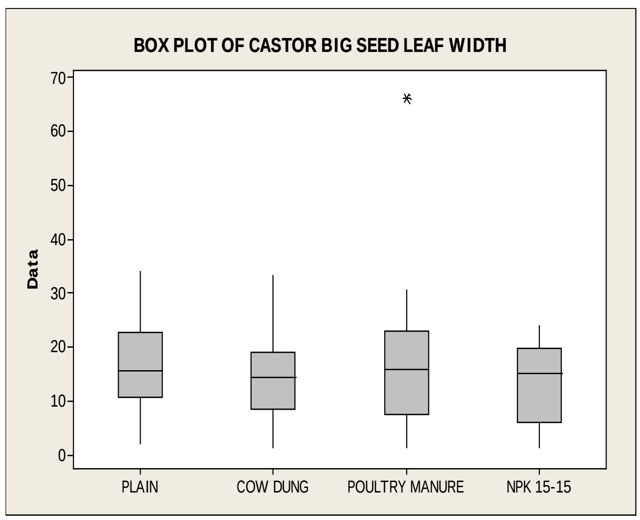

Figure 4. Box Plot of Castor Big Seed Leaf Width

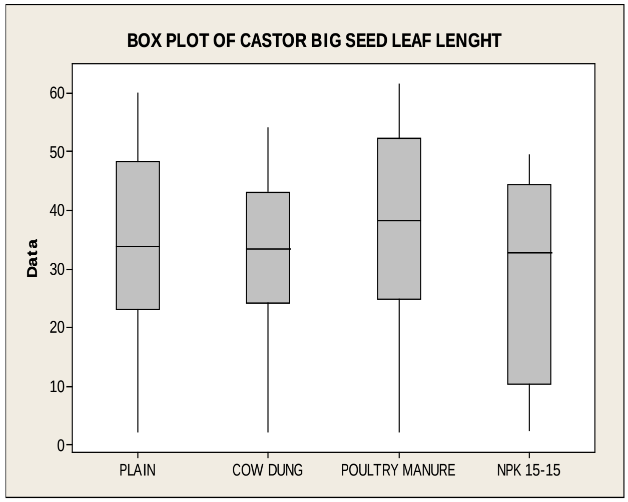

Figure 5. Box Plot of Castor Big Seed Leaf Length

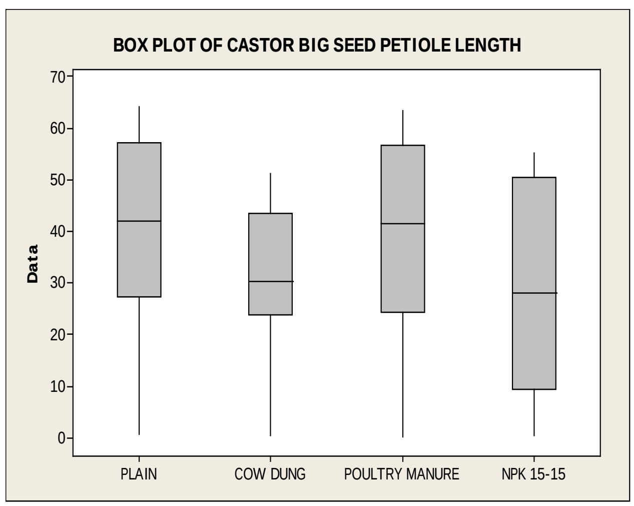

Figure 6. Box Plot of Castor Big Seed Petiole Length

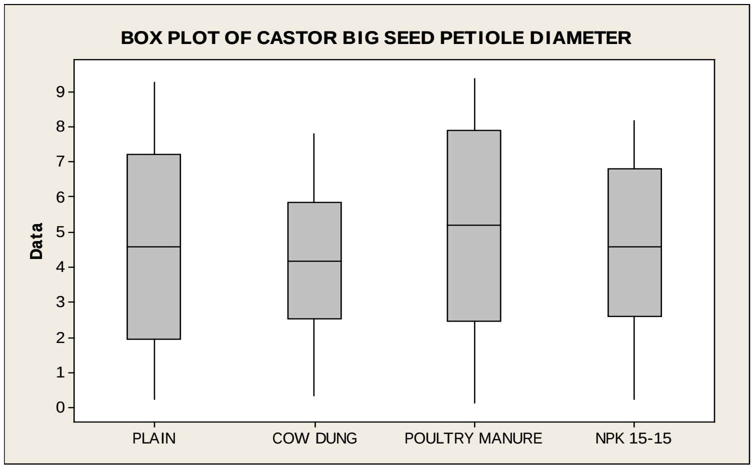

Figure 7. Box Plot of Castor Big Seed Petiole Diameter

A typical box plot was interpreted as follows. The horizontal bars across the vertical boxes depicted the means of the variables in question. The upper and lower lines stemming from the boxes, which was termed upper and lower whisker depict the variability outside the upper quartile and lower quartile represented by end horizontal lines on the boxes. The values associated with these figures were represented in the vertical scale as described in Table 2 to 7.

