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Growth performance of Araruta under different biofertilization regime

Wilson Odene da Silva Cá[1], Francisca Robevania Medeiros Borges[2]*, Albanise Barbosa Marinho[3], Ednângelo Duarte Pereira[4], Antonia Thayná Sousa Costa[1], Fáusia da Verónica Eduardo Pafo[1]

[1] Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Redenção, CE, Brasil. E-mail: wilsonodenedasilvaca@yahoo.com.br; thaynasousacosta@gmail.com; fauziaveronica@gmail.com
[2] Universidade Federal do Ceará, Fortaleza, CE, Brasil. E-mail: robevaniab@gmail.com
[3] Universidade Federal da Paraíba, João Pessoa, PB, Brasil. E-mail: albanisebmarinho@gmail.com.br
[4] Universidade Federal de Viçosa, Viçosa, MG, Brasil. E-mail: ednangelo.pereira@ufv.br

ABSTRACT: Mineral nutrition of arrowroot (*Maranta arundinacea* L.) has been little studied and knowing about the crop growth is required to develop a sustainable fertilization program with minor contamination risk for the environment. The use of biofertilizers is an option for arrowroot fertilization. This study was carried out with the objective of evaluating the vegetative growth of arrowroot fertilized by different biofertilizers sources and doses. The experiment was conducted in a randomized block, in subdivided plots, with four replicatens. The plots consisted of 17 growth evaluation periods, between 42 and 282 days after planting, the subplots by fertilizer sources (bovine and sheep manure) and the sub-plots by biofertilizer rates (0, 300, 600, 900, and 1,200 mL plant^{-1} week^{-1}). Plant height (PH), number of leaves (NL), number of tillers (NT) and pseudostem base diameter (D) were evaluated every two weeks. PH, NL, NT and D maximum were obtained with 1,200 mL plant^{-1} week^{-1} of bovine and ovine biofertilizers. Exception to PH in the sheep source, maximum at 1,045 mL plant^{-1} week^{-1}. Availability of nutrients was higher with 1,200 mL plant^{-1} week^{-1}, favoring the growth of plants. Bovine and sheep manure biofertilizers based are effective for supplying the nutritional requirements of common arrowroot.

Key words: *Maranta arundinacea* L.; mineral nutrition; unconventional food plants

Desempenho do crescimento da Araruta sob diferentes regimes de biofertilização

RESUMO: A nutrição mineral da araruta (*Maranta arundinacea* L.) ainda é pouco estudada e o conhecimento do crescimento da cultura é fundamental para desenvolver um programa de fertilização sustentável com menor risco de contaminação ao meio ambiente. O uso de biofertilizantes é uma opção para a fertilização de araruta. Este estudo foi realizado com o objetivo de avaliar o crescimento vegetativo da araruta adubada com diferentes fontes e doses de biofertilizantes. O experimento foi conduzido em blocos casualizados, em parcelas subdivididas, com quatro repetições. As parcelas constaram de 17 épocas de avaliação do crescimento, entre 42 e 282 dias após o plantio, as subparcelas por fontes de fertilizantes (esterco bovino e ovino) e as subparcelas por doses de biofertilizante (0, 300, 600, 900 e 1.200 mL por planta na semana). A altura da planta (PH), o número de folhas (NL), o número de perfilhos (NT) e o diâmetro da base do pseudocaule (D) foram avaliados quinzenalmente. PH, NL, NT e D máximos foram obtidos com 1.200 mL por planta na semana de biofertilizantes bovino e ovino. Exceção a PH na fonte ovina, com máximo valor na dose de 1.045 mL por planta e a disponibilidade de nutrientes foi maior com 1.200 mL por planta na semana, favorecendo o crescimento das plantas. Biofertilizantes à base de esterco de bovino e ovino são eficazes para suprir as necessidades nutricionais da araruta comum.

