


## SCIENTIFIC ARTICLE

# Semihydroponic and ebb-and-flow systems for calla lily cultivation

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## Abstract

The soilless cultivation of plants is an alternative for the production of flowers with high quality. Calla lily is normally produced on soil benches, but have shown some limitations as bacterial infections occur. One alternative may be a soilless cultivation. Hence, experiments were conducted with the objective to evaluate the development of calla lily in two types of hydroponic production systems. The semihydroponic system was tested using as substrates or growing media such as, coconut fiber, sand, vermiculite, and phenolic foam sheets. For the other system, ebb-and-flow, the substrates tested were vermiculite, coconut fiber, and expanded clay. Two different nutritional solutions were tested in both systems. In the semihydroponic system. In general, calla lily was adapted and showed a good development in a soilless cultivation. The best initial development of the calla lily was provided using vermiculite and sand as substrates on semihydroponic. And for the ebb-and-flow system, coconut fiber induced better development. As conclusion, hydroponic cultivation systems are efficient for the initial development of calla lily. The recommended substrates are those with lower porosity, such as sand, vermiculite, and coconut fiber.

**Keywords:** hydroponic systems, nutrient solution, seedlings, soilless cultivation, *Zantedeschia aethiopica*.

## Resumo

### Sistemas semi-hidropônico e ebb-and-flow para cultivo de copo-de-leite

O cultivo de plantas em sistema sem solo é uma alternativa para a produção de flores com alta qualidade. O copo-de-leite é normalmente produzido em canteiros, mas tem apresentado algumas limitações à medida que ocorrem infecções bacterianas. Uma alternativa pode ser um cultivo sem solo. Assim, experimentos foram conduzidos com o objetivo de avaliar o desenvolvimento do copo-de-leite em dois tipos de sistemas de produção hidropônicos. O sistema semi-hidropônico foi testado utilizando como substratos ou meios de cultivo fibra de coco, areia, vermiculita e espuma fenólica. Para o outro sistema, fluxo e refluxo, os substratos testados foram vermiculita, fibra de coco e argila expandida. Duas soluções nutricionais diferentes foram testadas em ambos os sistemas. Em geral, o cultivo de copo-de-leite foi adaptado e as plantas apresentaram bom desenvolvimento em cultivo sem solo. O melhor desenvolvimento inicial do copo-de-leite foi proporcionado pelo uso de vermiculita e areia como substratos em semi-hidropônico. E para o sistema de fluxo e refluxo, a fibra de coco induziu melhor desenvolvimento. Como conclusão, os sistemas de cultivo hidropônico são eficientes para o desenvolvimento inicial do copo-de-leite. Os substratos recomendados são os de menor porosidade, como areia, vermiculita e fibra de coco.

**Palavras-chave:** cultivo sem sol, mudas, sistemas hidropônicos, solução nutritiva, *Zantedeschia aethiopica*.

## Introduction

In the growing floriculture market, calla lily (*Zantedeschia aethiopica* L.) is an important source of cut flowers (Almeida and Paiva, 2012; Reis et al., 2020).

However, producers have detected some production limitations, such as its seasonality of production, dependence on environmental conditions, and phytosanitary problems, especially the incidence of *Pectobacterium carotovorum* (Sin: *Erwinia carotovora*) (Almeida and Paiva, 2012). The

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cultivation of calla lily in a protected environment provides ideal conditions for intensive production and higher-quality inflorescences, with an ideal cultivation temperature of 25-28 °C (Rodrigues et al., 2014).

One option for protected cultivation is a hydroponic system using a soilless cultivation for growing plants in solid, liquid, organic or inorganic material (Gautam et al., 2021). Hydroponic systems can be classified according to the technique used (Gautam et al., 2021). The semihydroponic system, where the solution is not returned to the storage tanks, in addition to ensuring the constant supply of water and nutrients to the roots of the plants, prevents water-borne diseases from spreading throughout the production process. Another system is the nutrient film technique (NFT), which minimizes the amount of cultivation substrates and their influence on plant growth, in addition to ensuring root oxygenation and hydration. This system is efficient for the production of calla lily (Landgraf et al., 2015; 2017).

