Pesquisa Agropecuária Brasileira

ISSN 1678-3921

Journal homepage: www.embrapa.br/pab

For manuscript submission and journal contents, access: www.scielo.br/pab

Fertilization/ Original Article

# Nitrogen and potassium application on yellow mombin initial growth

**Abstract** – The objective of this work was to evaluate the effects of the application of combined rates of nitrogen and potassium on the initial growth of 'Lagoa Redonda' yellow mombin. The experiment was carried out in a screen house, in a randomized complete block design, with a $5^2$ fractional factorial arrangement, with five N rates (0, 100, 200, 300, and 400 mg dm$^{-3}$), five K rates (0, 100, 200, 300, and 400 mg dm$^{-3}$), and five replicates. After 360 days, plants were evaluated for height, stem diameter, and number of leaves, as well as for stem, petiole, leaf, shoot, root, and total dry matter. Potassium fertilization and the N x K interaction did not have significant effects on the biometric and biomass characteristics. Nitrogen fertilization influenced the number of leaves, plant height and stem, petioles, leaves, shoot and total dry matter production. Fertilization at 296 mg dm$^{-3}$ N increases the total dry matter production in the initial growth of the 'Lagoa Redonda' yellow mombin.

**Index terms**: *Spondias mombin*, mineral fertilization, tropical fruits.

## Aplicação de nitrogênio e potássio no crescimento inicial de cajazeira

**Resumo** – O objetivo deste trabalho foi avaliar os efeitos da aplicação combinada de doses de nitrogênio e de potássio sobre o crescimento inicial da cajazeira 'Lagoa Redonda'. O experimento foi realizado em telado agrícola, em delineamento de blocos ao acaso, em arranjo fatorial $5^2$ fracionado, com cinco doses de N (0, 100, 200, 300 e 400 mg dm$^{-3}$), cinco doses de K (0, 100, 200, 300 e 400 mg dm$^{-3}$) e cinco repetições. Após 360 dias, as plantas foram avaliadas quanto à altura, ao diâmetro do caule e ao número de folhas, bem como quanto à massa de matéria seca de caule, pecíolos, folhas, parte aérea, raízes e total. A adubação potássica e a interação N x K não apresentaram efeitos significativos sobre as características biométricas e as de biomassa. A adubação nitrogenada influenciou o número de folhas, a altura de plantas e a produção de massa de matéria seca de caule, pecíolos, folhas, parte aérea e total da cajazeira. A adubação com 296 mg dm$^{-3}$ de N aumenta a produção da matéria seca total no crescimento inicial da cajazeira 'Lagoa Redonda'.

**Termos para indexação**: *Spondias mombin*, adubação mineral, frutas tropicais.

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Received
April 01, 2024

Accepted
August 07, 2024

**How to cite**
SILVA, W. da; NATALE, W.; TANIGUCHI, C.A.K.; SOUZA, F.X. de; ARTUR, A.G. Nitrogen and potassium application on yellow mombin initial growth. **Pesquisa Agropecuária Brasileira**, v.59, e03679, 2024. DOI: https://doi.org/10.1590/S1678-3921.pab2024.v59.03679.

## Introduction

Brazil has a great diversity of fruit species, which can be both explored for research and exploited for economic purposes; hence, there is a need for studies including these native and nontraditional species, such as the Anacardiaceae family (Souza et al., 2006; Vasconcelos et al., 2017).

Anacardiaceae is a plant family with 800 species and more than 80 genera globally distributed, predominantly in tropical and subtropical regions of the world (Mitchell et al., 2022). According to botanical classifications, yellow mombin (*Spondias mombin* L.), red mombin (*Spondias purpurea* L.), Brazil plum (*Spondias tuberosa* Arruda), and *umbu-cajá* (*Spondias bahiensis* P. Carvalho, Van den Berg & M. Machado) belong to this family (Mitchell & Daly, 2015; Mitchell et al., 2022).

The yellow mombin tree originated of the tropical region of the American continent (Sousa et al., 2023), and it is also distributed in the tropical and subtropical regions of Asia, Oceania, and the Neotropics (Machado et al., 2021). Yellow mombin cultivation is prominent in the regions where it is developed, but this agricultural activity does not yet fit into a commercial-scale production system. In its production, the extractive model predominates, in which species are still in the process of domestication. As a result, there are many gaps in the yellow mombin cultivation system, especially in relation to mineral nutrition, which makes current fertilization recommendations based on other fruit species.

Among the nutrients for the development of fruit trees, N and K stand out, as they are nutrients required for the adequate production quality of fruit (Xu et al., 2020). However, by applying N fertilization, the efficiency of nutrient use by young and mature fruit trees is generally less than 55% (Carranca et al., 2018). Therefore, the nutrients should be applied in adequate rates. This procedure can optimize the nutrient efficiency of use by plants and reduce the costs of unnecessary fertilizer application, minimizing nutrient losses, and ensuring environmental sustainability.