Palavras-chave: *Maranta arundinacea* L.; nutrição mineral; plantas alimentícias não convencionais

* Francisca Robevania Medeiros Borges - E-mail: robevaniab@gmail.com (Corresponding author)
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Introduction

Arrowroot (*Maranta arundinacea* L.) is a neglected non-conventional food specie. It almost disappeared with the market expansion of new flours derived from cassava, corn, oats, barley, and wheat at industrial level (Silveira et al., 2013). The center of diversity of Araruta is in South America. This species is distributed natively in Venezuelan forests and exported to Barbados Islands, Jamaica, and other Caribbean regions (Heredia-Zárate & Vieira, 2005).

Arrowroot is an erect plant, perennial, reaching between 1.0 to 1.5 m high, developing rhizomes as a strategy for storing starch. The edible tubers harvested presents potential application in food, industry, and medicine (Rohandi et al., 2017). As an evolutionary strategy to avoid water stress, the leaves are amphistomatic, coated by a thick cuticle which improves the ability to tolerate drought stress, enhances resistance to pathogens and insect attacks (Vilpoux et al., 2019).

Another evolutionary adaptation is the ability to store energy accumulating starch in the rhizomes, which are rich in phosphorus (P), sodium (Na), potassium (K), magnesium (Mg), iron (Fe), calcium (Ca), and zinc (Zn) (Amante et al., 2021). These subterranean modified stems, also known as "planting rhizomes" (Heredia-Zárate & Vieira, 2005), should be utilized as vegetative propagules for specie propagation, as well for extracting purposes, considering the commercial value of starch (Vilpoux et al., 2019).

In recent years, the food industry focused on arrowroot starch, mainly produced in the small farms. This interest was motivated by the quality of the starch, gluten free, easy digestibility and amylose percentage varying from 20 to 30% (Amante et al., 2021). This is an important characteristic because starches with a higher amylose content exhibits fewer crystalline regions and, consequently, lower gelatinization temperatures, reducing the amount of energy required to carry out this process (Denardin & Silva, 2009). Nowadays, starch has been utilized in different applications by the food and chemical industry, for example, in bakery products, packaging, drugs and cosmetics (Winarti et al., 2014; Waterschoot et al., 2015).

The process of revitalizing arrowroot for Brazilian agriculture is fundamental, especially in family farming, due to its rusticity, leaner technology operations at farm-level (Vieira et al., 2015), low demand for cultural tracts and affordable implantation, favoring its dissemination in tropical regions (Rohandi et al., 2017). Unconventional vegetables, such as arrowroot, have been poorly studied in fertilization and nutritional status (Sediyama et al., 2020). The information lack limits the cultivation of these species. To develop fertilization programs for the crop, it is essential to know the plant's growth stages. Biofertilizers can be a promising and low-cost strategy for managing arrowroot fertilization in small and medium-sized farms.

Biofertilizers are products that contain living microorganisms or natural organisms compounds that regulate soil biological properties, restoring its fertility, improving plant growth, and reducing pathogen impact on crops (Dong et al., 2019). The biofertilizers utilization, produced from bovine and sheep manure, provides an important nutrients source for plants, especially in areas of family farming (Souto et al., 2015). The relevance of the biofertilizers use is situated in its elements content, wide assortment of mineral nutrients and in the availability for biological activity, therefore stimulating plants growth and development (Pereira et al., 2019), and counterbalancing stressors, eventually increasing crop quality and productivity (Van Oosten et al., 2017).

Despite the optimal nutritional and sensory quality of gluten-free products produced with arrowroot, studies in the literature focusing crop growth stages are scarce. The aim of this study was to evaluate the vegetative growth of arrowroot fertilized with diverse biofertilizer sources (bovine and ovine manure) and rates. This information will be useful to compose a theoretical basis for future research and practice for farmers, setting cultivation managements according to the growth and duration of the arrowroot cycle, reducing costs, energy inputs and risks to the environment.

Materials and Methods

The experiment was performed at the Piróas Experimental Farm of the Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), located in Barra Nova, Piroás site, Redenção, Ceará State, Brazil, from November 2018 to August 2019, totaling 282 days.

Arrowroot (*Maranta arundinaceae* L.) common variety was grown in 39.5 L pots, with a 5 cm^3 layer of draining material (gravel) at the bottom and substrate composed of sand-clay and sand, in a 1:2 ratio. Seed rhizomes measuring 10 cm long were sown horizontally in pots at 5 cm depth.