Hydroponic cultivation systems work best with substrates and, among other advantages, have more efficient use of water and nutrients, together with their ability to yield better quality products (Pradhan and Deo, 2019; Waiba et al., 2020; Jani et al. 2021). The substrates for the anchoring of plants in hydroponic cultivation, either in soilless channels or in pots, are diverse and may be inorganic or organic, used alone or in blends (Gautam et al., 2021). The use of inert substrates avoids the exposure of seedlings to soil pathogens (Savvas and Gruda, 2018) in addition to changing the cultivation requirements (Boldrin et al., 2019).

It is noteworthy that the development of calla lily plants in a conventional production (cultivation in soil) system increases development and flower production (Carneiro et al., 2011). Regarding nutritional requirements, N, B, and S are the most demanded by calla lily plants (Almeida et al.,

2015). However, calla lily is sensitive to salinity caused by excessive doses of fertilizers (Almeida et al., 2012). Calla lily plants under salt stress conditions have reduced plant height, fewer leaves and shoots, and anatomical changes (Figueiredo et al., 2017). Thus, it is important to monitor its nutrient solutions.

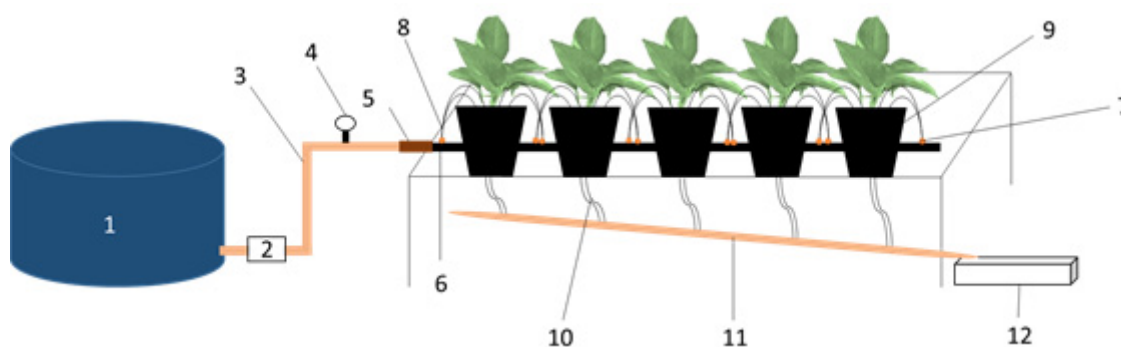
Considering the advantages of hydroponic cultivation, coupled with the lack of information on the quality of calla lily grown without soil, the objective of this study was to evaluate the reliability of two hydroponic systems, with different substrates and nutrient solutions, for the development of calla lily.

## Materials and Methods

For soilless cultivation of calla lily (*Zantedeschia aethiopica L.*), two different production systems, semihydroponic and ebb-and-flow were tested, in a protected cultivation (greenhouse) with shading provided by a plastic cover.

### Semi-hydroponic system

The semi-hydroponic system consisted of a non-circulating system, where plants cultivation was done in 9-liter pots, filled with the substrates tested: coconut fiber (medium), sand (medium size), vermiculite (0.2-0.4 cm), and phenolic foam sheet (5×5×5 cm, density 25 kg m<sup>-3</sup>). The pots received fertigation through the “spaghetti” (drip – Figure 1 n.8) system using two different solutions (“Leaves” and “Fruits” - Table 1). The hydraulic circuit for transporting the solution was individualized for each formulation, consisting of two water tanks and centrifugal motor pumps with a capacity of 3.0 m<sup>3</sup> h<sup>-1</sup>. The circulation of the solution was automatically activated once a day, around 11 am (Figure 1).



