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Electrical conductivity and frequency of fertilizer application on the growth of the *Brassia verrucosa* lindley orchid

Condutividade elétrica e frequência de aplicação de fertilizantes no crescimento da orquídea *Brassia verrucosa* lindley

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Highlights

The electrical conductivity of fertigation influences *Brassia verrucosa* growth.
Excessive frequency of fertigation is harmful to *Brassia verrucosa.*
The pH of the substrate is important in determining electrical conductivity.

Abstract

Electrical conductivity and frequency of fertigation application to orchids have not been established. This study aimed to evaluate the influence of electrical conductivity and fertilizer application frequencies on Brassia verrucosa growth and nutrition. *Brassia verrucosa* seedlings were grown for 18 months. Urea, potassium chloride, and monoammonium phosphate diluted in three concentrations, that is, C1 (0.5:0.5:0.5, g L^{-1}), C2 (1:1:1, g L^{-1}), and C3 (2:2:2, g L^{-1}) were used as sources of nitrogen (N), potassium (K), and phosphorus (P), respectively. The electrical conductivities reached values of 1.25, 2.5, and 4.7 mS cm^{-1}, respectively. Three application frequencies were adopted: monthly (F1), fortnightly (F2), and weekly (F3). The control consisted of plants that were only irrigated. The experimental design was completely randomized with 10 replications, in a 3x3+1 factorial scheme. The photometric parameters and macronutrient content in the shoot were subjected to analysis of variance and Tukey's test at a 5% significance. The conductivity of solutions resulted in higher increases over the phytometric variables. Increased electrical conductivity led to increments in *Brassia verrucosa* growth, as well as increases in N, P, and K contents. Conductivity C3 (4.7 mS cm^{-1}) associated with fortnightly (F2) or weekly (F3) application frequencies increased the number of shoots.

Key words: Salinity. Fertigation. Orchidaceae. Plant nutrition.

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Resumo

A condutividade elétrica e frequência de aplicação na fertirrigação de orquídeas, não estão estabelecidas. O objetivo foi avaliar a influência da condutividade elétrica e das frequências de aplicação de fertilizantes, no crescimento e nutrição de *Brassia verrucosa.* Mudas de Brassia verrucosa foram cultivadas por 18 meses. As fertilizações tiveram como fonte de nitrogênio (N), fósforo (P) e potássio (K): ureia, cloreto de potássio e fosfato monoamônico diluídos em três concentrações: C1 (0,5:0,5:0,5; g L^{-1}), C2 (1:1:1; g L^{-1}) e C3 (2:2:2; g L^{-1}). As condutividades elétricas apresentaram 1,25, 2,5 e 4,7 mS cm^{-1}, respectivamente. Foram adotadas três frequências de aplicação: mensal (F1), quinzenal (F2) e semanal (F3). Plantas somente irrigadas foram o controle. O delineamento foi inteiramente casualizado com 10 repetições, em esquema fatorial 3x3+1. Os parâmetros fotométricos e teores de macronutrientes na parte aérea, foram submetidos a ANOVA e teste Tukey a 5% de significância. A condutividade das soluções resultou em maiores incrementos sobre as variáveis fitométricas. Aumento da condutividade elétrica promoveu incrementos no crescimento da *Brassia verrucosa*, bem como aumentos nos teores de N, P e K. A condutividade C3 (4,7 mS cm^{-1}) aliada a frequências de aplicação quinzenais (F2) ou semanais (F3), resultaram no aumento de brotações.
Palavras-chave: Salinidade. Fertirrigação. Orchidaceae. Nutrição Vegetal.

Introduction

Fertilization is an essential management for the commercial production of flowers and ornamental plants, as it promotes gains in the final quality of products and reduces cultivation time. However, the fertilizers on the market do not consider the particularities of each species, resulting in a reduction in production efficiency and increased costs (Furtini Neto et al., 2015).

Nutrient supply through fertigation is commonly used in orchid cultivation, as it presents advantages such as controlling the concentrations and application frequencies of nutrient solutions, as well as nutritional relationships. The use of fertilizers in the irrigation of *Phalaenopsis* sp. promotes the anticipation of flowering, with improvements in vegetative growth and flowering quality (Wang & Gregg, 1994).

Wang (1995) reported no differences in vegetative growth when using intermittent fertilization or interspersed with irrigation for *Dendrobium nobile.* However, the solution salinity changes the growth pattern of this species. According to Bernardi et al. (2004), increasing the fertilization concentration by up to 150%, applied weekly, does not harm vegetative development.

