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Differential Growth of Genotypes of Physic Nut Conditioned by Nitrogen Fertilization

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Abstract

The adequate supply of nitrogen is essential for the plant metabolism. This nutrient has an irreplaceable role on the vegetative and reproductive growth of physic nut; therefore the correct management of the fertilization is very important, particularly in tropical regions, which present considerable losses of nitrogen by leaching and volatilization processes. This study was made with the objective of evaluating the growth of genotypes of physic nut conditioned by nitrogen fertilization. The experiment was conducted in controlled environment, following a factorial scheme 12 × 4, with 12 Brazilian genotypes of *Jatropha curcas* L. and 4 levels of nitrogen fertilization (0%, 50%, 100% and 150% of the recommendation), in completely randomized design, with four replications. The growth of the genotypes was evaluated at 100 days of cultivation. Positive response to the increase in the nitrogen supply was observed in most genotypes, with gain in plant height, stem diameter, number of leaves, leaf area and root volume. The levels of nitrogen fertilization promoted differential growth between genotypes, being possible to identify genotypes with superior growth for each level.

Keywords

***Jatropha curcas* L., Mineral Nutrition, Vegetative Growth**

1. Introduction

Given the rapid industrial growth and the intense exploration of non-renewable energy sources of the past decades, there is a global worry about researching new energy matrices based on renewable and sustainable processes,

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such as the use of vegetal oils to produce biofuels. Among the oilseeds species, the cultivation of physic nut (*Jatropha curcas* L.) has been researched due to its interesting agricultural characteristics, such as: great potential for production of oil, high crop yield, high oil content in the seeds and cultivation management compatible with the profile of family farming [1]-[3].

In Brazil, physic nut grows in different regions, being cultivated in a wide variety of environments, however, there is still a need for information to characterize and identify the conditions that guarantee its better development and a more safe and sustainable cultivation [4]. Associated with the need for technical and scientific information about the growth of *Jatropha curcas* L., recent studies reveal that the active germplasm bank in Brazil has a great genetic and phenotypic divergence and that knowledge of the genotypes being cultivated in Brazil is still primary [5]-[7].

The wide genetic variability in *Jatropha curcas* L. results in differential gene expression among genotypes in relation to environmental stresses, and the high genetic variability among Brazilian genotypes has been described in many studies [3] [5] [8] [9].

In addition to information about the characteristics of the genotypes that can be used, knowledge regarding the nutritional requirements of the crop is very valuable to achieve the productive potential of the species. For physic nut, nitrogen is the most required element in the plant cycle, thus demonstrating the indisputable essentiality of the nitrogen fertilization in the crop management [10]. Due to its important role in the vegetative and reproductive growth and development of plants [11] [12], there has been a growing need for studies to increase the efficiency of use of N in the agriculture.

The nutritional requirements of genotypes of *Jatropha curcas* L. in association with the proper level of nitrogen fertilization to guarantee its growth need to be studied, particularly in regions with acid soils of low natural fertility, which are the predominant regions where physic nut is being cultivated in Brazil [13].

Various studies conducted in Brazil have emphasized the need to increase the efficiency of nitrogen fertilization, mainly due to the high rate of nitrogen loss through volatilization and leaching in tropical soils [14]-[16]. This study was made with the objective of evaluate the growth of genotypes of physic nut conditioned by nitrogen fertilization.

2. Material and Methods

The study was conducted in a greenhouse, at the experimental site of the Centro de Ciências Agrárias da Universidade Federal do Espírito Santo (CCA-UFES), located in the municipality of Alegre-ES (latitude 20˚45'S and longitude 41˚33'W), at an average altitude of 277.41 meters, in the period between the months of December 2011 to March 2012 .

The experiment consisted of a 12 × 4 factorial scheme, studying 12 genotypes of *Jatropha curcas* L. from the Brazilian germoplasm bank (breeding program of the Empresa Brasileira de Pesquisa Agropecuária—Embrapa Agroenergia): CNPAE 110-II, CNPAE 127-I, CNPAE 161-II, CNPAE 167-II, CNPAE 180-I, CNPAE 191-I, CNPAE 192-I, CNPAE 210-II, CNPAE 255-I, CNPAE 275-I, CNPAE 300-I and CNPAE 302-I; in combination with four levels of nitrogen fertilization: corresponding to 0%, 50%, 100% and 150% of the recommended by [19]. The experiment followed a completely randomized design, with four replications.

The seeds of physic nut were originated from the germoplasm bank at 2011, benefited, packed and stored in refrigerator (3˚C), with humidity in the mass at 10% - 12%, until used.