The soil of the experimental area used in the pots was classified as sand-argisol (Santos et al., 2018), whose chemical characteristics of the 0–0.20 m layer were: pH (1:2.5 soil/$CaCl_2$ suspension 0.01 mol L^{-1}) 6.1; Carbon 3.46; organic matter 6.0 g kg^{-1}.$P_{\text{Mehlich 1 extractable}}$ 44 mg dm^{-3}, K, Ca, Mg, and Na 2.0, 21.4, 6.6, and 2.0 $mmol_c\ dm^{-3}$, respectively; total acidity in pH 7.0 (H+ Al), 11.0 $mmol_c\ dm^{-3}$, sum of bases 31.9 $mmol_c\ dm^{-3}$, cation exchange capacity (CEC), 42.9 $mmol_c\ dm^{-3}$, base saturation 74.7%, exchangeable sodium percentage 4.3%, and electric conductivity 0.6 dS m^{-1}. In the experimental period, the average luminous intensity between 10 and 14 h was 13193.3 lux.

The irrigation started right after planting of seed rhizomes, using a drip system daily activated, designed to operate emitters in line per row of plants, with an average flow of 8.0 L h^{-1} per individual. The irrigation time was calculated from the evaporation of the class "A" tank.

The experiment was carried out in a randomized blocks design, in a sub subdivided plot scheme, with four replicates. The plots consisted in periods of evaluation of the arrowroot's vegetative growth (15-day intervals), the subplots were related with the two biofertilizers sources (bovine and sheep manure) and the sub subplots corresponding to five biofertilizers rates (0, 300, 600, 900, and 1,200 mL plant^{-1} week^{-1}), partitioned and applied by manual fertilization twice a week.

Biofertilizers based on bovine and ovine manure were prepared with 100 L of bovine or ovine manure, according to treatment; 30 L of chicken manure; 5 L of coal ash and 270 L of water, homogenized in water tanks with a capacity of 500 L. The decomposition time of the biofertilizers was 30 days, meanwhile, it was submitted to manual mixing twice a day (Pereira et al., 2019).

The biofertilizers application started at 42 days after planting (DAP). PVC pipes, 30 cm long, were installed next to the plants reaching at 10 cm depth. Hence, the rate of the biofertilizer was applied to the pipe, facilitating the infiltration and uptake of the input to the substrate.

Plant height (PH), number of leaves (NL), number of tillers (NT) and pseudostem base diameter (D) were evaluated every two weeks, starting at 42 DAP until 282 DAP, period corresponding the cultivation cycle. The plants height was determined using a measuring tape graduated in centimeters, from the level of the ground until the highest leaf inflection. The number of leaves and the number of tillers were obtained by direct counting and the base diameter of the pseudostem was determined with a digital caliper, graduated in millimeters, positioned at a height of 5.0 cm in relation to the soil surface.

The data from plant height, number of leaves, number of tillers and base diameter of pseudostem according to development stage, the source of fertilization and the doses of biofertilizers, were submitted to the analysis of variance by the F test. When significant, the mean test or regression analyzes were performed. The means referring to the source of biofertilizer (bovine and ovine) were compared using the Tukey test ($P \leq 0.01$) and ($P \leq 0.05$). The averages for the development stage and the doses of biofertilizers were submitted to regression analysis. The significant interactions between development stage and the doses of biofertilizers were analyzed by response surface. The models were chosen based on the significance of the regression coefficients, the determination coefficient, and the biological significance of the phenomenon.

Results and Discussion

After 30 days of decomposition, the bovine biofertilizer was superior in all the analyzed levels, in relation to the ovine biofertilizer, except for electrical conductivity (Table 1). However, the K contents were equal (0.05 g L^{-1}) for the two analyzed biofertilizers.

NL and D of arrowroot individuals showed effect on the interaction between evaluation periods and biofertilizers sources (bovine and ovine). The NL adjusted to the quadratic polynomial model for both biofertilizers, with values of 60 and 72 leaves, obtained at 227 and 273 DAP, respectively (Figure 1A). The D had a quadratic response for the two biofertilizers, with maximum values corresponding to 16.2 mm at 190 DAP, for the bovine biofertilizer and 13.46 mm, at 180 DAP, for the sheep biofertilizer (Figure 1B).