Salinity also affects flowering. According to Wang (1998), increased salinity resulted in linear increases in the number of *Phalaenopsis* sp. flowers but led to a reduction in their diameter. However, according to this author, the increase resulted in injury to the root system, with an increase in the number of hollow and dead roots.

Naik et al. (2013) observed that fertigation with an electrical conductivity of 1.5 mS cm^{-1} resulted in improvements in vegetative characteristics such as increases in dry mass, leaf length, and number, length, and circumference of pseudobulbs of *Cymbidium* sp. In addition, the authors observed that 1.0 mS cm^{-1} provided longer stem length and a higher number of flowers per stem but 2 mS cm^{-1} inhibited flowering.

The correct management of fertilization may vary depending on the orchid species, the phenological development, the physicochemical characteristics of the substrate, and the watering, requiring detailed studies for more precise technical recommendations. Furthermore, fertilization in commercial management is known to provide an improvement in the quality and frequency of flowering, with an increase in the number and duration of flowers and anticipation of the first flowering. In this sense, incorrect management can result in damage due to salinity, nutritional imbalances, or physiological disorders, which affect the final quality of the product.

Therefore, studies that adapt the electrical conductivity of the nutrient solution and frequency of application have become an important strategy to increase production efficiency. This study aimed to evaluate the influence of electrical conductivity and fertilizer application frequencies on the growth and nutrition of Brassia verrucosa (Orchidaceae).

Material and Methods

Plant material and growing conditions

Orchid seedlings of Brassia verrucosa from clump divisions of plants cloned in vitro were used. Plant size was standardized after dividing the clumps, with one pseudobulb and one sprout, measuring approximately 15.2 ± 2 cm in height and 0.48 ± 0.2 g and 0.11 ± 0.05 g of shoot and root dry mass, respectively, remaining per pot. The seedlings were transplanted into a black polypropylene pot measuring 13 cm in diameter, 9.8 cm in height, and 1000 mL in volume. Composted pine bark sieved between sieves with 1.5 and 0.5 cm opening screens was used as substrate.

The pots remained in the Department of Agronomy of the State University of Londrina – UEL (51°11′ W; 23°23′ S; 566 m of altitude), inside a Van der Hoeven® climate-controlled greenhouse covered with transparent polycarbonate plates and diffuser, 50% light retention by an Aluminet® shading screen, and controlled temperature of 28 ± 3 °C by the humid cold system. Irrigation was applied manually by adding a 6-mm water depth daily in the morning.

Fertilization management

The newly transplanted seedlings remained for 30 days in the cultivation site before the beginning of the experiment. The plants were fertilized by watering after the initial adaptation period by adding 50 mL of NPK solution. Urea, monoammonium phosphate, and potassium chloride were used as sources of nitrogen (N), phosphorus (P), and potassium (K), respectively (Hoshino et al., 2016).

The fertilizers were diluted in three different concentrations of equal mass proportions: C1 (0.5:0.5:0.5, g L^{-1}), C2 (1:1:1, g L^{-1}), and C3 (2:2:2, g L^{-1}). The electrical conductivities of the solutions were 1.25, 2.5, and 4.7 mS cm^{-1}, respectively. Each solution was applied at three frequencies: monthly (F1), fortnightly (F2), and weekly (F3). The control consisted of plants that were only irrigated. The plants were not irrigated for 48 hours after fertilization.

The plants were transplanted into larger black polypropylene pots with a diameter of 17 cm, a height of 12.5 cm, and a volume of 2000 mL after 15 months of cultivation. Subsequently, a substrate with the same characteristics as previously described was added to the sides of the pots to complete the volume. Watering and fertilization practices were maintained for another three months.

Variables and data collection

The plants were removed from the pots after 18 months from the beginning of fertilization and washed in running water to remove the adhered substrate. Subsequently, the plants were sectioned into roots, pseudobulbs, and leaves. The different organs were washed in distilled water for subsequent evaluation of the following phytometric parameters: plant height, number of pseudobulbs, number of shoots, length and diameter of the largest pseudobulb, and root, pseudobulb, and leaf dry mass.

