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Response of gerbera inflorescences in function of electrical conductivity and pH solution in substrates

Inflorescências de gérberas em resposta à condutividade elétrica e ao pH da solução de substratos

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Abstract

The objective of this work was to evaluate the production of gerbera inflorescences under the influence of pH and the electrical conductivity of the solution of the substrates irrigated with liquid organic fertilizers. The experimental design was of randomized blocks, with four replications and five treatments. Treatments were defined according to fertilization source, which were mineral (NPK) and organic. Organic fertilization was obtained by diluting four organic compounds from agroindustry residue (reproductive poultry bedding, hatchery waste, flotation sludge, sausage skins, coal from boilers, truck wash residue solid fraction and sugar cane bagasse) in composting process in water. After compounds obtainment, water dilution was performed, adjusting nutritive solution electrical conductivity values. Substrate solution electrical conductivity (EC) and pH determination was held at 1, 14, 28, 42, and 56 days after acclimatization in a 1:5 dilution (m/v). Potted gerberas inflorescences were evaluated at 56 days after acclimatization. Number of inflorescences (NI), inflorescence dry matter (IDM), stem height (SH), head diameter (HD), and stem diameter (SD) were determined. The electrical conductivity of the solution of the substrate in the mineral fertilizer is above indicated for gerbera culture, reflecting the lower inflorescence stem height. The pH values obtained from the solution of the substrates are within the range for the development of potted gerberas.

Additional keywords: *Gerbera jamesonii*; liquid organic fertilizers; salinity.

Resumo

O objetivo do trabalho foi avaliar a produção de inflorescências de gérbera sob a influência do pH e da condutividade elétrica da solução dos substratos irrigados com fertilizantes orgânicos líquidos. O delineamento experimental foi o de blocos casualizados, com quatro repetições e cinco tratamentos. Os tratamentos foram definidos de acordo com a fonte de fertilização, mineral (NPK) e orgânico. Adubação orgânica foi obtida por meio da diluição de quatro compostos orgânicos diluídos em água, obtidos de resíduos agroindustriais (cama de frango, resíduos de incubadora, lodo de flotador, tripa celulósica de salsichas, carvão de caldeiras, fração sólida do dejeto suíno e bagaço de cana), no processo de compostagem. Após a obtenção dos compostos orgânicos, realizou-se a diluição com água, ajustando os valores de condutividade elétrica na solução nutritiva. A determinação na solução do substrato da condutividade elétrica (CE) e de pH foi realizada em 1; 14; 28; 42 e 56 dias após a aclimatização em 1:5 (m/v). As inflorescências das gérberas envasadas foram avaliadas aos 56 dias após a aclimatação. Foram determinados número de inflorescências, matéria seca de inflorescências, altura da haste, diâmetro do coleto e diâmetro da haste. A condutividade elétrica na solução do substrato no adubo mineral apresenta-se acima do indicado para a cultura de gérberas, refletindo na menor altura de haste das inflorescências. Os valores de pH medidos na solução dos substratos estão dentro da faixa adequada para o desenvolvimento de inflorescências de gérberas envasadas.

Palavras-chave adicionais: adubos orgânicos líquidos; *Gerbera jamesonii*; salinidade.

Introduction

Potted gerbera plants are moderately demanding in nutrition (Ludwig et al., 2008). This moderate fertility level produces plants with leaf area and inflorescence proportional ratio. Low fertility levels lead to leaves yellowing due to nutrient deficiency. Excessive fertility can lead to excessive growth and delayed flowering. The balance between plant needs and periodic monitoring can help ensure the nutritional needs (Jeong et al., 2009).

Knowledge on the culture nutritional needs is intrinsically related to fertilization, this has an important impact on inflorescences and plant quality, productivity, and longevity. In floriculture, whose market competition is intense, the productivity gap is in the appropriate management of these factors for a satisfactory production (Mota et al., 2013), what can be achieved with nutrition and proper substrates for the culture.

