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Diagnosis of leaf nutrient content for 'common' arrowroot plants fertilized with ovine manure

Diagnose foliar da araruta 'comum' adubada com biofertilizante ovino

Diagnóstico foliar de flecha 'común' fertilizada con biofertilizante oveja

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Abstract

Despite arrowroot's (*Maranta arundinaceae* L.) appeal in several industry sectors, which indicates high potential for large-scale production, few studies have investigated the nutritional status of this crop species. Given the economic relevance of the crop and the limited data in the literature, the objective of this work was to evaluate the nutritive effect of the ovine biofertilizer in the cultivation of arrowroot 'comum', in two evaluation periods 180 and 272 days after planting (DAP). The experiment was laid out as a split-plot randomized complete block design with four replicates. Leaf contents of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), boron (B), and sodium (Na) were determined. High K and Na contents were observed in arrowroot leaves. The sheep biofertilizer is suitable to meet the nutritional needs of arrowroot 'common'. The continuous application of biofertilizer provided higher levels of nutrients at 272 days after planting.

Keywords: Organic fertilizer; Vegetable crops; *Maranta arundinaceae* L.; Plant nutrition.

Resumo

Estudos sobre o estado nutricional da araruta (*Maranta arundinaceae* L.) são limitados, apesar desta planta possuir aplicações em diversos campos industriais demostrando alto potencial para produção em larga escala. Diante da relevância econômica da cultura e pela limitação de dados na literatura, o trabalho teve como objetivo avaliar o efeito nutritivo do biofertilizante ovino no cultivo da araruta 'comum', em dois períodos de avaliação 180 e 272 dias após o transplantio (DAP). O delineamento experimental foi em blocos casualizados, no esquema de parcelas subdivididas, com quatro repetições. Os teores foliares de nitrogênio (N), fósforo (P), potássio (K), cálcio (Ca), magnésio (Mg), enxofre (S), ferro (Fe), zinco (Zn), cobre (Cu), manganês (Mn), boro (B) e sódio (Na) foram determinados. Potássio e sódio foram os elementos encontrados em maiores concentrações nas folhas. O biofertilizante ovino é adequado para suprir as necessidades nutricionais da araruta 'comum'. A aplicação contínua de biofertilizante proporcionou maiores teores de nutrientes aos 272 dias após o plantio.

Palavras-chave: Adubo orgânico; Hortaliças; Maranta arundinaceae L.; Nutrição de plantas.

Resumen

Los estudios sobre el estado nutricional del arrurruz (*Maranta arundinaceae* L.) son limitados, aunque esta planta tiene aplicaciones en varios campos industriales mostrando un alto potencial para la producción a gran escala. Dada la relevancia económica del cultivo y los escasos datos en la literatura, el objetivo de este trabajo fue evaluar el efecto

nutritivo del biofertilizante ovino en el cultivo de arrurruz ‘comum’, en dos periodos de evaluación 180 y 272 días después de la siembra. El diseño experimental fue en bloques al azar, en un esquema de parcelas divididas, con cuatro repeticiones. Contenido foliar de nitrógeno (N), fósforo (P), potasio (K), calcio (Ca), magnesio (Mg), azufre (S), hierro (Fe), zinc (Zn), cobre (Cu), manganeso (Mn), boro (B) y sodio (Na) se determinaron. El potasio y el sodio fueron los elementos que se encontraron en mayor concentración en las hojas. El biofertilizante ovino es adecuado para cubrir las necesidades nutricionales del arrurruz ‘común’. La aplicación continua de biofertilizante proporcionó mayores niveles de nutrientes a los 272 días después de la siembra.
Palabras clave: Abono orgánico; Hortalizas; *Maranta arundinaceae* L.; Nutrición vegetal.

1. Introduction

Arrowroot (*Maranta arundinaceae* L.) is a starchy, herbaceous, erect, and rhizomatous vegetable crop, with little information about its optimal plant density, irrigation, and fertilization needs, as well as its adequate nutritional status available (Souza et al., 2018). Arrowroot’s commercial production is still small as a result of the non-adoption of technical practices during its cultivation (Moreno et al., 2017). However, this scenario may change with the establishment of new cropping systems, allowing its expansion, especially by small growers that will be able to take advantage of its market potential (Souza et al., 2018).

