The effects of supplemental nitrogen and calcium on the quality and postharvest life of cut gerbera

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Abstract

The objective of the present work was to evaluate the effect of nitrogen (N) and calcium (Ca), complementary to the complete fertilization established, on production, quality and postharvest shelf life of floral stems of gerbera as cut flower harvested 117 days after transplant. The experiment consisted of a combination of three doses of N.L⁻¹ substrate (0.07 g, 0.15 g and 0.2 g) and three doses of Ca.L⁻¹ substrate (0.02 g; 0.03 g and 0.04 g) and was conducted in a greenhouse in a bifactorial arrangement with an additional control treatment. Control plants were not supplemented with N or Ca. Both elements were diluted in water and applied manually every 15 days. Highest flower yields were obtained with application 0.2 g of N.L⁻¹ substrate and 0.04 g Ca.L⁻¹ substrate. Stem length, stem diameter, flower diameter, and longevity, relative fresh weight and solution uptake were highest in gerbera fertilized with 0.2 g of N.L⁻¹ substrate and 0.04 g Ca.L⁻¹ substrate. Applying every 15 days, 0.2 g of N.L⁻¹ substrate and 0.04 g of Ca.L⁻¹ substrate resulted in higher yields, better quality and postharvest shelf life of floral stems of gerbera as cut flower harvested 117 days after transplant.

Keywords: Gerbera hybrida Hort., fertilization, flower longevity.

Introduction

Gerbera (Gerbera hybrida Hort.) is one of the most important flower species cultivated as cut flower both at Brazilian and international markets, occupying the fifth position in volume in the ranking (Khosa et al., 2011). The attractiveness of the species derives from the large variety of colors, sizes and flower forms rendering it as an excellent flower for different uses in decoration and bouquets.

An adequate management of the fertilization is decisive for elevated yields and quality of flower stems (Ludwig et al., 2008). However, in Brazil, there is no information on nitrogen (N) and calcium (Ca) fertilization for gerberas as cut flower grown in containers with organic substrate. Thus, the choice to study these nutrients at the same time is due to the functions they perform in plants.

The growth and development of plants are highly dependent on supplies of nitrogen. Calcium, as well, is important for the quality of flowers because it is essential for membrane permeability and cell wall structural integrity (Taiz and Zeiger 2013).

Therefore, the present work intended to evaluate the effects of different doses of nitrogen and calcium, supplemented to the customary fertilization processes, on...
yields and the postharvest quality of gerbera flower stems cultivated in pots.

**Material and Methods**

The experiment was conducted in a protected environment covered with a low density polyethylene film of 150 micra with an incorporated UV additive. The gerberas were cultivated in that ambient from April 19th until August 14th 2013.

Along that period, at every 30 minutes, the temperature and relative humidity were recorded via a thermohygrometer model Klimalogg Pro®. The average values during the autumn period were 18.3 °C and 82.1%, respectively. Along the winter months the average temperature was 14.2 °C and the average relative humidity was 83%.

Gerbera plantlets of the cultivar Dino with 16 weeks were acquired from specialized producer. Each plantlet with seven leaves was transplanted to plastic pots of 2.8 L (15 cm height x 17.6 cm diameter) filled with commercial substrate based on pine bark. It presented electrical conductivity of 0.28 mS.cm⁻¹ and pH (H₂O) of 6.37, followed by the 1:5 dilution method (Brasil, 2007). Wet and dry density (Brasil, 2007) of 584.56 kg.m⁻³ and 342.76 kg.m⁻³, respectively, and total porosity, aeration area, available water and remaining water (De Boodt and Verdonck, 1972) of 77.46%, 27.22%, 14.60% and 35.65%, respectively.

The experiment was conducted in a customized block design, with four replicates and eight plants in each experimental unit. In total, 320 plants constituted the experimental unit. The treatments consisted of three doses of nitrogen (N): 0.07 g, 0.15 g or 0.2 g L⁻¹ substrate and three doses of calcium (Ca): 0.02 g, 0.03 or 0.04 g L⁻¹ substrate and control treatment (without N or Ca fertilization). Data were analyzed as a 3 x 3 bifactorial arrangement with an additional treatment.

After 27 days after transplant (DAT), the fertilization procedure started. All the plants received the following doses of P, K, and Mg for every L⁻¹ substrate: 0.03, 0.17 and 0.01, respectively and micronutrients at a concentration of 0.1 g L⁻¹ substrate applying Rexolin® (11.6% K₂O; 1.28% S; 0.86% Mg; 2.1% B; 0.36% Cu; 2.66% Fe; 2.48% Mn; 0.036% Mo and 3.38% Zn).