The main properties of substrates refer, especially, to pH and salinity (electrical conductivity) values. These are important chemical characteristics, particularly regarding plant nutrient availability (Ludwig et al., 2015). Electrical conductivity (EC) is the electric current passage between electrodes subjected to a solution resistance measure, where ionic solutes (cations and anions) are present. The higher the fertilizer amount applied to the substrate, the higher will be the EC value. Compared to other nutrient solution attributes, the EC is simple to measure, with relatively low cost and may, thus, become useful in plant nutritional management (Mota et al., 2013).

The pH is primarily related to nutrient availability to plants. Inadequate pH values may affect plant development, mainly under excessive acidity. Plants grown in acid environments have lower nutrient amounts at their disposal, besides being subjected to higher toxic element absorption, such as aluminum (Al^{+3}) and manganese (Mn^{+2}). However, species have genetic differences that give them different sensitivity degrees to the same pH value (Oldoni, 2009).

The electrical conductivity and pH measurement methods are based on aqueous extracts. The dilution of 1:2 (mass:volume) is routinely used by substrate companies in Brazil, in order to determine the pH and EC (Abreu et al., 2007), and by flower and ornamental plant producers. However, the 1:5 dilution (mass:volume) was adopted as the substrate solution EC and pH analysis standard, what was approved in the Instruction n.17 of May 21, 2007, Ministry of Agriculture, Livestock and Food Supply (Brasil, 2007).

In order to meet this growing demand, it is necessary to develop studies that maximize plant production, especially using organic fertilizer. An alternative to potted gerbera nutrition is the use, via fertigation, of organic compost from agro-industrial waste composting process (Castro et al., 2010).

However, the use of organic composts require care, because they can cause excessive acidity and/or salinity in the soil or substrate, besides generating nutritional stress in the plant, resulting on excess or deficiency of nutrients according to applied doses. The salinity of organic composts may be high because these are obtained from a waste rich in nutrients (Hernández et al., 2010; Mota et al., 2014). Thus, it is necessary to take some precautions in such use (Caballero et al., 2009). Therefore, the dilution of organic composts in water, referred to as liquid organic fertilizers, is presented as one way of meeting nutritional needs of gerbera culture through fertigation, without, however, raising the salinity to potentially toxic levels by controlling electrical conductivity (Santos et al., 2015).

Regular monitoring of electrical conductivity may eliminate problems associated with fertilization, indicating the availability of nutrients to crops, since complete tissue and substrate analysis are often costly (Ludwig et al., 2015). Given the occurrence of imbalance, negative to plant development, it is necessary to perform rapid tests to quantify the total available nutrients, which are expressed by electrical conductivity and pH. This periodic monitoring may prevent many problems related to fertilization and nutrition. The objective of this work was to evaluate the production of gerbera inflorescences under the influence of pH and the electrical conductivity of the solution of the substrates irrigated with liquid fertilizers.

Material and methods

The experiment was conducted in a greenhouse that has an arch structure, all covered with clear polyethylene of 150 microns, and an area of 96.0 m² (8.0 m wide, 12.0 m long) and 2.6 m height. To ensure uniformity of light intensity and transmission of diffuse light inside the greenhouse, a thermal reflector mesh (*Aluminet*®) of 30% shading was internally set. During the experimental period, the average temperature inside was 29.5 °C, and the average relative humidity was 58.5%. The experiment was developed from September to December 2011.

The treatments consisted of five nutrient solutions. The experimental design was in randomized blocks, with four replications. It was planted one plant per pot, being the plot made of six pots.

The experimental unit consisted of plastic pots of number 14 (10.5 cm height, 12.5 cm upper diameter, and 10.0 cm lower diameter), filled with 900 mL of commercial substrate. The commercial substrate consisted of pine bark, peat and vermiculite, fertilized with simple superphosphate and potassium nitrate, as indicated by the manufacturer. The chemical characteristics of the substrate are: EC = 0.5 dS m^{-1}; pH = 5.8 (Tedesco et al., 1985); macronutrients (g kg^{-1}): N = 0.06; P = 0.001; K = 0.06; Ca = 0.55; Mg = 0.28; and micronutrients (mg kg^{-1}): Na = 575.47; Cu = 0.27; Fe = 275.27; Mn = 3.587; and Zn = 4.08 (Embrapa, 2009). The physical characteristics of the substrate, provided by the manufacturer, are as follows: 60% humidity, water retention capacity of 130%, and wet density of 500 kg m^{-3}.