Arrowroot is a vegetable crop that can be used both for industrial and human consumption, although little research information about its physiology and nutrition is available to growers. However, attempts to investigate arrowroot nutrient status by assessing macro and micronutrient levels on leaf dry matter (Menezes Júnior et al., 2014), and therefore establish fertilization recommendations for the arrowroot crop have been made.

With the increasing expansion of organic agriculture in Brazil as well as in the rest of the world, biofertilizers have been more and more applied to agricultural fields. Several studies address the use of animal waste as an input for crop production, reducing costs and at the same time providing benefits to plants and soil (Sediyama et al., 2016). In addition, organic fertilizers can either supplement or even replace mineral fertilization in several crop fields (Azevedo et al., 2020).

Considering the arrowroot’s economic value, the lack of technical knowledge for proper arrowroot cultivation, and the increasing use of organic fertilizer sources, the objective was to evaluate the nutritive effect of the ovine biofertilizer in the cultivation of arrowroot ‘comum’ through foliar diagnosis in two evaluation periods.

2. Methodology

The experiment was carried out at full, from November 2018 to August 2019, at the Research Farm Unit Piroás (PRFU), belonging to Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), and located at Barra Nova, Redenção district-CE, Brazil, in Maciço de Baturité (04°13’S; 38°43’, and altitude of 340 m). The regional climate is characterized as hot semi-arid, with rainfall occurring from January to April, average temperature of 27° C, and average annual precipitation of 117.86 and 122.73 mm in 2018 and 2019, respectively.

‘Common’ arrowroot (*Maranta arundinaceae* L.) plants were grown out of rhizomes obtained from PRFU. Arrowroot rhizomes were planted in 39.5 L-pots with the following dimensions: upper diameter of 36.6 cm; lower diameter of 27.0 cm; and 50 cm in height. Pots and rows were spaced 0.5 m and 1.0 m apart, respectively.

Pots were filled with 5 L of nº 1 gravel, sand and soil at 2:1 ratio. Chemical attributes of the substrate at the beginning of the experiment were: C = 3.5 g kg^{-1}; O.M. = 6 g kg^{-1}; pH = 6.1; P = 44 mg dm^{-3}; K+ = 2 mmolc dm^{-3}; Ca^{2+} = 21.4 mmolc dm^{-3}; Mg^{2+} = 6.6 mmolc dm^{-3}; Na^{+} = 2 mmolc dm^{-3}; $H^{+}+Al^{3+}$ = 11 mmolc dm^{-3}; SB = 31.9 mmolc dm^{-3}; CEC = 42.9 mmolc dm^{-3}; BS = 75%; ESP = 4.33%, and EC = 0.62 dS m^{-1}.

The experiment was laid out as a split-plot randomized complete block design with four replicates. Two evaluation periods, 180 and 272 DAP were assigned to the main plots, and five increasing biofertilizer doses, 0, 300, 600, 900, and 1.200

mL per plant per week, were assigned to the sub-plots.

The fertilizer was produced in the Biofertilizer Station located at the PRFU by adding 100 L of fresh ovine manure, 30 L of chicken manure, 5 L of charcoal ashes, and 270 L of water. All ingredients were poured into a 500 L water tank where they remained for 30 days, the time needed to decompose the organic matter (Viana et al., 2013).

After the fermentation period, we performed a chemical analysis of the biofertilizer. Chemical attributes of the biofertilizer are following described. N = 0.32 g L^{-1}; P = 0.17 g L^{-1}; K = 0.05 g L^{-1}; Ca^{2+} = 0.74 g L^{-1}; Mg^{2+} = 0.28 g L^{-1}; Fe = 58 mg L^{-1}; Zn = 2 mg L^{-1}; Cu = 0 mg L^{-1}; Mn = 8 mg L^{-1}; EC = 7.5 dS m^{-1}; C = 0.17%; OM = 0.31%; C/N ratio = 5%, and pH = 6.7. Table 1 shows the total amount of each nutrient present in each dose supplied to the plants.

Table 1 - Quantities of nutrients present in the doses of ovine biofertilizer.

