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Bokashi, simple superphosphate, and fertigation for the growth and nutrition of hybrid Cattleya (Orchidaceae)

Bokashi, superfosfato simples e fertirrigação no crescimento e nutrição de Cattleya híbrida (Orchidaceae)

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Highlights

Fertigation with urea and potassium chloride promotes *Cattleya* growth.
Isolated use of superphosphates does not promote in *Cattleya* growth.
Bokashi may be a viable option as an organic fertilizer for *Cattleya.*

Abstract

Potted flower production is an important floricultural activity. However, there have been few studies on the fertilization management of orchids. Fertigation with urea and potassium chloride is feasible, but little information is available regarding the interaction of these fertilizers with other sources of nutrients. Thus, the present study evaluated the effects of application of bokashi and a simple superphosphate and their interactions with fertigation on the growth and nutrition of hybrid *Cattleya.* Seedlings of *Laeliocattleya* Drumbeat × *Laeliocattleya* Gold Digger hybrid were submitted to two ferti-irrigation levels (absent and present) using urea and potassium chloride as nitrogen and potassium sources, respectively. As complementary fertilization, bokashi and superphosphate were applied singly and in combination. A commercial fertilizer (Peters®) was used as an additional control. Fertigation increased plant height; leaf area; number, length, and diameter of pseudobulbs; dry mass of leaves, pseudobulbs, and roots; and content of chlorophyll, carotenoid, and nitrogen. The application of bokashi resulted in dry mass gain in all plant organs. The combination of fertigation and bokashi was superior to the commercial fertilizer in terms of increased leaf area, chlorophyll A content, carotenoid content, and dry mass.
Key words: Fertigation. Fertilizer. Orchid.

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Resumo

A produção de flores em vaso é uma importante atividade da floricultura. Todavia, são escassos os estudos sobre o manejo da fertilização em orquídeas. A fertirrigação com ureia e cloreto de potássio é uma prática comum; porém, pouco se sabe sobre suas interações com outras fontes de nutrientes. Nesse sentido, o objetivo do presente estudo foi avaliar o efeito do bokashi e do superfosfato simples e suas interações com a fertirrigação no crescimento e nutrição de um híbrido de *Cattleya.* Mudas do híbrido entre *Laeliocattleya* Drumbeat × *Laeliocattleya* Gold Digger foram submetidas à dois regimes de fertirrigação (ausência e presente) utilizando ureia e cloreto de potássio como fonte de nitrogênio (N) e potássio (K), respectivamente. Além disso, como fertilização complementar foi utilizado o bokashi e superfosfato, aplicados isolados e em combinação. O fertilizante comercial Peters® foi utilizado como testemunha adicional. A fertirrigação propiciou incrementos na altura, área foliar, número, comprimento e diâmetro dos pseudobulbos, bem como na massa seca de folhas, pseudobulbos e raízes, além de aumento nos teores de clorofila, carotenoides e teor de N. O uso do bokashi resultou em ganhos na massa seca em todos os órgãos da planta. A utilização combinada entre a fertirrigação e bokashi foi superior ao fertilizante comercial para as características área foliar, teor de clorofila A, carotenoides, além das características de massa seca.
Palavras-chave: Adubação. Fertilizantes. Orquídea.

Introduction

The genus *Cattleya* (Orchidaceae) represents over 50 species of orchids, with numerous interspecific and intergeneric hybrids, which are greatly appreciated in the market because of their large and showy flowers (Takane, Yanagisawa, & Pivetta, 2010). Fertilization is an essential management practice for commercial orchid production, as it promotes quality gains, allows for standardization, and reduces cultivation time (Furtini, Boldrin, & Mattson, 2015). Typically, however, most commercial fertilizers are not developed for a specific species, resulting in low final quality and high production cost. Thus, nutritional assessments are paramount for increasing production efficiency and quality (Furtini et al., 2015).

Fertigation using soluble formulations is advantageous for orchids because of the feasibility of controlling nutrient concentration and application frequency according to the requirements of the species (Naik, Barman, Rampal, & Medhi, 2013; Wang, 1996; Wang & Konow, 2002). According to Susilo, Peng, Lee, Chen and Chang (2013), during the vegetative growth of *Phalaenopsis* sp., newly formed tissues act as large nitrogen sinks, which tend to decrease with increasing age. However, according to Bichsel, Starman and Wang (2008), the use of 25 mg L^{-1} of phosphorus and 100 mg L^{-1} of nitrogen and potassium is suitable at the vegetative and reproductive stages of *Dendrobium* sp.

In general, orchids require large amounts of nitrogen and potassium (Takane et al., 2010). However, salts or even commercial formulations used for the preparation of nutrient solutions can increase production costs. In contrast, the use of agricultural fertilizers, such as urea and potassium chloride, is simple and economical, and these fertilizers are easy-to-buy alternatives for low-tech producers (Hoshino, Alves, Barzan, Fregonezi, & Faria, 2016a).

