Zantedeschia's root morphology influenced by nitrogen and phosphorus multiple deficiency[1]

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ABSTRACT

The knowledge of the phenomena that occur in root systems developed under nutritional deficiency is still limited. Among the factors that may raise doubt in the identification of nutritional state, multiple deficiencies stand out. This study aimed to evaluate the effect of multiple and single omission of nitrogen and phosphorus in nutrient solution on roots development in *Zantedeschia aethiopica*. For that, plants were cultivated over a period of eight months in treatments with complete Hoagland and Arnon solution (1950), with the omission of N (Nitrogen), omission of P (Phosphorus), omission of NP and nutrient solution with NP at concentrations of 25%, 50% and 75%, totaling seven treatments with four replications, in a completely randomized design. At the end of the experiment period, length, root volume, root dry mass and density were evaluated. Plants grown in solution with omission of P and with 25NP were those that most exploited space with their roots. The diameter of roots was influenced by multiple deficiencies of macronutrients. The mineral composition of the plant roots is influenced by multiple deficiencies of N and P.

Keywords: *Zantedeschia aethiopica*, calla lily, macronutrient, WinRhizo

RESUMO

Morfologia radicular de *Zantedeschia* influenciada pela deficiência múltipla de nitrogênio e fósforo

Os fenômenos e efeitos que ocorrem em sistemas radiculares desenvolvidos sob deficiência nutricional, ainda são de conhecimento restrito. Associado a isso, dentre os fatores que podem induzir a dúvidas na identificação de deficiências nutricionais, destaca-se a deficiência múltipla. Dessa forma, objetivou-se avaliar o efeito da omissão múltipla e isolada de nitrogênio e fósforo em solução nutritiva em raízes de plantas de copo-de-leite (*Zantedeschia aethiopica*). O copo-de-leite foi cultivado por um período de 8 meses em Solução Hoagland e Arnon (1950) completa ou com omissão de N (Nitrogênio), omissão de P (Fósforo), omissão de NP e ainda solução nutritiva com NP na concentração de 25%, 50% e 75% totalizando assim 7 tratamentos, com 4 repetições e delineamento inteiramente casualisado. Ao final do período experimental foram avaliados comprimento, volume, densidade da raiz e peso seco. As plantas cultivadas em solução com omissão de P e com 25NP exploraram melhor o espaço com o desenvolvimento de suas raízes. O diâmetro das raízes foi influenciado pela deficiência múltipla de N e P, sendo então reduzido. Também, a composição mineral das raízes foi influenciada pela deficiência múltipla de N e P.

Palavras-chave: *Zantedeschia aethiopica,* copo-de-leite, macronutriente, WinRhizo.

1. INTRODUCTION

Calla lily (*Zantedeschia aethiopica*) is a perennial species, cultivated for cut flower and as a garden plant. The production is mainly concentrated in the Southeast Region of Brazil, and is among the main species produced in the State of Minas Gerais (ALMEIDA and PAIVA, 2005; ALMEIDA et al., 2008; LANDGRAF and PAIVA, 2009a, 2009b). It is a rhizomatous plant, originating in South Africa and belonging to the araceae family (ALMEIDA and PAIVA, 2012).

In the development of this species, Carneiro et al. (2011) observed there is an increment in the root production; after 210 days, 18.83% of the amount of dry mass accumulation in the plant occurs in the root system. Almeida et al. (2009) also observed differences in dry mass production in roots of calla lily plants cultivated with different doses of silicon, demonstrating the influence of nutrients in the development of the root structure.

The full length of the root corresponds to the sum of the length of all the root axes formed. This parameter is an indicator of the potential of plants for absorbing water and nutrients in the cultivation substrate and, the longer the total length, the better the substrate exploration (ZONTA et al., 2006). However, the knowledge about the phenomena occurring in root systems developed under nutritional deficiency is still limited (WANG and ZHANG, 2009); among the factors raising doubts in the identification of nutritional deficiencies, multiple deficiencies stand out, as the plant may be deficient in two or more elements, which even more hinders the identification as compared to isolated occurrence (EPSTEIN and BLOOM, 2006). Manual measurement methods may thus be employed, despite automated systems having been widely used for assessing root morphology (WANG and ZHANG, 2009).

Hence, the aim was to analyze the root morphology of *Zantedeschia aethiopica* plants cultivated with multiple omissions of nitrogen and phosphorus.