	Nutrients								
	N	P	K	Ca^{2+}	Mg^{2+}	Fe	Zn	Cu	Mn
Doses (mL)	g $Dose^{-1}$					mg $Dose^{-1}$			
300	0.096	0.051	0.015	0.222	0.084	17.4	0.6	0.0	2.4
600	0.192	0.102	0.030	0.444	0.168	34.8	1.2	0.0	4.8
900	0.288	0.153	0.045	0.666	0.252	52.2	1.8	0.0	7.2
1.200	0.384	0.204	0.060	0.888	0.336	69.6	2.4	0.0	9.6

Source: Authors.

The biofertilizer was manually applied to the arrowroot plants according to the doses previously established for each treatment using a graduated container. We performed two biofertilizer applications per week, from the 15th DAP and on. Thirty centimeters-long PVC pipes were placed next to plants at a depth of 10 cm. The biofertilizer was poured inside the PVC pipes, making it easy fertilizer infiltration along the substrate and so nutrient uptake by plants.

Water was provided via drip irrigation, with two drippers per pot, and at an average flow rate of 8 L h^{-1}. Irrigation depth was calculated according to the evaporation of the class A-pan in a daily frequency.

To determine leaf nutrient content of arrowroot plants, we collected four mature leaves from the middle part of the main stem 180 and 272 days after planting. Leaf samples were sent to the Soil, Water and Plant Laboratory (LABSAT) located at Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE), Campus Limoeiro do Norte – CE, Brazil.

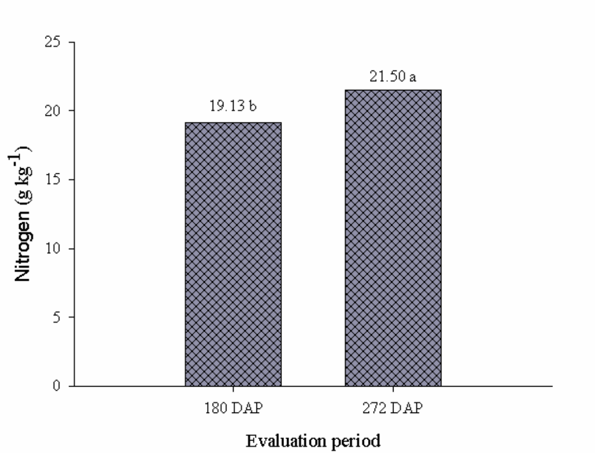
Dried ground leaf samples went through sulfur digestion, and the nitrogen (N) content was quantified through the Kjeldahl method. Sample solutions obtained after nitro perchloric digestion of dried ground leaf samples were used to quantify phosphorus (P) content through colorimetry; potassium (K), and sodium (Na) through flame photometry; calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) through atomic-absorption spectrophotometry; sulfur (S) was determined by turbidimetry; and boron (B) by colorimetry with curcumin after leaf sample incineration (Malavolta et al., 1997).

Data were subjected to an analysis of variance. When significant by the F test ($p<0.05$), evaluation periods were compared by the Tukey's post-hoc test, and the biofertilizer doses and the evaluation periods x doses interaction were studied via regression analysis. We selected the regression models that best fit our data by considering the significance of parameters and highest values for determination coefficients (R^2).

3. Results and Discussion

N content on leaves at 272 DAP increased 11% compared to that observed at 180 DAP (Figure 1). Such a result was already expected due to the frequent application of ovine biofertilizer during the experiment. Starchy vegetable crops are demanding in nitrogen, an important nutrient for vegetative growth, increased root size, and starch accumulation in storage organs (Foloni et al., 2013), pointing out the importance of providing this nutrient to arrowroot plants.

Figure 1 - Leaf nitrogen content on 'common' arrowroot plants fertilized with ovine manure in two evaluation periods. Redenção, Ceará, Brazil 2021.



Source: Authors.

In the arrowroot varieties Viçosa and Seta, Pereira (2019) observed highest N accumulation (239.0 kg ha^{-1} or 11.95 g kg^{-1}) 222 DAP, result lower than the 180 and 272 DAP evaluated in the study (19.13; 21.50 g kg^{-1} of N), respectively. Such difference may be related to the type of fertilizer used, in which the ovine biofertilizer of this study provided highest N accumulation on leaves. For Santos et al. (2017), organic fertilization releases nutrients slowly to plants, improving their nutritional status.