Plant height was measured using a ruler, starting from the base of the pseudobulb to the apex of the largest leaf. The number of pseudobulbs and shoots was obtained by counting. Pseudobulb length was measured using a ruler, starting from the root crown until the leaf insertion into the largest pseudobulb. Pseudobulb diameter was obtained using a digital caliper by measuring the largest diameter in the largest pseudobulb. Root, pseudobulb, and leaf dry masses were obtained after drying in a forced-air ventilation oven at 55 °C until reaching a constant mass, followed by weighing on an analytical balance with a precision of 0.001 g.

The macronutrient content in the shoot was determined from the dry tissues. For this purpose, pseudobulb and leaf samples were ground in an A11 IKA® analytical mill and the N, P, K, Ca, and Mg contents were quantified according to methodologies described by Silva and Silva (2009). The nitric-perchloric acid digestion allowed quantifying P by colorimetry, Ca and Mg by atomic absorption spectrophotometry, and K by flame photometry. The N content was obtained through sulfur digestion and quantified using the Kjeldahl method (Instituto Adolfo Lutz [IAL], 2008). The results were expressed in g kg^{-1}.

The pH and electrical conductivity (EC) of the substrates were determined following the methodology described by Abreu et al. (2007), using the extraction method 1:2 (in volume) of the substrate and deionized water, measured using a portable pH meter and conductivity meter.

Experimental design and statistical analysis

The experimental design was completely randomized in a 3x3+1 factorial scheme, with the combination between frequencies and electrical conductivities of the solutions, that is, F1C1, F1C2, F1C3, F2C1, F2C2, F2C3, F3C1, F3C2, F3C3, control (without fertilization), where F1, F2, and F3 consisted of the monthly, fortnightly, and weekly frequencies, respectively, and C1, C2, and C3 consisted of the electrical conductivities of 1.25, 2.5, and 4.7 mS cm^{-1}, respectively. Each treatment consisted of 10 replications, considering one plant per pot as an experimental unit.

The data were subjected to the Hartley and Shapiro-Wilk tests and the variables obtained by counting were subjected to the Box-Cox transformation. Subsequently, an analysis of variance was performed and the means were compared using Tukey's test at a 5% significance. The control was compared with the other treatments using Dunnett's contrast at a 5% probability of error, using the Action statistics supplement. Statistical analyses were conducted using the SISVAR software (Ferreira, 2011).

Results and Discussion

The increase in nutrient concentration proved to be more beneficial to the growth of Brassia verrucosa orchids than the increase in application frequency. The electrical conductivity of fertigation solutions was the main factor that increased phytometric variables, with significant increments in the diameter of the largest pseudobulb (DPB), number of pseudobulbs (PB), number of shoots (SHT), pseudobulb dry mass (PBDM), and leaf dry mass (LDM) using the highest electrical conductivities. In turn, the increase in application frequencies within each conductivity had no effects on the evaluated parameters, except for the number of shoots (SHT) and leaf dry mass (LDM) (Table 1).

Comparison of the average effect of electrical conductivities showed a significant increase in the use of conductivities C2 (2.5 mS cm^{-1}) and C3 (4.7 mS cm^{-1}) compared to the use of C1 (1.25 mS cm^{-1}) relative to the diameter of the largest pseudobulb (DPB). The use of C3 (4.7 mS cm^{-1}) resulted in a mean number of pseudobulbs (PB) higher than the other electrical conductivities. The number of shoots (SHT) increased significantly with an increase in the evaluated electrical conductivities (Table 1).

According to Bernardi et al. (2004), increasing the concentration of Sarruge nutrient solution in *Dendrobium nobile* results in linear gains in the diameter of pseudobulbs. Naik et al. (2013) reported that an increase from 1 mS cm^{-1} to 2 mS cm^{-1} provided significant increases in the number of shoots in *Cymbidium* sp. The authors also reported that the electrical conductivity of the fertigation solution had a positive correlation with the length, diameter, and number of pseudobulbs.