Table 3. Box Plot Analysis of Castor Seed Stem Diameter (Big Seed)

	Q_1	Median	Q_3	IQ Range	Whiskers to	N
Plain	2.325	4.525	7.475	5.15	0.35, 9.65	146
Cow dung	3.8375	5.925	8.175	4.3375	0.3, 10.55	146
Poultry Manure	4.7	7.975	10.775	6.075	0.9, 13.5	146
NPK 15-15-15	2.5375	5.95	9.1125	6.575	0.3, 11.5	146

Table 4. Box Plot Analysis of Castor Seed Leaf Width (Big Seed)

	Q_1	Median	Q_3	IQ Range	Whiskers to	N
Plain	10.675	15.65	22.8	12.125	2.05, 33.95	146
Cow dung	8.6625	14.325	19.1	10.4375	1.4, 33.25	146
Poultry Manure	7.5125	15.85	22.9375	15.425	1.4, 30.5	146
NPK 15-15-15	6.0375	15.275	19.875	13.8375	1.55, 23.95	146

Table 5. Box Plot Analysis of Castor Seed Leaf Length (Big Seed)

	Q_1	Median	Q_3	IQ Range	Whiskers to	N
Plain	23.2125	33.85	48.3875	25.175	2.4, 60.05	146
Cow dung	24.225	33.375	43.1875	18.9625	2.4, 54	146
Poultry Manure	24.975	38.325	52.2	27.225	2.35, 61.45	146
NPK 15-15-15	10.35	32.8	44.5	34.15	2.45, 49.35	146

Table 6. Box Plot Analysis of Castor Seed Petiole Length (Big Seed)

	Q_1	Median	Q_3	IQ Range	Whiskers to	N
Plain	27.4125	41.875	57.1875	29.775	0.6, 63.95	146
Cow dung	23.75	30.15	43.45	19.7	0.4, 51.15	146
Poultry Manure	24.4125	41.425	56.7125	32.3	0.3, 63.3	146
NPK 15-15-15	9.5	28.125	50.325	40.825	0.45, 55	146

Table 7. Box Plot Analysis of Castor Seed Petiole Diameter (Big Seed)

	Q_1	Median	Q_3	IQ Range	Whiskers to	N
Plain	1.95	4.575	7.2125	5.2625	0.25, 9.25	146
Cow dung	2.525	4.175	5.825	3.3	0.35, 7.8	146
Poultry Manure	2.45	5.2	7.875	5.425	0.15, 9.35	146
NPK 15-15-15	2.6	4.575	6.8	4.2	0.25, 8.15	146

4.2 Results of growth capacity

Considering a castor seed planted and sprouted after 7 days

The Growth Capacity simplified from equation 2 is given as $x = \frac{S}{k}$

where,

S = the size development coefficient i.e the height of the castor plant at maturity

k = the carrying capacity (nutrient) in the soil

From the field experiment carried out, S = 123.1cm, while $k = 1.51 g/kg$

Then, Growth Capacity

$$x = \frac{S}{k} = \frac{123.1}{1.51} = 81.53 cmg/kg .$$

This shows that in every 1kg of soil, we have 1.51g of Nitrogen and this level of Nutrient makes the plant to grow to 81.53 cm high.

Overall, the results of the study showed that the type of fertilizer affected growth and development rate of the castor shrub differently. The descriptive statistics suggested that poultry manure was the most potent. The efficacy ranking range was as follows: poultry manure, NPK 15:15:15, cow dung. This finding has been corroborated by other researchers for example, farm workers in the University where the research work was undertaken as well as Ugbaja [26] who reported castor seed yields (5.11 and 5.01 t ha^{-1}) to be the greatest with poultry or swine manure applied at the rate of 10 t ha^{-1}. The author experimented with four organic manures and NPK fertilizer, each at four rates, under field conditions for their comparative effects on the growth and yield of castor oil plant. Besides, the composition of fowl feed and the type of metabolic digestion in birds may account for this remarkable result. The study findings also suggest that growth capacity was 81.53 cm g/kg. This imports that in every 1 kg of soil examined or considered, there is likely going to be available 1.51 g of nitrogen for the castor plant to grow and develop well. It is believed that this threshold amount of nitrogen would provide seemly quantity of nutrient that would sustain growth to the capacity noted (81.53 cm). Interestingly too, the growth curves practically demonstrated that the maturity process follows a statistical graph called Ogive; see Figure 1. Taken together, it is evident that the Nigerian soils, particularly in the rain forest and sub-Sahara region (middle belt) are considered arable, and might not need irrigation. By extension, any region that shares the same climatic condition, especially in the tropics, can favour the growth and development of castor plant when the right treatments are applied.

5. Conclusion

Our experimental result showed that castor seed plant can grow well in Nigeria and flourishes under a variety of climatic conditions. The study has shown that castor seed sprouts in 7 days and grew to maturity in 146 days. The best fertilizer or manure discovered during this study was poultry manure even though other types of manure were good substitutes including chemical fertilizers. The study suggested that there was a differential treatment in the castor shrub growth response observed during the experiment. The author also admits that the types of fertilizer used have differential effects on the monthly growth observations of both the big seeded varieties and the small seeded varieties of castor seed plant. This result has also demonstrated that backward integration is a veritable means of ensuring sustainable supply of castor seed for both industrial and domestic uses.

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