The soil was collected at 20 - 40 cm of depth, discarding the first 20 cm of the soil in order to reduce the effect of organic matter present in the surface layer. A soil sample was sent to the laboratory for chemical and physical analyzes, performed accorded to the methodology of [17] (**Table 1**), being classified as a dystrophic oxisol [18].

After characterization, the soil was dried in the shade and homogenized in 2.0 mm mesh sieve. It was subsequently separated into samples of 10 dm^3, weighed on precision scale and placed in sealed plastic pots (14 dm^3 of capacity).

The fertilization was performed according to the recommendation for studies in a controlled environment [19], seeking to establish the nutritional balance of the soil. Phosphorus and potassium were supplied in single application before planting the seeds, using KH_2PO_4 (purity: 98%) diluted in distilled water and applied over the entire volume of soil. Nitrogen was supplied with NH_2CONH_2 (purity: 98%) diluted in distilled water and applied to the soil surface, around 10 cm of the collar of the plants. The nitrogen fertilization followed the treatments of

Table 1. Physical and chemical properties of the soil used as substrate.

Attributes	Values
Sand ($g \cdot kg^{-1}$)[1]	553.00
Silt ($g \cdot kg^{-1}$)[1]	43.60
Clay ($g \cdot kg^{-1}$)[1]	403.40
Soil density ($kg \cdot dm^{-3}$)[2]	1.21
pH[3]	6.00
P ($mg \cdot dm^{-3}$)[4]	3.00
K ($mg \cdot dm^{-3}$)[5]	59.00
Ca ($cmol_c \cdot dm^{-3}$)[6]	1.40
Mg ($cmol_c \cdot dm^{-3}$)[6]	1.00
Al ($cmol_c \cdot dm^{-3}$)[6]	0.00
H+Al ($cmol_c \cdot dm^{-3}$)[6]	1.70
Sum of bases ($cmol_c \cdot dm^{-3}$)	2.51
Potential CTC ($cmol_c \cdot dm^{-3}$)	4.18
Efetive CTC ($cmol_c \cdot dm^{-3}$)	2.51
Base saturation (%)	60.10

[1]Pipette method (slow agitation); [2]Beaker method; [3]pH in water (ratio 1:2.5); [4]Extracted by Mehlich 1 and determined by colorimetry; [5]Extracted by Mehlich 1 and determined by flame photometry; [6]Extracted with potassium chloride 1 $mol \cdot L^{-1}$ and determined by titration [17].

0%, 50%, 100% and 150%; respectively 0.00; 1.07; 2.15 and 3.25 g of nitrogen per plant, divided into four applications at 20, 40, 60 and 80 days after sowing.

Six seeds were sown per pot, with posterior thinning at 10 days after sowing, allowing only one plant to grow per pot. The irrigation was performed keeping the soil moisture during the entire period of the experiment at 60% of the total pore volume, calculated using the particle density and soil density, determined by the beaker method according to [17]. The control of weeds, pests and diseases was done according to the need and manually (weed and pest plant); by washing with distilled water (disease); when necessary.

After 120 days of cultivation, the growth was evaluated through biometric evaluations, measuring: plant height (cm), stem diameter (mm), number of leaves, leaf area (cm^2) and root volume (cm^3). Plant height was measured using a graduated ruler (precision: 1 mm), from the soil level to the apex of the stem. Stem diameter was measured using a digital caliper (MITUTOYO 500-197-20B; precision: 0.01 mm). Number of leaves was obtained by direct counting and leaf area was quantified with an area meter integrator (LICOR AREA METER LI-3100; precision: 0.01 cm^2). The roots were extracted from the soil and washed in running water, their volumes were measured using the water dislocation method in a measuring cylinder (precision: 1 mL).

The data were subjected to analysis of variance ($p \leq 0.05$), using the statistical software SISVAR [20]. According to the significance of the sources of variation, the data were subject to used regression analysis to demonstrate the responses of each genotype depending on the levels of nitrogen fertilization, or compared using the Scott-Knott test ($p \leq 0.05$) to compare genotypes within each level of nitrogen. Regression models were chosen based on the significance of the coefficients, using the Student's t test at 5% probability and the coefficient of determination (R^2).

3. Results and Discussion

The results evidenced differential behavior between genotypes of physic nut for each level of nitrogen available in the soil, being possible to identify different groups of genotypes with homogeneous growth for all the parameters evaluated.

Considering plant height, it was possible to identify at least five different groups for each level of nitrogen. Overall, the genotype CNPAE 300-I presented larger growth in height within each level of N fertilization up to 100% of the recommendation, applying more nitrogen than the recommended level (150%) caused the genotype CNPAE 180-I to grow more in height than all the others. The genotypes of physic nut showed an increase in plant height in response to application of nitrogen in the soil, being this increase linear up to 150% of the recommendation for most genotypes evaluated in this study (**Table 2**).