Table 1
Means of the variables plant height (PH), length (LPB) and diameter (DPB) of the largest pseudobulb, number of pseudobulbs (PB), number of shoots (SHT), and leaf (LDM), pseudobulb (PBDM), and root dry mass (RDM) of *Brassia verrucosa* subjected to fertigation with different electrical conductivities (1.25 mS cm^{-1} – C1, 2.5 mS cm^{-1} – C2, and 4.7 mS cm^{-1} – C3) and application frequencies (monthly – F1, fortnightly – F2, and weekly – F3) during 18 months of cultivation, Londrina – PR, 2017

		PH		LPB		DPB		PB		SHT		LDM		PBDM		RDM	
Treatment		(cm)		(cm)		(cm)		(n°)		(n°)		(g)		(g)		(g)	
Control		35.50		7.75		3.12		3.17		1.00		2.81		1.79		9.79	
	F1	39.33	b	9.40	a	3.11	a	5.17	a	2.00	b	7.76*	b	5.08	a	16.76*	a
C1	F2	42.50*	ab	10.62*	a	3.41	a	4.33	a	3.33	b	9.51*	ab	5.52*	a	18.26*	a
	F3	46.00*	a	9.35*	a	3.53	a	6.00*	a	6.67*	a	11.80*	a	7.23*	a	14.85*	a
Mean		fi	AB	9.79	A	3.35	B	5.17	B	4.00	C	9.69	C	5.94	B	16.62	A
	F1	47.00*	a	10.12	a	3.45	a	5.67*	a	3.50	b	12.29*	b	6.68*	a	17.02*	a
C2	F2	44.67*	a	10.68*	a	3.79*	a	6.17*	a	6.67*	a	14.63*	ab	6.57*	a	17.58*	a
	F3	45.17*	a	11.45*	a	3.92*	a	5.50*	a	7.00*	a	17.42*	a	8.36*	a	18.62*	a
Mean		45.61	A	10.75	A	3.72	A	5.78	B	5.72	B	14.78	B	7.20	B	17.74	A
	F1	39.83	a	10.83*	a	4.04*	a	7.00*	a	7.67*	b	15.06*	b	8.33*	a	17.38*	a
C3	F2	40.67	a	10.12*	a	3.76*	a	7.83*	a	10.83*	a	19.33*	a	9.13*	a	18.68*	a
	F3	43.00*	a	11.27*	a	3.93*	a	6.67*	a	10.67*	a	21.45*	a	10.46*	a	17.70*	a
Mean		41.17	B	10.74	A	3.91	A	7.17	A	9.72	A	18.61	A	9.31	A	17.92	A
CV (%)		9.92		14.15		11.62		13.38		26.28		15.99		31.70		17.69	

Control: non-fertigated plants.
Means followed by the same uppercase letter between conductivities and lowercase letters within each conductivity do not differ from each other by the Tukey test at a 5% significance.
Means followed by * differ statistically from the control by the Dunnett test at a 5% probability of error.
CV: coefficient of variation.

Regarding application frequency, Wang (1995) reported that fertilization with 1 g L^{-1} of NPK 20-20-20 soluble fertilizer applied at each watering to *Dendrobium* sp. had little effect on the parameters number of shoots and height and diameter of pseudobulbs when compared to fertilization interspersed between watering practices.

The electrical conductivity of the solution for dry mass variables was also the main factor that contributed to increasing the means. In this case, the use of C3 (4.7 mS cm^{-1}) resulted in an accumulation of leaf dry mass 25.91% higher compared to C2 (2.5 mS cm^{-1}), which in turn was 52.53% higher compared to C1 (1.25 mS cm^{-1}) (Table 1). Regarding application frequencies, in general, weekly fertilization (F3) was higher than monthly application (F1) for leaf dry mass.

Significant increases were observed for pseudobulb dry mass (PBDM) in C3 (and 4.7 mS cm^{-1}). This increase in dry mass accumulation was due to the increase in the number of pseudobulbs (PB), which occurred in treatments in which the highest electrical conductivity was used. However, no significant differences were found between treatments for root dry mass, probably due to the pot size, which became a limitation for root growth (Table 1).

Jiménez-Pena et al. (2013) reported that the electrical conductivity of 2.11 mS cm^{-1} was adequate for *Laelia anceps* development. According to the authors, the increase in the electrical conductivity to 2.81 mS cm^{-1} resulted in a reduction in leaf, pseudobulb, and root dry masses, which was not observed in our results. This divergence may be related to the fertilization frequency, as the fertilization solution was applied with each watering in the study by Jiménez-Pena et al. (2013).

The comparison between the control and the other fertilized treatments showed that the variables length and diameter of the largest pseudobulb (LPB and DPB) and the number of pseudobulbs and shoots (PB and SHT) were simultaneously high in the electrical conductivity C2 (2.5 mS cm^{-1}) from fortnightly applications (F2), while C3 (4.7 mS cm^{-1}) was equally effective in monthly applications (F1) (Table 1).

