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Scientific Article

Yield and quality of gerbera floral stalks in substrate supplemented with different doses of nitrogen and calcium

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Abstract

Success in production and quality of gerbera flower stalks over time depends on environmental factors and on appropriate fertilization procedures. The objective of the present work was to evaluate the production and quality of flower stalks of gerberas as cut flower cultivated for 28 months (with 25 months of harvest) in a pine bark-based substrate supplemented with different doses of nitrogen and calcium. The experiment was conducted in a greenhouse. Three doses of nitrogen (N) (0.07 g, 0.15 g and 0.20 g L^{-1} substrate) and three doses of calcium (Ca) (0.02 g, 0.03 g and 0.04 g L^{-1} substrate) were applied every 15 days along the cultivation period. The control was considered an additional treatment to which neither N nor Ca was supplemented to the plants in the pots. Highest flower yields and best flower quality were obtained in months in which the temperatures were in the range of 20 ºC to 25 ºC. The highest number of floral stalks and the largest diameter of the capitulum had a significant quadratic adjustment according to N doses. The maximum values were obtained with 0.14 g of N L^{-1} substrate. Whereas for Ca fertilization, a significant positive linear adjustment was determined, *i.e.*, the highest values were obtained with the highest dose (0.04 g Ca L^{-1} substrate). There was a monthly variation in the yield and quality of cut gerberas grown in commercial substrate based on pine bark regardless of the different doses of nitrogen and calcium used in the experiment.
Keywords: floriculture, gerbera fertilization, *Gerbera hybrida* H., soilless cultivation.

Resumo

Produção e qualidade de hastes florais de gérbera em substrato suplementado com diferentes doses de nitrogênio e cálcio

O sucesso da produção e da qualidade das hastes florais de gérbera depende, principalmente, dos fatores ambientais e do correto manejo da adubação. O objetivo do trabalho foi avaliar a variação da produção e da qualidade de hastes florais de gérbera de corte cultivada em substrato à base de casca de pinus durante 28 meses (sendo 25 meses de colheita), com diferentes doses de nitrogênio (N) e cálcio (Ca). O experimento foi conduzido em ambiente protegido, e consistiu da combinação de três doses de N L^{-1} de substrato (0,07 g, 0,15 g e 0,2 g) e de três doses de Ca L^{-1} de substrato (0,02 g, 0,03 g e 0,04 g), aplicadas a cada 15 dias, além da testemunha, sem adubação com N e Ca. A maior produção e a melhor qualidade das hastes florais por planta ocorreram nos meses com temperatura do ar média entre 20 ºC e 25 ºC. A produção de hastes florais planta^{-1} mês^{-1} e o diâmetro do capítulo tiveram os máximos valores obtidos com 0,14 g de N L^{-1} de substrato. Já para as doses de Ca, observou-se um ajuste linear positivo significativo, ou seja, os maiores valores foram obtidos com a dose de 0,04 g de Ca L^{-1} de substrato. Ocorre variação mensal da produção e da qualidade das hastes florais de gérbera de corte cultivada em substrato comercial, à base de casca de pinus, e é independente do uso de diferentes doses de nitrogênio e de cálcio.
Palavras-chave: cultivo sem solo, floricultura, fertilização de gérbera, *Gerbera hybrida* H.

Introduction

Gerberas (*Gerbera hybrida* H.) as cut flower fit well in as the species presents continuous flowering turning into an exceptional option to supply different periods of the year and its commemorative occasions when higher flower demands come about, and according to Cardoso and Imthurn (2018) is one of most important ornamental species for cut-flower production.

The success in production and quality of gerbera inflorescences along a production period depends,

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essentially, on ambient factors such as: temperature, relative humidity and solar radiation beyond the interactions in between these factors. Additionally, adequate cultural practices and a correct fertilization program will also influence the flower yields (Mercurio, 2002).

