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Quality of *Genipa Spruceana* steyerm seedlings submitted to fertigation

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ABSTRACT

Jenipapo (*Genipa spruceana*) is a native species of the Amazon that has great potential in producing seedlings for reforestation. This study aimed to evaluate the effect of nutrient doses applied through fertigation on the quality of *Genipa spruceana*. The experimental design was completely randomized with five replications, totaling seven treatments. The treatments were: control (without fertilization); 900 mg N L^{-1} and 750 mg K L^{-1} with and without micronutrients; 1800 mg N L^{-1} and 1500 mg K L^{-1} with and without micronutrients, 3600 mg N L^{-1} and 3000 mg K L^{-1} with and without micronutrients. The experiment was conducted in a greenhouse for 35 days. Then, the following variables were evaluated: stem diameter, height, root and shoot dry matter, and total dry matter. From these measurements, the following ratios were calculated: height/stem diameter, height/shoot dry matter, shoot dry matter/root dry matter, and Dickson quality index. Weekly fertigation applying 1800 mg N^{-1} and 1500 mg K L^{-1} provided the best Dickson Quality Index of *Genipa spruceana* seedlings. The hypothesis of the present study was confirmed, and the *Genipa spruceana* did not have a tolerance to high N e K fertilization.

Keywords: Amazon, Dickson Quality Index, Forest essences

Qualidade de mudas de *Genipa Spruceana* Steyerm submetidas a fertirrigação

RESUMO

Jenipapo (*Genipa spruceana*) é uma espécie nativa da Amazônia que possui grande potencial na produção de mudas para reflorestamento. O objetivo desse estudo foi avaliar o efeito de doses de nutrientes aplicadas por meio de fertirrigação na qualidade de mudas de *Genipa spruceana*. O delineamento experimental foi inteiramente casualizado com cinco repetições, totalizando sete tratamentos. Os tratamentos foram: testemunha (sem fertilização); 900 mg N L^{-1} e 750 mg K L^{-1} com e sem micronutrientes; 1800 mg N L^{-1} e 1500 mg K L^{-1} com e sem micronutrientes, 3600 mg N L^{-1} e 3000 mg K L^{-1} com e sem micronutrientes. O experimento foi conduzido em casa de vegetação por 35 dias. Em seguida, foram avaliadas as seguintes variáveis: diâmetro do caule, altura da parte aérea, matéria seca da raiz e parte aérea e matéria seca total. A partir dessas medidas, foram calculadas as seguintes relações: altura / diâmetro do caule, altura / matéria seca da parte aérea, matéria seca da parte aérea / matéria seca da raiz e índice de qualidade de Dickson. A fertirrigação semanal com N e K, com e sem micronutrientes em solo corrigido, com a aplicação de 1800 mg N^{-1} e 1500 mg K L^{-1} sem micronutrientes proporcionou o melhor índice de qualidade de Dickson para as mudas de *Genipa spruceana*. E a hipótese do presente foi confirmada e a *Genipa spruceana* não apresentou tolerância a altas doses de aplicação de N e K.

Palavras-chave: Amazon, Forest essences, Plant nutrition, Seedling production.

1. Introduction

Genipa spruceana Steyerm, popularly known as jenipapo, belongs to the *Rubiaceae* family, and its occurrence is frequent in the Brazilian Amazon (Gonçalves et al., 2012). It is a semi-deciduous species, heliophyte, and selective hygrophyte, which has a medium size and can reach up to 12 meters in height (Gonçalves et al.., 2013). The specie has great economic potential (Sassaqui et al., 2013), either for the commercialization of the fruits or wood used in naval and civil construction. In addition, *Genipa spruceana* trees are sources of ecological importance in the recovery of riparian forests, as they develop well in flooded environments.

In this context, nursery seedling production of native species is essential for restoring new forest stands (Dionisio et al., 2019). Using fertilizers accelerates growth and provides well-nourished plants with morphophysiological properties that strongly contribute to transplanting success (Marques et al., 2018). Paiva et al. (2009) affirmed that the best morphological parameters to determine seedlings with quality are stem diameter and shoot height. Fertilization of seedlings with mineral fertilizers to supply essential elements (macronutrients and micronutrients) is performed initially by applying solid fertilizer to the substrate. After the beginning of the seedlings grows, liquid fertilizers with Nitrogen (N) and Potassium (K) can be used in plants.