Leaf P content data did not fit any regression model tested. Average P content on arrowroot leaves was 2.35; 2.67; 2.40; 2.45, and 2.30 g kg^{-1} at biofertilizer doses of 0; 300; 600; 900; and 1.200 mL $plant^{-1}$ $week^{-1}$, respectively. Highest leaf P content (0.22 g kg^{-1}) was verified when 300 mL $plant^{-1}$ $week^{-1}$ of biofertilizer was applied.

Average P content on leaves obtained with the ovine biofertilizer was consistent with that found by Sediyama et al. (2020) (2.71 g kg^{-1}) that fertilized 'common' arrowroot plants with cow manure. However, it differed from that of Pereira (2019), which observed average leaf P content of 3.8 g kg^{-1} for the variety Viçosa. The difference between P content on leaf tissues may be a result of different fertilizer properties, which directly influence nutrient accumulation in plants (Croft et al., 2017).

Leaf K content data at 180 DAP best fitted a quadratic regression model (Figure 2A). Highest K accumulation was 30.43 g kg^{-1} observed for the dose 905 mL $plant^{-1}$ $week^{-1}$. This means an increase of 40% in K content (8.70 g kg^{-1}) compared to the control (dose 0). At 272 DAP, K content on leaves increased linearly from 18.20 to 29.83 g kg^{-1}, with an increment of 2.91 g kg^{-1} per dose of biofertilizer applied.

According to Marschner (2012), critical K content of most crops range from 30 to 60 g kg^{-1}. Our results show that at 180 DAP K content of 'common' arrowroot plants fertilized with ovine manure was within the recommended nutrient range. On the other hand, at 272 DAP, leaf K content was within the recommended nutrient range only on those plants that received 600 mL of biofertilizer or more. Such result may be explained by the translocation of this nutrient to sink organs in full growth, such as rhizomes, and by the senescence of leaves (Oliveira et al., 2011), suggesting a need for higher biofertilizer doses to meet K requirements in arrowroot plants.

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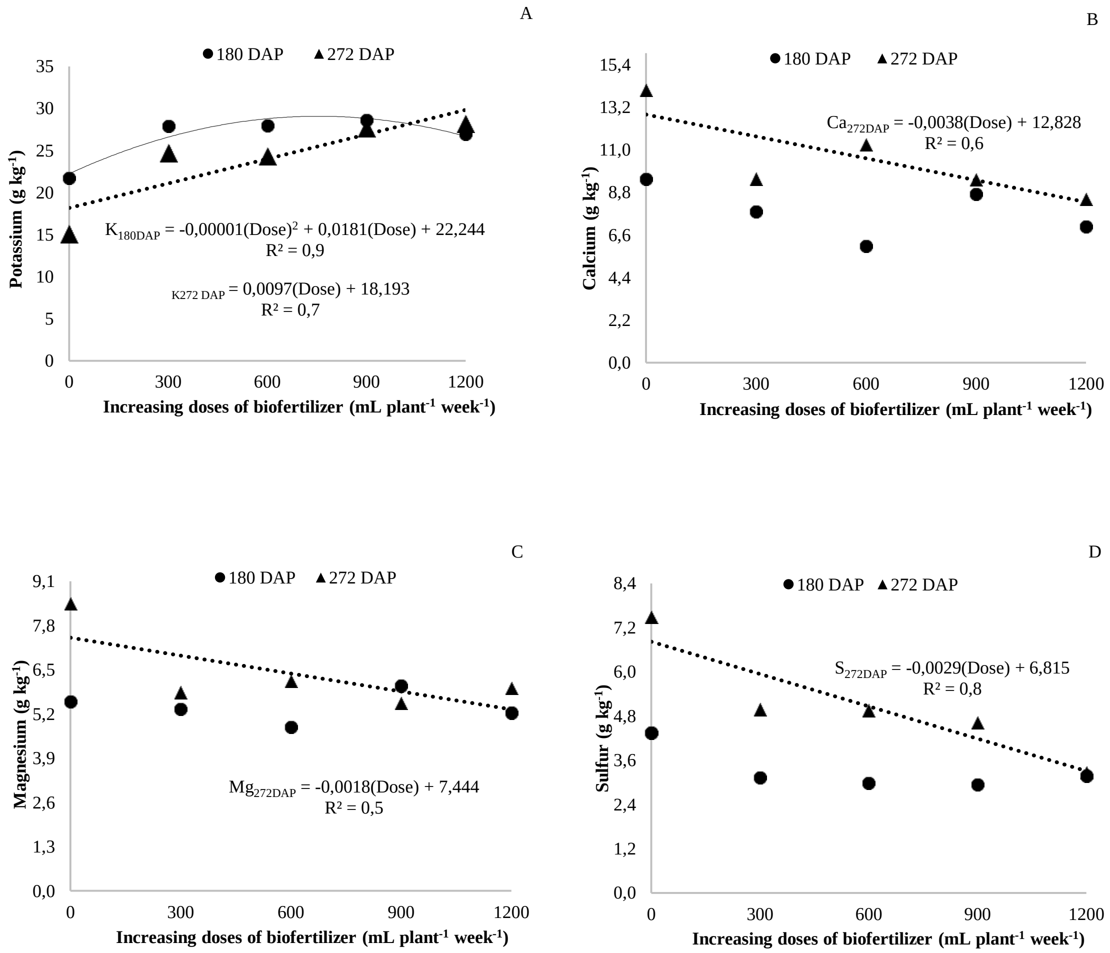
Figure 2 - Potassium (A), calcium (B), magnesium (C), and sulfur (D) content on 'common' arrowroot leaves fertilized with increasing doses of ovine manure, assessed 180 and 272 days after planting. Redenção, Ceará, Brazil 2021.



