

Effect of the Incorporation of Hydrogel on the Growth of *Dendrocalamus asper* and *Bambusa vulgaris* var. *Vittata* Seedlings

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Abstract

Hydrogel has important functions, being a soil and substrate conditioner, improving the ability to retain water and nutrients, making them available and improving the development of bamboo seedlings in nursery. The objective of the study is to evaluate the effect of different doses of hydrogel on the development and quality of seedlings of *Dendrocalamus asper* and *Bambusa vulgaris* Schrad. var. *vittata*. Additionally, it was to investigate on the three types of propagules (Lateral regrowth + disc, Lateral regrowth and Disc). Four doses of hydrogel (1, 2, 3 and 4g) were used and one fifth treatment control (0g). The recorded traits were numbers of shoots and roots and their variations in relation to size and weight. Every 60 days the height of the shoot (cm) and the number of shoots were measured. At 180 days, shoot dry weight and root dry weight were performed. For all variables, the disc propagule was the one that provided the greatest growth and establishment of the seedlings, which was indicated for the production of seedlings by cutting. For the hydrogel, the dose 4g/liter was the one that proposed more vigorous seedlings, showing that the incorporation in this amount is ideal, with values of 117.1 and 113.1 for the aerial part for *Dendrocalamus asper* and *Bambusa vulgaris* respectively. Regarding the number of roots the highest values were 49 for *Dendrocalamus asper* and 64.3 for *Bambusa vulgaris*.

Keywords: cuttings, vegetative propagating, Bamboo, cloning, nursery

1. Introduction

Earth is a plant-oriented planet and plants has special importance. Plants are adding value of earth's diversity and fundamental to all life. Living things need plants to live—they eat them and live in them. Plant products are a source of industrial products and they are also a great source of medicine even for life-threatening diseases (Gecer et al., 2020; Guney et al., 2019; Senica, Stampar, & Mikulic-Petkovsek, 2019; Zia-Ul-Haq et al., 2014).

Bamboo species have stood out as new fibrous-based raw material alternatives for multiple uses, being recognized worldwide due to their numerous applications involving from pulp and paper production, energy, biofuel and starch extraction to use in construction, bioengineering, furniture manufacturing, handicrafts, pharmaceuticals, food and medicine (Singh et al., 2013).

In Brazil, approximately 258 species of native's bamboo distributed in 35 genus. The Olyreae tribe is composed of herbaceous bamboos and has 17 genus and 93 species, while Bambuseae is composed for 18 genus and 165 species. In Brazil, the number of endemic bamboos is high: there are 12 genus and 175 species (Filgueiras & Viana, 2017).

Dendrocalamus asper it is originally from Southeast Asia, has sympodial growth, has stems with height between 20 to 30 m, and diameters from 8 to 20 cm. It develops in humid tropical regions and in subtropical regions, preferring rich soils, supporting temperatures of up to -5°C. It is a bamboo of great strength and excellent durability. Its shoots are edible and can be commercially exploited also within the food sector (Liana et al., 2017; Pereira & Beraldo, 2016).

Bambusa vulgaris var. *vittata*, also an exotic species, is originally from India and China, presents itself as an excellent source of energy biomass. Its height can reach up to 30 meters, and the diameter of the stems between 20 and 25 cm, with elongated leaves and parallel ribs. Also known as bambu-brasil, brasileiro, bambu-brasileiro

(due to the color green and yellow) and bamboo-imperial, has arguably great aesthetic appeal to your favor, because of its colors. It differs from the typical cultivar by the internodes of intense yellow to greenish-yellow coloration with uneven dark green striae (Cusack, 2000).

Currently in Brazil, studies demonstrate the applicability of bamboo cultivation to biomass production, and the species *Dendrocalamus asper* and *Bambusa vulgaris* present potential for the composition of commercial plantations, standing out for their high economic value, adaptability and rapid growth (Dos Reis Pereira, Gomes Battistelle, & Chiappetta Jabbour, 2014).