The highest NL at 227 DAP for bovine biofertilizer occurred due to the faster mineralization of this compound in relation to sheep based fertilizer. Thus, the availability of nutrients occurs for leaf production in the initial phase, being surpassed in the final stage of cultivation by the sheep source, when the availability of nutrients is greater than in bovine biofertilizer. The reduction in D from 190 and 180 DAP for bovine and ovine biofertilizers, respectively, may be related to oxidative stress caused by high light intensity (13,193.3 lux) in the growing environment. Arrowroot is an

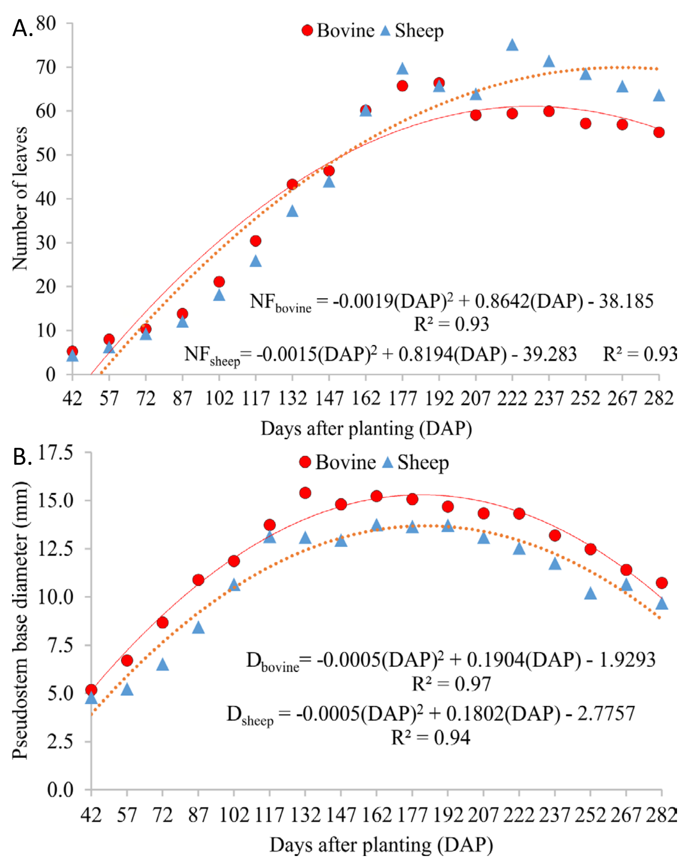


Figure 1. Number of leaves (A) and pseudostem base diameter (B) of arrowroot plants depending on the source and development stage.

Table 1. Chemical characterization of bovine and ovine biofertilizer.

N	P	K^+	Ca^{2+}	Mg^{2+}	Fe	Zn	Cu	Mn	CE	C	MO	C/N	pH
(g L^{-1})					(mg L^{-1})				(dS m^{-1})	(%)			
Chemical characteristics – Bovine biofertilizer													
1.06	0.47	0.05	1.91	0.49	194	6	2	27	6.14	1.09	1.97	10	7.01
Chemical characteristics – Ovine Biofertilizer													
0.32	0.17	0.05	0.74	0.28	58	2	0	8	7.47	0.17	0.31	5	6.91

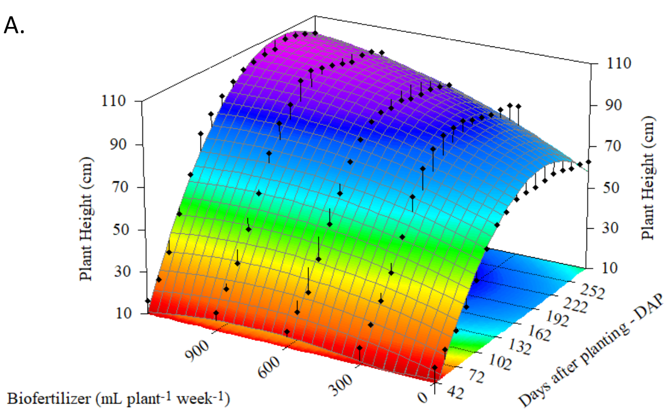
adaptable plant, thriving in low light conditions. Remarkably, light intensities above 7,400 lux provoked limitation in crop growth (Oktafani et al., 2018).