Source: Authors.

Leaf calcium content was higher in older plants (Figure 2B). Data from 180 DAP did not fit any regression model tested in this study. Average Ca contents on 'common' arrowroot leaves were 9.49; 7.82; 6.04; 8.71 and 7.03 g kg^{-1} for the doses 0; 300; 600; 900; and 1.200 mL $plant^{-1}$ $week^{-1}$ of biofertilizer, respectively. At 272 DAP, leaf Ca content data fitted a decreasing linear model and ranged from 12.83 g kg^{-1} in the lowest dose to 8.27 g kg^{-1} in the highest dose.

Leaf Ca content at 272 DAP decreased as biofertilizer doses increased, whereas potassium increased. Such a decrease in Ca concentrations on leaves with more nutrients being applied to plants through organic fertilization may be a result of Ca and K competition for absorption sites (Fageria, 2001; Coelho et al., 2017). However, the leaf Ca levels found in this study for the increasing biofertilizer doses and both evaluation periods were greater than 4.27 g kg^{-1}, which was the average Ca content found by Sediyama et al. (2020) for the arrowroot crop.

Leaf magnesium content decreased with the increase in the biofertilizer dose (Figure 2C). At 180 DAP, Mg content data did not fit any regression model tested in this study. Average leaf Mg contents were 5.56; 5.35; 4.82; 6.03 and 5.23 g kg^{-1} of Mg for the doses 0; 300; 600; 900; and 1.200 mL $plant^{-1}$ $week^{-1}$ of biofertilizer, respectively. At 272 DAP, Mg content data fitted a decreasing linear regression model with 30% reductions observed between the lowest (7.44 g kg^{-1} of Mg) and the highest dose applied (5.28 g kg^{-1} of Mg). In other words, a decrease of 0.54 g kg^{-1} in Mg accumulation on leaves was observed with the increase in the biofertilizer dose.

Decreasing Mg contents may be associated with Ca antagonistic results since Ca concentration was high in the leaf tissues. Moreover, these two nutrients have very similar chemical properties, including degree of valence and mobility, and therefore they compete with one another by adsorption sites in the soil and absorption sites on roots (Nascimento et al., 2012).

Another possible explanation was provided by Fernandes et al. (2017), where reductions in leaf Mg content with increasing doses may be linked to potassium concentrations in the biofertilizer. Well-K fertilized plants show significant growth so that Mg concentrations on leaves are low due to a dilution effect.

Santos et al. (2017) studied the nutritional status of banana trees subjected to different doses of biofertilizer, and they also observed that leaf Mg content decreased with increasing biofertilizer doses. Yet, according to them, this result may be linked to the antagonistic effect of K and the toxic effect of Na present in the organic fertilizer.