Seedlings of gerbera (*Gerbera jamesonii* L. Bolus), Florist Red Black cultivar, acquired in trays from Ball® Horticultural do Brasil Ltda., were used. The seedlings had four definitive leaves at transplantation and were acclimated for 15 days, irrigated only with water. After this period, mineral fertilizer and organic fertigations began.

Irrigation of mineral treatment and fertigation of organic treatments were carried out according to daily weighing of the pots, considering daily evaporation, according to difference in weight compared to water retention capacity. The pots were then kept at 70% water retention capacity in the vegetative period and 80% in the reproductive period (Ludwig et al., 2008). The maximum amount of available water in the substrate was defined based on the water retention capacity of the substrate, measured from the weighing of 10 pots per block. Irrigation and fertigation were performed manually using graduated containers, on an average of 120 mL pot^{-1} day^{-1}.

The pots were arranged on wooden tables (0.80 m wide, 2.20 m long, and 1.10 m high), without spacing. After overlapping of the leaves, the pots were spaced in 0.20 m x 0.20 m. Experimental evaluation was initiated after acclimatization and the results were expressed in days after acclimatization (DAA).

The treatment with mineral fertilizer, called treatment 1 (T_1), was performed every 15 days, with 5.0 g per pot with 4-10-8 formula (Stancato, 2015), using 0.2 g of ammonium sulfate ($(NH_4)_2SO_4$ - 21% N); 0.4 g of superphosphate (P_2O_2 - P 18%) and 0.3 g of potassium chloride (KCl - 61% K).

Liquid organic fertilizers were obtained from organic compost dilution resulting from agroindustrial waste composting processes. The initial composition (before composting) of each treatment is shown in Table 1. Each composting windrow was made with 500 kg (natural material) of agroindustrial wastes. Details on the composting process are described in Bernardi (2011).

Table 1 - The initial composition of agroindustrial wastes before composting of each treatment (T_2, T_3, T_4, and T_5) (kg).

Wastes	T_2	T_3	T_4	T_5
Corn residue	145	50	0	0
Hatchery residue	80	70	40	35
Flotation sludge	30	50	45	35
Wheat husks	50	50	0	0
Cellulosic casing	20	110	50	75
Pig manure solid fraction	90	45	100	75
Boiler remaining coal	25	0	70	30
Boiler remaining ash	30	30	80	150
Truck wash residue solid fraction	30	45	15	15
Poultry litter	0	50	0	10
Sugar cane bagasse	0	0	100	75

At the end of the composting process, organic composts with high electrical conductivity (EC) of 5.63; 8.29; 3.63; and 5.46 dS m^{-1}, for treatments 2, 3, 4, and 5, respectively, were generated, limiting their use as substrates for the production of potted gerbera. Thus, the dilution of organic composts in water presents a way of supplying the nutritional needs of gerbera's culture, as well as adjusts the EC (Santos et al., 2017). Then, a dilution of the organic compost in order to use only the liquid fraction of fertigation for culture was performed. Plants need nutrients in different amounts in the growing period and in the reproductive period. In this way, after dilution, nutrient solutions with EC 0.56; 0.51; 0.36; and 0.27 dS m^{-1} were obtained in the growing period for T_2, T_3, T_4, and T_5, respectively, and 1.52; 1.38; 0.97; and 0.73 dS m^{-1} for T_2, T_3, T_4, and T_5, respectively, in the reproductive period.

In order to obtain an optimal dilution of the organic composts, dilution tests were performed. The dilution was based on potassium nutrient, because this showed the highest values among those present in liquid organic fertilizers. After dilution tests, the quantity of 27 kg of each organic compost, placed in barrels of 100 L, was established. The volume was completed with water, and this solution was stirred by hand every day for 30 minutes during 60 days. After this period, the solution was filtered and only the liquid phase was used, phase known as liquid organic fertilizer (LOF). LOF was chemically characterized. Total nitrogen was quantified by means of digestion in distiller Kjedahl, according to the methodology proposed by Malavolta et al. (1997). Other macronutrients and micronutrients were determined according to the methodology of Embrapa (2009) (Table 2).