Every 15 days all the emitted leaves and floral stems were counted. After 117 DAT, floral stems at the commercial harvesting point (Oliveira et al., 2012) were harvested for after harvest evaluations. The floral stems were evaluated for stem length (SL), stem diameter (SD) measured 20 cm below the flower capitulum and the diameter of each flower capitulum (DF). After these measurements the floral stems were standardized to a length of 35 cm, weighed and placed individually in glass containers (500 mL capacity) containing 250 mL distilled water. The containers were sealed with a polyethylene stretch film involving the floral stem in order to avoid water evaporation and placed on a wooden bench under continuous light of 10 μmol.m⁻².s⁻¹.

Flower shelf life was evaluated visually every day. To determine the number of days of shelf life, the period encompassing the day of experiment set up until the day the flower was considered not marketable anymore was recorded. The criteria to discard a flower were adapted from Schmitt et al. (2014): turgidity of the floral stem, pigmentation and abscission of petals.

After 2, 5, 7, 9, 12, 15 and 18 days DAT, the floral stems were evaluated for relative fresh weight and water uptake. To establish relative fresh weight, the floral stems were weighed in the morning hours. Relative fresh weight (RFW) was calculated by the formula:

\[
\text{RFW} = \left( \frac{M_t}{M_{t=0}} \right) \times 100\% \quad (1)
\]

Where Mt is the mass of the floral stem on day t (days after harvest) and M₀ the fresh mass of the flower stem on day zero. On day zero the RFW was considered, according to Schmitt et al. (2014) as being 100% with the intent to standardize the differences in fresh mass of the stems.

Water uptake of the floral stems was calculated according to Schmitt et al. (2014) using the mass of the glass container plus the water content (250 mL), but without the floral stems. The following formula was used to calculate water uptake.

\[
\text{Water uptake (mL.day}^{-1}.g^{-1} \text{ fresh weight}) = \left( \frac{S_{t=0} - S_t}{M_{t=0}} \right) \quad (2)
\]

Where S₀ refers to the weight of the container plus the water inside after t days of harvest and S₀ is the weight of the container and water inside the day before of an evaluation and M₀ is the fresh mass of the flower stem on the day of harvest.

Data on relative fresh weight and water uptake were
analyzed as a trifactorial since days after harvest where considered as a cause of variation besides the doses of N and Ca. All the data were submitted to analysis of variance at $p < 0.05$ and subsequent regression analysis for doses of N and Ca and days after harvest applying the statistical package Sisvar.

**Results and Discussion**

In between doses of N and Ca no significant interaction was determined in all analyzed variables and, therefore, only the main effects were evaluated (Table 1).

| Causes of Variation | G.L. | NF | TH |
|---------------------|------|----|----|
| Blocks              | 3    | 0.10** | 40.60** |
| N                   | 2    | 2.54** | 15.73** |
| Ca                  | 2    | 3.85** | 10.09** |
| N x Ca              | 4    | 0.30ns | 3.32ns |
| Factorial vs Ad.    | 1    | 0.64 | 1.93 |
| Error               | 27   | 6.11 | 4.10 |
| Overall Average     | 13.91 |

| CH       | DH       | DC       | L         |
|----------|----------|----------|-----------|
| Blocks   | 3        | 9.19ns   | 0.30ns    | 0.44ns    | 8.86ns    |
| N        | 2        | 44.61**  | 0.72**    | 0.88**    | 102.58**  |
| Ca       | 2        | 33.58**  | 1.16**    | 0.95**    | 146.74**  |
| N x Ca   | 4        | 4.39**   | 0.21ns    | 0.05ns    | 6.54ns    |
| Error    | 24       | 9.43     | 0.21      | 0.20      | 18.32     |
| Overall Average | 35.34 | 5.50     | 9.82      | 16.08     |
| CV (%)   | 8.85     | 8.35     | 4.59      | 16.62     |

| MF       | A        |
|----------|----------|
| Blocks   | 3        | 2092.98**| 0.03** |
| N        | 2        | 2772.3** | 0.12** |
| Ca       | 2        | 2495.07**| 0.22** |
| Time     | 6        | 11163.98**| 1.22** |
| N x Ca   | 4        | 1293.47**| 0.02** |
| N x Time | 12       | 30.33**  | 0.005ns  |
| Ca x Time| 12       | 218.57** | 0.02**  |
| Error    | 186      | 554.46   | 0.03     |
| Overall Average | 81.21 | 0.46     | 25.23    |
| CV (%)   | 18.99    | 25.23    |

* 2, 5; 7; 9; 12; 15 or 18 days after harvest of floral stems.
** and ns, significant at 5% probability and not significant, respectively.