Orchids have characteristics that combine water and nutrient storage capacity in pseudobulbs with high efficiency in nutrient absorption and mobilization (Ng & Hew, 2000). Nutrient absorption is an important evolutionary strategy of these plants, adapted to the nutritional scarcity of epiphytic habitats. Therefore, favoring nutrient absorption by increasing the electrical conductivity of the solution proved to be beneficial and interesting from the point of view of productive flower management.

One of the causes of this phenomenon may be related to the kinetics of nutrient absorption, influenced by the concentration of nutrients in the rhizosphere, which are absorbed by transmembrane proteins divided into pumps, channels, and carriers. K absorption at low concentrations occurs via symport by carriers but absorption begins to be carried out through channels when the ion concentration increases, showing higher speed and being able to absorb up to 10^8 molecules per second compared to carriers, which absorb at a speed of 103 molecules per second (Taiz & Zeiger, 2004). Furthermore, the increase in nutrient concentration favors absorption in carriers of low selectivity, but this type of transport tends to a maximum speed, which is reached when saturation of the binding sites of carrier proteins occurs although the increase in nutrient concentration can lead to a double absorption mechanism (Malavolta, 2006).

However, despite the gains in shoot dry mass and the number of pseudobulbs in C3 (4.7 mS cm^{-1}), its use associated with fortnightly (F2) or weekly (F3) frequencies resulted in oversprouted plants (Figure 1), which are only desired for vegetative propagation. Thus, as flowers are the final product of interest, excessive shoot growth is undesirable because it causes an imbalance between flowering and vegetative development of plants. According to Naik et al. (2013), increased conductivity values favor vegetative development in *Cymbidium* sp. although an electrical conductivity of 2 mS cm^{-1} applied biweekly inhibited flowering.