Substrate fertilization becomes fundamental to increasing the growth and quality of seedlings of forest tree species (Navroski et al., 2016), stimulating seedling growth (Costa et al., 2015), and favoring biomass increase (Afonso et al., 2020). Fertilizers can induce changes in rhizosphere electrical conductivity and relation to forest tree seedling roots (Jacobs and Timmer, 2005). However, nutritional deficiency or excess affects plant growth (Brdar-Jokanović 2020) and can cause nutrient imbalance.

Thus, established the following hypothesis: The *Genipa spruceana* tree species has no tolerance to high doses of nitrogen and potassium, and the application of high doses reflects in lower quality of the seedlings. It is important to note that the information about the management of fertilization and nutrition of forest seedlings, mainly the native ones, is incipient (Berghetti et al., 2019). Given the differences in nutritional requirements between species, studies are needed to show a pattern of fertilization that meets their nutritional requirements (Reis et al. 2012). This study aimed to evaluate the effect of nutrient doses applied by fertigation on the growth and quality of *Genipa spruceana* seedlings.

2. Material and Methods

This study was conducted under protected environment conditions in a greenhouse of the Mato Grosso State University – UNEMAT (09°51’42’’ S and 56º04’07’’ W; altitude of 320 m). The climate of the region is tropical rainy, according to the Köppen classification, with temperatures of 20-38 °C and annual rainfall of 2300 mm (Rodrigues et al., 2017). The experimental design was completely randomized with seven treatments and five replications. The treatments were T1= Control; T2= 900 mg N L^{-1} and 750 mg K L^{-1} without micronutrients, T3= 900 mg N L^{-1} and 750 mg K L^{-1} with micronutrients, T4= 1800 mg N L^{-1} and 1500 mg K L^{-1} without micronutrients, T5= 1800 mg N L^{-1} and 1500 mg K L^{-1} with micronutrients, T6= 3600 mg N L^{-1} and 3000 mg K L^{-1} without micronutrients, and T7= 3600 mg N L^{-1} and 3000 mg K L^{-1} with micronutrients.

Ammonium sulfate (18% N) and potassium chloride (60% K_2O) were used to supply N and K to the seedlings. Micronutrient solution consisted of 1 mL L^{-1} stock solution, obtained using 2.86 g L^{-1} of H_3BO_3, 1.81 g L^{-1} of $MnCl_2$, 0.10 g L^{-1} of $ZnCl_2$, 0.04 g L^{-1} of $CuCl_2$, 0.02 g L^{-1} of H_2MoO_4, and 0.03 g L^{-1} of FeEDTA, diluted in one liter of deionized water. The *Genipa spruceana* sowing took place in an open-air seedbed. Three weeks after sowing, the seedlings were transplanted into 2.8-L plastic bags (28 x 22 x 0.020 cm). During the first 20 days after transplanting, the *Genipa spruceana* seedlings were kept under a screenhouse with 60% shading. The seedlings were irrigated once a day. After 35 days, the respective treatments were applied to the seedling. Thus, the soil used was corrected and appropriately stored in containers. Soil chemical and granulometric characteristics were determined according to the methodology of Embrapa (Teixeira et al., 2018), as presented in Table 1.

At the beginning of the experiment, phosphate fertilizer was applied in the plastic bags (200 mg dm^{-3} of P), using triple superphosphate as a source (41% P_2O_5). The treatments were applied weekly via fertigation, using a volumetric test tube. The other daily irrigations were conducted only with water, maintaining the soil at approximately 60% of its water retention capacity. Therefore, 70 days after transplanting, the following variables were evaluated in the seedlings: stem diameter (SD), shoot height (SH), root dry matter (RDM), shoot dry matter (SDM), and total dry matter (TDM). SH and SD were measured using a ruler graduated in centimeters and a digital caliper, respectively. After the measurements, roots were separated from the shoot, then packed in kraft paper bags and taken to a forced-air oven at 65 °C for 72 hours until reaching constant mass to determine RDM, SDM, and TDM.

Table 1- Chemical and particle-size analysis of the Latossolo Vermelho in the 20-40 cm layer.