In the regression analysis and having as independent variables the doses of N.L$^{-1}$ substrate and Ca.L$^{-1}$ substrate a linear effect on the evaluated variables is determined (Figures 1, 2 and 3).
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Figure 1: Gerberas cv. Dino cultivated in pots with different doses of nitrogen (g L\(^{-1}\) substrate) and calcium (g L\(^{-1}\) substrate) supplied every 15 days: number of leaves with different doses of nitrogen (A) and calcium (B) and yields of floral stems with different doses of nitrogen (C) and calcium (D). *Significant at 5% probability.

The highest average numbers of emitted leaves: 7.12 and 6.57 were determined when the highest doses of both N and Ca, respectively were applied every 15 days (Figure 1A and B). The leaves are the primary source of photoassimilates and, as such, the number of leaves of each plant has a direct influence on the development of that plant and on the quality of its floral stem (Albuquerque et al., 2010).

The doses of 0.2 g N L\(^{-1}\) substrate and 0.04 g Ca L\(^{-1}\) substrate applied every 15 days resulted in a higher average number of floral stems: 5.6 and 5.3, respectively (Figure 1C and D). With the highest dosage of N there was a higher number of leaves and consequently, more photoassimilates were synthesized to be available to yield higher numbers of emitted flower stems. Furthermore, Albino-Garduño et al. (2008) concluded that the number of capitula of gerberas cultivated in 15 L pots, was 60 to 70% less in the presence of low concentrations of calcium (120 mg L\(^{-1}\)). Almeida et al. (2009) indicate that calla lilies (Zantedeschia aethiopica) stopped emitting leaves at low Ca dosages.

When the gerberas were not supplied with nitrogen and calcium not sufficient flower stems were emitted to continue with the postharvest evaluations. At least two stems per experimental unit of any treatment are necessary for further evaluations. Therefore, the variables stem length, stem diameter, capitulum diameter, longevity, fresh weight and water uptake are not available when N and Ca were not supplied (Figures 2 and 3).
Figure 2: Gerbers cv. Dino cultivated in pots with different doses of nitrogen (g L\(^{-1}\) substrate) and calcium (g L\(^{-1}\) substrate) supplied every 15 days: length of floral stem (cm) with different doses of nitrogen (A) and calcium (B); floral stem diameter (mm) with different doses of nitrogen (C) and calcium (D) and diameter of capitulum (cm) with different doses of nitrogen (E) and calcium (F). * Significant at 5% probability.
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Figure 3: Gerberas cv. Dino cultivated in pots with different doses of nitrogen (g L⁻¹ substrate) and calcium (g L⁻¹ substrate) supplied every 15 days before harvest: after harvest longevity (days) with different doses of nitrogen (A) and calcium (B); relative fresh weight (%) with different doses of nitrogen (C) and calcium (D); water uptake (mL day⁻¹ g⁻¹ fresh weight) with different doses of nitrogen (E) and calcium (F); relative fresh weight (%) with different doses of nitrogen (G) and water uptake (mL day⁻¹ g⁻¹ fresh weight) after varying periods after harvest (H). *Significant at 5% probability.
That circumstance reveals the importance of an accurate nutrient equilibrium in view of the fact that an inappropriate fertilization might result in nutritional deficiencies and affect plant development and production, consequence of a reduction of photoassimilates, particularly carbohydrates (Castro et al., 2007). Ludwig et al. (2008) point out that Ca has to be supplied the length of the whole life cycle of the gerberas.

Considering that gerberas as cut flowers are commercialized in bunches of 20 stems, independently of the mass (Muniz et al., 2013) cultivation with correct fertilization with N and Ca it is crucial. Farias et al. (2013) concluded that flower and ornamental plant production is associated to several factors, nonetheless nutrition of the plants is one of the main factors that influence production.

Moreover, when gerberas are used as cut flower, the floral stem is the outcome, therefore, for the grower a higher number of floral stems represents a lower production cost and, as a consequence better profitability and competitiveness (Albuquerque et al., 2010; Paulino et al., 2013). With a dose of 0.2 g N.L⁻¹ substrate and of 0.04 g Ca.L⁻¹ substrate every 15 days longer floral stems were determined: 39.74 cm and 38.96 cm, respectively (Figures 2 A and B). A longer floral stem is advantageous as floral longevity might be extended by cutting back the stems with the purpose to remove tissues that do not contribute anymore to water uptake and, even so, the stem being at marketable condition (Schwab et al., 2015).