There is little scientific knowledge about bamboo species, especially regarding reproduction mechanisms through vegetative propagation, especially by cutting. What's more, the flowering of many bamboo species is a rare phenomenon and, several species die to bloom due to the energy released by the plant for the formation of seeds (Mudo et al., 2013; Tang, Li, & Zhu, 2007).

Success in the production of bamboo seedlings is directly linked to their water needs, thus, the use of hydrogel is one of the management techniques advised to meet this demand for water (Araújo et al., 2013). Hydrogel comes from the arrangement of molecules that can increase the storage capacity when hydrated (Ahmed, 2015; Navroski et al., 2015). Among the main characteristics of its use, we highlight the improvement of the availability and retention of water and nutrients to plants in a controlled way (Pereira et al., 2019; Ullah et al., 2015).

Thus, the hydrogel, arise as a soil and substrate conditioner, improving their ability to retain water and nutrients making them available and improving the development of bamboo seedlings in nursery (Garnica-Palafox & Sánchez-Arévalo, 2016). In this context, we aimed evaluate the effect of different doses of hydrogel (Forth Gel®) on the development and quality of seedlings of *Dendrocalamus asper* (Schult. & Schult. f.) Backer ex K. Heyne) and *Bambusa vulgaris* Schrad. var. *vittata* A. et C. Riv.

2. Method

The experiment was conducted at the Forest Nursery, at Fazenda Água Limpa - FAL, belonging to the University of Brasília, located in the Federal District, at 15° 56' S and 47° 46' W, altitude of 1,100 m asl. The climate of the region is of type Aw, according to Köppen classification, with average annual temperature ranging from 12 to 28.5 °C (Munhoz & Felfili, 2005).

The clonal genetic material of the species was collected at the Brazilian Institute for Geography and Statistics Ecological Reserve, located in the south-central of the Federal District, an integral protection conservation unit, through by cutting stems and shoots (Figure 1). For this purpose, a machete and a chainsaw were used, cutting approximately 20 centimeters above the ground, and just above the knot, to avoid the entry of water and rot of the stem part.

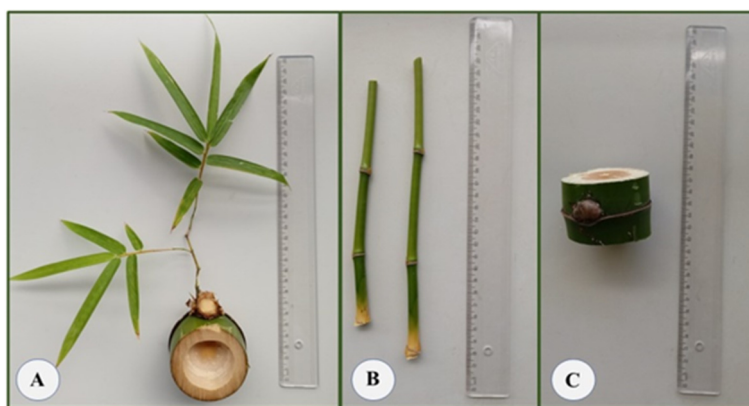


Figure 1. Types of propagules: (A) Lateral regrowth + disc; (B) Lateral regrowth and (C) Disc

The sectioning of the stem to obtain the propagating material was done using an arch with saw and machete. The parameter used in the choice of the stems that were cut was age (2 years), and diameters $8 \leq d \leq 12$ cm for main stem and $5 \leq d \leq 8$ cm for secondary branch were selected.

Soon after the sectioning of the stems and the removal of the lateral branches, the propagules were packed in containers with 20 liters with water up to the time of planting, aiming at maintaining the viability. The experiment

was installed in a completely randomized design, with 5 treatments and three sources of propagule (secondary lateral regrowth with one node, secondary lateral regrowth with two nodes and main stem discs with a yolk) with five combinations hydrogel doses. For each treatment, 21 sample units were used, totaling 315 bamboo seedlings per species.

Polyethylene bags (25 x 35 cm) containing 3 liters soil (Red-yellow latosol with pH of 4.8, P: 2.9 mg/dm³, k: 21 mg/dm³, Ca²⁺ + 0.16, Al³⁺ + 0.70 cmolc /dm³) with 4 doses of hydrogel (1, 2, 3 and 4 g.L⁻¹) added to the substrate, and a treatment without the addition of hydrogel (control).