According to [21], nitrogen directly participates in the metabolism of aminoacids, proteins, amines, amides, amino sugars, purines, pyrimidines, alkaloids, coenzymes, vitamins and pigments, having a direct effect over the photosynthesis processes. Therefore, the availability of this nutrient is required to plants to grow properly and the increase of its availability can enhances the plant metabolism and favors the growth.

The small plant height observed when less nitrogen was applied is related to the deficit of this nutrient. This deficit may cause blockage in the synthesis of the cytokinin hormone responsible for the growth of plants, which causes the limitation their size [22]. In a similar study with other oilseed, [23] reported that, under nitrogen deficiency, there is a significant reduction in plant growth, which the authors related to the decrease in nitrate assimilation, photosynthesis and stomatal conductance.

Regarding stem diameter, differential performance was observed for each level of availability of nitrogen. The genotype CNPAE 255-I showed higher means at 0% and 100% of the recommendation. At 50%, the genotype CNPAE 275-I presented thicker stems, while CNPAE 127-I and CNPAE 191-I responded to the higher supply of nitrogen (150%), developing stems with bigger diameters (**Table 3**).

The different growth pattern observed between genotypes indicates the presence of differential responses to the fertilization between the Brazilian genotypes of physic nut. This is an evidence of the possibility to identify genotypes of higher responsivity, which can be used in intense cultivation systems, and genotypes with tolerance to lower level of fertilization, which can be cultivated in soils with chemical limitations or less technically sophisticated systems.

The genotypes CNPAE 180-I, CNPAE 191-I, CNPAE 192-I and CNPAE 302-I linearly increased the stem diameter in function of the increase in the levels of nitrogen available in the soil. The genotypes CNPAE 161-II, CNPAE 210-II and CNPAE 255-I presented stem diameter increasing up to maximum values at 125%, 116% and 100% of the recommendation, respectively, with reduction after that point (**Table 3**). According [24], studying

Table 2. Means of plant height (PH), regression equations and coefficients of determination (R^2) of genotypes of physic nut grown with different levels of nitrogen available in the soil.

Genotype	Level of nitrogen fertilization				Equation	R^2
	0%	50%	100%	150%		
CNPAE 110-II	38.5 e	49.3 e	58.5 f	62.6 h	$PH = 0.163N + 40.03^*$	0.96
CNPAE 127-I	40.0 d	50.8 d	59.3 f	60.0 i	$PH = -0.001N^2 + 0.28N + 39.78^*$	0.99
CNPAE 161-II	42.4 c	59.4 a	61.6 e	64.2 g	$PH = 0.134N + 46.83^*$	0.78
CNPAE 167-II	44.8 b	61.2 a	63.2 d	69.1 d	$PH = 0.150N + 48.36^*$	0.86
CNPAE 180-I	44.4 b	57.6 b	67.2 b	77.2 a	$PH = 0.215N + 45.43^*$	0.99
CNPAE 191-I	31.6 g	55.1 c	62.3 e	65.7 f	$PH = 0.219N + 37.27^*$	0.84
CNPAE 192-I	38.5 e	60.5 a	67.4 b	70.5 c	$PH = 0.206N + 43.82^*$	0.84
CNPAE 210-II	35.4 f	55.5 c	65.4 c	66.2 f	$PH = -0.002N^2 + 0.49N + 35.45^*$	0.99
CNPAE 255-I	43.3 c	54.3 c	67.6 b	67.8 e	$PH = -0.001N^2 + 0.33N + 42.55^*$	0.97
CNPAE 275-I	42.8 c	57.2 b	62.9 d	65.2 f	$PH = 0.145N + 46.12^*$	0.87
CNPAE 300-I	51.3 a	59.9 a	73.2 a	75.8 b	$PH = 0.173N + 52.06^*$	0.94
CNPAE 302-I	44.0 b	60.3 a	67.0 b	67.9 e	$PH = -0.001N^2 + 0.39N + 44.19^*$	0.99

Means followed by the same letter in the row do not differ from each other by the Scott-Knott test ($p > 0.05$). *Significative by the t test, at 5% of probability.

Table 3. Means of stem diameter (SD), regression equations and coefficients of determination (R^2) of genotypes of physic nut grown with different levels of nitrogen available in the soil.