The effectiveness of the application of a single nutrient depends on the presence of others. Thus, an option to complement fertigation with urea and potassium chloride is simple superphosphate, which contains phosphorus, calcium, and sulfur (Hoshino et al., 2016a). Another option is to combine fertigation with organic fertilization, because evidence indicates that the combined use of organic and mineral fertilizers favors orchid growth (Rodrigues, Novais, Alvarez, Dias, & Villani, 2010a). According to Hoshino et al. (2016b), fertigation with Peters® (N-P-K, 20-20-20) combined with bokashi application favored the development of the *Cattlianthe* hybrid 'Chocolate drop'.

Bokashi is an organic compound obtained from the fermentation of cereal bran and oilseed cakes, and it is widely used by orchid producers as an organic fertilizer (Takane, Yanagisawa, & Vendrame, 2015). Among the various advantages of bokashi, its varied composition of nutrients and their gradual availability stand out (Naik et al., 2009). To this end, the present study evaluated the effects of the application of bokashi and simple superphosphate and their interaction with fertigation using urea and potassium chloride on the growth and nutrition of a *Cattleya* hybrid.

Material and Methods

Plant material

Seedlings cloned via micropropagation of the stem apices of a hybrid obtained by crossing *Laeliocattleya* Drumbeat and *Laeliocattleya* Gold Digger were used. The stem apices were removed from adult plants and sprouted in a culture medium supplemented with growth regulators. The shoots were sub-cultured. The seedlings were transferred to MS growth medium (Murashige & Skoog, 1962) lacking growth regulators and grown for 6 months before being acclimatized.

The seedlings were acclimatized in polystyrene trays of 128 cells containing sphagnum as the substrate. During this period, the trays were maintained in a *warm greenhouse* located at the Department of Agronomy of the State University of Londrina (UEL), Londrina, Brazil (51°11'W 23°23'S; 566 m asl). The greenhouse is of the Van der Hoeven® model, covered with transparent polycarbonate plates and diffusers, with 50% luminous retention through an Aluminet shade screen; temperature was controlled at 28 ± 3°C. During this period, the seedlings were manually irrigated twice a week for 6 months. The seedlings were 7 ± 2 cm in height and bore a pseudobulb and a bud.

Design and experimental conditions

The trial period was 20 months. Initially, the seedlings were transplanted into black polypropylene pots (diameter, 10.2 cm; height, 7.8 cm; volume, 415 mL) for 10 months. Following this period, the seedlings were transferred to black polypropylene pots (diameter, 13 cm; height, 9.8 cm, volume, 1000 mL) and maintained for additional 10 months until the end of the experiment. During both periods, a mixture of composted pine bark and charcoal was used as the potting medium. The substrates were mixed at equal proportions (1:1, v/v) and passed through sieves with a mesh size of 1.5 and 0.5 cm. Throughout the experimental period, irrigation was performed manually, with 6 mm of water added in the morning daily, except on days when the plants were fertigated.

Two fertigation regimes were used: (1) presence (NK1) and (2) absence (NK0) of urea and potassium chloride. As complementary fertilizers, two sources were used, namely mineral and organic, applied individually or combined. Simple superphosphate (SS) and bokashi (BO) were used as the mineral and organic fertilizers, respectively. In addition, a commercial soluble fertilizer (Peters®; NPK 20-20-20) was used as an additional control.

The amounts and concentrations of the fertilizers applied in the treatments were set to be equivalent to fertilization with Peters®, which was used at a concentration of 3 g L^{-1} and applied in the form of 50 mL of solution per pot every 15 days. For NK1 fertigation, urea (45% nitrogen) and potassium chloride (49.8% potassium) were used at a concentration of 1.34 and 0.98 g L^{-1}, respectively. The fertilizers were weighed on an analytical balance and subsequently diluted in distilled water before each application. Each pot was fertilized with 50 mL of NK1 solution every 15 days.

SS was used as a complementary chemical fertilizer containing 7.9% phosphorous, 16% calcium, and 8% sulfur. BO used as the organic source was the obtained from Bio Bokashi® (MAPA number: SP-80613 10000–8). SS (3 g) was applied once on the substrate at the beginning of the experiment and reapplied after the pot transfer. BO (5 g) was applied over the substrate and reapplied every 5 months. The experimental design was completely randomized in a 2 × 4 + 1 factorial scheme with 12 replicates. Each pot containing a plant was considered as an experimental unit.