During the preparation of the substrate, an initial fertilisation of the soil to be used was performed. The composition added to the soil was NPK (4-14-8), with the proportion of 3 g for kg⁻¹ of soil, and also Micronutrients (FTE BR 12) were also added at the proportion of 1 g for kg⁻¹ of soil. The temperature varied from 20.3 to 29.9°C and irrigation was performed by drip with scheduled schedules, occurring twice a day (09:00h and 16:00h), in the proportion of 5 ml.

Every 60 days were evaluated the height of shoot (cm), using a graduated ruler, and the number of shoots (unit) obtained direct count (Leitão et al., 2009). At 180 days (last evaluation) shoots and roots were separated from 7 individuals of each treatment. They were then packed in a paper bag and taken to a greenhouse at 70 °C for 72 hours. Subsequently, they were weighed to determine the dry weight of shoots and dry weight of the root evaluating the quality of the seedling (Prado, 2008, 2020).

The data were submitted to statistical analysis of variance (ANOVA) and in the occurrence of significance between interactions, simple regression analysis was performed using the statistical program RBio: Biometrics in R (Bhering, 2017) and comparison of means by Tukey's test, performed using SISVAR statistical software v. 5.6 (Ferreira, 2014).

3. Results

The evaluation of the effects of the different doses of hydrogel on the three types of propagules, significant differences in seedling growth and establishment were observed. The mean height of the aerial part in the disc propagation on the effect of the 4g dose of hydrogel was statistically higher than the means observed in the others (Table 1), with a difference of 91.2 cm in relation to the lowest mean in the same disc propagule for *Dendrocalamus asper* and 78.9 cm in relation to the lowest mean in the lateral regrowth propagule, both in the control treatment. The effect of hydrogel doses indicated significant interaction in propagules (Figure 2).

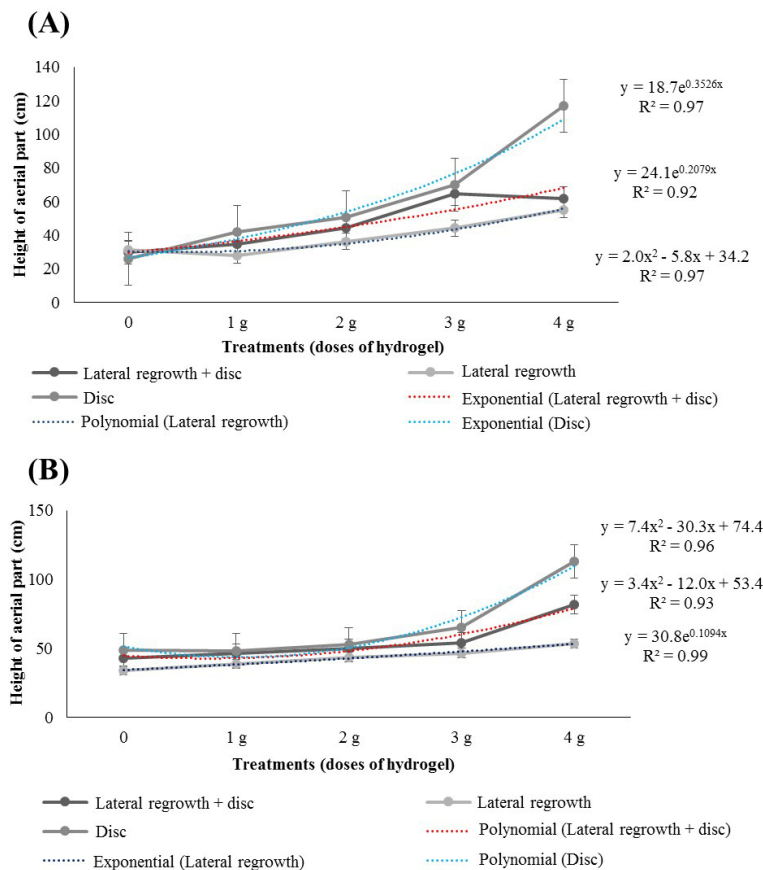


Figure 2. Seedling height of: (A) *Dendrocalamus asper* and (B) *Bambusa vulgaris* var. *vittata*

The exponential equations in the disc propagules and lateral regrowth + disc in the species *D. asper*, indicate proportionality as the hydrogel dose increases, while in the polynomial equation in the lateral regrowth propagule, with the increase of the hydrogel dosage the average height of the plants increases up to 3cm (Table 1).