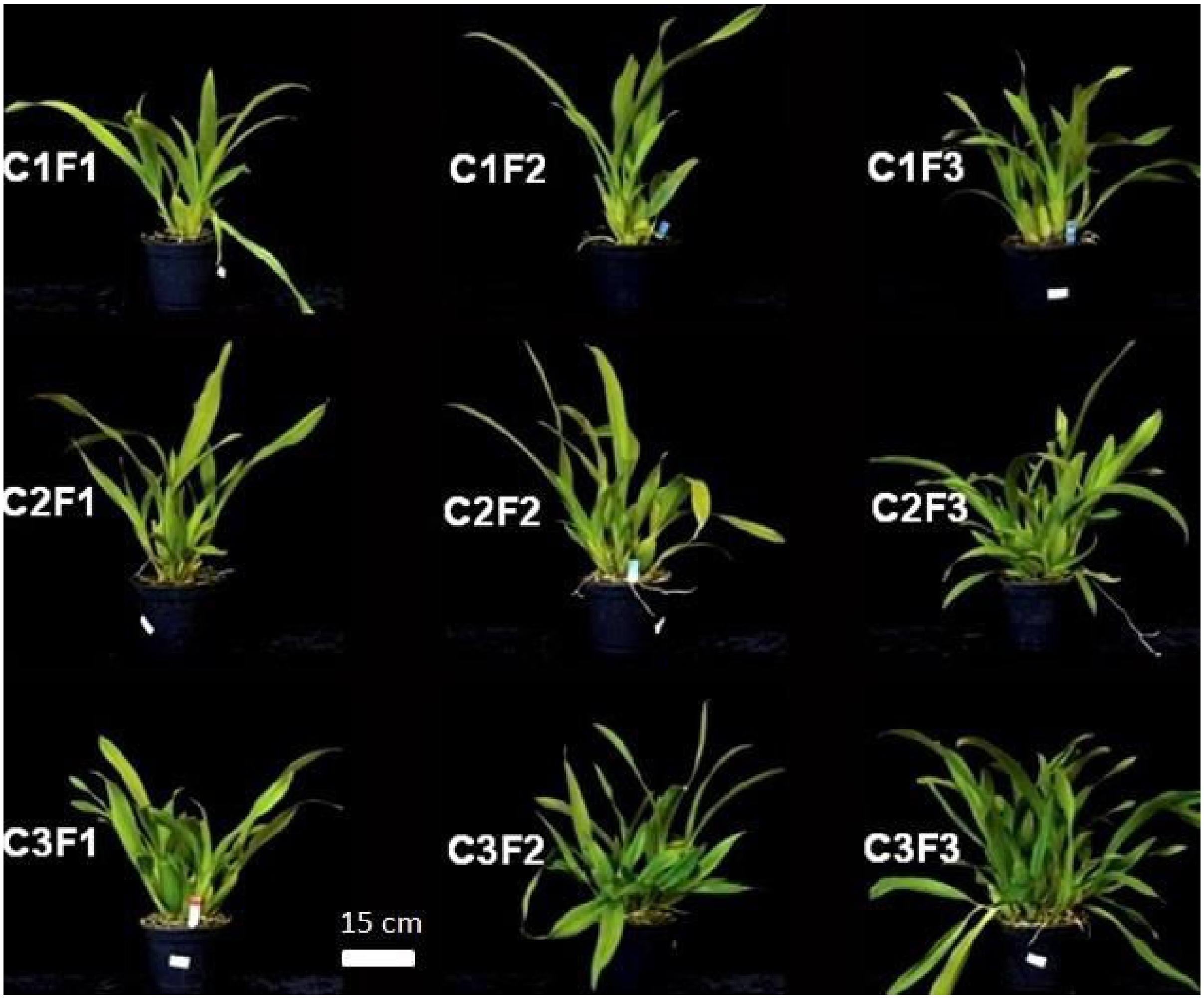

Figure 1. Plants of *Brassia verrucosa* subjected to fertigation with different electrical conductivities (1.25 mS cm^{-1} – C1, 2.5 mS cm^{-1} – C2, and 4.7 mS cm^{-1} – C3) and application frequencies (monthly – F1, fortnightly – F2, and weekly – F3) during 18 months of cultivation, Londrina – PR, 2017.

The substrate pH was reduced with an increase in fertigation frequencies in treatments that used conductivity C1 (1.25 mS cm^{-1}), showing a reduction in mean values from 5.85 to 5.47 and 5.22 in frequencies F1, F2, and F3, respectively. However, the values remained similar for the other electrical conductivities (C2 and C3), regardless of the frequency, with mean values of 4.82 for C2 (2.5 mS cm^{-1}) and 4.77 for C3 (4.7 mS cm^{-1}) (Figure 2 B). Moreover, the pH presented an average value of 5.67 when the plants were only irrigated, not receiving fertigation (control) (Figure 2A).

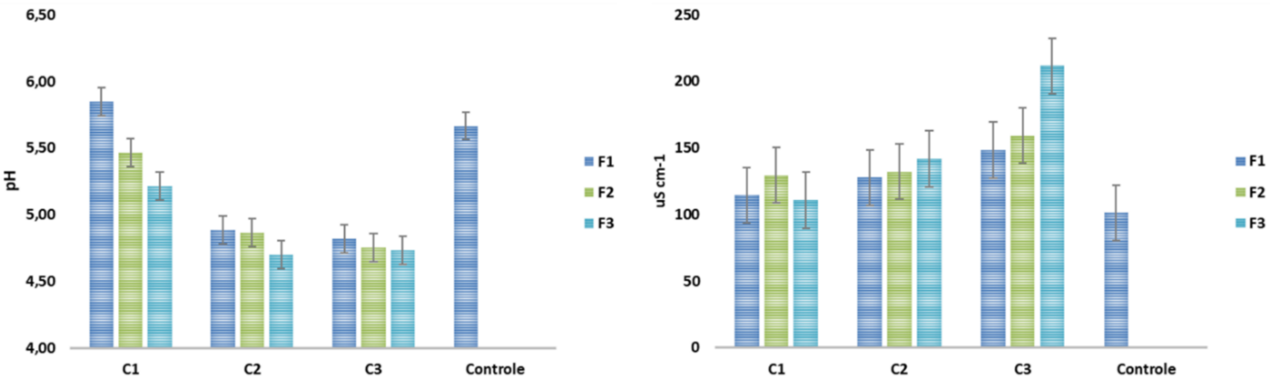

Figure 2. Plants of *Brassia verrucosa* after 18 months of cultivation subjected to fertigation with different electrical conductivities (1.25 mS cm^{-1} – C1, 2.5 mS cm^{-1} – C2, and 4.7 mS cm^{-1} – C3) and application frequencies (monthly – F1, fortnightly – F2, and weekly – F3), Londrina – PR, 2017. [A] pH of the substrate. [B] Electrical conductivity of the substrate.