Characteristics evaluated

Phytometric characteristics

Twenty months after the beginning of fertilization, the plants were washed with running water to remove the adhered substrate. Subsequently, they were sectioned into roots, pseudobulbs, and leaves. The different organs were washed with distilled water for further evaluation of the following phytometric parameters: plant height (H, cm), measured with a ruler, starting from the plant's neck to the apex of the longest leaf; total number of pseudobulbs (NP, n), obtained by counting; length of pseudobulbs (LP, cm), measured with a ruler, starting from the plant's neck until the insertion of the leaf in the largest pseudobulb; diameter of pseudobulb (DP, cm), measured using a digital caliper on the largest pseudobulb; leaf area (LA, cm^2), measured on images of leaves digitized and analyzed using SisCob (Jorge & Silva, 2009); and root dry mass (RDM, g), pseudobulb dry mass (PDM, g), leaf dry mass (LDM, g), and shoot dry mass (SDM, g) obtained after drying in a forced ventilation oven at 55°C until reaching a constant weight and subsequent weighing on an analytical balance to the nearest 0.001 g.

Chlorophyll and carotenoid content

Content of chlorophyll A (Clf A, mg g^{-1}), chlorophyll B (Clf B, mg g^{-1}), total chlorophyll (Clf A+B, mg g^{-1}), and total carotenoids (Crt, mg g^{-1}) was evaluated using the methodology described by Meschede, Velini, Carbonari and Silva (2011). Fresh leaf tissue samples (0.2 g) were macerated in acetone using a mortar and pestle. The samples were then transferred to 15 mL Falcon tubes, and the volume was raised to

10 mL with acetone. The extracts were filtered and analyzed using a spectrophotometer at 663, 645, and 434 nm to detect Clf A, Clf B, and carotenoids, respectively. Chlorophyll and carotenoid content was determined based on the following equations (Whitham, Blaydes, & Devlin, 1971): Clf A = $(11.24 \times A_{663} - 2.04 \times A_{645})$; Clf B = $(20.13 \times A_{645} - 4.19 \times A_{663})$; and carotenoids = (1000 × A434 − 1.90 Clf A − 63.14 Clf B)/214, where A is the absorbance at the indicated wavelength.

Nutritional characteristics

Shoot macronutrient content was determined from dry tissues. Briefly, pseudobulb and leaf samples were ground in an analytical mill (model A11; IKA Equipment). Nitrogen, phosphorus, potassium, calcium, and magnesium content was determined according to the methodologies described by Silva (2009). Phosphorus content was quantified using colorimetry; calcium and magnesium content was quantified using atomic absorption spectrophotometry; and potassium content was quantified using flame photometry following nitroperchloric digestion. Nitrogen content was quantified using the Kjeldahl method following sulfuric digestion (Instituto Adolfo Lutz [IAL], 2008). The results were expressed in grams per kilogram.

Substrate pH and electrical conductivity (EC)

After completing the assays, pH and EC (μS cm^{-1}) of the substrates were measured according to the methodology described by Abreu, Abreu, Sarzi and Padua (2007) using a pH meter and a portable conductivity meter, respectively.

Statistical analysis

After verifying the normality and homogeneity of variance using the Shapiro–Wilk and Bartlett tests, respectively, the data were subjected to analysis of variance (ANOVA), and the treatment means were compared using the Tukey test (α = 0.05). Treatment means were compared with the additional control means using Dunnett's test (α = 0.05). Multivariate data analysis was performed using principal component analysis (PCA). All statistical analyses were performed using R (https://www.r-project.org/).

Results and Discussion

Phytometric characteristics

Fertigation with urea and potassium chloride (NK1) was statistically superior to no fertigation (NK0) in terms of all phytometric characteristics evaluated, indicating its utility as an efficient alternative to improve the morphoagronomic traits of *Cattleya* orchids (Table 1). Although few studies have verified the effects of urea and potassium chloride fertigation on orchid management, Hoshino et al. (2016a,b) have demonstrated positive outcomes in terms of improvements in several phytometric traits of *Cattleya* spp.

Our results are consistent with previous reports in other Orchidaceae species, highlighting the importance of nitrogen supplementation during growth. According to Zong-Min, Ning, Shu-Yun and Hong (2012), fertilization with 210 mg L^{-1} nitrogen increased leaf area and length during vegetative growth in *Paphiopedilum.* Furthermore, the form in which nitrogen is available to plants affects the efficiency of its use. According to Trépanier,

Table 1

Means height (H), leaf area (LA), number of pseudobulbs (NP), length of the largest pseudobulb (LP), diameter of the largest pseudobulb (DP), root dry mass (RDM), pseudobulbs dry mass (PDM), leaf dry mass (LDM), and shoot dry mass (SDM) of hybrid *Laeliocattleya* Drumbeat × *Laeliocattleya* Gold Digger (Orchidaceae) after 20 months of fertilization management