According to the response surface model, the optimum biofertilizer rate to maximize plant height (108.5 cm) was 1,200 mL plant^{-1} week^{-1} at 231 DAP (Figure 2A). Maximum NL, 99 leaves, was verified with 1,200 mL plant^{-1} week^{-1} at 282 DAP (Figure 2B). Throughout the cycle, the increased NT, maximum value of 6 tillers, were achieved at 282 DAP with 1,200 mL plant^{-1} week^{-1} (Figure 2C). Maximum D of 16 mm, at the 1,200 mL plant^{-1} week^{-1} was verified at 188 DAP (Figure 2D).

PH, NL, NT, and D at their maximum values were observed in the highest dose of biofertilizers applied (1,200 mL plant^{-1} week^{-1}). The amounts of biofertilizer nutrients were readily available to the crop, favoring the absorption and promoting plant growth. The maximum PH value of 108.5 cm, observed at 231 DAP, indicates that the plant reached its maximum vegetative growth at this phase, followed by the commencement of senescence phase, as revealed to taro culture (Puiatti et al., 2015). The PH observed in this study was higher than 88.74 cm, reported in common arrowroot at 191 DAP (Moreno et al., 2017). The largest NL (99 leaves), at 282 DAP, demonstrates that the plants still developing with the sprout of new tillers, which contributed to the increase of leaves number. It probably increased photosynthesis, providing carbohydrates to the development of new organs of plants (Walter et al., 2009). The increase in NT during the entire cultivation cycle is a common response in species that stores energy as strategy, indicating that starch accumulation in rhizomes allows the emission of new shoots throughout the crop lifespan, as reported in arrowroot (Souza et al., 2019). The higher D at 282 DAP is probably due to the nutrient's translocation from the tissue sources to growing organs, for example rhizomes, followed by natural senescence characterized by the yellowing leaves and aerial part withering, evidencing that through this stage, rhizomes becomes main drains, as reported in the taro (Garcia, 2017).

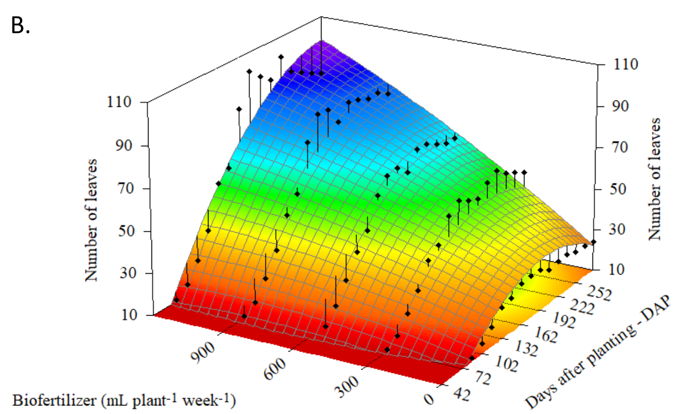
The interaction between biofertilizers sources and rates provided a significant effect on PH, NL, NT, and D in arrowroot plants. The maximum ALT of arrowroot plants fertilized with bovine biofertilizer was adjusted to a growing linear model, with a value of 92.2 cm obtained at the dose of 1,200 mL plant^{-1} week^{-1}, whereas for ovine biofertilizer, the adjustment was quadratic polynomial with a value of 54.2 cm obtained at 1,045 mL plant^{-1} week^{-1}dose (Figure 3A). NL, NT and D adjusted into the increasing linear model. The maximum NL of 59 and 65 leaves were obtained in the dose of 1,200 mL plant^{-1} week^{-1} for bovine and ovine biofertilizer, respectively (Figure 3B). The

A.