Soil properties	Oxisol
pH ($CaCl_2$)	5.90
C org (g kg^{-1})	16.31
$P_{Mehlich-1}$ (mg kg^{-1})	2.00
K^+ ($cmol_c$ kg^{-1})	0.14
Ca^{+2} ($cmol_c$ kg^{-1})	6.96
Mg^{+2} ($cmol_c$ kg^{-1})	1.07
Al^{+3} ($cmol_c$ kg^{-1})	0.00
H^+ ($cmol_c$ kg^{-1})	2.48
SB ($cmol_c$ kg^{-1})	8.40
CEC_{pH7} ($cmol_c$ kg^{-1})	10.90
Base saturation (%)	77.10
Sand (g kg^{-1})	258
Silt (g kg^{-1})	250
Clay (g kg^{-1})	493

From the data obtained, the following ratios were calculated: shoot height/stem diameter (SH/SD), shoot height/shoot dry matter (SH/SDM), shoot dry matter/root dry matter (SDM/RDM), and the Dickson Quality Index (DQI), according to the following equation:

$$DQI = \frac{\text{TDM (g)}}{[SH(cm)/SD(mm)] + [SDM(g)/RDM(g)]}$$

The data obtained in the experiments were submitted to the tests of residual normality (Shapiro-Wilk test at 5% probability level) and homogeneity of variances (Bartlett's test). Then the analyses of variance were performed by the F test ($P < 0.01$). The means were compared by the Tukey test using the Agricolae package (Mendiburu and Simon 2015). Statistical analysis was performed using the statistical software RStudio, version 1.1.456 (R CORE TEAM, 2018).

3. Results and Discussion

There was a significant ($p<0.05$) effect of treatments on the variables SD, SH, RDM, SDM, and TDM (Table 2). Applications of the 3600 mg N L^{-1} and 3000 mg K L^{-1} with micronutrients differed from T1, T2, T4, and T5 (Table 2). The explanation for applications of the 3600 mg N L^{-1} and 3000 mg K L^{-1} with and without the use of micronutrients not differing is possibly justified by the higher doses of N and K. Thus, doses increased (K and N), and there was a reduction in diameter growth, possibly due to substrate salinization at these higher doses. Gonçalves et al. (2012) reported that Genipa spruceana is considered a pioneer specie and usually requires low nutrient availability for its development. Thus, it is a desirable species for recovering degraded areas, mainly in riparian forests (Gama et al., 2020).

Gonçalves et al. (2002) also affirm that adequate stem diameter for good-quality seedlings is between 5 and 10 mm for native forest species. Thus, fertigation with doses higher than 3000 mg N L^{-1} and 1500 mg K L^{-1} affect SD, leading to *Genipa spruceana* seedlings of lower quality. For shoot height, the application of 3600 mg N L^{-1} with the use of micronutrients differed statistically ($p <0.05$) from the T1 (control). The T7 provided the lowest value in comparison to other treatments. Thus, T7 concerning T1 was reduced by 53.35% (Table 2).

The period of 70 days after transplanting the seedlings possibly contributes to the seedlings not reaching the desired heights. Gonçalves et al. (2002) affirmed that the standard shoot height for quality seedlings of native forest species is from 20 to 35 cm on average. However, it is worth emphasizing the generalization of the standard for the native species, requiring new eco studies that allow considering the physiological characteristics of each species.

The applications of 3600 mg N L^{-1} and 3000 mg K L^{-1} with the use of micronutrients differed ($p<0.05$) from the application of 1800 mg N L^{-1} and 1500 mg K L^{-1} without micronutrients (Table 2). There was a reduction of 47% in RDM with the application of 3600 mg N L^{-1} and 3000 mg K L^{-1} with micronutrients, compared to the application of 1800 mg N L^{-1} and 1500 mg K L^{-1} without micronutrients. According to Abanto-Rodríguez et al. (2018), in a study on the production of camu-camu (*Myrciaria dubia* (Kunth)) seedlings, proposed doses up to 80 mg dm^{-3}. They noted that nitrogen fertilizer applications tended to cause causes toxicity or induce deficiency of other nutrients.

Another important fact related to the decrease of RDM in the seedlings is that, in larger applications of K, excess KCl may increase the chloride content in the plant and cause toxicity. According to Costa et al. (2019), applying the 200 mg dm^{-3} of K in araticum (*Annona crassiflora*) seedlings caused a reduction of 30% in RDM. Therefore, the excess K content in the root system tends to cause toxicity, directly affecting growth and harmful to seedling development in the field (Costa et al., 2019, Saiz-Fernández et al., 2015).