Genotype	Level of nitrogen fertilization				Equation	R^2
	0%	50%	100%	150%		
CNPAE 110-II	21.4 c	23.0 e	21.6 g	23.5 d	SD = 22.4	-
CNPAE 127-I	22.8 b	25.5 b	24.5 d	25.5 a	SD = 24.6	-
CNPAE 161-II	22.4 b	24.3 c	25.4 b	24.8 b	$SD = -0.0002N^2 + 0.05N + 22.36^*$	0.99
CNPAE 167-II	22.2 b	24.4 c	23.5 e	23.6 d	SD = 23.4	-
CNPAE 180-I	20.7 d	23.7 d	24.2 d	25.0 b	$SD = 0.027N + 21.40^*$	0.86
CNPAE 191-I	20.6 d	23.6 d	24.3 d	25.6 a	$SD = 0.032N + 21.15^*$	0.92
CNPAE 192-I	21.6 c	24.4 c	24.1 d	24.7 b	$SD = 0.018N + 22.36^*$	0.70
CNPAE 210-II	20.7 d	22.9 e	24.9 c	23.7 d	$SD = -0.0003N^2 + 0.07N + 20.55^*$	0.95
CNPAE 255-I	23.4 a	25.4 b	25.8 a	24.2 c	$SD = -0.0003N^2 + 0.06N + 23.38^*$	0.99
CNPAE 275-I	22.4 b	26.3 a	23.8 e	25.0 b	SD = 24.4	-
CNPAE 300-I	20.9 d	24.4 c	21.8 g	24.6 b	SD = 22.9	-
CNPAE 302-I	22.5 b	23.3 d	23.2 f	24.1 c	$SD = 0.009N + 22.57^*$	0.84

Means followed by the same letter in the row do not differ from each other by the Scott-Knott test ($p > 0.05$). *Significative by the t test, at 5% of probability.

physic nut along 150 days after planting, the application of nitrogen up to 44.3 $mg \cdot dm^{-3}$ promoted greater plant height, but also reported that the nitrogen negatively influenced the responses in stem diameter.

In addition, the genotypes CNPAE 110-II, CNPAE 127-I, CNPAE 167-II, CNPAE 275-I and CNPAE 300-I had no adjustment to regression models, keeping similar growth of stem diameter disregarding the level of nitrogen applied in the fertilization. It is possible that the secondary stem growth was not expressive enough to allow the differentiation of the characteristics of stem growth, in diameter, during the extension of the evaluation period for these genotypes. In contrast, some genotypes presented linear or quadratic adjustment in function of fertilization, evidencing the existence of variability for rate of stem expansion, which allowed the genotypes with higher rates to express response to nitrogen fertilization, even with the limited duration of the experiment.

The genotypes CNPAE 255-I, CNPAE 161-II and CNPAE 180-I developed more leaves when fertilized with 100% of the recommendation (**Table 4**). In the absence of fertilization with N, the genotype CNPAE I-255 still presented considerable leafiness, growing more leaves then all the others. Overall, in all treatments with nitrogen fertilization, the genotype CNPAE I-180 had tendency to produce more leaves, developing the higher mean (59.6 leaves) between all genotypes in the level of 150% of the recommendation. A linear increase on number of leaves for all genotypes were observed due to the increase in the levels of N in the soil up to the level of 150%.

The behavior of the genotypes in relation to number of leaves were divergent when compared to their leaf area (**Table 4** and **Table 5**). This fact indicates the existence of diversity regarding the morphology of the leaves, some genotypes, even with small number of leaves, can still have a larger leaf area due to their leaves being larger in size than in number. The genotypes CNPAE 275-I and CNPAE 210-II developed larger leaf area under low supply of N supply (0% to 50%), demonstrating efficiency to grow even with the limited nutritional condition of the soil. Overall, the genotype CNPAE 210-II presented superiority to develop leaf area in conditions of both lower and higher supply of N (**Table 5**).

The increase in the supply of N promoted the growth of the leaves, resulting in linear gains for most genotypes (**Table 5**), the appropriate nitrogen content in leaf green tissues promote changes in the morphology that increases leaf area of most plants [25]. These morphological changes can be differentiated according to the ability of expression of different genotypes. [3] has reported structural adaptations and morphological modifications in Brazilian genotypes of physic nut being modulated by nutritional factors.

The smaller leaf area observed for most of the genotypes at the level of 0% was expected, as the low availability

Table 4. Means of number of leaves (NL), regression equations and coefficients of determination (R^2) of genotypes of physic nut grown with different levels of nitrogen available in the soil.