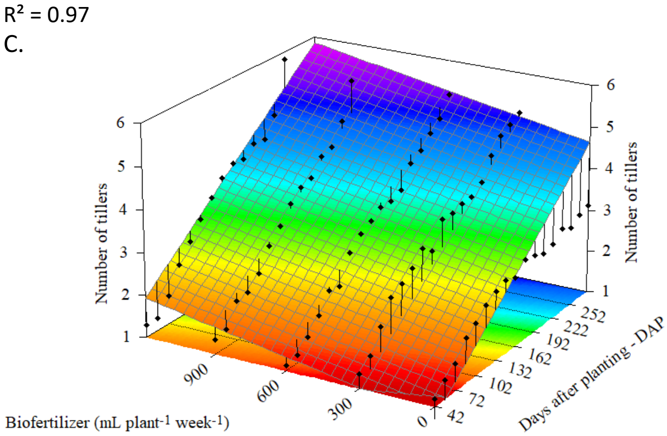
$PH = -36.76 + 1.1052^{**}(DAP) + 0.0233^{**}(Bio) + 0.0027^{**}(DAP)^2 + 0.00002^{**}(Bio)^2 + 0.0001^{**}(DAP) \times (Bio)$
$R^2 = 0.97$

B.



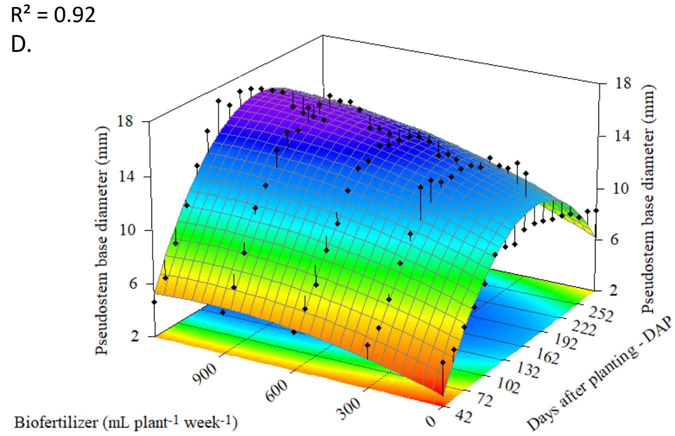
$NL = -33.3363 + 0.6799^{**}(DAP) + 0.0016(Bio) - 0.0017^{**}(DAP)^2 - 0.00001(Bio)^2 + 0.0003^{**}(DAP) \times (Bio)$
$R^2 = 0.92$

C.



$NT = 0.0308 + 0.0164^{**}(DAP) + 0.0010^{**}(Bio)$
$R^2 = 0.85$

D.



$D = -3.8907 + 0.1795^{**}(DAP) + 0.0051^{**}(Bio) - 0.0005^{**}(DAP)^2 - 0.000003^{**}(Bio)^2 + 0.00001^{**}(DAP) \times (Bio)$
$R^2 = 0.92$

Figure 2. Response surfaces for plant Height (A), number of leaves (B), number of tilles (C) and pseudostem base diameter (D) as a function of biofertilizer doses (Bio) and days after planting (DAP).