Table 1. Comparison between aerial part height averages (cm) of *Dendrocalamus asper* and *Bambusa vulgaris* var. *vittata* at 180 days

Species	Propagules	Doses of hydrogel				
		0	1g	2g	3g	4g
<i>Dendrocalamus asper</i>	Lateral regrowth + disc (cm)	29.7 ⁱ	34.8 ^{gh}	44.6 ^f	64.5 ^c	61.7 ^c
	Lateral regrowth (cm)	31.5 ^{hi}	28.0 ^{ij}	36.3 ^g	44.1 ^f	55.2 ^d
	Disc (cm)	25.9 ^j	42.2 ^f	50.6 ^e	70.2 ^b	117.1 ^a
<i>Bambusa vulgaris</i> var. <i>vittata</i>	Lateral regrowth + disc (cm)	42.7 ^{gh}	46.6 ^{efg}	50.1 ^{cdc}	54.4 ^c	81.9 ^b
	Lateral regrowth (cm)	34.1 ⁱ	38.7 ^{hi}	43.7 ^{gh}	46.7 ^{efg}	53.6 ^{cd}
	Disc (cm)	48.9 ^{def}	48.4 ^{def}	52.7 ^{cd}	65.3 ^b	113.0 ^a

Note. Averages followed with same letter in the row or column do not differ significantly from each other ($p \leq 0.05$).

In the species *Bambusa vulgaris* var. *vittata*, regression analysis highlights a positive polynomial growth in relation to hydrogel doses in the disc propagules and lateral regrowth + disc, indicating that the hydrogel doses provided a low growth up to the 3g dose.

The behavior of the number of shoots (Table 2) demonstrates that there were significant differences, with the highest value (49 and 64.3 units) found in the highest dose in the propagule disc. At the end of the experiment, it was found that the polynomial model better described the behavior of the propagules ($R^2 > 0.9$), from the dose 2g in *D. asper* and 3g in *B. vulgaris* var. *vittata*. A greater variation of 21 to 49 shoots was also observed in the species *D. asper* and 33 to 64 shoots in the species *B. vulgaris* var. *vittata*.

Table 2. Comparison between means of the number of shoots (unit) of *D. asper* and *B. vulgaris* at 180 days

Species	Propagules	Doses of hydrogel				
		0	1g	2g	3g	4g
<i>Dendrocalamus asper</i>	Lateral regrowth + disc (cm)	17.6 ^{ef}	17.1 ^{efg}	15.9 ^{fg}	18.3 ^c	23.7 ^c
	Lateral regrowth (cm)	15.1 ^{gh}	15.0 ^{gh}	13.2 ^h	15.5 ^{fg}	20.6 ^d
	Disc (cm)	21.2 ^d	21.1 ^d	21.9 ^{cd}	31.2 ^b	49.0 ^a
<i>Bambusa vulgaris</i> var. <i>vittata</i>	Lateral regrowth + disc (cm)	33.0 ^{ef}	28.4 ^{gh}	32.2 ^f	32.3 ^{ef}	36.9 ^{cd}
	Lateral regrowth (cm)	27.5 ^{gh}	26.8 ^h	30.7 ^{fg}	28.5 ^{gh}	32.9 ^{ef}
	Disc (cm)	33.0 ^{ef}	35.9 ^{dc}	39.6 ^c	43.7 ^b	64.3 ^a

Note. Averages followed with same letter in the row or column do not differ significantly from each other, significant to the level of 5% ($p \leq 0.05$).