The objective of this work was to evaluate the effects of N and K combination rates on the initial growth of 'Lagoa Redonda' yellow mombin.

## Materials and Methods

The experiment was carried out at Embrapa Agroindústria Tropical, located in the municipality of Fortaleza, in the state of Ceará, Brazil (3°45'05.0"S, 38°34'35.5"W, at 19.5 m altitude), in a screen house, covered with plastic to reduce solar radiation by 50%. It was conducted in a randomized block design, with $5^2$ fractional factorial arrangement with five N rates (0, 100, 200, 300, and 400 mg dm$^{-3}$), five K rates (0, 100, 200, 300, and 400 mg dm$^{-3}$), with five replicates. According to procedures described by Littel & Mott (1975), 13 combinations were obtained: 0 N and 0 K; 0 N and 200 K; 0 N and 400 K; 100 N and 100 K; 100 N and 300 K; 200 N and 0 K; 200 N and 200 K; 200 N and 400 K; 300 N and 100 K; 300 N and 300 K; 400 N and 0 K; 400 N and 200 K; and 400 N and 400 K. Nitrogen and potassium rates were based on the fertilizer recommendation for the first year of *Spondias* sp. cultivation, proposed by Souza et al. (2020): 250 g urea per plant; and 180 g potassium chloride per plant. Each experimental unit consisted of a 20 L pot of soil and one yellow mombin seedling.

Soil samples of an Argissolo Vermelho-Amarelo, according to Brazilian Soil Classification System (Santos et al., 2018), corresponding to an Arenic Haplustults, were collected at 0–20 cm soil depth. Subsequently, the samples were air dried, sieved through a 2 mm mesh, homogenized and subjected to chemical analyses according to procedures described in Teixeira et al. (2017). The soil presented the following characteristics: pH $H_2O$, 6.1; soil organic matter (Walkley-Black method), 5.0 g kg$^{-1}$; P, 42 g kg$^{-1}$; $K^+$, 0.6 mmol$_c$ kg$^{-1}$; $Na^+$, 2.2 mmol$_c$ kg$^{-1}$; $Ca^{2+}$, 11.9 mmol$_c$ kg$^{-1}$; $Mg^{2+}$, 4.4 mmol$_c$ kg$^{-1}$; $Al^{3+}$, 0.0 mmol$_c$ kg$^{-1}$; H+Al, 8.9 mmol$_c$ kg$^{-1}$; CEC (T), 28.0 mmol$_c$ kg$^{-1}$; base saturation (V), 68.2%; Cu, 0.4 mg kg$^{-1}$; Fe, 17.0 mg kg$^{-1}$; Mn, 15.0 mg kg$^{-1}$; and Zn, 6.7 mg kg$^{-1}$. The soil granulometric analysis by pipette method showed the following results: sand, 915 g kg$^{-1}$; silt, 34 g kg$^{-1}$; and clay, 51 g kg$^{-1}$.

Plastic pots with a 20 L capacity were used, which were filled with 23.4 kg soil, equivalent to 18 L soil. Liming was not applied, since the soil had a base saturation close to 70%, which is recommended for *Spondias* sp. (Neves et al., 2008). The amount of phosphorus was based on the recommendation of 300 g per pothole of simple superphosphate (20% of $P_2O_5$), proposed by Souza et al. (2020). The amount of micronutrients was based on the recommendation of 5 mg dm$^{-3}$ of Zn (Corrêa et al., 2014), using FTE BR-12 as Zn source (9% of Zn; 1.8% of B; 0.8% of Cu; 0.1% of Mo; and 2.0% of Mn).

'Lagoa Redonda' yellow mombin (*Spondias mombin*) seedlings were obtained from a commercial nursery. This clone was used because it is very vigorous, with very thick stems and high productivity (Souza et al., 2006). One yellow mombin seedling was grown in each pot. Afterwards, water was added to reach 70% of the water retention capacity, previously determined in the laboratory.

The seedlings were transplanted into the pots in May 2021, and the treatments began one month after. The fertilizer rates containing N and K were diluted in deionized water and divided over 12 months to avoid soil salinization, and the solution was applied to the soil surface. Urea (45% N) and potassium chloride (60% $K_2O$) were used as sources of N and K, respectively.

During the experiment, the irrigation was applied manually three times a week, to maintain the water retention capacity mentioned above. Weeds were removed manually, and agricultural pesticides were applied to control aphids and mites.

In June 2022, one year after the start of the treatments, the plants were evaluated as following descriptions. Height (cm) was measured from the soil surface to the apex of the plant, with the aid of a graduated ruler. The number of leaves was counted in plants with 13 to 15 leaflets. Stem diameter (mm) was determined with a digital caliper, at the base of the stem, one centimeter from the soil surface. Subsequently, the plants were cut and separated into leaves, petioles, stem, and roots, which were washed in tap water, 3% hydrochloric acid solution, and deionized water. After these procedures, the plants were dried in a forced-air circulation oven at 65°C, until constant mass was attained, to obtain leaves, stem, petiole and roots dry matter (g per plant).