Treatment[1]		H (cm)	LA (cm^2)	NP (nº)	LP (cm)	DP (cm)	RDM (g)	PDM (g)	LDM (g)	SDM (g)
NK0	–	22.93^{b-}	132.09^{b-}	3.29^{b-}	7.71^{b-}	1.97^{bc-}	2.12^{b-}	1.34^{b-}	3.00^{b-}	4.34^{b-}
NK0	SS	21.13^{b-}	125.85^{b-}	2.64^{b-}	6.53^{b-}	1.86^{c-}	1.77^{b-}	0.98^{b-}	2.69^{b-}	3.67^{b-}
NK0	BO	30.42^{a}	362.73^{a}	5.40^{a}	11.27^{a}	2.22^{ab-}	3.80^{a}	3.15^{a}	8.99^{a}	12.14^{a}
NK0	BO+SS	31.32^{a}	384.71^{a}	5.07^{a}	10.81^{a}	2.55^{a}	3.63^{a}	3.53^{a}	8.80a	12.34^{a}
Medium		26.45^{B}	251.35^{B}	4.10^{B}	9.08^{B}	2.15^{B}	2.83^{B}	2.25^{B}	5.87^{B}	8.12^{B}
NK1	–	31.27^{ab}	335.81^{c-}	4.71^{bc}	10.86^{a}	2.46^{ab-}	3.47^{b-}	3.18^{b}	8.25^{c-}	11.42^{c-}
NK1	SS	29.93^{ab}	326.52^{c-}	4.33^{c}	10.98^{a}	2.62^{ab}	3.18^{b-}	3.11^{b}	8.41^{c-}	11.53^{c-}
NK1	BO	32.55^{a}	503.56^{a+}	6.13^{ab}	10.96^{a}	2.79^{a}	5.26^{a+}	5.20^{a+}	12.65^{a+}	17.86^{a+}
NK1	BO+SS	28.45^{b}	430.15^{b}	6.15^{a}	9.95^{a}	2.30^{b-}	3.30^{b-}	3.79^{b}	10.53^{b}	14.32^{b}
Medium		30.55^{A}	399.01^{A}	5.33^{A}	10.69^{A}	2.54^{A}	3.80^{A}	3.82^{A}	9.96^{A}	13.78^{A}
CV (%)		14.41	21.83	24.95	19.40	14.95	25.24	25.72	20.75	18.30
Peters®		31.83	423.53	5.13	11.40	2.88	4.39	3.58	10.46	14.03

[1]NK0, absence of fertigation; NK1, presence of fertigation; SS, simple superphosphate; BO, Bokashi.
CV: Coefficient of variation. Values followed by the same letters are not significantly different (Tukey's test, at 5% probability).
Means differing positively (+) or negatively (−) from the control (Peters® commercial fertilizer) (Dunnett's contrast, at 5% probability).

Lamy and Dansereau (2009), *Phalaenopsis* preferentially absorbs nitrogen in the form of urea and ammonium. Wang and Konow (2002) reported that in *Phalaenopsis,* formulations containing urea increased shoot weight and leaf area by 40-50% compared with other fertilizers without urea.

In the present study, when fertigation was not used (NK0), treatments containing BO (single BO and BO+SS) were superior to unfertilized treatments and fertilization with SS alone (Table 1). These results indicate that in the impossibility of fertigation, BO may serve as an efficient alternative, since its use, isolated or combined with SS, can improve phytometric characteristics compared with unfertilized treatments and fertilization with SS alone. In contrast, in the presence of fertigation (NK1), the benefits of BO were observed even when not combined with SS, as evidenced by the highest means of most of the evaluated phytometric characteristics under the NK1+BO treatment (Table 1).

Regarding the commercial fertilizer (Peters®), unfertilized treatments and fertilization with SS alone were inferior in terms of all characteristics (Table 1). The use of BO in any combination proved to be equivalent to that of Peters®, except in terms of pseudobulb diameter. In contrast, under the NK1+BO treatment, LA, RDM, PDM, LDM, and SDM were statistically superior to the values under fertilization with Peters® (Table 1). Thus, the combination of fertigation with BO achieved superior results compared with fertilization with the commercial control. Positive results with the use of bokashi have also been reported in different cultures (Álvarez-Solís, Mendoza-NIñeZ, León-Martínez, Castellanos-Albores, & Gutiérrez-Miceli, 2016; Peralta-Antonio, Freitas, Watthier, & Santos, 2019; Raya-Hernández et al., 2020).

Chlorophyll and carotenoid content

The content of Clf A, Clf B, Clf A+B, and Crt was mainly affected by fertigation use. As such, the means of all evaluated characteristics under the fertigated treatments were higher than the values under non-fertigated treatments (Table 2). Contrary to the commercial control, the NK1+SS treatment increased mean Clf A and Clf A+B content (8.22 and 11.20 mg g^{-1}, respectively). In addition, compared with Peters®, the NK1+BO combination increased mean Clf A (5.85 versus 7.33 mg g^{-1}) and Crt (4.78 versus 5.81 mg g^{-1}) content. In *Paphiopedilum arminiacum*, increase in nitrogen concentrations in fertigation increased the Clf A+B content (Zong-Min et al., 2012). Likewise, Maass, Céspedes and Cárdenas (2020) observed that the fertilization of *Petroselinum crispum* with the highest concentrations of bokashi increased shoot dry mass and chlorophyll content.