It is also noteworthy, positive response in relation to hydrogel doses in the equation adjusted for the number of shoots, which presented significant polynomial behavior for all propagules for *D. asper* and *B. vulgaris* var. *vittata* (Figure 3).

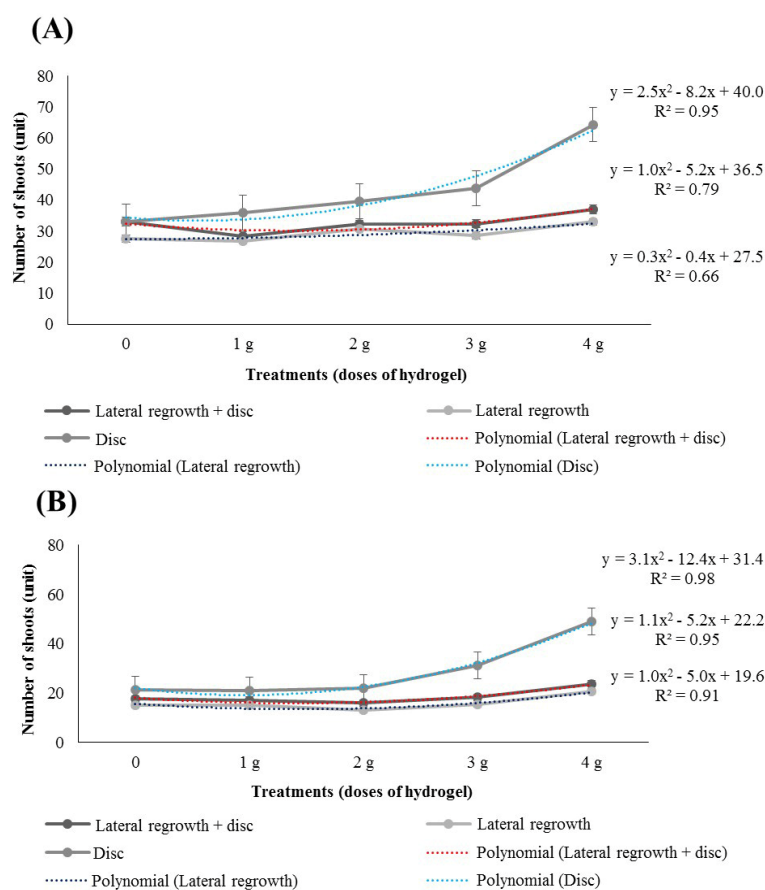


Figure 3. Number of shoots (unit) of seedlings of: (A) *Dendrocalamus asper* and (B) *Bambusa vulgaris* var. *vittata*

Analyzing the regression (Figure 4), it is possible to highlight the positive response of bamboo seedlings in relation to hydrogel doses in which the equation adjusted for this parameter presented significant polynomial behavior for all propagules for *D. asper*, logarithmic in the propagule lateral regrowth + disc and polynomial in the disc propagules and lateral regrowth in *B. vulgaris*.