Data were analyzed using the SAS software (SAS Institute Inc, 2012). The F-test was applied, and the polynomial regression analysis, using response surface, was calculated by the PROC RSREG function when N x K interaction was significant. In the absence of N x K interaction, the models of first- and second-degree regression analyses were adjusted using the PROC GLM function, at 5% probability. When the second-degree regression model was significant, the maximum point was obtained by using the first derivative of the regression equation.

## Results and Discussion

Nitrogen rates promoted changes in the number of leaves and height of 'Lagoa Redonda' yellow mombin (Table 1).

The number of leaves was adjusted to the positive linear model (Figure 1 A), while the height of plants was adjusted to the second-order polynomial regression, and the maximum value was obtained with the application of 340 mg $dm^{-3}$ N (Figure 1 B). Height of yellow mombin seedlings had 46% increase, in comparison with the treatment not fertilized with N, confirming the importance of this nutrient for plant growth, especially in the first year of cultivation.

In a study by Neves et al. (2007a), the height of Brazil plum seedlings was adjusted to the second-order polynomial regression, with the highest value obtained with 272 mg $dm^{-3}$ N.

Excess application of fertilizers, when requirements are low, or when local conditions are unfavorable, surpass the plant’s needs, causing various physiological reactions, nutritional imbalances, decline of soil organic matter content, and decrease of soil quality and low quality of orchards (Albornoz, 2016). Excess N application causes yield reduction to various crops, and severely threat the orchard ecological environment (Zhu et al., 2018). Fruit trees can be more susceptible to disease attack and show premature fruit fall (Carranca et al., 2018).

Young fruit trees need N fertilizer, and the supply of this nutrient should never be limited. Low rates make it difficult to uptake and transport nitrate ($NO_3^-$) and ammonium ($NH_4^+$) ions to plant cells, thus harming the vegetative development of the tree (Carranca et al., 2018; Façanha et al., 2019).

**Table 1.** Biometric parameters of 'Lagoa Redonda' yellow mombin (*Spondias mombin*) plant as affected by N and K rates.

| Factor | Rate (mg $dm^{-3}$) | Number of leaves | Stem diameter (mm) | Plant height (cm) |
|---|---|---|---|---|
| | 0 | 15.8 | 19.0 | 48.7 |
| | 100 | 22.0 | 24.7 | 68.0 |
| N | 200 | 20.2 | 22.4 | 68.9 |
| | 300 | 23.3 | 26.0 | 69.8 |
| | 400 | 28.2 | 23.9 | 75.3 |
| | 0 | 18.4 | 23.6 | 63.6 |
| | 100 | 25.5 | 25.9 | 73.8 |
| K | 200 | 21.4 | 21.2 | 68.5 |
| | 300 | 20.1 | 24.8 | 64.1 |
| | 400 | 22.8 | 20.6 | 60.8 |
| | | F-test | | |
| N | | 3.72* | $2.63^{ns}$ | 3.38* |
| K | | $0.20^{ns}$ | $0.73^{ns}$ | $0.97^{ns}$ |
| N x K | | $0.16^{ns}$ | $0.82^{ns}$ | $0.10^{ns}$ |
| CV (%) | | 38.21 | 22.34 | 17.63 |

*Significant at 5% probability. $^{ns}$Nonsignificant. CV, coefficient of variation.


DOI: 10.1590/S1678-3921.pab2024.v59.03679

Nitrogen rates applied to the soil did not affect stem diameter, which corroborates the results for Brazil plum plants found by other authors (Melo et al., 2005; Neves et al., 2007a; Lacerda et al., 2009; Andrade et al., 2013).

Potassium rates, as well as the interaction with N, did not influence the number of leaves, stem diameter, and plant height of 'Lagoa Redonda' yellow mombin (Table 1). A possible explanation for the lack of effect of the K rates could be the low demand for the nutrient in the initial growth of yellow mombin, even when grown in soil with a low K concentration (0.6 $mmol_c\ kg^{-1}$).

Although the lack of K effect on yellow mombin was observed in the present experiment, other authors found otherwise for the biometric characteristics in Brazil plum (also a species of the *Spondias* genus), since K influenced plant height and stem diameter in this species (Neves et al., 2007b). Stem thickness of Brazil plum decreased linearly with K fertilization; and seedling height was adjusted to the second-order polynomial regression, with the maximum height obtained with 188.14 mg $dm^{-3}$ of K (Neves et al. 2007b).

Several external factors affect the nutrient uptake by plants, such as temperature, humidity, aeration, pH, ionic interactions, and symbiotic interactions with soil organisms (Façanha et al., 2019). Ionic interactions between ammonium ($NH_4^+$) and potassium ($K^+$) ions can reduce K availability to plants, such as the N amount applied, the time of application, and the source used, as they can influence these interactions (Zhang et al., 2010).