Table 2

Mean content of chlorophyll A (Clf A), chlorophyll B (Clf B), total chlorophyll (Clf A+B), carotenoids (Crt), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in hybrid Laeliocattleya Drumbeat × Laeliocattleya Gold Digger (Orchidaceae) after 20 months of fertilization management

Treatment[1]		Clf A (mg g^{-1})	Clf B (mg g^{-1})	Clf A+B (mg g^{-1})	Crt (mg g^{-1})	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})
NK0	–	4.79^{a}	1.97^{a-}	6.89^{a-}	3.15^{ab-}	12.26^{a-}	2.01^{c-}	24.52^{a-}	24.29^{a}	5.83^{ab}
NK0	SS	4.34^{a-}	2.02^{a-}	6.36^{a-}	2.81^{b-}	11.12^{a-}	3.51^{a}	25.51^{a}	29.57^{a}	5.83^{ab}
NK0	BO	5.04^{a}	2.25^{a-}	7.29^{a}	3.72^{ab-}	12.70^{a-}	3.09^{b-}	24.05^{a-}	12.85^{b-}	6.35^{a+}
NK0	BO+SS	4.96^{a}	2.35^{a}	7.31^{a}	3.84^{a}	14.10^{a-}	3.82^{a}	21.09^{b-}	12.57^{b-}	5.61^{b+}
Medium		4.78^{B}	2.15^{B}	6.96^{B}	3.38^{B}	12.54^{B}	3.11^{A}	23.79^{A}	19.82^{A}	5.91^{A}
NK1	–	6.47^{b}	3.30^{b}	10.20^{a}	5.58^{a}	22.22^{b}	2.02^{c-}	26.33^{a}	7.18^{c-}	4.33^{b}
NK1	SS	8.22^{a+}	3.25^{b}	11.20^{a+}	5.47^{a}	18.526^{b}	3.33^{b}	23.63^{a-}	13.46^{ba-}	4.13^{b}
NK1	BO	7.33^{ab+}	2.78^{b}	10.15^{a}	5.81^{a+}	20.72^{b}	3.02^{b-}	25.10^{a}	7.56^{cb-}	5.28^{a+}
NK1	BO+SS	7.97^{a+}	3.95^{a+}	11.92^{a+}	5.99^{a+}	27.80^{a+}	4.07^{a}	24.56^{a-}	17.34^{a-}	4.67^{ab+}
Medium		7.50^{A}	3.32^{A}	10.87^{A}	5.71^{A}	22.32^{A}	3.11^{A}	24.90^{A}	11.39^{B}	4.60^{B}
CV (%)		23.01	22.51	22.58	22.36	36.76	11.03	12.18	32.52	14.25
Peters®		5.85	2.98	9.12	4.78	19.80	3.57	27.95	29.72	3.72

[1]NK0, absence of fertigation; NK1, presence of fertigation; SS, simple superphosphate; BO, Bokashi.
CV: Coefficient of variation. Values followed by the same letters are not significantly different (Tukey's test, at 5% probability).
Means differing positively (+) or negatively (–) from the control (Peters® commercial fertilizer) (Dunnett's contrast, at 5% probability).

Macronutrients

Regarding the macronutrients evaluated, fertigation (NK1) increased nitrogen content but decreased calcium and magnesium content (Table 2). Meanwhile, there were no significant differences in the overall mean phosphorus and potassium content between the NK0 and NK1 treatments. In the absence of fertigation (NK0), BO, SS, and BO+SS increased mean phosphorus content (3.51, 3.09, and 3.82 g kg^{-1}, respectively). Similarly, in the presence of fertigation (NK1), the BO and SS fertilizers increased phosphorus content, with the NK+BO+SS combination achieving the phosphorus content of 4.07 g kg^{-1} (Table 2).

Potassium content was slightly affected. In the absence of fertigation (NK0), potassium content under the BO+SS treatment was lower than that under the rest of the treatments. In the absence of fertigation (NK0), BO decreased calcium content from 24.29 to 12.85 g kg^{-1}. In the presence of fertigation (NK1), SS increased calcium content from 13.46 to 17.34 g kg^{-1}. Furthermore, BO increased magnesium content in the presence of fertilization (NK1) (5.28 g kg^{-1}), and the value under the BO+NK1 treatment was statistically superior to that under the NK1+SS treatment (Table 2).

Phosphorus is essential for the growth and development of epiphytic orchids; however, within the plant, phosphorus is mobilized with greater efficiency than nitrogen, increasing the plant's efficiency to use this element. As such, phosphorus can be absorbed and stored in pseudobulbs, making it readily available according to growth demand. In addition, the N/P ratio in nature is rather plastic, ranging from 20:1 to 7:1, depending on the species (Zotz, 2004).