Genotype	Level of nitrogen fertilization				Equation	R^2
	0%	50%	100%	150%		
CNPAE 110-II	24.3 b	42.0 c	46.0 b	52.0 d	$NL = 0.174N + 28.03^*$	0.89
CNPAE 127-I	23.0 b	27.6 g	46.0 b	44.0 f	$NL = 0.162N + 22.96^*$	0.83
CNPAE 161-II	20.0 c	44.6 b	51.0 a	58.0 b	$NL = 0.240N + 25.36^*$	0.88
CNPAE 167-II	19.6 c	34.3 e	40.6 d	49.0 e	$NL = 0.188N + 21.76^*$	0.96
CNPAE 180-I	17.3 d	50.0 a	52.0 a	59.6 a	$NL = 0.258N + 25.40^*$	0.79
CNPAE 191-I	20.0 c	34.0 e	41.0 d	49.0 e	$NL = 0.188N + 21.90^*$	0.97
CNPAE 192-I	20.6 c	30.3 f	34.0 e	42.3 g	$NL = 0.137N + 21.53^*$	0.97
CNPAE 210-II	17.6 d	34.0 e	47.0 b	49.6 e	$NL = 0.218N + 20.73^*$	0.92
CNPAE 255-I	31.0 a	37.0 d	51.0 a	56.0 c	$NL = 0.178N + 30.40^*$	0.96
CNPAE 275-I	24.6 b	30.0 f	43.0 c	39.0 h	$NL = 0.112N + 25.76^*$	0.75
CNPAE 300-I	23.3 b	41.0 c	46.3 b	56.0 c	$NL = 0.206N + 26.16^*$	0.94
CNPAE 302-I	21.0 c	33.0 e	43.0 c	48.0 e	$NL = 0.182N + 22.60^*$	0.97

Means followed by the same letter in the row do not differ from each other by the Scott-Knott test ($p > 0.05$). *Significative by the t test, at 5% of probability.

Table 5. Means of leaf area (LA), regression equations and coefficients of determination (R^2) of genotypes of physic nut grown with different levels of nitrogen available in the soil.

Genotype	Level of nitrogen fertilization				Equation	R^2
	0%	50%	100%	150%		
CNPAE 110-II	161.3 c	165.8 d	154.8 d	166.4 e	$LA = 162.1$	-
CNPAE 127-I	170.3 c	191.5 c	227.6 c	285.7 b	$LA = 0.764N + 161.45^*$	0.95
CNPAE 161-II	212.4 b	225.9 b	241.0 b	297.3 a	$LA = 0.539N + 203.72^*$	0.87
CNPAE 167-II	201.5 b	212.3 c	281.5 a	284.9 b	$LA = 0.638N + 197.16^*$	0.86
CNPAE 180-I	200.7 b	211.7 c	162.0 d	242.7 c	$LA = 204.3$	-
CNPAE 191-I	178.1 c	222.7 b	256.5 b	286.2 b	$LA = 0.716N + 182.18^*$	0.99
CNPAE 192-I	174.1 c	247.8 a	252.8 b	227.4 c	$LA = -0.010N^2 + 1.81N + 176.1^*$	0.98
CNPAE 210-II	235.7 a	243.0 a	256.1 b	299.6 a	$LA = 0.409N + 227.88^*$	0.85
CNPAE 255-I	189.2 c	262.5 a	294.3 a	303.4 a	$LA = 0.748N + 206.27^*$	0.87
CNPAE 275-I	226.6 a	239.1 a	254.3 b	278.1 b	$LA = 0.339N + 224.10^*$	0.97
CNPAE 300-I	166.8 c	200.9 c	212.8 c	189.5 d	$LA = -0.005N^2 + 1.02N + 166.1^*$	0.99
CNPAE 302-I	178.4 c	242.7 a	251.0 b	270.2 b	$LA = 0.567N + 193.01^*$	0.84

Means followed by the same letter in the row do not differ from each other by the Scott-Knott test ($p > 0.05$). *Significative by the t test, at 5% of probability.

of nitrogen causes reduction in the size of leaves of many species, a consequence of the injury to their metabolism and growth [26]. The different levels of nitrogen fertilization also influenced the growth of the roots of the genotypes of physic nut. At the recommended level of nitrogen (100%), better root development was observed in the genotypes CNPAE 180-I, CNPAE 210-II, CNPAE 300-I and CNPAE 302-I. Considering the treatments with absence of nitrogen fertilization, the genotype CNPAE 127-I presented superior root growth (**Table 6**).

Table 6. Means of root volume (RV), regression equations and coefficients of determination (R^2) of genotypes of physic nut grown with different levels of nitrogen available in the soil.