A study on nutrient stocks and nutritional efficiency of woody species in tropical forests showed that Brazil plum (*Spondias tuberosa*) was one of the species that best utilized potassium (Barbosa et al., 2019). It also suggests that, even in conditions of low nutrient

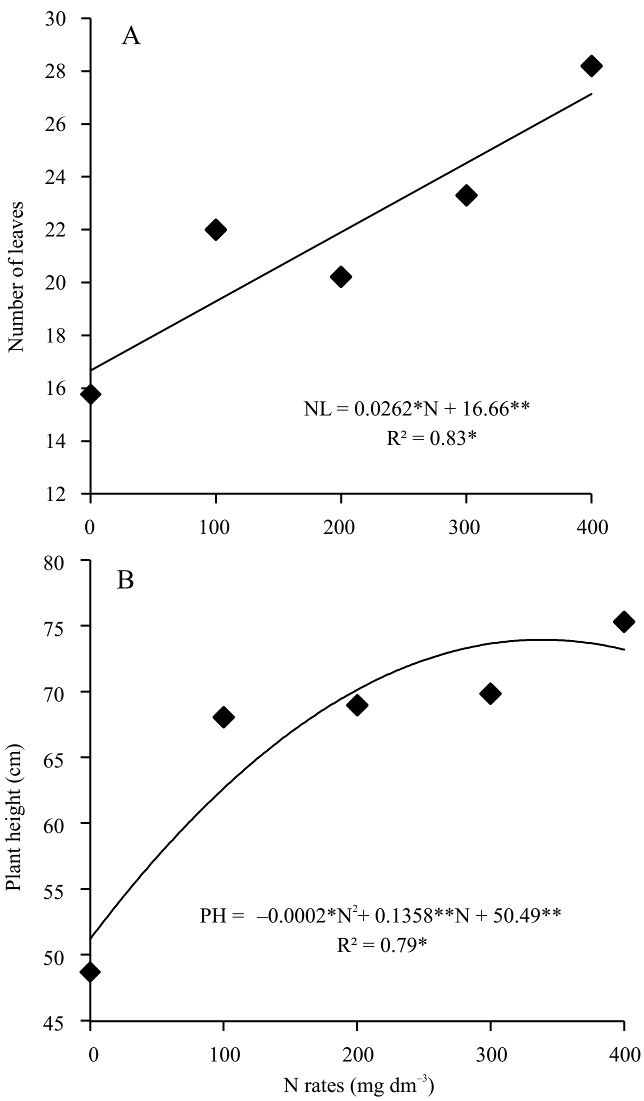


**Figure 1.** 'Lagoa Redonda' yellow mombin (*Spondias mombin*) as affected by nitrogen rates for: NL, number of leaves; PH, plant height. **, *Significant at 1% and 5% probability, respectively.

**Table 2.** Biomass characteristics of 'Lagoa Redonda' yellow mombin (*Spondias mombin*) as affected by N and K rates.

| Factor | Rates (mg $dm^{-3}$) | StDM | PDM | LDM | ShDM | RDM | TDM |
|---|---|---|---|---|---|---|---|
| | | (g per plant) | | | | | |
| N | 0 | 21.9 | 2.9 | 12.3 | 37.1 | 83.8 | 120.9 |
| | 100 | 47.2 | 5.9 | 30.3 | 83.4 | 107.3 | 190.7 |
| | 200 | 43.4 | 5.1 | 22.0 | 70.6 | 115.1 | 185.7 |
| | 300 | 52.7 | 5.9 | 27.9 | 86.6 | 156.4 | 243.0 |
| | 400 | 51.6 | 6.4 | 26.7 | 84.7 | 109.9 | 194.6 |
| K | 0 | 45.2 | 5.3 | 23.4 | 74.0 | 112.7 | 186.7 |
| | 100 | 44.8 | 6.1 | 29.4 | 80.2 | 139.9 | 220.1 |
| | 200 | 39.7 | 5.1 | 20.7 | 65.4 | 99.5 | 165.0 |
| | 300 | 55.2 | 5.7 | 28.9 | 89.7 | 123.8 | 213.5 |
| | 400 | 32.0 | 4.0 | 16.9 | 52.9 | 96.5 | 149.4 |
| | | F-test | | | | | |
| N | | 6.87** | 5.93** | 3.77* | 8.21** | $2.40^{ns}$ | 4.92** |
| K | | $0.76^{ns}$ | $1.70^{ns}$ | $1.15^{ns}$ | $1.31^{ns}$ | $0.59^{ns}$ | $0.87^{ns}$ |
| N x K | | 0.05 | $1.39^{ns}$ | $0.42^{ns}$ | $0.05^{ns}$ | $0.75^{ns}$ | $0.35^{ns}$ |
| CV (%) | | 34.99 | 34.96 | 39.87 | 29.91 | 39.09 | 30.79 |

**, *Significant at 1% and 5% probability. $^{ns}$Nonsignificant. Dry matter of the following plant parts: StDM, stems; PDM, petioles; LDM, leaves; ShDM, shoots; RDM, roots (RDM); and TDM, total dry matter.