Leaf sulfur content on arrowroot plants at 180 DAP did not fit into any regression model tested in this study. Average S contents found were 4.34; 3.12; 2.98; 2.94 and 3.17 g kg^{-1} for the doses 0; 300; 600; 900; and 1,200 mL $plant^{-1}$ $week^{-1}$, respectively. Average S contents observed 272 DAP, on the other hand, fitted a decreasing linear regression model, with the highest value 6.82 and the lowest value 3.34 g kg^{-1} found for the doses 0 and 1,200 mL $plant^{-1}$ $week^{-1}$, respectively (Figure 2D). A total reduction of 51% resulted in a decrease of 0.87 g kg^{-1} of S for each unit dose applied. Consistent with this result, Pereira (2019) verified a leaf S accumulation of 6.2 g kg^{-1} for the arrowroot variety Seta 285 DAP.

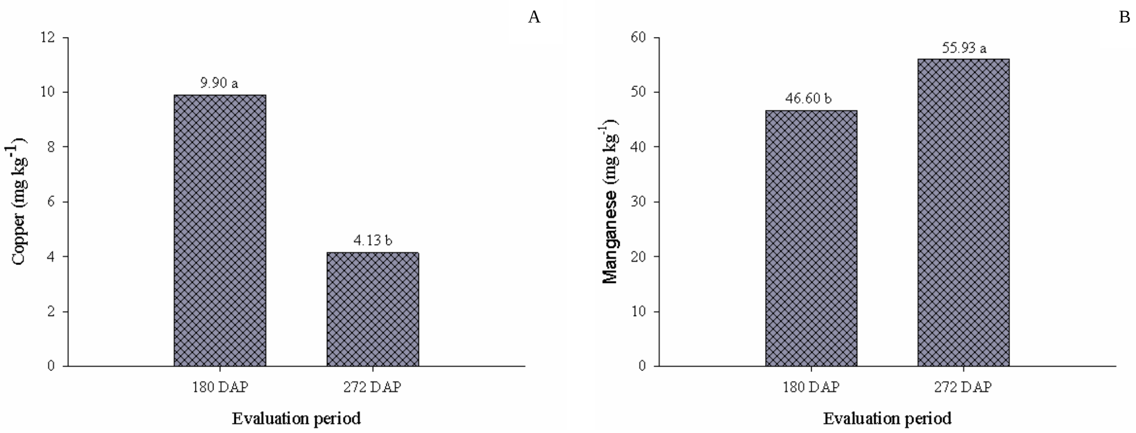
Although S content on leaves decreased with increasing biofertilizer doses, older plants had higher S concentrations than younger plants, suggesting that arrowroot plants need more S at the end of their growth cycle or that S took long to be available for root absorption. For Silva & Trevizam (2015), S is considered an important macronutrient for plant metabolism since, like N, S also participates in the synthesis of some proteins in plants.

Leaf Cu content on ‘common’ arrowroot plants 180 DAP differed from Leaf Cu content 272 DAP by the Tukey’s test ($p< 0.01$) (Figure 3A). Leaf samples collected 180 DAP had 58% more Cu than those collected 272 DAP.

More Cu accumulated in younger plants may suggest that for arrowroot plants, Cu requirement is higher in early than in late stages of plant growth. Also, like Mg, low Cu concentrations in old plants may be a result of either a dilution effect or an antagonistic interaction between (Ca^{2+}) and copper (Cu^{2+}) cations (Silva & Trevizam, 2015).

Leaf Mn content at 272 DAP was 16.7% higher than at 180 DAP (Figure 3B). Such result means that either old arrowroot plants require more Mn than young plants or that young arrowroot plants have higher relative growth rate of dry matter compared to Mn relative absorption rate, which leads to a dilution in the concentration of this nutrient. (Maia et al., 2005; Teixeira et al., 2019).

Figure 3 - Leaf copper (A) and manganese (B) content of ‘common’ arrowroot plants fertilized with ovine manure, assessed 180 and 272 days after planting. Redenção, Ceará, Brazil 2021.