Genotype	Level of nitrogen fertilization				Equation	R^2
	0%	50%	100%	150%		
CNPAE 110-II	34.6 e	54.0 g	50.0 e	56.0 f	$RV = 0.120N + 39.66^*$	0.64
CNPAE 127-I	63.0 a	70.0 b	53.0 d	70.6 c	$RV = 64.1$	-
CNPAE 161-II	50.0 b	72.0 a	69.6 a	67.0 d	$RV = -0.002N^2 + 0.47N + 51.20^*$	0.90
CNPAE 167-II	50.0 b	61.0 e	49.3 e	66.0 e	$RV = 56.6$	-
CNPAE 180-I	42.3 d	56.3 f	69.6 a	72.3 b	$RV = 0.206N + 44.66^*$	0.93
CNPAE 191-I	41.0 d	66.0 d	60.3 c	70.6 c	$RV = 0.166N + 47.00^*$	0.68
CNPAE 192-I	39.3 d	69.0 b	62.0 c	68.6 d	$RV = -0.002N^2 + 0.51N + 41.85^*$	0.78
CNPAE 210-II	40.6 d	64.6 d	70.0 a	67.0 d	$RV = -0.002N^2 + 0.57N + 41.18^*$	0.99
CNPAE 255-I	51.0 b	67.6 c	62.0 c	64.0 e	$RV = -0.001N^2 + 0.28N + 52.50^*$	0.71
CNPAE 275-I	49.0 c	60.0 e	65.0 b	65.0 e	$RV = -0.001N^2 + 0.27N + 49.05^*$	0.99
CNPAE 300-I	48.0 c	69.6 b	69.0 a	70.3 c	$RV = -0.002N^2 + 0.44N + 49.21^*$	0.91
CNPAE 302-I	48.6 c	65.3 d	71.0 a	74.3 a	$RV = 0.165N + 52.43^*$	0.87

Means followed by the same letter in the row do not differ from each other by the Scott-Knott test ($p > 0.05$). *Significative by the t test, at 5% of probability.

Overall, the genotype CNPAE 110-II had the smaller root growth, presenting root system with poor ability to explore the soil (**Table 6**). This fact may be the cause for the smaller growth of the aerial part of plants of this genotype, as observed for the previous variables. The genotypes CNPAE 110-II, CNPAE 180-I, CNPAE 191-I and CNPAE 302-I had their capacity to explore the soil growing linearly according to the increasing levels of nitrogen supply. Another behavior was observed for the genotypes CNPAE 161-II, CNPAE 192-I, CNPAE 210-II, CNPAE 255-I, CNPAE 275-I and CNPAE 300-I, which showed adjustment to quadratic model with maximum points of root volume within the range of 110% to 142% of the recommended level (**Table 6**). Therefore, the fertilization with nitrogen above the actual recommendation level favors the root development for most genotypes of physic nut, which is a primary evidence of the variability of response of Brazilian genotypes of physic nut to nitrogen fertilization.

Promoting the growth of both the aerial part and the root system, the nitrogen fertilization is responsible for increasing the vegetative vigor of plants. According to [27], physic nut plants showed better results of biomass accumulation and vigor when subjected to fertilization with higher rates of nitrogen.

The interaction between the metabolism of carbon and nitrogen determines the plant growth, being these processes interconnected to each other. The energy expended to assimilate nitrogen comes directly or indirectly from photosynthesis. Concomitantly, the photosynthetic capacity depends on the supply of nitrogen, since this nutrient is largely allocated in leaf proteins, which are involved in the photosynthetic process [28]-[30]. The strict relationship between the nitrogen content in the leaves and the photosynthetic capacity of the plants is numerously reported in studies with various species of plants [28] [29] [31]-[33].

Overall, these results can be exploited for scientific advances on the recommendation of N rates for the cultivation of *Jatropha curc*as L. and selection of genotypes with high N response and tolerance to environments with low N supply in breeding programs genetic culture. This study is part of a universe of many efforts to enhance the *Jatropha curcas* L. as a sustainable energy matrix.

4. Conclusions

Positive response to the increase in the nitrogen supply is observed in most genotypes, with gain in plant height, stem diameter, number of leaves, leaf area and root volume.

The levels of nitrogen fertilization promote differential growth among genotypes, being possible to identify genotypes of physic nut with superior growth for each condition of nitrogen supply.