DOI: 10.1590/S1678-3921.pab2024.v59.03679

availability in the soil, the plant showed efficiency in uptake, transport, and use of K for its growth and development, and it is recommended as an alternative for reforestation plants in less fertile soils, such as those of Brazil's Northeastern Semiarid region.

The N rates promoted changes in the following analyzed parameters: stem, petiole, leaves, shoot, and total dry matter (Table 2). The dry matter (DM) of the plants parts – stem (StDM), petiole (PDM), leaves (LDM) and shoots (ShDM) – were adjusted to the second-order polynomial regression (Figures 2 A, B, C, and D). The maximum productions of StDM, PDM, LDM, and ShDM were obtained by the application of 288, 292, 225, and 280 mg dm$^{-3}$ N, respectively.

Neves et al. (2007a) also studied responses of Brazil plum seedlings to N rates, and they observed an increase of the dry matter accumulation of stem, leaves, roots, and total dry matter. The N rates of

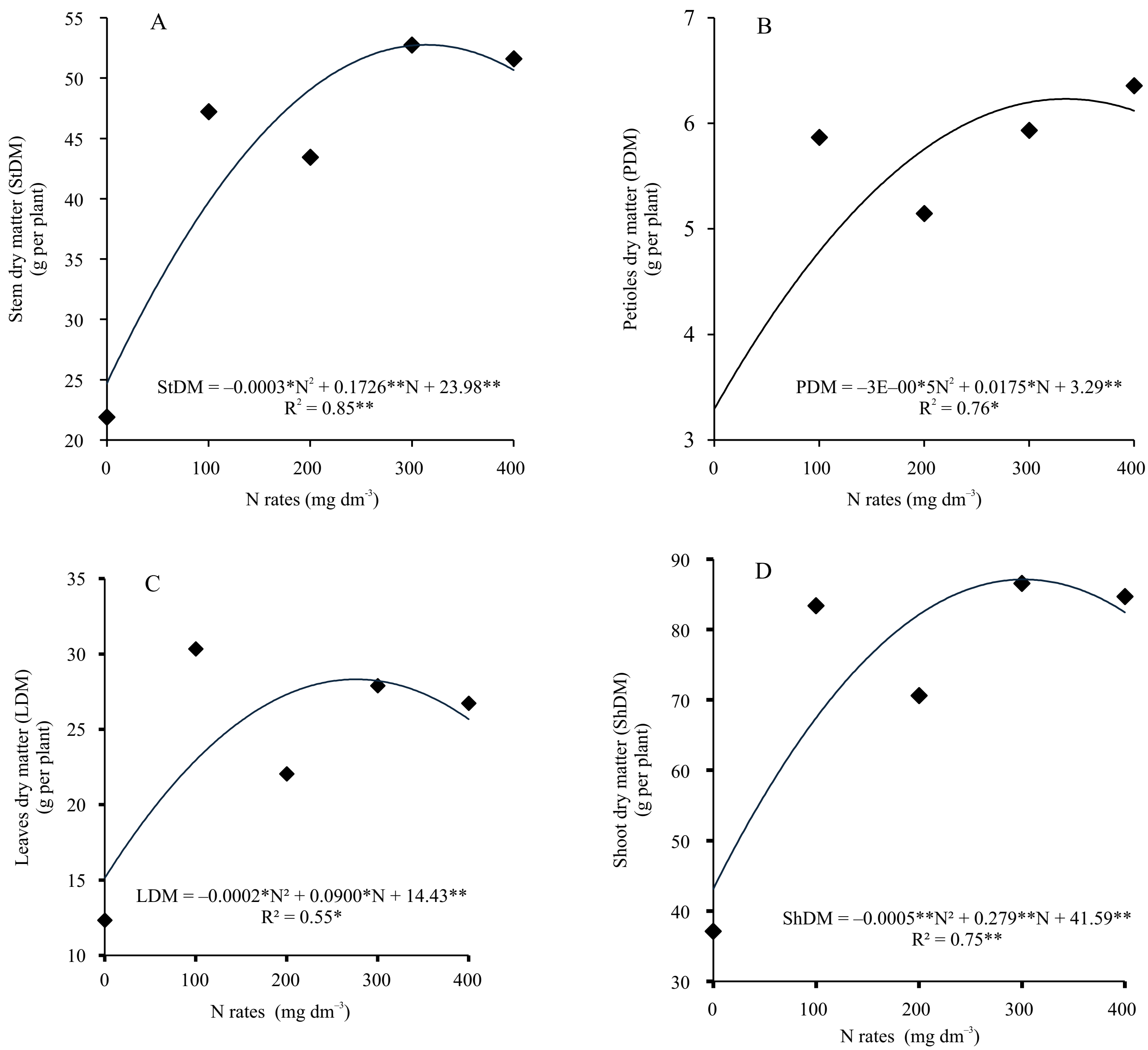


**Figure 2.** Dry matter of 'Lagoa Redonda' yellow mombin (*Spondias mombin*) as affected by N rates in the following plant parts: A, StDM, stems; B, PDM, petioles; C, LDM, leaves; and D, ShDM, shoots. **, *: Significant at 1% and 5% probability, respectively.