Amongst the nutrients, nitrogen (N) is the most required for vegetables and is related to physiological processes: photosynthesis, respiration, development and root activity (Taiz et al. 2017). Therefore, applying appropriate levels of N fertilizer according to the different kinds of production systems can improve plant growth and flowering quality (Lin et al., 2019). Calcium (Ca) is essential for membrane permeability and cell wall structural integrity. Calcium presence in cell walls imparts mechanical resistance contributing to increases in cut flower longevity (Taiz et al., 2017).

In Brazil, however, information on nitrogen and calcium fertilization of gerberas growing on substrate is not available. Therefore, the objective of the present work was to evaluate along 25 months in a protected cultivation system the development and the variations in production and quality of flower stalks of gerberas cultivated in pots with substrate and supplemented with different doses of nitrogen and calcium.

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, 2013 until August 29th, 2015.

During the summer months when the light intensity was higher than 60.000 lux a reflective aluminum net with 50% shading was placed over the plants (Mercurio, 2002). Daily, at 30-minute intervals along the experiment, the temperature and relative humidity were recorded on a Klimalogg Pro® thermohigrometer.

Gerbera plantlets of the cultivar Dino were purchased from a specialized flower plantlet producer. The 16-week-old plantlets presented, on average, seven fully expanded leaves. The plantlets were transplanted into plastic pots of 2.8 L internal volume and 15 cm height. The substrate was a pine bark based commercial substrate.

The substrate was analyzed at the beginning and at the end of the experiment chemical and physical parameters. Chemical analyses consisted of determinations of pH in water and electric conductivity (mS cm^{-1}) via the dilution 1:5 method (Brasil, 2007). Physical analyses consisted of determination of dry density (kg m^{-3}), total porosity (%), aeration space (%), available water (%) and remaining water (%) according to the methodology of De Boodt and Verdonck (1972).

Three doses of nitrogen (N) L^{-1} substrate (0.07 g, 0.15 g and 0.20 g) and three doses of calcium (Ca) L^{-1} substrate (0.02 g, 0.03 g and 0.04 g) were applied every 15 days along the cultivation period. The control was considered an additional treatment to which neither N nor Ca was supplemented to the plants in the pots. The experiment was conducted in complete randomized block design with four replicates and eight plants as experimental unit summing up to a total 320 plants arranged in a density of 11 plants m^{-2}.

After 27 days of transplant (DOT), fertilization was started and ended after 833 DOT. The plants received the nutrients diluted in water. 50 mL pot^{-1} were applied every 15 days. The doses of N and Ca were applied in the form of ammonium nitrate (30% total N: 15% NO_3^{-2} + 15% NH_4^+) and calcium nitrate (15.5% NO_3^{-2} + 19% Ca). At the end of the experiment a total of 3.94, 8.58 and 11.83 g N L^{-1} substrate and 0.93, 1.86 and 2.55 g Ca L^{-1} substrate had been applied. A complementary fertilization was applied in which all plants received the same dose of potassium (K), phosphorus (P) and Magnesium (Mg) in the form of potassium chloride (60% K_2O + 45% Cl), monopotassium phosphate (52% P_2O_5 + 34% K_2O), and magnesium sulphate (9% Mg), respectively. The total amounts of P, K, and Mg supplied to the plants for the duration of the experiment were: 0.08, 0.32 and 0.02 g L^{-1} substrate, respectively.

The beginning of the reproductive period was established after 91 DOT (August 2013). At that time 80% of the gerbera plants presented a visible flower capitulum of a size of ± 1 cm (Milani et al., 2019) and all plants were supplemented with 1.63 P, 8.77 K and 0.61 Mg g.L^{-1} substrate. Micronutrients were applied through a commercial formulation (5.1 g Rexolin®.L^{-1} substrate) containing: 11.6% K_2O, 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.

Along 25 months (August 2013 to August 2015) of evaluations the total amount of harvested flowers, the length and diameter of the flower stalk and the diameter of the capitulum of the flowers were determined. The amount of flower stalks obtained from every plant in every month was calculated by summing the amount of flower stalks harvested from every plant in every month of evaluation.