Higher phosphorus content increased plant height with more nodes in *Dendrobium* sp. (Bichsel et al., 2008), whereas nitrogen application increased plant height in *Vanda* sp. even in the absence of phosphorus (Higaki & Imamura, 1987). In *Cymbidium sinense,* shoots have the greatest demand for phosphorus, followed by pseudobulb and leaves, indicating the importance of this nutrient for young tissues (Pan, Ye, & Hew, 1997). In a study on *Phalaenopsis* sp., Wang and Konow (2002) reported that the NPK 20-05-19 and 20-20-20 formulations increased leaf area regardless of the phosphorus concentrations.

According to Naik et al. (2009), the effectiveness of the application of a nutrient depends on the presence of others, and evidence indicates that the combination of organic and mineral fertilizers favors the growth of orchids. In the present study, BO combined with NK1 increased magnesium content (5.28 g kg^{-1}) compared with NK1 applied alone (4.33 g kg^{-1}). Poole and Seeley (1974) have recommended daily fertigation with 50 mg L^{-1} of a nutrient solution containing nitrogen, potassium, and magnesium for *Cattleya* orchids, highlighting the importance of magnesium in orchid cultivation.

Substrate pH and EC

Regarding the chemical characteristics of the substrate, fertigation produced opposite effects on pH and EC (Figure 1). The NK1 treatment reduced pH but increased EC compared with the NK0 treatment. Regarding pH, BO and SS produced no significant effects under any fertigation regime. Conversely, SS increased EC, with the highest mean values observed under the NK1+SS (1021.07 µS cm^{-1}) and NK1+BO+SS (1157.92 µS cm^{-1}) treatments

(Figure 1). According to Takane et al. (2010), most orchids can tolerate substrates with an EC of 500 μS cm^{-1}. However, salinity tolerance may vary depending on the substrate used and irrigation frequency. According to Wang et al. (2008), in *Phalaenopsis* sp., salinity stress damage were observed using a substrate with an EC of ~1,100 μS cm^{-1}.