**Figure 1.** Schematic representation of the semihydroponic system. 1) Nutrient solution reservoir box; 2) centrifugal motor pump; 3) PVC pipes for nutrient solution; 4) manometer; 5) hydraulic control; 6) irrigation hose (principal); 7) valves; 8) drip emitters; 9) cultivation pots; 10) drains; 11) drainage pipe; 12) collector basin;

The absorption of water and nutrients occurred from the substrates that was maintained humid, but without soak. Excess solutions are drained by fine drains (Figure 1 n.10) arranged at the pot base and then collected by drainage pipe (Figure 1 n.11) to the collection basin (Figure 1 n.12). As the

collected solution was not clear and to avoid contamination, it was not reused in the experiment, but reused for garden irrigation. The pH (6.0) and electrical conductivity (1.2 ds m<sup>-3</sup>) of the nutrient solutions were monitored throughout the cultivation period.

For planting, rhizomes with 3.0 cm diameter (in average) were obtained from mother plants cultivated in greenhouse. The rhizomes were arranged directly on the substrates, allowing to develop one plant per pot.

The seedlings were kept in greenhouse with under natural light conditions (irradiance of 250-450  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) and temperature (16 to 22 °C) adequate for the good development of this species.

The experiment was set up in a randomized experimental design in a 2 (solutions)  $\times$  4 (substrates) factorial arrangement, totaling 8 treatments with 4 replicates and 3 plants per plot, each plot consisting of 1 pot with 1 plant. The evaluations were performed at 75 days of cultivation, characterizing the end of the initial development period defined by the beginning of flowering. Plant height (cm), number, length (cm), and width (cm) of leaves, and formation of new shoots were evaluated.

### Ebb-flow system

The ebb-and-flow hydroponic system consisted of the

arrangement of pots in containers (boxes) where water and fertilizers were provided by fertigation (Figure 2). In this system, the seedlings were planted in 9-liter pots, placed in boxes at 2 pots per box. The pots were filled with the tested substrates: coconut fiber, expanded clay, and vermiculite and maintained at a greenhouse with under natural light conditions (irradiance of 250-450  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) and temperature (16 to 22 °C). For planting, rhizomes with an average diameter of 3.0 cm were used, arranged directly on the substrates, allowing the growth of 1 plant per pot. Each box received irrigation through tubes, until filled them. The solution was then absorbed by the pots by capillarity. The two nutrient solutions tested were kept in individual boxes outside of the greenhouse, and the pH and electrical conductivity were frequently monitored. Along with the boxes with the solutions, a box with water was also used, which alternated with the solutions in supplying the plants. The solutions were pumped into the irrigation channels using motor pumps. The system was activated by a timer two to three times a day.



**Figure 2.** Ebb-and-flow system in a Greenhouse, 50% shade

The experiment was set up in randomized block design in a 3 (substrates)  $\times$  2 (nutrient solutions) factorial arrangement. Two pots with one plant each were placed in each box. Each pair of pots constituted one plot, for a total of four replicates. At 75 days after planting the rhizomes, the seedlings were evaluated for height (cm), number, length (cm), and width (cm) of leaves and formation of new shoots.

The fertilization of the calla lily in both systems was performed by applying a nutrient solution prepared with water-soluble fertilizers, according to the solutions recommended for the production of fruit and leafy vegetables (Landgraf et al., 2015, 2017). These solutions (Table 1) had been already tested for calla lily. In the nutrient solutions, the following fertilizers were used:

potassium nitrate (36% K and 13% N-NO<sub>3</sub>), calcium nitrate (17% Ca and 12% N-NO<sub>3</sub>), magnesium sulfate (10% Mg and 13% S), monobasic potassium phosphate (29% K and 23% P), boric acid (17% B), copper sulfate (24% Cu and 12% S), manganese sulfate (25% Mn and 21% S), zinc sulfate (22% Zn and 11% S), sodium molybdate (39% Mo), and Fe-EDDHA (6% Fe).