Plant growth is known to lead to natural acidification of the substrate due to the mineral absorption process, as roots release H+ into the rhizosphere to obtain a difference in electrochemical potential (Taiz & Zeiger, 2004). However, the pH in C3 was not lower than C2 despite the difference in plant growth, showing a possible limit for the Brassia verrucosa orchid in acidifying the substrate. In general, orchids develop in acidic environments in which pH values from 4.8 to 6.2 are considered normal for the genus Cattleya (Takane et al., 2010).

The contents of the macronutrients N, P, and K in the leaves increased significantly with an increase in the electrical conductivity of the solutions. The mean leaf contents of N were 20.5 g kg^{-1} in C1, 26.08 g kg^{-1} in C2, and 28.98 g kg^{-1} in C3, while the mean leaf contents of K were 18.97 g kg^{-1} in C1, 21.25 g kg^{-1} in C2, and 24.66 g kg^{-1} in C3. Moreover, the significant difference in leaf P contents only occurred between C1 and C3, which presented values of 1.64 and 2.17 g kg^{-1}, respectively. Ca and Mg contents showed no significant differences, regardless of the electrical conductivity (Table 2).

Table 2
Contents of the macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and Magnesium (Mg) present in leaves of *Brassia verrucosa* subjected to fertigation with different electrical conductivities (1.25 mS cm^{-1} – C1, 2.5 mS cm^{-1} – C2, and 4.7 mS cm^{-1} – C3) and application frequencies (monthly – F1, fortnightly – F2, and weekly – F3) during 18 months of cultivation, Londrina – PR, 2017

Treatment		N		P		K		Ca		Mg	
		g kg^{-1}									
Control		20.80		1.53		17.21		8.35		1.26	
	F1	19.16	b	1.39	A	16.72	b	6.66	a	1.48	a
C1	F2	20.42	ab	1.69	A	20.43	a	6.88	a	1.44	a
	F3	21.92	a	1.84	A	19.77	ab	5.69	a	1.22	a
Mean		20.50	C	1.64	B	18.97	C	6.41	A	1.38	A
	F1	22.52	b	1.61	A	18.53	b	6.08	b	1.31	a
C2	F2	27.60*	a	2.01	A	22.90*	a	6.98	ab	1.40	a
	F3	28.10*	a	2.07	A	22.33*	a	8.04	a	1.40	a
Mean		26.08	B	1.90	AB	21.25	B	7.03	A	1.37	A
	F1	27.34*	b	2.09	A	22.74*	b	7.26	a	1.54	a
C3	F2	28.72*	ab	2.17*	A	24.97*	ab	7.23	a	1.39	a
	F3	30.88*	a	2.26*	A	26.29*	a	7.51	a	1.30	a
Mean		28.98	A	2.17	A	24.66	A	7.33	A	1.41	A
CV (%)		6.84		13.84		10.34		16.77		14.36	

Control: non-fertigated plants.
Means followed by the same uppercase letter between conductivities and lowercase letters within each conductivity do not differ from each other by the Tukey test at a 5% significance.
Means followed by * differ statistically from the control by the Dunnett test at a 5% probability of error.
CV: coefficient of variation.

The application frequencies also influenced the leaf N and K contents, which present higher levels in the weekly frequency (F3) than the monthly frequency (F1). However, in general, the application frequencies did not change the leaf contents of the other macronutrients. Plants in the control treatment (without fertigation) showed significant increases in leaf N and K contents in C2 from the fortnightly frequency (F2) when compared by contrast to fertigated plants. The accumulations observed under these conditions may indicate a possible excess supply of these nutrients (Table 1).

The most demanded nutrients for orchids are K and N (Ichinose, 2008). N is highly required as it is a constituent of proteins and nucleic acids and its deficiency quickly affects metabolism since biochemical reactions are mediated by enzymes. K has its main function related to the plant water relations, also acting as an enzymatic activator of respiration and photosynthesis (Malavolta, 2006).

Phosphorus is a constituent of sugar phosphates, membrane phospholipids, nucleotides, and a source of energy, but it is only the fourth element most required by orchids. According to Zotz (2004), epiphytes in natural conditions only present P limitations when the N:P ratio is higher than 16. The N:P ratios in Brassia verrucosa leaves were 6.25, 6.86, and 6.67 when using C1, C2, and C3, respectively.

This reduction is expected under cultivation conditions due to the high P absorption capacity of epiphytes, related to the scarcity of this nutrient in natural systems (Zotz, 2004). Thus, the use of lower amounts of P in formulations may be indicated.