286 and 226 mg dm$^{-3}$ were those that provided the maximum production of stem and leaves dry matter, respectively.

Shoot dry matter (ShDM) is a parameter that shows the vigor of plants and their photosynthetic capacity in response to fertilization, being an important characteristic for the evaluation of biomass (Cruz et al., 2010). Using the nutrient omission methodology, Silva et al. (2005) found that the absence of N, followed by those of P and Ca, were the ones that most limited the growth of height and diameter, as well as the ShDM of Brazil plum plants.

Yellow mombin root dry matter (RDM) was not influenced by N rates. RDM is an important indicator to assess the survival and initial development of seedlings in the field, and at this stage of development, N plays a more relevant role in the plant shoots, that is, in the bud formation and leaf area expansion (Pinto et al., 2016).

Nitrogen rates influenced the yellow mombin total dry matter (TDM) (Figure 3). The estimated rate of 296 mg dm$^{-3}$ N resulted in maximum TDM production, representing a greater increase of 80% in relation to the N absence, showing how N rates positively influenced the plant biomass production. Similar results were obtained by Neves et al. (2007a), who found that 286 mg dm$^{-3}$ N provided the maximum Brazil plum TDM production.

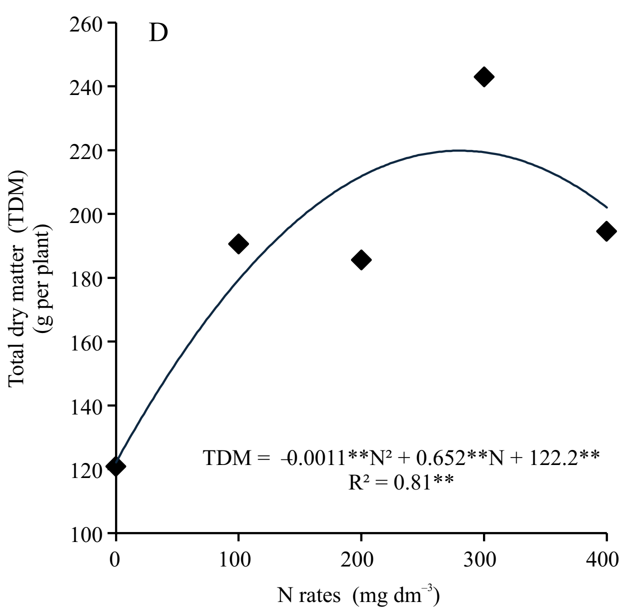


**Figure 3.** Total dry matter (TDM) of 'Lagoa Redonda' yellow mombin (*Spondias mombin*) as affected by N rates. **Significant at 1% probability.

Thus, high N rates, in addition to not leading positive results to plant development, can promote soil acidification, since N-transformation processes contribute to the production and consumption of $H^+$ ions, affecting the soil pH (Wang et al., 2023).

Potassium rates, as well as the interaction between the factors, did not influence the biomass parameters.

Divergent results were found in the study on Brazil plum seedlings, in which K fertilization significantly affected the dry matter of roots, stem, leaves, and total dry matter, as well as the shoot/root ratio of seedlings (Neves et al., 2007b).

## Conclusions

1. Potassium rates, as well as the interaction with nitrogen, do not promote an increase in the initial growth and dry matter production of 'Lagoa Redonda' yellow mombin (*Spondias mombin*).
2. Fertilization at 296 mg dm$^{-3}$ N increases the total dry matter production in the initial growth of the 'Lagoa Redonda' yellow mombin.

## Acknowledgments

To Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes, Finance Code 001), for the grant to the first author; and to Empresa Brasileira de Pesquisa Agropecuária (Embrapa), for financial support.

## References

ALBORNOZ, F. Crop responses to nitrogen overfertilization: a review. **Scientia Horticulturae**, v.205, p.79-83, 2016. DOI: https://doi.org/10.1016/j.scienta.2016.04.026.

ANDRADE, M.W. de; MENDONÇA, V.; HAFLE, O.M.; MEDEIROS, P.V.Q. de; MENDONÇA, L.F. de M. Adubos nitrogenados e potássicos na produção de porta-enxertos de umbuzeiro (*Spondias tuberosa* Arr. Cam.). **Revista Caatinga**, v.26, p.117-122, 2013.