The data were subjected to analysis of variance, and the means were compared using the Scott-Knott test at 5% probability.

An overview of the experiments is provided in Figure 3, showing the systems (Figure 3-A and F), the reservoir (Figure 3-D), the pot with the substrates (Figure 3-B), the water collection (Figure 3-C), the Web and Flow system recipient with the full volume of the solution (Figure 3-E).

**Table 1.** Amounts of nutrients (mg L<sup>-1</sup>) applied in the different nutrient solutions.

Nutrient	Quantity (mg L <sup>-1</sup> )	
	“Fruit Solution”	“Leaf Solution”
N-NO <sub>3</sub> <sup>-</sup>	169.0	238.0
P	62.0	62.0
K	311.0	426.0
Ca	153.0	161.0
Mg	43.0	24.0
S	50.0	32.0
B	0.2	0.3
Cu	0.03	0.05
Fe	4.3	5.0
Mn	1.1	0.4
Mo	0.05	0.05
Zn	0.3	0.3

Source: according to Landgraf et al. (2015, 2017)

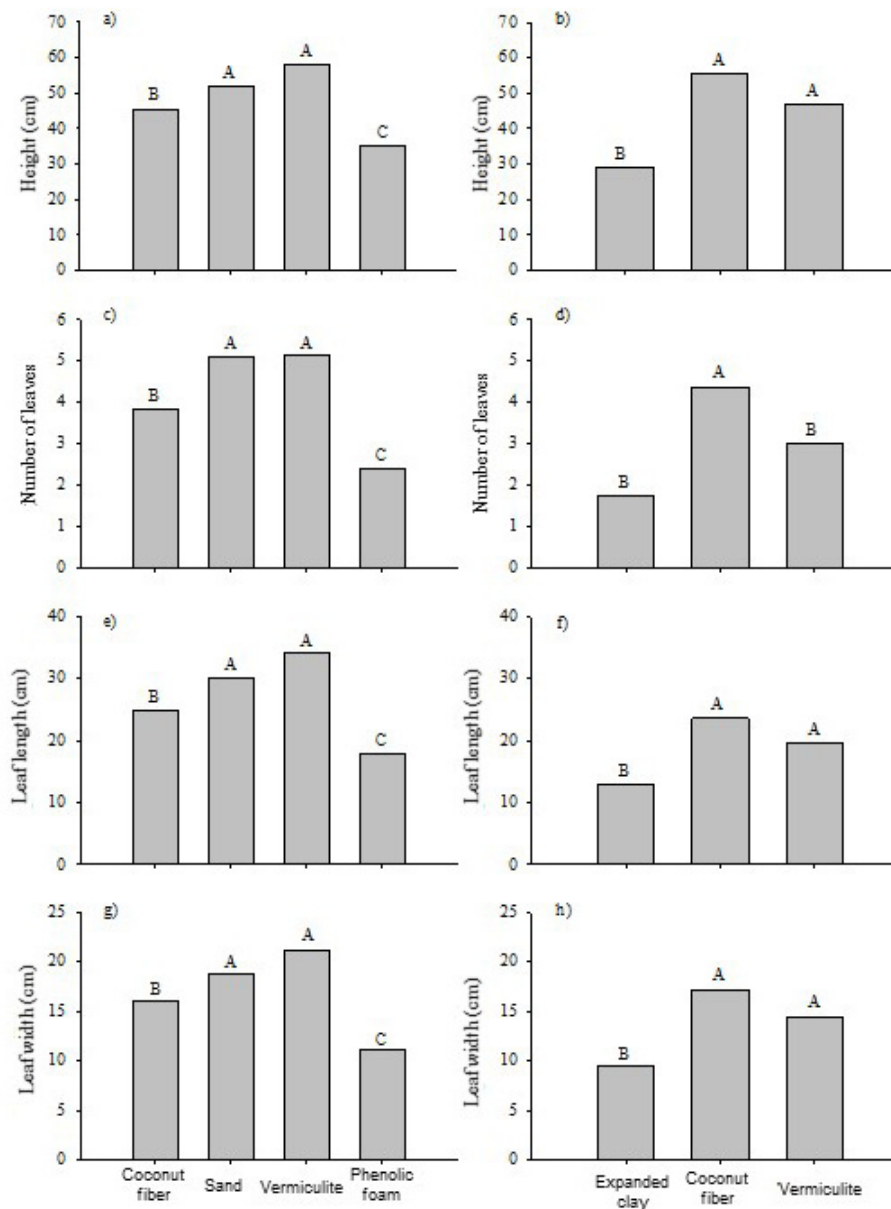


**Figure 3.** The hydroponic systems. A) Detail of the Semihydroponic system B) Plants, substrates on the Semihydroponic system C) Water collection on the semihydroponic system D) Reservoirs for water and solutions E) Web and Flow system detail F) Web and Flow system

## Results

There was no interaction between substrates and solutions tested. The substrates used affect the plant development in bolt systems. The substrate used

influenced plant development in the tested systems. In the semihydroponic system, plants grown in vermiculite or sand grew higher. In the ebb-and-flow hydroponic system, greater height was obtained in plants grown in coconut fiber or vermiculite (Figure 4).