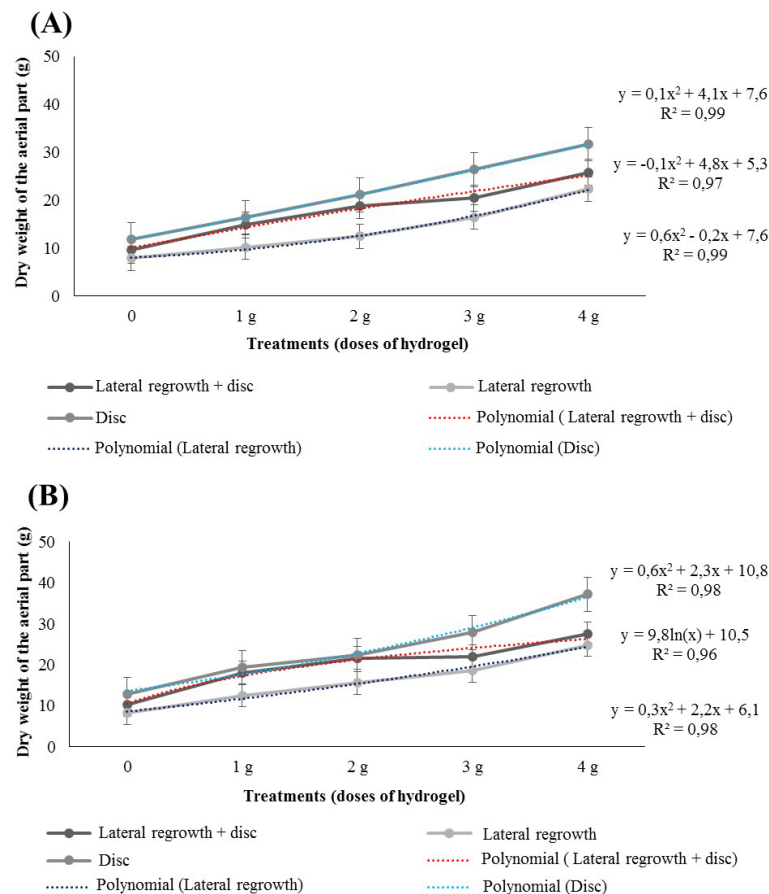


Figure 4. Dry weight of the aerial part (g) of seedlings: (A) *Dendrocalamus asper* and (B) *Bambusa vulgaris* var. *vittata*

According to the polynomial adjustment, the dry weight of the shoot increases linearly as a function of the increase in hydrogel doses. The logarithmic adjustment indicates growth of the variable, according to the hydrogel doses, up to a certain value. There was a significant linear effect in the regressions (Figure 5), highlighting positive responses of bamboo seedlings in relation to hydrogel doses in which the equation adjusted for dry root weight presented polynomial behavior in disc propagules, lateral regrowth and logarithmic for lateral regrowth + disc in *D. asper*.

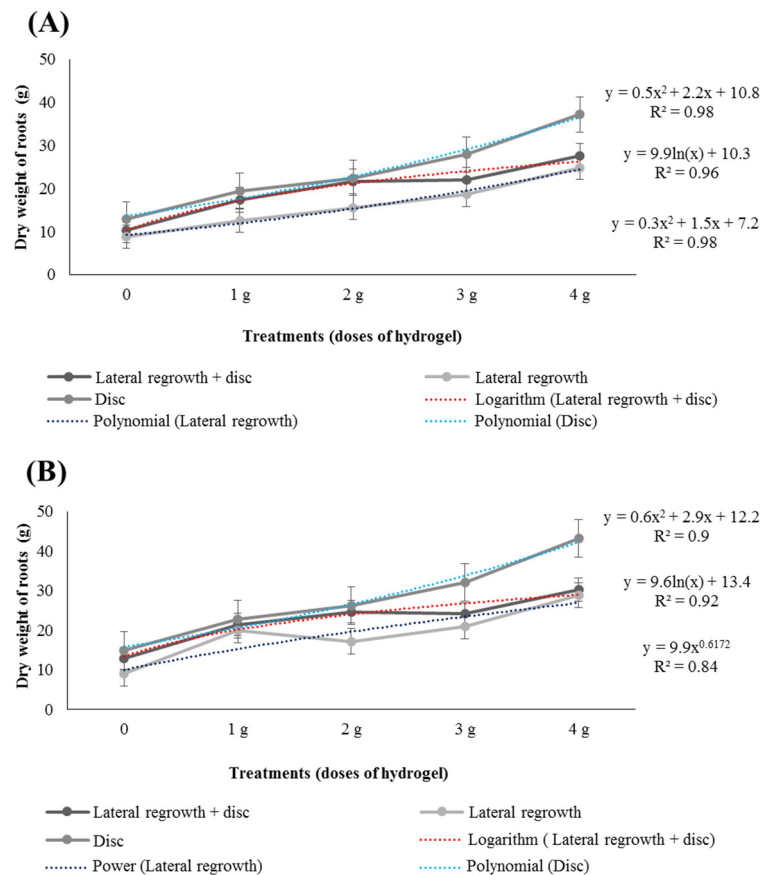


Figure 5. Dry weight of roots (g): (A) *Dendrocalamus asper* and (B) *Bambusa vulgaris* var. *vittata*

The dry weight growth of the roots of *B. vulgaris* var. *vittata* behaved in a logarithmic manner in the lateral regrowth propagule + disc, potential in the lateral and polynomial regrowth propagule in the disc propagulum. According to the polynomial adjustment, the dry weight of the shoot increases linearly as a function of the increase in hydrogel doses regardless of the tested propagule.