The average diameter of floral stems from the three doses of N and Ca was between 5 and 6 mm (Figure 2 C and D). Under the highest doses of N and Ca, a thicker average diameter was determined: 5.7 and 5.6 mm, respectively. The resistance of the floral stem is directly influenced by its thickness, i.e., floral stems with wide diameters present better resistance to mechanical injuries that might occur still in the field caused by wind or along the postharvest procedures (Albuquerque et al., 2010; Farias et al., 2013).

The same observations occurred with the variable capitulum diameter (Figure 2 E and F). The highest doses of N and Ca resulted in bigger flowers. Average values were in the range of 10.03 to 10.13 cm. These figures are similar to the flower sizes determined by Oliveira et al. (2012). The authors report that gerberas cultivated in 5 L containers had flower sizes ranging from 7.64 to 10.94 cm.

Flower longevity after harvest (Figure 3 A and B) was also positively influenced with increasing pre-harvest doses of N and Ca. In average, gerbera flowers were marketable after 16 days of vase life when 0.2 g N.L⁻¹ substrate was applied every 15 days. Applying 0.04 g Ca.L⁻¹ substrate, at the same two week intervals, gerberas were marketable up to 17 days after harvest. After harvest the flower stems were not supplemented with additional nutrients and, therefore, those flowers stems that had received more carbohydrates along the development presented a higher longevity as previously reported by Nowak and Rudnicki (1990).

Gerberas, after harvest maintain a marketable quality for about 7 to 12 days (Emongor 2004) and Fischer et al. (2015) determined a shelf life of 7 days.

In the present work, vase life was two times longer than those periods related in the literature when the highest doses of N and Ca were supplied to the plants. De Castro et al. (2007) concluded that heliconias had its shelf life compromised when grown under N deficiency. As for Ca, Barbosa et al. (2010) mentioned that a longer longevity of chrysanthemums was observed with increases in Ca concentrations.

Triple interaction (N doses versus Ca doses versus time) and double interactions (N doses versus Ca doses, N doses versus time and Ca doses versus time) were not statistically significant for fresh weight of gerbera floral stems and water uptake and therefore, only the main effects of each variable were investigated (Table 1).

A significant positive linear data adjustment was determined for fresh weight and water uptake with regards to N and Ca doses. The highest doses of both nutrients resulted in maximum average relative fresh weight values, 91.7% and 92.9%, respectively (Figure 3 C and D). The highest water uptake by the floral stems for N and Ca was 0.55 mL day⁻¹ g⁻¹ fresh weight and 0.61 mL day⁻¹ g⁻¹ fresh weight, respectively (Figure 3 E and F).

According to Carneiro et al. (2002) with an adequate provision of carbohydrates for cut flowers, apart energy provision for the maintenance of the primary metabolism, these carbohydrates play a role as tissue osmotic regulator resulting in higher water uptake and as a result sustain longer hydration periods of the tissues prolonging after harvest shelf life.

Analyzing the different after harvest periods (time) affecting the relative fresh mass and water uptake of flower stems (Figure 3 G and H), a significant negative linear adjustment of the data was determined. An observation concurring with data published by Oliveira et al. (2012).

A water deficit occurs provided that the transpiration rates are higher than the rates of water uptake resulting in turgescence losses of flower stems (Van Doorn, 1999). In relation to fresh mass losses, Nowak and Rudnicki (1990) stated that a loss of 10% to 15% compromises the quality and longevity of the flowers. Under that condition of fresh weight losses, the flowers may already be wilted, which is the main symptom of senescence (Schmitt et al., 2014). In the present work, only after 15 days after harvest of the flowers fresh weight losses reached 10% while 15% of fresh weight losses were only determined after 19 days after harvest (Figure 3 G). I.e., after 15 days after harvest the flower stems were still turgid, without quality downgrading being, for that reason, a sign of flower longevity.

Conclusion

An application of 0.2 g N.L⁻¹ substrate and 0.04 g Ca.L⁻¹ substrate, every 15 days, as a complement to a complete fertilization program resulted in higher production, quality and post-harvest longevity of floral stems of gerberas as cut flower harvested at 117 days after transplantation.
Author Contribution

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G.S. 0000-0001-1242-3001: advisor, participating in the conception and planning of the experiment and in the correction of the scientific article; R.J.B. 0000-0002-1504-0557: advisor, participating in the conception and planning of the experiment and in the correction of the scientific article.

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