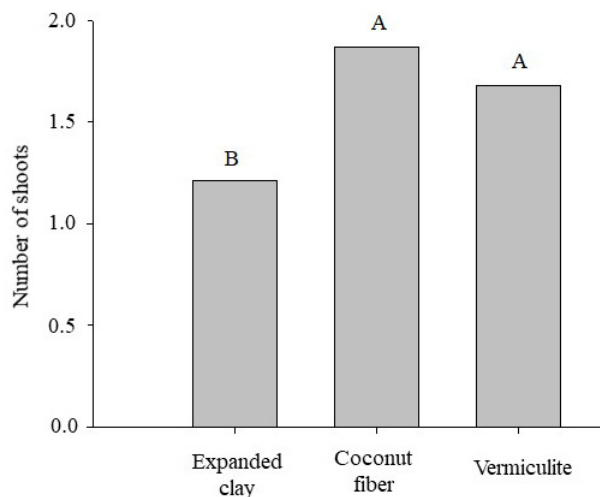
**Figure 4.** Development of calla lily plants grown in a semihydroponic system (left) or an ebb-and-flow hydroponic system (right) from rhizomes grown in different substrates.

The calla lily plants had more leaves when grown in vermiculite or sand in the semihydroponic system and in coconut fiber in the ebb-and-flow system, regardless of the nutrient solution applied (Figure 4).

The substrates that promoted longer calla lily leaves in the semihydroponic system were vermiculite and sand (Figure 4). The leaves in the vermiculite group averaged 34.3 cm long, and the plants grown in sand in the solutions recommended for fruit and leafy vegetables had leaves 30.18 cm in length. Plants grown in phenolic foam showed lower growth, with leaves approximately 17.8 cm long. In the ebb-and-flow system, the coconut fiber and vermiculite substrates promoted the best leaf development, with lengths of 23.5 and 19.6 cm, respectively.

The plants grown in vermiculite or in sand also had greater leaf widths, 21.1 cm or 18.9 cm, respectively, in the semihydroponic system. In the ebb-and-flow system, the substrates coconut fiber and vermiculite provided the greatest leaf widths of approximately 17.2 and 14.5 cm, respectively (Figure 4). Phenolic foam and expanded clay, in the hydroponic system and in the ebb-and-flow system, provided smaller leaf widths, regardless of the nutrient solution used, with leaves 11.1 cm and 9.58 cm wide, respectively.