For SDM, application above 1800 mg N L^{-1} and 1500 mg K L^{-1} with or without micronutrients caused a reduction in the SDM. With the application of 3600 mg N L^{-1} and 3000 mg K L^{-1}, there is a reduction of 45% in comparison to the absence of fertilization to variable SDM, differing from other applications (Table 2). The justification may be for applying N-$NH4^+$ source, and in higher doses, it causes adverse effects on the seedlings (Guo et al., 2019).

Table 2. Stem diameter (SD), shoot height (SH), root dry matter (RDM), shoot dry matter (SDM), and total dry matter (TDM) in *Genipa spruceana* seedlings fertilized with N and K with and without micronutrients.

Treatments ($g\ L^{-1}$)	SD	SH	RDM	SDM	TDM
	mm	cm	---------------------g----------------------		
T1	6.11±0.77 a	12.80±2.33a	1.74±0.69ab	2.11±0.51a	3.85±0.73a
T2	6.19±0.31 a	11.90±1.41ab	1.79±0.25ab	2.17±0.14a	3.96±0.28a
T3	5.70±0.28ab	11.24±1.38ab	1.48±0.26ab	2.10±0.44a	3.58±0.67a
T4	6.24±0.38a	10.03±0.64ab	1.85±0.44a	2.19±0.34a	4.04±0.72a
T5	6.07±0.63 a	10.06±2.0bc	1.82±0.26ab	1.69±0.30ab	3.51±0.55a
T6	4.94±0.24bc	9.05±1.43bc	1.27±0.12ab	1.71±0.20ab	2.98±0.23ab
T7	4.43±0.58c	6.83±0.42c	0.88±0.09b	0.94±0.12b	1.82±0.18b
F value	19.43**	37.27**	7.7*	23.07**	20.65 **
CV (%)	10.86	14.52	27.72	20.49	19.51

** and * significant at 0.01 and 0.05 probability levels by the F test. Means followed by the same letters in the columns do not differ statistically at the 5% probability level by the Tukey test. T1= Control; T2= 900 mg N L-1 and 750 mg K L-1 without micronutrients, T3= 900 mg N L-1 and 750 mg K L-1 with micronutrients, T4= 1800 mg N L-1 and 1500 mg K L-1 without micronutrients, T5= 1800 mg N L-1 and 1500 mg K L-1 with micronutrients, T6= 3600 mg N L-1 and 3000 mg K L-1 without micronutrients and T7= 3600 mg N L-1 and 3000 mg K L-1 with micronutrients.

The applications of 3600 mg N L^{-1} and 3000 mg K L^{-1} with and without micronutrients did not influence ($p>0.05$) the TDM (Table 2). There was a reduction of 45% with applications of 3600 mg N L^{-1} and 3000 mg K L^{-1} with micronutrients in comparison with application of the 1800 mg N L^{-1} and 1500 mg K L^{-1} with micronutrients. The lowest values of TDM and SDM, with high applications, are justified by the N source used in the study (N-NH_4^+). Tsay et al. (2011) confirm that the interaction between N and K, due to the similarities of charges, size, and state of hydration, leads to an antagonistic effect between NH_4^+ and K^+ ions, and the toxic effects caused by the excessive application of N-NH_4^+ are observed.

There was no significant effect ($p<0.05$) on the variable indicative of seedling quality SH/SDM and SDM/RDM. However, for RHDC and DQI, there was an effect of the applications ($p<0.05$) (Table 3). For RHDC, the applications of 3600 mg N L^{-1} and 3000 mg K L^{-1} with micronutrients noted the lower values, differing ($p<0.05$) from the absence application (T1) (Table 3). The present study provides evidence of the positive effects promoted by N and K. However, with increased applications, there was a significant reduction in seedling quality, and negative effects were predominant.