4. Discussion

The logarithmic adjustment indicates growth of the variable, according to the hydrogel doses, up to a certain value (2g), not continuing with the gain in weight increase of the roots in the higher doses (3 and 4g). The potential adjustment indicates growth at the lower dose (1g) and soon after low hydrogel effect at the following doses (2, 3 and 4g).

The improvement in the growth and quality of seedlings is attributed to the changes conditioned by the hydrogel, and in the physical and chemical characteristics of the substrates used (Barbosa, Rodrigues, & Couto, 2013; Bernardi et al., 2012; Felipe et al., 2016; Lopes et al., 2010; Moreira et al., 2011). Being no different for bamboo propagation, where the growth gain of morphological variables in response to hydrogel doses is similar to that observed by these authors.

The dose 4g/liter of subsoil land in the disc propagule directly influenced the growth in height, the emission of shoots and leaves, greater increase of dry weight of shoot and root. Studies report that a greater development of morphological variables, greater allocation of dry matter weight of shoot and root is provided by the adequate supply of water and nutrients, provided by adequate doses of hydrogel, prolonging moisture in the rhizosphere and minimizing the effects of root system dehydration on the vegetative propagation of bamboo, corroborating with studies conducted by the authors (Felipe et al., 2019; Sarvaš, 2003; Sarvaš, Pavlenda, & Takáčová, 2007).

The dry weights of the shoots and roots are important in the development of bamboo seedlings, because, when they are well rooted, they have greater growth capacity provided by the greater availability of water. In addition, the use of hydrogel reduces losses from nutrient percolation and leaching and improves soil aeration and drainage,

accelerating the development of the root system and the aerial part of plants (Eloy et al., 2013).

Both species responded in a similar way to the use of the propagules, being the disc propagule more efficient in all morphological variables, height of shoot (cm), number of shoots and roots (un) and dry weight (g) of the experiments. Studies of vegetative propagation of bamboo, in nursery, using these types of propagules are nonexistent, however (Saad, Kumar, & Umrao, 2016) used kaolinitic cuttings in the study of the growth of *Bambusa ventricosa*, found significant results in height, number of leaves, leaf length compared to control and other treatments.

In the study of (Vamil, Agnihotri, & Sharma, 2011) using primary and secondary kaolinitic cuttings of *Bambusa arundinacea* observed significant differences in height, number of shoots and number of leaves. Other authors, also in studies with *Dendrocalamus asper*, observed higher growth efficiency in shoot height, number of shoots and number of leaves in cuttings obtained from basal kaolinitic portions (Arya et al., 1999; Singh et al., 2012).

In works with *Guadua angustifolia* that propagules obtained from the basal and median parts of the plant showed greater capacity for the formation and growth of shoots and roots (Jiménez et al., 2006; Kaur Nadha et al., 2011; Sandhu, Wani, & Jiménez, 2018). In The study of (Mudoi et al., 2013) evaluating cuttings taken from rods between 1 and 2 years of age from *Bambusa vulgaris* Schrad. ex J.C. Wendl, found that the highest rooting index and vegetative growth occurred in cuttings of the basal and median positions, both in the primary and secondary branches.

5. Conclusions

The treatment with 4g/liter of hydrogel provided the best morphological growth patterns of clonal seedlings of *Dendrocalamus asper* and *Bambusa vulgaris* var. *Vittata*. The propagule disc was that it provided better morphological growth patterns of both species.

Based on the results obtained, it is recommended the use of water retention polymers in the planting of bamboo seedlings, since it increases the retention of water in the soil avoiding water stress and provides better development of seedlings. However, further studies are needed in real field conditions and follow-up of seedlings for a longer period.

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