The ebb-and-flow hydroponic system promoted the formation of shoots, and the plants grown in coconut fiber or vermiculite produced the most shoots (Figure 5).



**Figure 5.** Number of shoots produced by calla lily plants grown from rhizomes cultivated in an ebb-and-flow hydroponic system.

Up to 75 days of cultivation, no calla lily plants of the semihydroponic system produced new shoots, which may be associated with our use of rhizomes as the propagation material, as they require a longer cultivation period for the formation of new shoots.

## Discussion

The adequate conditions provided by the protected environment for the cultivation of calla lily, such as greater control of temperature, shading, and irrigation, favored the rapid sprouting of rhizomes and the initial development of calla lily plants in both cultivation systems. The cultivation of several crops in a protected environment and the production of high-quality and high-yield products are possible with the use of hydroponics, mainly due to the precise control of mineral nutrition and several factors related to the good growth and development of plants (Gautam et al., 2021).

In the hydroponic systems evaluated, there was no effect of nutrient solution on the initial development of calla lily plants. The same situation was observed in roses cultivation (Avellar et al., 2021). In an earlier study, the development of calla lily in the NFT hydroponic system was also not influenced by nutrient solution. The authors used similar solutions as there were tested in this study – both “Fruit” and “Leaf” solutions (Landgraf et al., 2015). In order study, Landgraf et al., 2017 identified that the “Fruit Solution” provided better results for calla lily production. Due to that e in order to improve and aiming for a better result, the compositions of the nutrient solutions used in that study were adapted from those previously tested.

The worst growth occurred with the use of expanded clay in the ebb-and-flow system. Since this substrate, expanded clay, do not retain much water (only sustain the plants) and in this system the water plus nutrients were available for the plant for a limited period of time, we figure out that the nutrients absorption may be limited. Due to that, plants did not absorb the enough amounts of nutrients need to their growth Calla lily rhizomes grown in phenolic

foam developed the worst in the semihydroponic system. It is important to consider that phenolic foam correspond to a larger material and thus leave large spaces between their components. Those larger spaces favor aeration but can impair the water retention by the material (Zorzeto et al., 2014). The opposite is true for the substrates sand and vermiculite, which despite providing excellent porosity have small spaces, providing longer retention with higher values of available water.

In the cited NFT system, in which water circulation is constant, the development of calla lily plants was favored by the use of larger phenolic foam (PF2, 5.0×5.0×3.8 cm), providing greater dry matter accumulation in the shoots and rhizome, as well as higher photosynthetic rates, regardless of the nutrient solution used (Landgraf et al., 2015). However, when different profile sizes of an NFT system were used, there was an effect of the nutrient solution used, with production being favored by the use of the leaf solution in a larger profile (Landgraf et al., 2017).

Flood irrigation systems such as the ebb-and-flow system are characterized by less water use and greater leaching control, which contributes to the reduction of environmental impacts (Montesano et al., 2010). Regarding the benefits of the ebb-and-flow hydroponic system, in addition to the constant supply of nutrient solution, which enables a higher nutrient use efficiency, there is also no loss of water to the environment due to the reduction in evaporation losses (Gent and McAvooy, 2011).

Cultivation in vermiculite or sand allowed the development of five leaves per plant, while the plants that grew in phenolic foam had on average two leaves. Plants grown in coconut fiber in the ebb-and-flow system produced four leaves on average. Carneiro et al. (2011) observed, at 75 days of cultivation of calla lily on a coconut fiber substrate in a greenhouse, approximately 14 leaves per plant. This difference may be a consequence of the propagation material used because Carneiro et al. (2011) started cultivation with seedlings, while rhizomes were used here. Also, the substrates used were different, affecting plant development.