The length (LS), the diameter of the stalk (DS) and the diameter of the capitulum (DC) of the harvested flower stalks were determined. The LS was measured with the aid of a ruler graduated in centimeters, from the base to the insertion of the capitulum. The DS was determined at 20 cm, from the insertion of the capitulum, with the aid of a digital caliper, and the result was expressed in millimeters. And the DC was measured with the aid of a ruler graduated in centimeters, in the horizontal direction of the inflorescence (extremity from one petal to the other).

The variables were analyzed as a trifactorial at $p < 0.05$ (the months of harvest were considered a factor of variation, in addition to the doses of N and C) and furthermore via orthogonal polynomials for N and Ca doses. The averages of every month were compared via Scott-Knott at $p < 0.05$. The statistical software SISVAR was used for the statistical analyzes (Ferreira, 2021). Also, linear Pearson correlations amongst the physical and chemical properties of the substrate and amongst the production and quality data of the flowers and the ambient temperature and relative humidity were determined at $p < 0.05$ via the Action software (Estatcamp, 2021).

Results and Discussion

A triple interaction (N doses x Ca doses x months of harvest) and double interactions (doses of N x months of harvest; doses of Ca x months of harvest and doses of N x doses of Ca) were not significant for any of the analyzed variables. Because of that only the main effects were evaluated for every parameter.

On the chemical characteristics of the substrate the conductivity was influenced by the N and Ca doses (Figure 1 A and B). The pH was affected by the N doses (Figure 1 C) indicating that there was a change in these parameters after the cultivation period of gerberas when compared to the values at the start of the experiment: pH 6.37 and 0.28 mS cm^{-1}, both at a dilution of 1:5.