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2. MATERIAL AND METHODS

The calla lily seedlings were produced by *in vitro* cultivation and acclimatized in greenhouse with intermittent mist, for a 60-day period, in 24-cell plastic trays containing Plantmax® substrate. Then, the seedlings were transferred to plastic trays containing 36 L of 30% of the salts of Hoagland and Arnon (1950) n°2 solution, with constant aeration, for a 20-day period to adaptation. After this period, the plants were transferred to individual pots of 3.0 L capacity, fixed by means of a polystyrene plate of 30 cm in diameter and 4.0 cm thick. The nutritious solution was kept constantly aerated all along the experimental period, and changes were made every two weeks. At the intervals for renewing the solutions, the pots volume was completed with deionized water whenever necessary. The experiment was conducted for 240 days in a greenhouse with a 50% shading screen.

The experimental setting used was fully casualized with 7 treatments in 4 repetitions, being 2 pots per parcel and one plant per pot. The treatments consisted in Hoagland and Arnon (1950) full nutritious solution and Hoagland and Arnon (1950) nutritious solution with N omission, P omission, N and P omission, besides Hoagland and Arnon nutritious solution at 25%, 50% and 75% of the initial N and P concentration.

The WinRHIZO® system was used for analyzing the roots; images were acquired by an Epson® Perfection 3200 photo scanner. Measures related to morphology and root system growth were analyzed, such as total length (cm), total surface area (cm^2), total volume (cm^3), diameter (mm) and root length density (cm m^{-3}). Later, the roots were washed separately in running water and next in distilled water. They were then placed in brown paper bags, identified and dried in a forced-air circulation oven; the temperature was adjusted between 65 ºC and 70 ºC up to constant weight. After this process, the dry mass of the roots and the chemical analysis for determining the N and P contents were set following the methods described by Malavolta et al. (1997).

The data obtained were submitted to variance analysis and the averages were compared by the Scott-Knott test, aided by the SISVAR statistical software (FERREIRA, 2011).

3. RESULTS AND DISCUSSION

The root system development was influenced by the multiple deficiencies applied as treatments (Table 1).

Table 1. Root system characteristics of calla lily plant grown under macronutrients omission multiple.

Solutions *	Length (cm)**	Volume (cm^3)**	Surface Area (cm^2)**	Diameter (mm)**	Density (cm/ m^3)**	Dry mass of root (g)**
Complete	10997.57 c	60.15 a	2838.87 a	0.849 a	10997.39 c	2.63 b
75NP	9624.39 c	44.52 a	2311.06 a	0.770 a	9624.57 c	1.87 b
50NP	12806.62 c	58.37 a	2994.56 a	0.780 a	12806.62 c	2.74 a
25NP	15680.80 b	62.19 a	3446.32 a	0.728 b	15680.79 b	3.04 a
-NP	11255.36 c	57.66 a	2827.40 a	0.815 a	11255.00 c	3.06 a
-N	11558.89 c	48.10 a	2579.96 a	0.703 b	11558.90 c	2.88 a
-P	18188.14 a	41.49 a	3024.80 a	0.544 c	18188.14 a	2.96 a

* Hoagland and Arnon (1950)

**Averages followed by same letter in columns do not differ by the Scott-Knott test at 5%.

No difference was observed in the analyses of volume and surface area of the calla lily roots, suggesting that the concentration of the nutrients supplied or even their omission in the solution is not related to these root system characteristics.

The length of the roots of the plants cultivated in solution with simple and multiple N and P omission was similar to that of the roots cultivated in complete solution. Yet plants cultivated in P-omission solution presented longer root length as compared to the other treatments. A similar behavior was verified for the root diameter analyses. When the plant presents P deficiency, one of the symptoms is the roots tendency to grow, which facilitates finding the nutrient in question (SCHULZE et al., 2005). The efficiency in absorbing vegetal resources is associated to the capacity of exploring the environment; the scarcer the resources present in the environment, the greater the investment in the root system. The plants capacity for obtaining nutrients is related to its capacity to develop an extensive root system (TAIZ and ZEIGER, 2013; ZONTA et al., 2006). Thus, root length and length density are important indicators of the potential of the plants to absorb water and nutrients (HIMMELBAUER, 2004; ZONTA et al., 2006). For example, bean roots suffering from phosphorus stress present radial expansion in favor of continuous root elongation, a process called root etiolation (LYNCH, 2011). The same can be justified for calla lily plants cultivated in P omission, since its roots were longer and thinner, similarly to etiolation.

Furthermore, when analyzing the length density, the plants cultivated in solution with P omission are observed to present a larger space explored by its roots, with greater root length per m^3. For soybean, plants growing in soils poor in P were observed to present size (each root segment) and height (root length) values relatively higher in their root systems as compared to plants cultivated in fertile soils, indicating an adaptive strategy of plants for greater soil exploration efficiency (TERUEL et al., 2001). Several mechanisms have been developed by plants to allow P absorption and use, in environments in which nutrient supply is limited, such as the root growth associated with the root architecture alteration and to the expansion of the root surface due to the proliferation of root hairs (ARAUJO and MACHADO, 2006).