Thus, RHDC values above 1.9 are good indicators for *Genipa spruceana* seedlings. This is because this parameter is widely used in measuring the quality of seedlings and reflects a greater increase in reserve accumulation, greater resistance, and potential of seedlings in their establishment (Smiderle and Souza, 2016). For DQI, applications of 3600 mg L^{-1} of N and 3000 mg L^{-1} of K, with the use of micronutrients, differed (0.05) from the application of the1800 mg N L^{-1} and 1500 mg K L^{-1} with micronutrients (Table 3). The DQI values observed in the present study indicated that values above the application of the 1800 mg N L^{-1} and 1500 mg K L^{-1} with micronutrients corroborated the results found by Sassaqui et al. (2013). They reported DQI from 1.28 to 1.5 in *Genipa spruceana* seedlings grown in the greenhouse. Therefore, it is worth noting that T4 provided the highest DQI value. The DQI is a balanced formula, including the morphometric parameters stem diameter, shoot height, root, shoot and total dry matter; the higher the result of this index, the better the quality of the seedlings produced (Zuffo et al., 2014; Caione et al., 2013), because of the balance between seedling biomass and vigor (Silva et al. 2019).

Table 3. Ratios of shoot height/stem diameter (RHDC) and Dickson Quality Index (DQI) in *Genipa spruceana* seedlings fertilized with N and K with and without micronutrients.

Treatments ($g\ L^{-1}$)	RHDC	DQI
	---- cm ----	------ g -------
T1	2.08±0.16a	1.17±0.05ab
T2	1.92±0.18ab	1.26±0.18ab
T3	1.98±0.24ab	1.03±0.40bc
T4	1.91±0.13ab	1.46±0.12a
T5	1.75±0.29ab	1.34±0.23ab
T6	1.83±0.23ab	0.94±0.06bc
T7	1.85±0.13b	0.70±0.08c
F value	12.77**	16.62**
CV %	11.77	27.84

** and * significant at 1% probability levels, and not significant, respectively, by the F test. Means followed by the same letters in the columns do not differ statistically at the 5% probability level by the Tukey test. T1= Control; T2= 900 mg N L^{-1} and 750 mg K L^{-1} without micronutrients, T3= 900 mg N L^{-1} and 750 mg K L^{-1} with micronutrients, T4= 1800 mg N L^{-1} and 1500 mg K L^{-1} without micronutrients, T5= 1800 mg **N** L^{-1} and 1500 mg K L^{-1} with micronutrients, T6= 3600 mg N L^{-1} and 3000 mg K L^{-1} without micronutrients, and T7= 3600 mg N L^{-1} and 3000 mg K L^{-1} with micronutrients.

Given the results, it can be observed that the species Genipa spruceana has a reduced nutritional requirement since the soil used in the present study was already corrected (Table 1), with high levels of elements required in large amounts by forest species, such as Ca and Mg, and without problems of aluminum toxicity. Thus, these initial correction practices were essential to ensure good seedling growth, and fertigation during initial growth had little effect.

4. Conclusions

The application of doses above the 1800 mg N L^{-1} and 1500 mg K L^{-1}, with and without micronutrients, reduced the morphometric variables: shoot height and stem diameter of *Genipa spruceana* seedlings. Weekly fertigation with doses above the 1800 mg N L^{-1} and 1500 mg K L^{-1} without micronutrient (T4) provided the best DQI of *Genipa spruceana* seedlings. However, higher doses could affect the quality. The hypothesis of the present study was confirmed, and the *Genipa spruceana* do not have a tolerance to the application of high doses of N e K.

Authors' Contribution

Luciano de Souza contributed to the installation of the experiment, data collection, and manuscript writing. Fernando Saragosa Rossi performed the corrections of data and manuscript writing. Pedro Paulo Gomes de Oliveira performed the data tabulation, writing and manuscript corrections. Nayara Bertolino contributed manuscript corrections and checked the manuscript guidelines. Gustavo Caione assisted in the installation of the experiment, carried out the data analysis and graph preparation, and guided the first author of the manuscript

Bibliographic References

Abanto-Rodríguez, C., Chagas, E.A., Siqueira, R.H.S., Araújo, W.F., Zborowski. LG.C., Souza, C.C.P., Sakasaki, R.T., Monteiro Neto, J.L.P., Sánchez-Choy, J. 2018. Nutrient contents and fertirrigation in camu (*Myrciaria dubia* (Kunth) McVaugh) crop with different nitrogen doses. Acta Agronómica, 67 (1), 79. DOI: http://dx.doi.org/10.15446/acag.v67n1.64667.