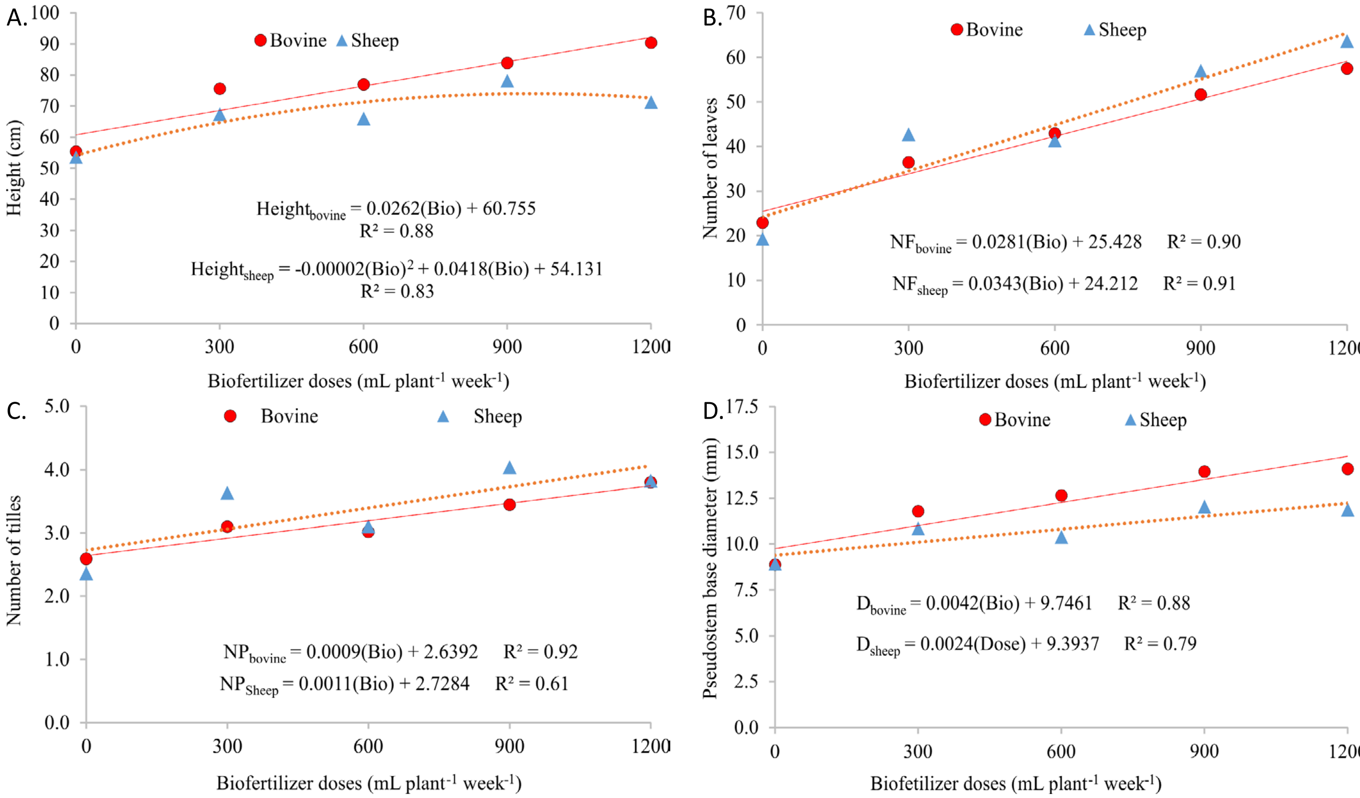


Figure 3. Plant Height (A), number of leaves (B), number of tilles (C) and pseudostem base diameter (D) of arrowroot plants corresponding to different sources and doses of biofertilizers.

maximum NT observed was four tillers for bovine and ovine biofertilizer, obtained at the 1,200 mL plant^{-1} week^{-1} (Figure 3C). The maximum D was 14.8 and 12.3 mm for bovine and ovine biofertilizer, respectively, obtained at the dose of 1,200 mL plant^{-1} week^{-1} (Figure 3D).

The higher PH and NL values found for bovine biofertilizer, in relation to the sheep, may be related to chemical characterizations of the biofertilizers (Table 1). The bovine biofertilizer exhibited higher nutrients concentrations, except for K. In this study, the NL values (59 and 65 leaves) were higher than 34 leaves reported in arrowroot fertilized with chicken litter at 179 DAP (Abrão, 2019). The increase in NT during the entire cultivation cycle, at 1,200 mL plant^{-1} week^{-1} is a consequence of the amounts of nutrients readily available in biofertilizers, favoring the uptake, and the arise of growth of tillers. The maximum tillers (4), for both biofertilizer sources, was inferior in comparison to those found in arrowroot previously (4.7 and 10.7) (Oktafani et al., 2018). The D increased linearly in response to the biofertilizer applications regardless of the source, confirming that the nutritional demand of the plant was satisfied.

Conclusion

Biofertilizers derived from bovine and sheep manure are effective to supply the nutritional need of common arrowroot. The 1,200 mL plant^{-1} week^{-1} of the bovine or ovine biofertilizers increased the growth of the common arrowroot.

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Compliance with Ethical Standards

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