The simple and multiple omissions of P were observed to influence the root dry mass of plants cultivated with different treatments, being smaller in plants cultivated in complete solution, supplied with 75 NP and greater biomass in the other treatments. There are two types of root respiration: growth and maintenance respiration (LYNCH and HO, 2005). Growth respiration is usually associated to the synthesis of new structural biomass, whereas maintenance respiration is generally associated to the maintenance of tissues, enzymes, membrane potential as well as ion transport, and is proportional to the existing biomass.

The low phosphorus availability usually increases the root/aerial part ratio, thus increasing the proportion of daily photosynthates dedicated to root respiration. A growth rate associated to the low availability of phosphorus can be observed in the roots of plants cultivated with multiple omission of phosphorus and nitrogen at the different levels, and maintenance respiration in the roots of plants cultivated in complete solution and 75 NP, not altering their biomass.

The analysis of the root/aerial part ratio (Table 2) shows it is higher in plants formed under total omission of P, indicating there is a greater root development as a way to explore the environment to search for that nutrient, whereas the aerial part has its growth affected by the deficiency of that nutrient.

Table 2. Root/shoot ratio of calla lily grown under macronutrients multiple omission

Solutions*	Root/shoot ratio
Complete	0.24 b
75NP	0.24 b
50NP	0.30 b
25NP	0.35 b
-NP	0.52 a
-N	0.46 b
-P	0.52 a

* Hoagland and Arnon (1950)

** Averages followed by same letter in columns do not differ by the Scott-Knott test at 5%.

Plants have evolved two general strategies to use P in environments in which this nutrient is limited: conservation and active acquisition strategies, which complement each other. Among the acquisition strategies when P availability is low, plants present greater root/aerial part ratio (LYNCH and HO, 2005; BROWN et al., 2013).

The root main functions are absorption and water and solute distribution (CASTRO et al., 2009). An investment in root by the calla lily plants in their first cultivation year may provide a greater and more efficient root system, and especially in their second cultivation year, when the better nourished plants may produce more or longer stems according to the commercial standard.

The main function of P in the plant is that of storing and exchanging energy for synthesizing proteins. In turn, N participates in the development of structures (proteins, enzymes, vitamins, etc.) and processes such as ionic absorption, cell multiplication and absorption, among others (MALAVOLTA, 2006). Roots of plants cultivated in solution with simple omission of N and P presented similar N accumulation as compared to roots cultivated in complete solution (Table 3).

Table 3. Content and accumulation of macronutrients (g kg^{-1}) present in the plants root of calla lily grown under omission of nitrogen (N) and phosphorus (P)

Solutions*	Nitrogen		Phosphorus	
	Content **	Accumul **	Content **	Accumul ***
Complete	2.95 a	7.77 a	1.58 b	3.98 c
75 NP	2.72 a	6.01 b	2.88 a	7.89 a
50 NP	2.19 b	5.09 c	1.32 b	2.48 d
25 NP	2.29 b	6.96 a	1.58 b	4.81 b
-NP	1.60 c	4.89 c	0.66 c	2.05 d
- N	2.29 b	6.61 a	2.46 a	7.11 a
- P	2.25 b	6.68 a	1.76 b	5.21 b

* Hoagland and Arnon (1950)

** Averages followed by same letter in columns do not differ by the Scott-Knott test at 5%.

*** Transformed data $(x+1)^2$

For phosphorus, smaller accumulation was observed to occur in the roots of calla lily cultivated in solution with multiple omissions of NP and 50 NP. As verified in Table 1, the roots of the plants cultivated in these solutions were some with the least growth. This evidences that the multiple deficiency in macronutrients affects the development of calla lily plants more than the simple deficiency of a single nutrient, seeing that the deficiency of one nutrient alone, as verified for P, can stimulate root growth for a while (Table 1), differently from multiple deficiency, with two nutrients. This was also proven in guava seedlings, which presented more intensified visual symptoms of NK and NS multiple deficiencies as compared to N deficiency symptoms in isolation (SALVADOR et al., 1999). Several mechanisms have been developed by plants to allow absorbing and using P in environments where the supply of this nutrient is limited, with greater root growth associated to changes in the root architecture (ARAUJO and MACHADO, 2006).

4. CONCLUSION

Greater length, root/aerial part ratio and root density are observed in calla lily plants cultivated in solution with multiple omission of NP and -P, showing that, in the conditions of this experiment, certain levels of N and P omission at an early growth stage stimulate root development.

The deficiency of a single nutrient, such as P, may stimulate root growth, differently from the multiple deficiency of N and P.

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