Afonso, M.V., Paranhos, J.P., Tabaldi, L.A., Soriani, H. H., Saldanha, C.W. 2020. Tabernaemontana catharinensis A. DC. Seedling Emergence and Growth in Different Substrates. Floresta e Ambiente, 27 (2), 1–7. DOI: https://doi.org/10.1590/2179-8087.077017.

Berghetti, A.L.P., Araujo, M.M., Tabaldi, L.A., Rorato, D.G., Aimi, S.G., Fárias, J.G. 2019. Growth and Physiological Attributes of Cordia Trichotoma Seedlings in Response to Fertilization with Phosphorus and Potassium. Floresta, 49 (1), 133–42. DOI: https://doi.org/10.5380/rf.v49 i1.57892.

Brdar-Jokanović, M., 2020. Boron Toxicity and Deficiency in Agricultural Plants. International Journal of Molecular Sciences, 21 (4), 202-214. DOI: https://doi.org/10.3390/ijms21041424.

Caione, G., Fernandes, F.M., Lange, A., 2013. Efeito Residual de Fontes de Fósforo Nos Atributos Químicos Do Solo, Nutrição e Produtividade de Biomassa Da Cana-de-Açúcar. Revista Brasileira de Ciencias Agrarias, 8 (2), 189–96. DOI: https://doi.org/10.5039/agraria.v8i2a2016.

Costa, A.M., Carlos, L., Silva, P.O., Barbosa, K.P., Rodrigues, C.R., 2019. Nitrogen and Potassium Fertilization in the Initial Growth of Annona crassiflora Mart. Floresta e Ambiente, 26(2), e20170341 DOI: https://doi.org/10.1590/2179-8087.034117.

Costa, E.; Dias, J.G., Lopes, K.G., Binotti, F.F.S., Cardoso, E.D., 2015. Telas de sombreamento e substratos na produção de mudas de Dipteryx alata Vog. Floresta e Ambiente, 22 (3), 416-425. DOI: http://dx.doi.org/10.1590/2179-8087.071714.

Dionisio, L.F.S.; Auca, E.C., Bardales-Lozano, R.M., Schwartz, G., Rodrigues, R.P., Corvera-Gomringer, R., 2019. Production of Bertholletia excelsa Humb. Bonpl., (Lecythidaceae) seedlings in microenvironments under different substrates. Revista Brasileira de Ciências Agrárias, 14(3), e5847. DOI: https://doi.org/10.5039/agraria.v14i3a5847.

Gama, D.C., Ferreira, R.A., Jesus, J.B., 2020. Establishment of native forest species in recovery planting of riparian forest in the piauitinga river, Sergipe, Brazil. Floresta, 50(2), 1325 – 1334. DOI: http://dx.doi.org/10.5380/rf.v50i2.62987.

Gonçalves, J.F.C., Melo, E.G.F., Ferreira, M.J., Silva, C.E.M., Gomes, I.B. 2013. Crescimento, partição de biomassa e fotossíntese em plantas jovens de *Genipa Spruceana* submetidas ao alagamento. Cerne, Lavras, 19(2), 193-200. DOI: https://doi.org/10.1590/S0104-77602013000200003.

Gonçalves, J.L.M., Santarelli, G., Moraes Neto, S.P., Manara, M.P., 2002. Produção de Mudas de Espécies Nativas: Substrato, Nutrição, Sombreamento e Fertilização. In Gonçalves, J.L.M.; Benedetti, V. (Eds.) Nutrição e Fertilização Florestal, Editora IPEF, Piracicaba, p. 191 – 268.

Gonçalves, J.F.C., Melo, E.G.F., Silva, C.E.M., Ferreira, M.J., Justino, G.C., 2012. Estratégias no uso da energia luminosa por plantas jovens de Genipa Spruceana Steyerm submetidas ao Alagamento. Acta Botanica Brasilica, 26 (2), 391–98. DOI: https://doi.org/10.1590/s0102-33062012000200014.

Guo, J., Jia, Y., Chen, H., Zhang, L., Yang, J., Zhang, J., Hu, X., Ye, X., Li, Y., Zhou, Y., 2019. Growth, photosynthesis, and nutrient uptake in wheat are affected by differences in nitrogen levels and forms and potassium supply. Scientific Reports, 9(1), 1–12. DOI: https://doi.org/10.1038/s41598-018-37838-3.