The plants were evaluated at the end of the vegetative season (28 DAA) and at the end of the reproductive period (56 DAA). The vegetative season finished when plants showed the first flower buds. Towards the end of the reproductive period, the marketing point was adopted, when flowers reached two open circles.

Table 2 - Chemical composition of liquid organic fertilizers (LOF) after dilution for fertigation in vegetative and reproductive periods of gerberas.

Nutrients	Vegetative period (28 days after acclimatization)			
	LOF 1	LOF 2	LOF 3	LOF 4
	---------------------------- ($mg\ kg^{-1}$) ----------------------------			
Macronutrients				
N	7,200.00	4,700.00	2,400.00	3,000.00
P	0.04	0.02	0.02	0.01
K	105.00	105.00	105.00	105.00
Ca	159.53	118.88	99.05	47.48
Mg	25.78	14.80	19.00	15.51
Micronutrients				
Na	59.27	51.10	120.18	30.81
Cu	0.19	0.01	0.04	0.05
Fe	20.07	17.08	11.50	5.72
Mn	0.32	0.63	0.03	0.08
Zn	0.71	0.68	1.29	0.15
	Reproductive period (56 days after acclimatization)			
Nutrients	LOF 1	LOF 2	LOF 3	LOF 4
	---------------------------- ($mg\ kg^{-1}$) ----------------------------			
Macronutrients				
N	23,000.00	21,600.00	13,500.00	14,700.00
P	0.11	0.09	0.13	0.08
K	285.00	285.00	285.00	285.00
Ca	432.79	542.68	538.61	260.27
Mg	70.08	67.57	82.26	84.85
Micronutrients				
Na	160.79	233.28	653.45	168.55
Cu	0.51	0.05	0.23	0.30
Fe	54.45	77.90	67.83	31.31
Mn	0.87	2.91	0.17	0.44
Zn	1.93	3.11	7.04	0.86

Number of inflorescences, inflorescence dry matter, stem height, head diameter, and stem diameter were determined. For evaluation of inflorescence dry matter, drying was carried out in an oven at 65 °C with forced air circulation, until constant mass was reached. Stem height was measured using a ruler graduated in millimeters from the upper pot portion to below the inflorescence insertion. Head diameter and stem diameter were measured with a digital caliper, with stem diameter being measured at 5.0 cm below the inflorescence insertion.

To ensure correct substrate sampling, plants were removed from pots, since inflorescences were assessed separately and destructively. The pot substrate was homogenized in order to ensure substrate representative collection. After 1, 14, 28, 42, and 56 DAA, EC and pH of all treatments (substrate solutions) were assessed according to the 1:5 (mass:volume) methodology proposed by Brasil (2007).

Initially, exploratory data analysis was performed and analysis of variance assumptions were verified. Later, data were submitted to analysis of variance to see if there was any treatment significant effect. When there was significance, Tukey's test at 5% probability was applied to compare means.

Results and discussions

There was a statistically significant difference ($p \leq 0.05$) among treatments at 28 and 14 DAA. However, T_1 was similar to T_3 and T_4, with low pH, resulting in a higher EC.

The minimum pH for gerbera cultivation in substrate solution is 5.5 (Cavins et al., 2000), given that values above 6.5 cause decreased production in these plants (Savvas & Gizas, 2002). The pH values in all treatments were within the range indicated as ideal (pH 5.5 to 6.5) (Table 3). These values are important, according to Barbosa et al. (2009), for toxic aluminum neutralization, Mn toxicity elimination, better nutrient utilization, and appropriate conditions for organic matter nutrient release occur at a pH of 5.5 to 6.5.

At 14 DAA, T_1 had the lowest pH value (5.58), differing from the others, while the other treatments did not differ statistically. However, T_1 showed higher electrical conductivity (Table 4). This fact is related to lower pH, as well as the other treatments had higher pH and reduced EC. Ludwig et al. (2014), Mota et al. (2014), and Ludwig et al. (2015) prove this fact.

Table 3 - Substrate solution pH mean values related to mineral fertilization and organic fertilization with liquid organic fertilizers.