BARBOSA, M.D.; FREIRE, F.J.; MARANGON, L.C.; FELICIANO, A.L.P.; LIMA, R.B. de A.; SILVA, R.K.S. da. Nutrient stock and nutritional efficiency of woody species in dry tropical forest as reforestation indicators. **Revista Ceres**, v.66, p.387-394, 2019. DOI: https://doi.org/10.1590/0034-737X201966050008.

CARRANCA, C.; BRUNETTO, G.; TAGLIAVINI, M. Nitrogen nutrition of fruit trees to reconcile productivity and environmental concerns. **Plants**, v.7, art.4, 2018. DOI: https://doi.org/10.3390/plants7010004.

CORRÊA, M.C. de M.; ALMEIDA, E.I.B.; MARQUES, V.B.; SILVA, J.C. do V.; AQUINO, B.F. de. Crescimento inicial de pitaia em função de combinações de doses de fósforo-zinco. **Revista Brasileira de Fruticultura**, v.36, p.261-270, 2014. DOI: https://doi.org/10.1590/0100-2945-297/13.

CRUZ, C.A.F. e; PAIVA, H.N. de; NEVES, J.C.L.; CUNHA, A.C.M.C.M. da. Resposta de mudas de *Senna macranthera* (Dc. ex collad.) H.S. Irwin & Barnaby (Fedegoso) cultivadas em Latossolo Vermelho-Amarelo distrófico a macronutrientes. **Revista Árvore**, v.34, p.13-24, 2010. DOI: https://doi.org/10.1590/S0100-67622010000100002.

FAÇANHA, A.R.; CANELLAS, L.P.; DOBBSS, L.B. Nutrição Mineral. In: KERBAUY, G. B. **Fisiologia Vegetal**. 3.ed. Rio de Janeiro: Guanabara Koogan, 2019. p.35-51.

LACERDA, J.S.; PEREIRA, W.E.; DIAS, T.J.; FREIRE, J.L.O.; BRITO NETO, J.F.; COSTA, D.S.; OLIVEIRA, C.J. de. Avaliação do crescimento de porta-enxertos de umbuzeiro (*Spondias tuberosa*) em substratos adubados com nitrogênio e boro. **Engenharia Ambiental**, v.6, p.519-531, 2009.

LITTEL, R.C.; MOTT, G.O. Computer assisted design and analysis of response surface experiments in Agronomy. **Soil and Crop Science Society of Florida Proceedings**, v.34, p.94-97, 1975.

MACHADO, C. de F.; OLIVEIRA, V.R. de; ALVES, R.M.; VASCONCELOS, L.F.L.; SOUZA, F.X. de; RITZINGER, R.; FONSECA, N.; SOARES FILHO, W. dos S.; CASTRO, A.C.R. de. Bancos genéticos de cajá, umbu e espécies afins. In: SILVA JUNIOR, J.F. da; SOUZA, F.V.D.; PADUA, J.G. (Ed.). **A arca de Noé das frutas nativas brasileiras**. Brasília: Embrapa, 2021. p.120-140.

MELO, A.S. de; GOIS, M.P.P.; BRITO, M.E.B.; VIÉGAS, P.R.A.; ARAÚJO, F.P. de; MÉLO, D.L.M.F. de; MENDONÇA, M. da C. Desenvolvimento de porta-enxertos de umbuzeiro em resposta à adubação com nitrogênio e fósforo. **Ciência Rural**, v.35, p.324-331, 2005. DOI: https://doi.org/10.1590/S0103-84782005000200012.

MITCHELL, J.D.; DALY, D.C. A revision of *Spondias* L. (Anacardiaceae) in the Neotropics. **PhytoKeys**, v.55, p.1-92, 2015. DOI: https://doi.org/10.3897/phytokeys.55.8489.

MITCHELL, J.D.; PELL, S.K.; BACHELIER, J.B.; WARSCHEFSKY, E.J.; JOYCE, E.M.; CANADELL, L.C.; SILVA-LUZ, C.L. da; COIFFARD, C. Neotropical Anacardiaceae (cashew family). **Brazilian Journal of Botany**, v.45, p.139-180, 2022. https://doi.org/10.1007/s40415-022-00793-5.

NEVES, O.S.C.; CARVALHO, J.G. de; FERREIRA, E.V. de O.; ASSIS, R.P. de. Nutrição mineral, crescimento e níveis críticos foliares de cálcio e magnésio em mudas de umbuzeiro, em função da calagem. **Ceres**, v.55, p.575-583, 2008.

NEVES, O.S.C.; CARVALHO, J.G. de; FERREIRA, E.V. de O.; PEREIRA, N.V. Crescimento, nutrição mineral e nível crítico foliar de K em mudas de umbuzeiro, em função da adubação potássica. **Ciência e Agrotecnologia**, v.31, p.636-642, 2007b. DOI: https://doi.org/10.1590/S1413-70542007000300006.