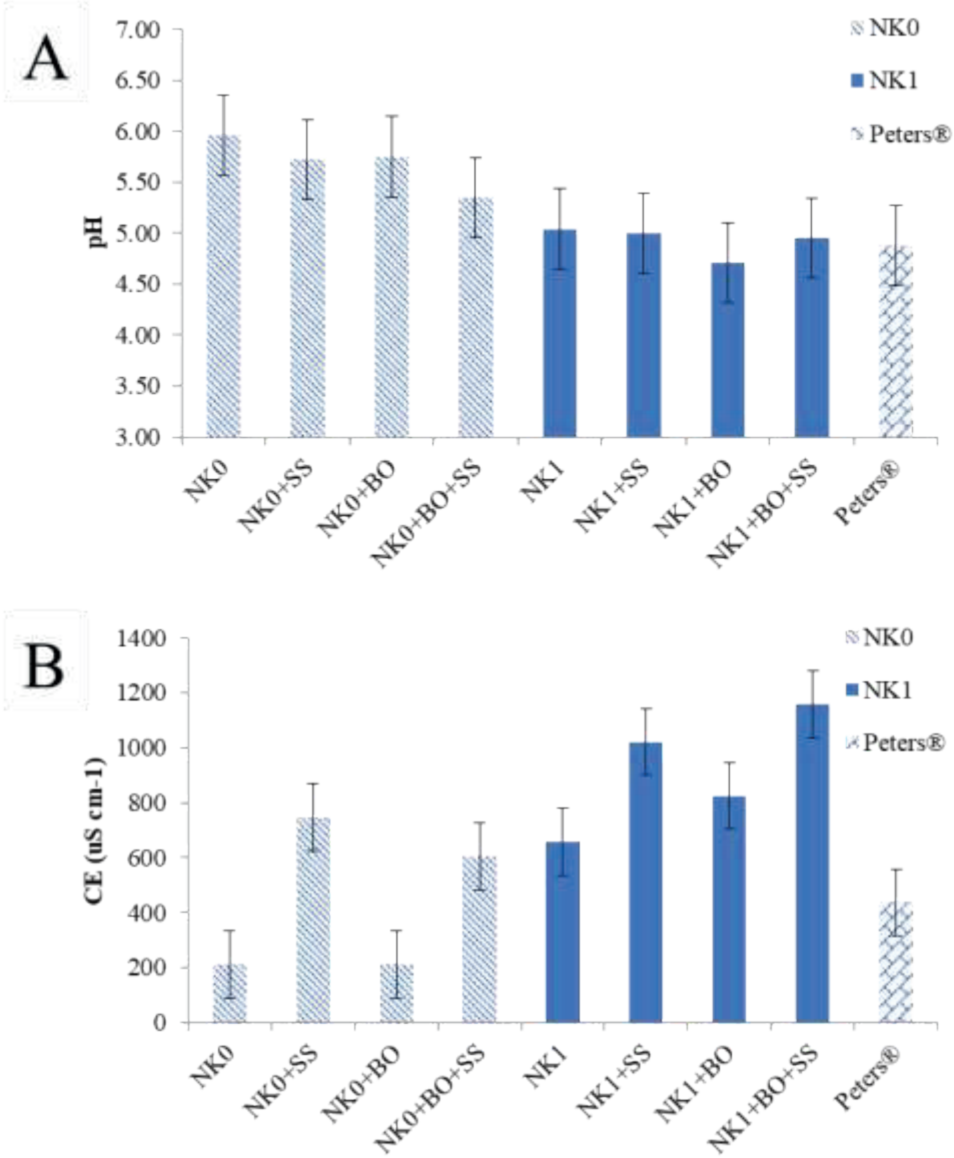

Figure 1. Mean pH (A) and electrical conductivity (B) of substrates from hybrid *Laeliocattleya* Drumbeat × *Laeliocattleya* Gold Digger (Orchidaceae) after 20 months of fertilization. Vertical bars indicate standard deviation of the mean.

PCA

The results of PCA under the conditions of NK0 and NK1 are presented in Figure 2. The first two principal components (PC1 and PC2, respectively) explained 92.35% and 84.72% of the total variation under NK0 and NK1 conditions, respectively. Overall, the PCA results were consistent with the results of Tukey's test. Under NK0, the BO and BO+SS treatments could be differentiated from the rest of the treatments (based mainly on PC1) in terms of being associated with the vectors for growth traits and nitrogen content. These results indicate that in the absence of fertigation with urea and potassium chloride, BO acted as a source of nitrogen, promoting plant growth and vegetative development (Figure 2a).

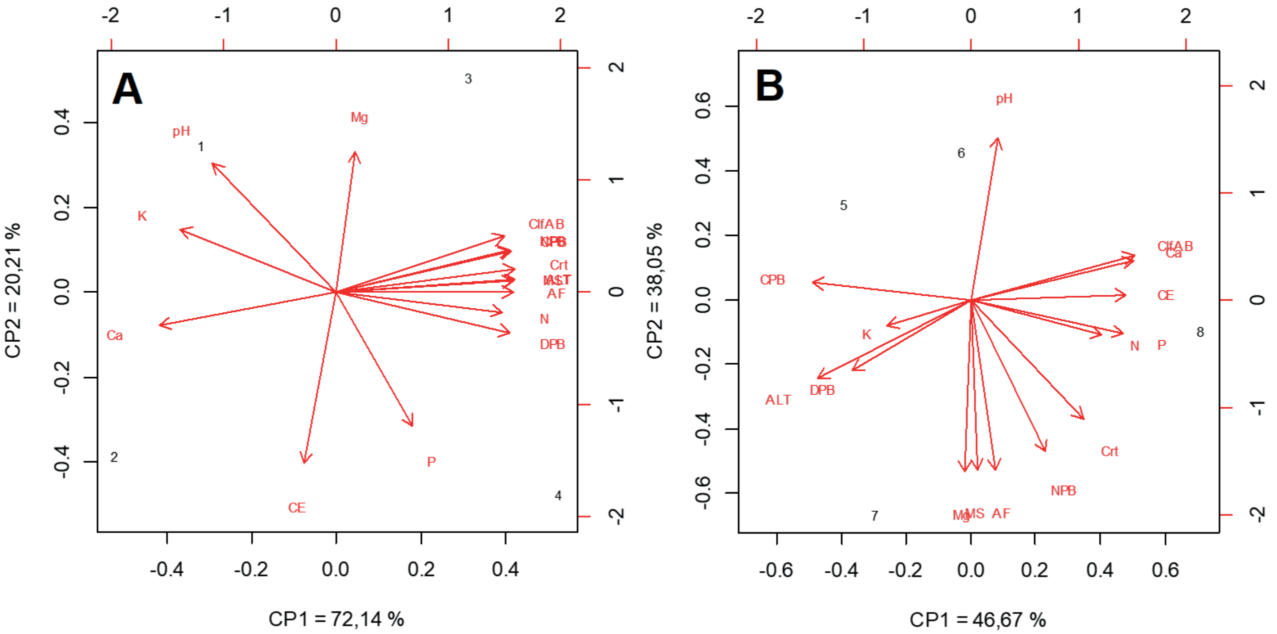

Figure 2. Principal components analysis (PCA) of the characteristics of hybrid *Laeliocattleya* Drumbeat × *Laeliocattleya* Gold Digger (Orchidaceae) in the (A) absence and (B) presence of fertigation with potassium and chloride urea. Height (H), leaf area (LA), number of pseudobulbs (NP), length of the largest pseudobulb (LP), diameter of the largest pseudobulb (DP), shoot dry mass (SDM), chlorophyll A content (Clf A), chlorophyll B content (Clf B), total chlorophyll content (Clf A+B), carotenoid content (Crt), nitrogen content (N), phosphorus content (P), potassium content (K), calcium content (Ca), magnesium content (Mg), pH, and electrical conductivity (EC) were evaluated under the conditions of (1) no fertigation (NK0), (2) simple superphosphate without fertigation (NK0+SS), (3) bokashi without fertigation (NK0+BO), (4) bokashi plus simple superphosphate without fertigation (NK0+BO+SS), (5) fertigation (NK1), (6) fertigation with simple superphosphate (NK1+SS), (7) fertigation plus bokashi (NK1+BO), and (8) fertigation with bokashi plus simple superphosphate (NK1+BO+SS).