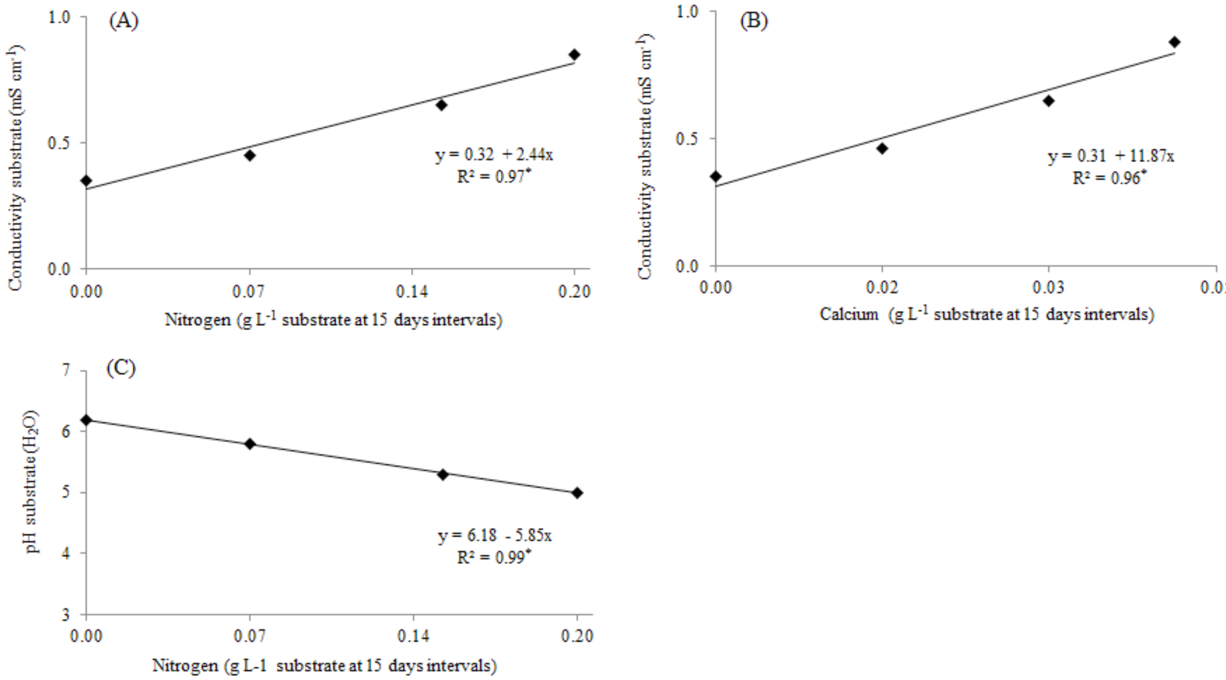

Figure 1. Chemical characteristics of the substrate after 28 months of cultivation of gerberas cv. Dino. Electric conductivity (EC mS cm^{-1}; 1:5 dilution method) in response to nitrogen (A) and calcium (B) doses (g L^{-1} substrate applied at 15 days intervals) and pH (in H_2O; 1:5 dilution method) also in response to nitrogen (g L^{-1} substrate applied every 15 days) fertilization (C). *significant at $p < 0.05$.

The conductivity of the substrate presented a tendency of a significant linear increase in response to increasing doses of N and Ca (Figure 1 A and B), *i. e.*, at the highest doses of both N (0.20 g L^{-1} substrate) and Ca (0.04 g L^{-1} substrate) applied every 15 days the highest conductivity values were determined: 0.81 mS cm^{-1} and 0.78 mS cm^{-1}, respectively. The conductivity values determined in the present experiment are in accordance to the values indicated by Mercurio (2002). The author recommends conductivities for gerberas below 0.9 mS cm^{-1}.

Substrate pH presented the opposite behavior of the conductivity for N (Figure 1 C) since a decreasing linear adjustment was determined. At the highest dose of N, the lowest average pH value (4.98) was determined. That response in the substrate is possibly a consequence of the N source used: ammonium nitrate generating an acid effect to the substrate.

The average value for pH was 5.8. Mercurio (2002) indicates that the ideal pH for gerberas should be in between 5.5 and 6.0. Ludwig et al. (2020) detail further that extreme pH values in substrates, below 5.0 and beyond 7.0 are inadequate to grow gerberas. Inappropriate pH affects the availability of nutrients. At pH lower than 5.0, deficiency symptoms of N, K, Ca, Mg and B might become evident. P, Fe, Mn, Zn, and Cu availability might occur at pH past 6.5 (Kämpf, 2005).

Regarding physical properties of the substrate, no polynomial adjustment for N and Ca turned out to be significant. However, there was a variation in the parameters when comparing initial values to the values after the end of the experiment (Table 1), which is an expected result when growing plants on organic substrates. Dry density (DD) of the substrate, when setting up the experiment had an average value of 342.76 kg m^{-3}. At the end of the experiment that value had reduced to 337.96 kg m^{-3}. That range is in accordance to the limits established by Kämpf (2005) who recommends a DD to vary from 250 kg m^{-3} up to 400 kg m^{-3} in pots of 15 cm height.

Table 1. Physical characteristics of a commercial pine bark-based substrate at the beginning and at the end of an experiment of 28 months with cv. Dino gerberas.

Physical characteristics of the substrate on the experiment beginning		After 28 months of cultivation
Dry density (kg m^{-3})	342.76	337.96
Total porosity (%)	77.46	86.23
Aeration space (%)	27.22	37.22
Available water (%)	14.60	10.50
Remaining water (%)	35.65	38

The value for total porosity (TP) of the substrate (86.23%) presented an increment of 10% after finishing the gerbera cultivation period. That TP is close to the recommendation of 85% indicated by De Boodt and Verdonck (1972) as ideal. In the same way aeration space (AS) also presented an increment of 10% at the end of the cultivation period. The average value was at 37.22% of AS, which is a little beyond the percentage suggested of 20% to 30% by De Boodt and Verdonck (1972).

A reduction in available water (AW) was determined at the end of the experiment. The average value was equal to 10.5%. A range in between 25% and 35% for AW is considered as ideal by De Boodt and Verdonck (1972) and Schafer et al. (2008). The studies of Ludwig et al. (2011) on quality of gerberas cultivated in pots in response to physical and chemical characteristics of different substrates led to the conclusion that an aeration space of 17% and available water of 36% do result in better quality of the flowers.