Substrates with smaller spaces between particles retain more water and nutrients, which has been shown to favor the development of calla lily (Figure 3). The length of the calla lily leaves grown in vermiculite or sand was quite satisfactory, and they grew fast, compared to plants grown in a traditional cultivation system for a longer time (Carneiro et al., 2011 and Souza et al., 2010). However, when grown in phenolic foam or expanded clay, the length of the leaves, 17.8 cm, resembled the 16.79 cm reported in plants grown in water with nutrient solution (Almeida et al., 2015). This indicates that this species, despite adapting to hydroponic cultivation, presents better development when inert substrates with lower porosity are used.

As observed for leaf length in calla lily (Figure 3), Carneiro et al. (2011) and Souza et al. (2010) found similar values for leaf widths of 24.77 cm and 20.99 cm for the same crop at 210 days of cultivation. Almeida (2015) observed leaves of calla lily plants approximately 11.25 cm wide at 360 days, again similar to the result obtained with plants grown in phenolic foam in the semihydroponic system.

The average size of the substrate particles and the porosity provided affect the water retention and supply capacity (Figure 4). It was thus shown that the best performance of the calla lily plants occurred in crops grown in sand or vermiculite in the semihydroponic system and in coconut fiber or vermiculite in the ebb-and-flow system.

It is important to consider that in the ebb-and-flow hydroponic system, the nutrient solution comes into contact with the roots of the plants by capillary action, a process that is conditioned on the properties of the substrates. Thus, in capillary irrigation systems, it is essential to take into account the attributes related to particle size and substrate porosity to allow the water to rise to the upper layers of the containers to become easily available (Barreto et al., 2012). The use of substrates with a fine texture, such as coconut husk fiber, is recommended in systems with capillarity irrigation (Barreto et al., 2012).

The cultivation of calla lily in coconut fiber substrate in the ebb-and-flow hydroponic system favored the development of the plants, thus confirming the need to select the right substrate with adequate porosity. The main advantages of coconut fiber as a substrate are related to its good physical properties, its nonreaction with nutrients applied to plants, and the high durability and abundance of this raw material (Gautam et al., 2021).

Calla lily plants grown in phenolic foam or expanded clay in the semihydroponic or ebb-and-flow hydroponic system, respectively, exhibited worse development, which may be related to the large component size and thus greater aeration of these substrates; however, they do not retain moisture as well as substrates composed of smaller particles.

The different nutrient solutions used did not promote differences in the initial formation or development of calla lily seedlings in the tested ebb-and-flow hydroponic or semihydroponic system. Landgraf et al. (2015) also found

that the initial development of calla lily was not affected by the solution in their NFT system (Landgraf et al., 2015), indicating that in this initial phase, the formulations used were equally efficient. However, in the production phase, the specific formulation is relevant (Landgraf et al., 2017). The different systems tested here, semihydroponic and ebb-and-flow, were efficient for the initial development of the calla lily. The NFT can also provide efficiency for the cultivation of this species (Landgraf et al., 2015; 2017), and all are viable alternatives for the production of calla lily.

Despite the efficiency of calla lily production in the hydroponic systems evaluated in this study, the main advantage of the ebb-and-flow system over the semihydroponic system is the reuse of the nutrient solution. This feature reinforces the efficiency of water use and thereby reduces environmental impacts, enabling more sustainable production.

## Conclusions

Hydroponic cultivation systems are efficient for the initial development of calla lily, although the ebb-and-flow system has more sustainable characteristics. Substrates with lower porosity, such as sand, vermiculite, and coconut fiber, are recommended for cultivation in the evaluated systems.

## Author contribution

**KVFB:** methodology, experiment conduction, data collected; analysis, writing; **PDOP:** conceptualization, resources, supervision, analysis, writing, review and editing; **JCVB:** methodology, experiment conduction, data collected; **SST:** methodology, experiment conduction, data collected; **EFAA:** conceptualization, supervision, methodology, data collected, analysis, review; **SNR:** conceptualization, supervision, methodology, data collected, analysis, review; **PRCL:** conceptualization, supervision.

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