Treatments	pH				
	Days after acclimatization				
	1	14	28	42	56
T_1	6.27 a	5.58 b	6.10 b	6.13 a	6.12 a
T_2	6.24 a	6.10 a	6.30 a	6.19 a	6.15 a
T_3	6.28 a	6.10 a	6.25 a	6.20 a	6.11 a
T_4	6.30 a	6.06 a	6.23 ab	6.17 a	6.12 a
T_5	6.27 a	6.04 a	6.20 ab	6.19 a	6.09 a
CV (%)	1.72	1.65	1.00	1.17	1.13

Means followed by the same letter in the column do not differ by Tukey's test at 5% significance level. T_1 - commercial substrate (pine bark, peat, and vermiculite): mineral fertilization (NPK) irrigated with water. T_2 - commercial substrate fertilized with T_2 composition (corn residue). T_3 - commercial substrate fertilized with T_3 composition (cellulosic casing). T_4 - commercial substrate fertilized with T_4 composition (pig manure solid fraction). T_5 - commercial substrate fertilized with T_5 composition (boiler remaining ash). CV – coefficient of variation.

Table 4 - Electrical conductivity of substrate solution mean values related to mineral fertilization and organic fertilization with liquid organic fertilizers.

Treatments	EC (dS m^{-1})				
	Days after acclimatization				
	1	14	28	42	56
T_1	1.42 a	3.89 a	2.03 a	1.50 a	1.33 a
T_2	1.02 a	1.51 b	1.21 b	1.06 a	1.33 a
T_3	0.89 a	1.70 b	1.31 b	1.11 a	1.36 a
T_4	1.04 a	1.75 b	1.35 b	1.35 a	1.35 a
T_5	1.04 a	1.67 b	1.34 b	1.53 a	1.61 a
CV (%)	29.82	35.51	13.93	17.38	14.96

Means followed by the same letter in the column do not differ by Tukey's test at 5% significance level. T1 - commercial substrate (pine bark, peat, and vermiculite): mineral fertilization (NPK) irrigated with water. T2 - commercial substrate fertilized with T2 composition (corn residue). T3 - commercial substrate fertilized with T3 composition (cellulosic casing). T4 - commercial substrate fertilized with T4 composition (pig manure solid fraction). T5 - commercial substrate fertilized with T5 composition (boiler remaining ash). CV – coefficient of variation.

According to Mota et al. (2014), pH values for Golden Yellow cultivar, throughout the crop cycle, were slightly higher than the Cherry cultivar, unlike the observed behavior for EC values, as they were low. The authors found that, the lower applied solution concentration, higher the pH, proving the positive inclusion of low EC on the development of plants. Because the EC expresses ion amount in the substrate, and high ion concentrations in the soil solution or in the substrate can hinder plant development, causing toxicity. Thus, the dilution of EC in the liquid organic fertilizers in this study is justified.

The EC values showed significant differences at 14 and 28 DAA. T_1 had the highest values, 3.89 and 2.03 dS m^{-1}, at 14 and 28 DAA, respectively, and these values were above what is recommended for the crop. This fact occurs because in the mineral treatment the nutrients are readily available to the plants, whereas in the organic fertigation, the nutrients are released over time. At 14 DAA, EC was higher than the values studied by Mota et al. (2014), which suggested an EC of 2.0 dS m^{-1} for gerbera proper development.

According to Ludwig et al. (2008), when cultivars were grown under a nutrient solution with 50% concentration, ECs were lower, with significant differences from the nutrient solution with 100% concentration. At 100% solution, there was a salt concentration higher than the at 50% concentration, which was possibly higher than what is recommended for the crop. Thus, plants could not totally absorb it, tending to concentrate part of these salts in the substrate. The authors conclude that the macronutrient demand is differentiated among gerbera cultivars, and it is therefore necessary that they receive individualized management for the expression of their genetic potentials.

In the inflorescences assessment (Table 5), there was adequate development related to the pH of substrate solutions, ensuring there were no statistical differences among gerbera inflorescence dry matter, stem diameter, and head diameter conducted in organic and mineral treatments. Head number assessment showed no variances, thus it was impossible to compare means. According to descriptive analysis, overall means for head number, for all treatments, was 2.5. The number of heads of this study was similar to that found by Guerrero et al. (2013) and Guiselini & Sentelhas (2004), who obtained means of 2.8 and 2.7 inflorescences, respectively.