Jacobs, D.F., Timmer, V.R., 2005 Fertilizer-induced changes in rhizosphere electrical conductivity: relation to forest tree seedling root system growth and function. New Forests, 30(3), 147-166.

Marques, A.R.F., Oliveira, V.S., Boligon, A.A., Vestenaet, S., 2018. Produção e qualidade de mudas de Psidium cattleianum var. cattleianum Sabine (Myrtaceae) em diferentes substratos. Acta Biológica Catarinense, 5(1), 5-13. DOI: http://dx.doi.org/10.21726/abc.v5i1.374.

Mendiburu, F., Simon, R., 2015. Agricolae - Ten Years of an Open Source Statistical Tool for Experiments in Breeding, Agriculture and Biology, PeerJ 3(21), 1–17. DOI: https://doi.org/10.7287/peerj.preprints.1404.

Navroski, M.C., Tonett, E.L., Mazzo, M.V., Frigotto, T., Pereira, M.O., Galvani, L.V., 2016. Procedência e adubação no crescimento inicial de mudas de cedro. Pesquisa Florestal Brasileira, 36(85), 17-24. DOI: https://doi.org/10.4336/2016.pfb.36.85.966.

Paiva, A.V., Poggiani, F., Gonçalves, J.L.M., Ferraz, A.V., 2009. Crescimento de Mudas de Espécies Arbóreas Nativas, Adubadas Com Diferentes Doses de Lodo de Esgoto Seco e Com Fertilização Mineral. Scientia Forestalis/Forest Sciences, 37(84), 499–511.

R CORE TEAM. 2018. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria.

Reis, B.E., Paiva H.N., Barros, T.C., Ferreira, A.F., Cardoso W.C. 2012. Crescimento e qualidade de mudas de Jacarandá-da-Bahia (*Dalbergia nigra* (Vell.) Allemão ex Benth.) em resposta à adubação com potássio e enxofre. Ciência Florestal, 22(2), 389-396. DOI: https://doi.org/10.5902/198050985746.

Rodrigues, M., Rabêlo, F.H.S., Castro, H.A., Roboredo, D., Carvalho, M.A.C., Roque, C.G., 2017. Changes in Chemical Properties By Use and Management of an Oxisol in the Amazon Biome. Revista Caatinga, 30(2), 278–86. DOI: https://doi.org/10.1590/1983-21252017v30n202rc

Saiz-Fernández, I., Diego, M., Sampedro, M.C., Mena-Petite, A., Ortiz-Barredo, A., Lacuesta, M., 2015.High nitrate supply reduces growth in maize, from cell to whole plant. Journal of Plant Physiology, 173(1), 120-129. DOI: http://dx.doi.org/10.1016/j.jplph.2014.06.018.

Sassaqui, A.R., Terena, T.F.S., Costa, E., 2013. Protected Environments and Substrates for Production of Genipap Seedlings. Acta Amazonica, 43(2), 143–52. DOI: https://doi.org/10.1590/s0044-59672013000200003.

Silva, D., Stuepp, C.A., Wendling, I., Helm, C., Angelo, A.C., 2019. Influence of Seed Storage Conditions on Quality of Torresea Acreana Seedlings. Cerne, 25 (1), 60–67. DOI: https://doi.org/10.1590/01047760201925012611.

Smiderle, O.J., Souza, A.G., 2016. Production and Quality of Cinnamomum zeylanicum Blume Seedlings Cultivated in Nutrient Solution. Revista Brasileirade Ciencias Agrarias, 11 (2), 104–10. DOI: https://doi.org/10.5039/agraria.v11i2a5364.

Teixeira, P.C., Donagemma, G.K., Fontana, A., Teixeira, W. G., 2018. Manual de Métodos de Análise de Solo. Embrapa solos, Rio de Janeiro.

Tsay, Y.F., Ho, C.H., Chen, H.Y., Lin, S.H., 2011. Integration of Nitrogen and Potassium Signaling. Annual Review of Plant Biology, 62(5), 207–26. DOI: https://doi.org/10.1146/annurev-arplant-042110-103837.

Zuffo, A.M., Jesus, A.P.S., Dias, S.G.F., 2014. Posição de semeadura na emergência e desenvolvimento inicial de plântulas de Baru. Pesquisa Florestal Brasileira, 34 (79), 251. DOI: https://doi.org/10.4336/2014.pfb.34.79.650.