References

[1] Silva, M.B.R., Dantas Neto, J., Fernandes, P.D. and Farias, M.S.S. (2009) Cultivation of Physic Nut under Salinity and Hydric Stress Conditions in a Controlled Envoroment. *Revista de Biologia e Ciências da Terra*, **9**, 74-79. [in Portuguese]

[2] Drumond, M.A., Santos, C.A.F., Oliveira, V.R., Martins, J.C., Anjos, J.B. and Evangelista, M.R.V. (2010) Agronomic Performance of Different Genotypes of Physic Nut in the Semi-Arid Zone of Pernambuco State. *Ciência Rural*, **40**, 44-47. [in Portuguese] http://dx.doi.org/10.1590/S0103-84782009005000229

[3] Amaral, J.F.T., Martins, L.D., Laviola, B.G., Christo, L.F., Tomaz, M.A. and Rodrigues, W.N. (2012) A Differential Response of Physic Nut Genotypes Regarding Phosphorus Absorption and Utilization Is Evidenced by a Comprehensive Nutrition Efficiency Analysis. *Journal of Agricultural Science*, **4**, 164-173. http://dx.doi.org/10.5539/jas.v4n12p164

[4] Durães, F.O.M., Laviola, B.G., Sundfeld, E., Mendonça, S. and Bhering, L.L. (2009) Research, Development and Inovation in Physic Nut for the Biofuel Production. Embrapa Agroenergia, Brasília. [in Portuguese]

[5] Laviola, B.G., Rosado, T.B., Bhering, L.L., Kobayashi, A.K. and Resende, M.D.V. (2010) Genetic Parameters and Variability in Physic Nut Accessions during Early Developmental Stages. *Pesquisa Agropecuária Brasileira*, **45**, 1117-1123. http://dx.doi.org/10.1590/S0100-204X2010001000010

[6] Laviola, B.G., Bhering, L.L., Mendonça, S., Rosado, T.B. and Albrecht, J.C. (2011) Morpho-Agronomic Characterization of the Germplasm Bank of Jatropha Young Stage. *Bioscience Journal*, **27**, 371-379. [in Portuguese]

[7] Laviola, B.G., Alves, A.A., Gurgel, F.L., Rosado, T.B., Costa, R.D. and Rocha, R.B. (2012) Estimate of Genetic Parameters and Predicted Gains with Early Selection of Physic Nut Families. *Ciência e Agrotecnologia*, **36**, 163-170. http://dx.doi.org/10.1590/S1413-70542012000200004

[8] Christo, L.F., Amaral, J.F.T., Laviola, B.G., Martins, L.D. and Amaral, C.F. (2012) Biometric Analysis of Seeds of Genotypes of Physic Nut (*Jatrophacurcas* L.). *Agropecuária Científica no Semi-Árido*, **8**, 1-6.

[9] Martins, L.D., Lopes, J.C., Laviola, B.G., Colodetti, T.V. and Rodrigues, W.N. (2013) Selection of Genotypes of *Jatrophacurcas* L. for Aluminium Tolerance Using the Solution-Paper Method. *Idesia*, **31**, 81-86. http://dx.doi.org/10.4067/S0718-34292013000400011

[10] Laviola, B.G. and Dias, L.A.S. (2008) Nutrient Concentration in *Jatropha curcas* L. Leaves and Fruits and Estimated Extraction at Harvest. *Revista Brasileira de Ciência do Solo*, **32**, 1969-1975. http://dx.doi.org/10.1590/S0100-06832008000500018

[11] Yong, J.W.H., Ng, Y.F. and Tan, S.N. (2010) Effect of Fertilizer Application on Photosynthesis and Oil Yield of *Jatropha curcas* L. *Photosynthetica*, **48**, 208-214. http://dx.doi.org/10.1007/s11099-010-0026-3

[12] Batista, K., Giacomini, A.A., Gerdes, L., Mattos, W.T., Colozza, M.T. and Otsuk, I.P. (2014) Influence of Nitrogen on the Production Characteristics of Ruzi Grass. *African Journal of Agricultural Research*, **9**, 533-538. http://dx.doi.org/10.5897/AJAR2013.7302

[13] Souza, K.S., Oliveira, F.A., Guedes Filho, D.H. and Brito Neto, J.F. (2009) Evaluation of the Components of Production of the Ricinus According of Rates of Calcareous and Phosphorus. *Revista Caatinga*, **22**, 116-122. [in Portuguese]

[14] Collier, L.S., Castro, D.V., Dias Neto, J.J., Brito, D.R. and Ribeiro, P.A.A. (2006) Nitrogen Fertilization Management for Maize on Legume Straw Crop with No Tillage Cultivation in Gurupi, Tocantins State. *Ciência Rural*, **36**, 1100-1105. http://dx.doi.org/10.1590/S0103-84782006000400009

[15] Silva, E.C., Muraoka, T., Buzetti, S. and Trivelin, P.C.O. (2006) Nitrogen Management in Corn under No-Tillage with Different Cover Crops in a Rhodic Hapludox Soil. *Pesquisa Agropecuária Brasileira*, **41**, 477-486. [in Portuguese]