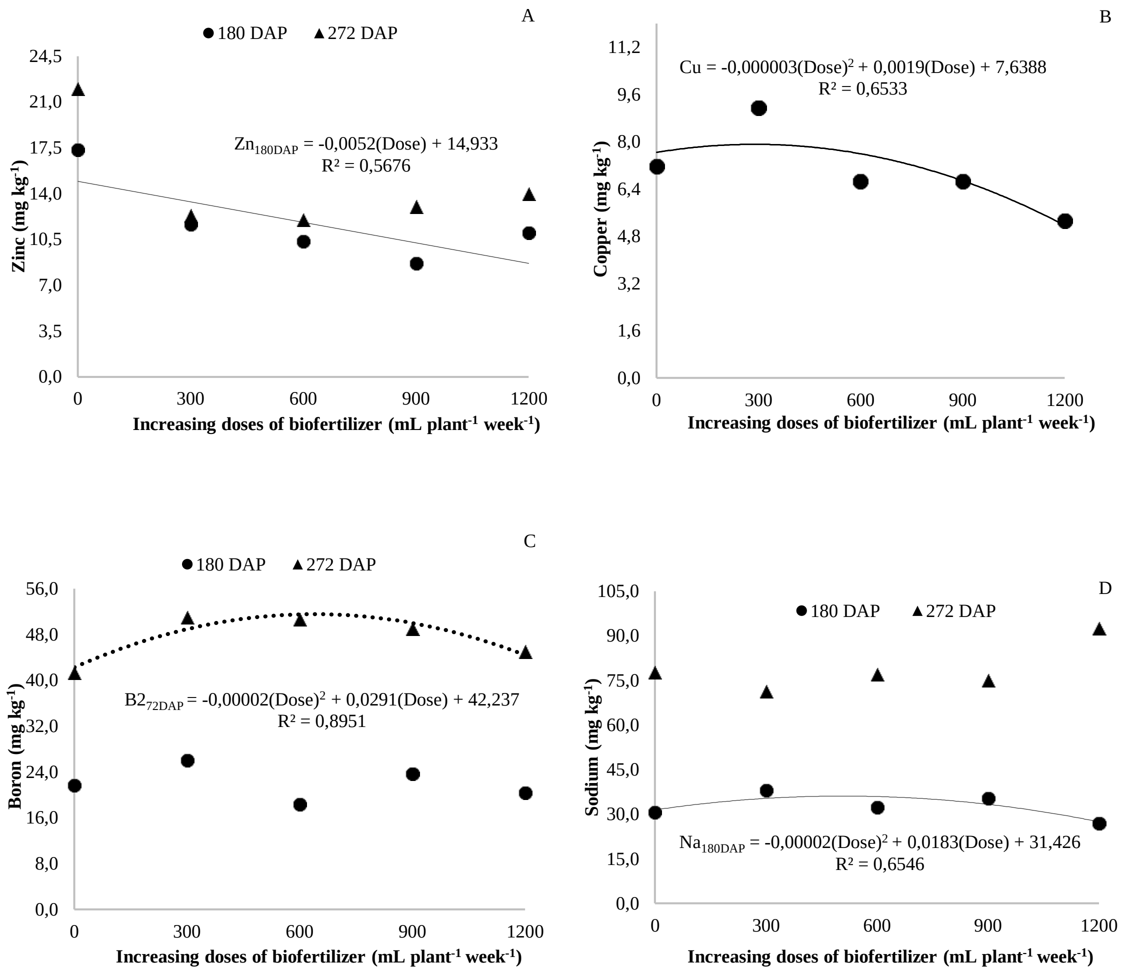


Source: Authors.

Manganese concentrations between 20-500 mg kg^{-1} are considered ideal for plant growth and development (Furlani, 2004). Here, 'common' arrowroot plants, in both evaluation periods, had Mn levels within the recommended range for this nutrient. However, average Mn levels observed in this study were lower than those observed by Sediyama et al. (2020), which found 334.90 and 194.11 mg kg^{-1} of Mn for the varieties 'common' and Seta, respectively.

Zinc content data at 180 DAP did not fit any regression model tested in this study. Average Zn contents on arrowroot leaves 180 DAP were 17.33; 11.66; 10.33; 8.66 and 11.0 mg kg^{-1} for the doses 0; 300; 600; 900; and 1,200 mL $plant^{-1}$ $week^{-1}$, respectively. Zn content data at 272 DAP, on the other hand, fitted a decreasing linear regression model and indicated a reduction of 42% from dose 0 to the dose 1,200 mL $plant^{-1}$ $week^{-1}$ of biofertilizer (Figure 4A).

Figure 4 – Leaf Zinc (A), copper (B), boron (C), and sodium (D) content of 'common' arrowroot plants fertilized with ovine manure, assessed 180 and 272 days after planting. Redenção, Ceará, Brazil 2021.