Table 5 - Inflorescence dry matter (IDM), stem height (SH), head diameter (HD), and stem diameter (SD) of gerberas cultivated under mineral fertilizer and liquid organic fertigations, obtained at 56 days after acclimatization.

Treatments	IDM (g)	SH (cm)	HD (mm)	SD (mm)
T_1	6.97 a	17.55 b	86.07 a	4.44 a
T_2	7.35 a	22.20 a	82.90 a	4.46 a
T_3	6.65 a	20.32 ab	88.42 a	4.54 a
T_4	7.17 a	18.02 b	90.42 a	4.52 a
T_5	7.44 a	23.30 a	79.90 a	4.43 a
CV(%)	11.89	6.89	7.24	6.43

Means followed by the same letter in the column do not differ by Tukey's test at 5% significance level. T1 - commercial substrate (pine bark, peat, and vermiculite): mineral fertilization (NPK) irrigated with water. T2 - commercial substrate fertilized with T2 composition (corn residue). T3 - commercial substrate fertilized with T3 composition (cellulosic casing). T4 - commercial substrate fertilized with T4 composition (pig manure solid fraction). T5 - commercial substrate fertilized with T5 composition (boiler remaining ash). CV – coefficient of variation.

In this study, plants grown under all treatments fall within the recommendation of the Brazilian Institute of Floriculture (IBRAFLOR), which are defined by Veiling Holambra (2017), being the heights of the plants 22.92; 24.67; 20.35; 19.62; and 26.97 cm for T_1, T_2, T_3, T_4, and T_5, respectively. Regarding plant height, IBRAFLOR recommends that the ideal measure is between 14 to 30 cm at marketing time (Veiling Holambra, 2017).

Another classification proposed by Veiling Holambra (2017) refers to plant quality according to the number of inflorescences per pot, ranging from class I (one inflorescence) to class IV (four inflorescences). Considering the results of this experiment, there were an average of two flowers per pot, therefore, class II. Ludwig et al. (2010) analyzed two gerbera cultivars (Red and Cherry) grown in different substrates, and found that the Red cultivar was characterized by being more floriferous when compared to Cherry, which had fewer inflorescences, however larger. The authors found a propensity towards a better acceptance by plants consisted of inflorescences with a larger diameter, even if their number is lower. According to the aforementioned study, the fact that the present study achieved an average yield of 2.5 inflorencences per plant, shows that the consuming option at the time of purchase is the diameter of the chapter and not the quantity of flowers, favoring the acquisition of the gerberas produced under the liquid organic fertilizers.

In T_1, the inflorescences had lower stem height (17.55 cm) compared to T_4, with 22.20 and 23.30 cm, respectively (Table 5). Thus, high EC along plant cycle may impair plant development and flowering by causing substrate solution excessive salinity, so gerbera is classified as moderately sensitive to high EC. In addition, Barbosa et al. (2009) stated that phosphorus is the most affected macronutrient with pH below 5.5, because there is P adsorption by the substrate. In the flowering stage, P needs are higher and its deficiency is reflected in flower quality reduction. In addition to the T_1 substrate solution EC being high, the pH was close to the minimum acidity limit (5.8) for the culture, although it was within the range considered ideal for gerbera proper development, that is from 5.0 to 6.5.

When P supply is limited, plants grow more roots, increase the rate of uptake by roots from the soil, re-translocate P from older leaves, and deplete the vacuolar stores of P. Conversely, when plants have appropriate P supply but absorbing it at rates that exceed demand, a number of processes can act to prevent the accumulation of toxic P concentrations (Schachtman et al., 1998). Barbosa et al. (2009) report that in the early development of ornamental plants the required amounts of P are smaller, increasing with time and coinciding with flowering. This was observed in the present study because P levels in the vegetative period are lower when compared to the reproductive period.

Conclusion

The electrical conductivity of the solution of the substrate under the mineral fertilizer is above that indicated for gerbera culture, reflecting the lower inflorescence stem height. The pH values measured in the solution of the substrates are within the range for the development of inflorescences of potted gerberas.

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