[16] Lara Cabezas, W.A.R. and Souza, M.A. (2008) Ammonia Volatilization, Leaching of Nitrogen and Corn Yield in Response to the Application of Mix of Urea and Ammonium Sulphate or Gypsum. *Revista Brasileira de Ciência do Solo*, **32**, 2331-2342. [in Portuguese]

[17] Empresa Brasileira de Pesquisa Agropecuária—Embrapa (1997) Guidelines of Methods for Soil Analyses. Embrapa Solos, Rio de Janeiro. [in Portuguese]

[18] Empresa Brasileira de Pesquisa Agropecuária—Embrapa (2006) Brazilian System of Soil Classification. Embrapa Solos, Rio de Janeiro. [in Portuguese]

[19] Novais, R.F., Neves, J.C.L. and Barros, N.F. (1991) Experiments in Controlled Environment. In: Oliveira, A.J., Garrido, W.E., Araújo, J.D. and Lourenço, S., Eds., *Methods of Research of Soil Fertility*, Embrapa/SAE, Brasília, 189-254. [in Portuguese]

[20] Ferreira, D.F. (2011) Sisvar: A Computerstatistical Analysis System. *Ciência e Agrotecnologia*, **35**, 1039-1042.

[21] Taiz, L. and Zeiger, E. (2012) Plant Physiology. Artmed, Porto Alegre. [in Portuguese]

[22] Mengel, K. and Kirkby, E.A. (2001) Principles of Plant Nutrition. Kluwer Academic Publishers, Dordrecht. http://dx.doi.org/10.1007/978-94-010-1009-2

[23] Carelli, M.L.C., Ungaro, M.R.G., Fahl, J.I. and Novo, M.C.S.S. (1996) Nitrogen Levels, Metabolism, Growth and Yield of Sunflower. *Revista Brasileira de Fisiologia Vegetal*, **8**, 123-130. [in Portuguese]

[24] Freiberger, M.B. (2012) Initial Growth of Physic Nut in Function of the Fertilization NPK. Dissertation (Master Degree), Universidade Estadual Paulista, Faculdade de Ciências Agronômicas, Botucatu. [in Portuguese]

[25] Marschner, H. (2012) Mineral Nutrition of Higher Plants. Academic Press, London.

[26] Maffeis, A.R., Silveira, R.L.V.A. and Brito, J.O. (2000) Macronutrients and Boron Deficiencies Reflexes on Plant Growth, Production and Essential Oil in *Eucalyptus citriodora*. *Scientia Forestalis*, **57**, 87-98. [in Portuguese]

[27] Freitas, R.G., Araujo, S.F., Matos, F.S., Missio, R.F. and Dias, L.A.S. (2012) Development of Seedlings Physic Nut Doses of Nitrogen. *Revista Agrotecnologia*, **3**, 24-35. [in Portuguese]

[28] Seemann, J.R., Shaiey, T.D., Wang, J.L. and Osmond, C.B. (1987) Environmental Effects on Photosynthesis, Nitrogen Use Efficiency, and Metabolic Pools in Leaves of Sun and Shade Plants. *Plant Physiology*, **84**, 796-802. http://dx.doi.org/10.1104/pp.84.3.796

[29] Evans, J.R. (1983) Nitrogen and Photosynthesis in the Flag Leaf of Wheat (*Triticum aestivum* L.). *Plant Physiology*, **72**, 297-302. http://dx.doi.org/10.1104/pp.72.2.297

[30] Evans, J.R. and Seemann, J.R. (1984) Differences between Wheat Genotypes in Specific Activity of Ribulose-1,5-bisphosphate Carboxylase and the Relationship to Photosynthesis. *Plant Physiology*, **74**, 759-765. http://dx.doi.org/10.1104/pp.74.4.759

[31] Natr, L. (1972) Influence of Mineral Nutrition on Photosynthesis of Higher Plants. *Photosynthetica*, **6**, 80-99.

[32] Sinclair, T.R. and Horie, T. (1989) Leaf Nitrogen, Photosynthesis, and Crop Use Efficiency: A Review. *Crop Science*, **29**, 90-97. http://dx.doi.org/10.2135/cropsci1989.0011183X002900010023x

[33] Fahl, J.I., Carelli, M.L.C., Vega, J. and Magalhães, A.C. (1994) Nitrogen and Irradiance Levels Affecting Net Photosynthesis and Growth of Young Coffee Plants (*Coffea arabica* L.). *Journal of Horticultural Science*, **69**, 161-169.