Under NK1, the BO treatment could be differentiated from the rest of the treatments in terms of being associated with the vectors for SDM, NP, and LA, growth traits, and magnesium content. These results indicate that the presence of urea and potassium chloride, that is, under non-limiting nitrogen conditions, BO provided other nutrients, such as magnesium, which favored the nutritional balance of plants (Figure 2b). Thus, the NK1+BO treatment is considered the most promising for the growth and development of *Cattleya* orchids (Figure 3).

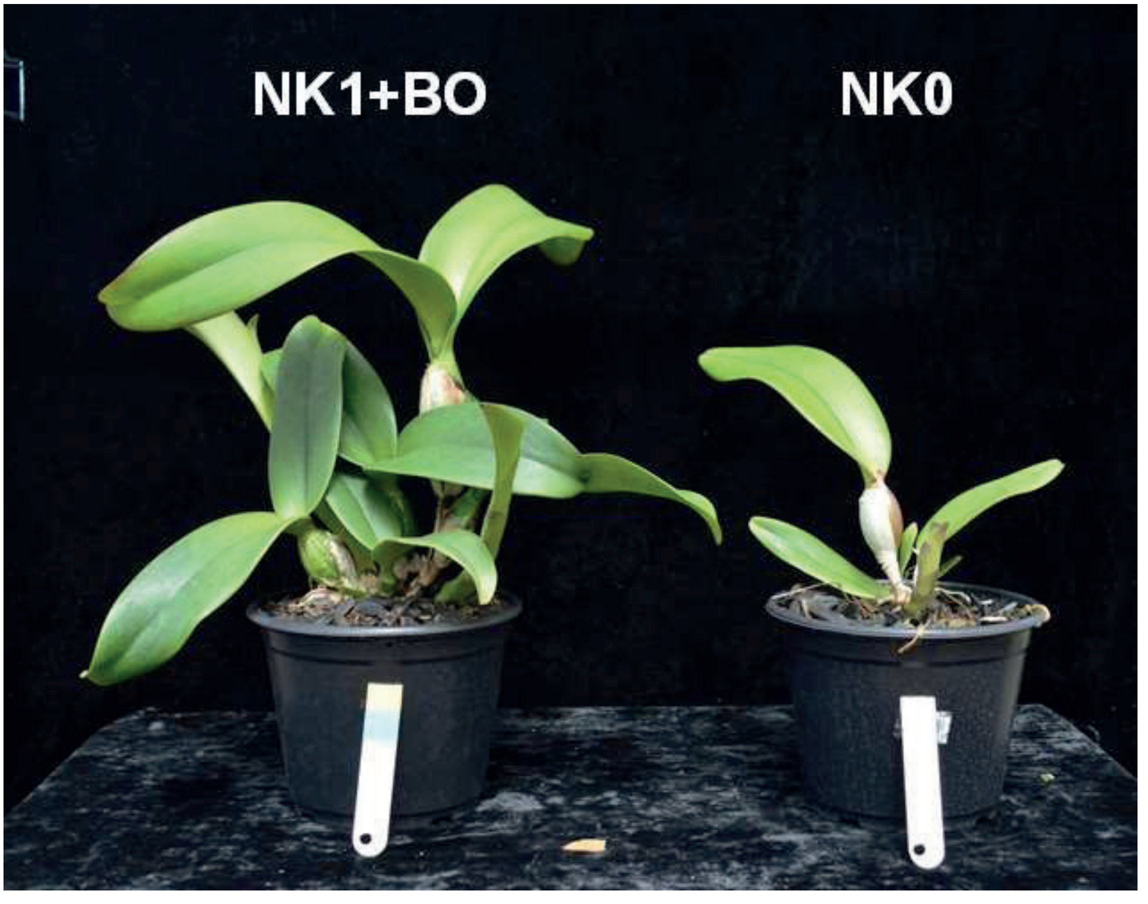

Figure 3. Effect of fertilization management of hybrid *Laeliocattleya* Drumbeat × *Laeliocattleya* Gold Digger (Orchidaceae) using fertigation with urea and potassium chloride in combination with bokashi (NK1+BO) and no fertigation (NK0) for 20 months.

Conclusion

The present study demonstrated that fertigation with urea and potassium chloride promoted plant growth. While the use of SS cannot be justified, BO appears to be as a viable option as an organic fertilizer. However, when applied in combination with urea and potassium chloride fertigation, BO may serve as an excellent option for the fertilization management of *Cattleya* orchids.

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