Regarding the contents of macronutrients in the pseudobulbs, the increase in conductivity resulted in less evident effects than those observed for the leaves, probably due to the higher metabolic activity of leaves relative to pseudobulbs. However, the increase in conductivity increased N, P, and K contents and decreases in Ca and Mg. N contents showed significant increases for each electrical conductivity. Conductivities C1 and C2 did not differ from each other for P and K contents, both being lower than C3 (Table 3)3

Table 3
Contents of the macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and Magnesium (Mg) present in pseudobulbs of Brassia verrucosa subjected to fertigation with different electrical conductivities (1.25 mS cm^{-1} – C1, 2.5 mS cm^{-1} – C2, and 4.7 mS cm^{-1} – C3) and application frequencies (monthly – F1, fortnightly – F2, and weekly – F3) during 18 months of cultivation, Londrina – PR, 2017

Treatment		N		P		K		Ca		Mg	
		------------------------------------g kg^{-1}-------------------------------									
Control		11.22		1.30		31.65		13.89		2.89	
	F1	10.46	a	1.19	a	25.71*	a	15.12	a	3.44	a
C1	F2	12.10	a	1.20	a	25.96*	a	16.05	a	3.34	a
	F3	11.08	a	1.34	a	23.89*	a	11.12	b	2.60	b
Mean		11,22	C	1.24	B	25.19	B	14.10	AB	3.13	A
	F1	11.22	b	1.16	a	21.83*	b	13.31	b	3.00	a
C2	F2	13.36	ab	1.39	a	25.46*	ab	17.67	a	3.11	a
	F3	16.42*	a	1.55	a	26.64	a	15.84	ab	2.92	a
Mean		13,66	B	1.37	B	24.65	B	15.61	A	3.01	A
	F1	14.62	c	1.43	b	27.36	b	15.49	a	2.87	a
C3	F2	20.80*	b	1.69	ab	26.95	b	13.01	ab	2.79	a
	F3	30.84*	a	2.00*	a	33.23	a	11.71	b	2.47	a
Mean		22.08	A	1.71	A	29.18	A	13.40	B	2.71	B
CV (%)		14.44		14.58		11.98		16.21		9.95	

Control: non-fertigated plants.
Means followed by the same uppercase letter between conductivities and lowercase letters within each conductivity do not differ from each other by the Tukey test at a 5% significance.
Means followed by * differ statistically from the control by the Dunnett test at a 5% probability of error.
CV: coefficient of variation.

Furthermore, the N contents in the pseudobulbs increased more evidently when the conductivity C3 was used at frequencies F2 and F3, reaching contents of 20.80 and 30.84 g kg^{-1}, respectively (Table 3). These increases in N content in pseudobulbs may have been the possible cause of the increase in the number of shoots and, consequently, the number of pseudobulbs in these treatments.

In general, N and P contents in the leaves were higher than those found in the pseudobulbs. However, these contents in pseudobulbs became similar to those in leaves when the conductivity C3 was combined with a higher application frequency.

Nitrogen is one of the most demanded nutrients but its excessive application can change the relationship between roots and shoots (Geary et al., 2015) due to stimuli on vegetative development. The increase in N concentration in the nutrient solution led to increased leaf expansion in *Paphiopedilum* sp. (Zong-Min et al., 2012). Excess N in garlic cultivation results in oversprouting (Resende & Souza, 2001).

According to Royer et al. (2013), the C:N ratio in tissues is positively correlated with concentrations of soluble sugars and starch. Therefore, N accumulations may indicate a reduction in carbohydrate production due to metabolic competition between amino acids and carbohydrates for carbon skeletons produced by photosynthesis (Xu et al., 2012). Thus, the use of the conductivity C3 associated with frequencies F2 or F3 may have led to higher accumulations of amino acids and other soluble forms of N due to the high availability of the nutrient, resulting in increased N content and the number of small shoots and pseudobulbs.

Conclusion

The increase in electrical conductivity and application frequency within each conductivity resulted in increases in the growth of the *Brassia verrucosa* orchid. The management also promoted increases in N, P, and K contents in pseudobulbs and leaves.

The pH of the substrates was initially reduced with increasing application frequencies at the lowest conductivity and subsequently remained stable at the highest conductivity, regardless of the frequency. Fertilization increased the electrical conductivity of the substrates. The most evident increase occurred in the conductivity C3 (4.7 mS cm^{-1}) associated with the weekly application frequency (F3).

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