Source: Authors.

Such decrease in leaf Zn content with the increase in biofertilizer dosage may be a result of P and Zn interactions. A remarkable interaction between these two nutrients is antagonism, which makes it difficult transportation of Zn from roots to top plant parts. (Araújo & Machado, 2006; Silva & Trevizam, 2015). Mattias et al. (2010) consider that Zn may suffer metabolic changes provoked by the nutrients Cd, Ca, Cu, Fe, Mn, and Se, which prevents Zn absorption from occurring.

Although there is no report of ideal micronutrient content interval on arrowroot leaves up to now, 20 to 100 mg kg^{-1} has been considered adequate for most crops (Raij et al., 1997). Leaf Zn content in this study was lower than 20 mg kg^{-1}, suggesting either nutrient deficiency or low nutrient requirement for the arrowroot crop.

The evaluation period did not affect leaf Cu content of arrowroot plants. Leaf Cu content data best fitted a quadratic regression model (Figure 4B). Highest Cu content was 7.94 mg kg^{-1} of Cu observed with the application of 316.67 mL $plant^{-1}$ $week^{-1}$ of biofertilizer. This means an increase of about 30 % compared to the dose 1.200 mL $plant^{-1}$ $week^{-1}$.

For Sweet potato plants, adequate Cu content interval on leaves is 10-20 mg kg^{-1} (Lorenzi et al., 1997), whereas, for banana trees, adequate Cu content interval is 7.2 – 8.0 mg kg^{-1}(Silva & Borges, 2008). We can then state that the dose of 316.67 mL $plant^{-1}$ $week^{-1}$ was enough to meet Cu requirements of arrowroot plants.

Leaf boron content at 180 DAP did not fit any regression model tested. Average B content on arrowroot leaves were 21.66; 26.0; 18.33; 23.66; and 20.33 mg kg^{-1} observed for the doses 0; 300; 600; 900; and 1.200 mL $plant^{-1}$ $week^{-1}$, respectively. At 272 DAP, B content data best fitted a quadratic regression model, with highest B concentration of 52.91 mg kg^{-1} observed for the dose of 727.5 mL $plant^{-1}$ $week^{-1}$ (Figure 4C), which represents a 20% increase in B accumulation compared to the control.

Studies about arrowroot's nutritional requirement in B are rare. However, for tuberous vegetable crops, like sweet potato and cassava, ideal B contents range on leaves are 25-75 mg kg^{-1} for sweet potato and 15-50 mg kg^{-1} for cassava, respectively (Lorenzi et al., 1997). Therefore, we can infer that leaf B content in 'common' arrowroot plants was within the established critical threshold on both evaluation periods (180 and 272 DAP).

After analyzing the leaf nutritional status of 'common' arrowroot plants 120 DAP, Sediyama et al. (2020) observed an average B content of 23.97 mg kg^{-1}, which is very similar to the average leaf B content observed in this study at 180 DAP (22.0 mg kg^{-1}). Highest leaf B content was 52.91 mg kg^{-1} observed at 272 DAP, 140.5% higher than that observed at 180 DAP, suggesting a positive effect of frequent fertilization with ovine manure for this nutrient.

Leaf sodium content data at 180 DAP best fitted a quadratic regression model (Figure 4D). Highest Na content observed was 35.61 mg kg^{-1} for the dose of 457.5 mL $plant^{-1}$ $week^{-1}$. At 272 DAP, Na content data did not fit any regression model tested in the study. Average Na content on 'common' arrowroot leaves were 77.66; 71.33; 77.0; 75.0; and 92.5 mg kg^{-1} for the doses 0, 300, 600, 900 and 1.200 mL $plant^{-1}$ $week^{-1}$, respectively.

Older arrowroot plants (272 DAP) had higher Na accumulation than younger plants, suggesting that older plants require more Na than younger plants and or they are more efficient in absorbing this cation. Na is considered a beneficial nutrient to some crops and is known for playing a role in plant growth, production, and or adaptation to harsh environmental conditions (Malavolta, 2006).

4. Conclusion

The sheep biofertilizer is suitable to meet the nutritional needs of arrowroot 'common'. The continuous application of biofertilizer provided higher levels of nutrients at 272 days after planting. The sheep manure-based biofertilizer is an efficient alternative for the use of solid waste from the activity.

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