NEVES, O.S.C.; CARVALHO, J.G. de; FERREIRA, E.V.O.; PEREIRA, N.V.; NEVES, V.B.F. Efeito da adubação nitrogenada sobre o crescimento e acúmulo de nutrientes em mudas de umbuzeiro. **Revista Brasileira de Ciências Agrárias**, v.2, p.200-207, 2007a. DOI: https://doi.org/10.5039/agraria.v2i3a384.

PINTO, J.V. da C.; VIEIRA, M. do C.; ZÁRATE, N.A.H.; FORMAGIO, A.S.N.; CARDOSO, C.A.L.; CARNEVALI, T.O.; SOUZA, P.H.N. de. Effect of soil nitrogen and phosphorus on early development and essential oil composition of *Schinus terebinthifolius* Raddi. **Journal of Essential Oil-Bearing Plants**, v.19, p.247-257, 2016. DOI: https://doi.org/10.1080/0972060X.2014.977561.

SANTOS, H.G. dos; JACOMINE, P.K.T.; ANJOS, L.H.C. dos; OLIVEIRA, V.Á. de; LUMBRERAS, J.F.; COELHO, M.R.; ALMEIDA, J.A. de; ARAÚJO FILHO, J.C. de; OLIVEIRA, J.B. de; CUNHA, T.J.F. **Sistema brasileiro de classificação de solos**. 5.ed. rev. e ampl. Brasília: Embrapa, 2018. 356p.

SAS INSTITUTE INC. **SAS/STAT 12.1 User's Guide**. Cary, 2012.

SILVA, E. de B.; GONÇALVES, N.P.; PINHO, P.J. de. Limitações nutricionais para crescimento de mudas de umbuzeiro em Latossolo Vermelho distrófico no Norte de Minas. **Acta Scientiarum. Agronomy**, v.27, p.55-59, 2005. DOI: https://doi.org/10.4025/actasciagron.v27i1.1923.

SOUSA, R.P. de; ASSIS, J.P. de; LIMA, I.R.P. de; FRANÇA, J. de A.; SOUSA, R.P. de. Biometric analysis of cajazeira fruits (*Spondias mombin* L.) in the northeastern Brazil. **Revista Observatorio de La Economia Latinoamericana**, v.21, p.8804-8826, 2023. DOI: https://doi.org/10.55905/oelv21n8-054.

SOUZA, F.X. de; COSTA, J.T.A.; LIMA, R.N. de; CRISÓSTOMO, J.R. Crescimento e desenvolvimento de clones de cajazeira cultivados na Chapada do Apodi, Ceará. **Revista Brasileira de Fruticultura**, v.28, p.414-420, 2006. DOI: https://doi.org/10.1590/S0100-29452006000300017.

SOUZA, F.X. de; PORTO FILHO, F. de Q.; MENDES, N.V.B. **Umbu-cajazeira**: descrição e técnicas de cultivo. Mossoró: EdUFERSA, 2020. DOI: https://doi.org/10.7476/9786587108599.

TEIXEIRA, P.C.; DONAGEMMA, G.K.; FONTANA, A.; TEIXEIRA, W.G. (Ed.). **Manual de métodos de análise de solo**. 3.ed. rev. e ampl. Brasília: Embrapa, 2017.

VASCONCELOS, L.H.C.; EVANGELISTA, Z.R.; CAMPOS, A.J. de; TEIXEIRA, I.R. Diferentes embalagens na conservação pós-colheita de cajá-manga. **Revista Espacios**, v.38, p.26, 2017.

WANG, Z.; TAO, T.; WANG, H.; CHEN, J.; SMALL, G.E.; JOHNSON, D.; CHEN, J.; ZHANG, Y.; ZHU, Q.; ZHANG, S.; SONG, Y.; KATTGE, J.; GUO, P.; SUN, X. Forms of nitrogen inputs regulate the intensity of soil acidification. **Global Change Biology**, v.29, p.4044-4055, 2023. DOI: https://doi.org/10.1111/gcb.16746.

XU, X.; DU, X.; WANG, F.; SHA, J.; CHEN, Q.; TIAN, G.; ZHU, Z.; GE, S.; JIANG, Y. Effects of potassium levels on plant growth, accumulation and distribution of carbon, and nitrate metabolism in apple dwarf rootstock seedlings. **Frontiers in Plant Science**, v.11, art.904, 2020. DOI: https://doi.org/10.3389/fpls.2020.00904.

ZHANG, F.; NIU, J.; ZHANG, W.; CHEN, X.; LI, C.; YUAN, L.; XIE, J. Potassium nutrition of crops under varied regimes of nitrogen supply. **Plant and Soil**, v.335, p.21-34, 2010. DOI: https://dx.doi.org/10.1007/s11104-010-0323-4.

ZHU, Z.; JIA, Z.; PENG, L.; CHEN, Q.; HE, L.; JIANG, Y.; GE, S. Life cycle assessment of conventional and organic apple production systems in China. **Journal of Cleaner Production,** v.201, p.156-168, 2018. DOI: https://doi.org/10.1016/j.jclepro.2018.08.032.