In the present work the substrate ended with 38% of remaining water (RW). At the beginning of the experiment that value was of 35.65%. De Boodt and Verdonck (1972) recommend that this parameter should stay in the range of 20% to 30%.

The variations in the physical characteristics of cultivation, probably, are significantly influenced by the long evaluation period, 25 months. That time frame might have resulted in a rearrangement of the particles or a degradation of those particles of the substrate. The main outcome of these phenomenon is an increase in the volume of macropores and micropores and aeration space boosting the remaining water. Both, macro and micropores increase total porosity (Schafer et al., 2008).

The comparison floral stalk production, floral stalk length and diameter and size of the capitulum of every gerbera plant along the evaluation months indicate significant differences in those determined parameters (Figure 2).

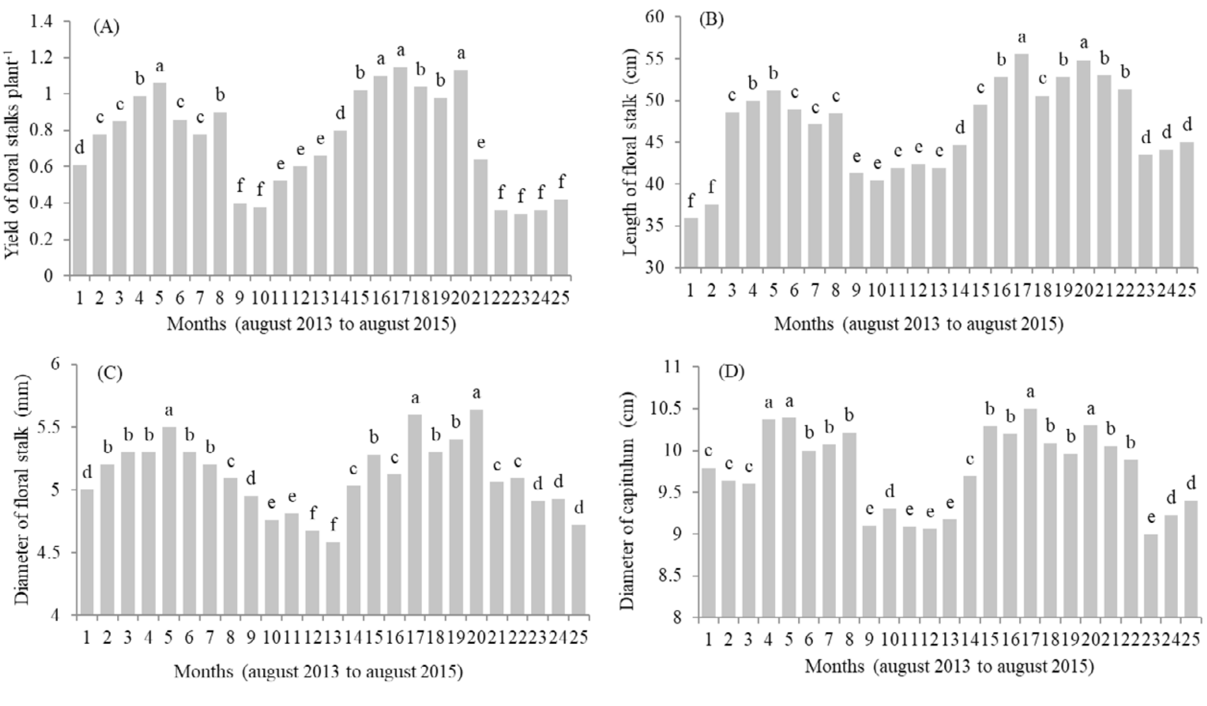

Figure 2. Gerbera plants cv. Dino cultivated on substrate: yield of floral stalks plant^{-1} (A); length of floral stalk (cm) (B); diameter of floral stalk (mm) (C) e diameter of flower capitulum (cm) (D), along 25 months of cultivation. *Columns with the same letter do not differ statistically via the Scott-Knott test at $p < 0.05$.

All these variables were independent of the applied N and Ca doses. That variation in between evaluation months might have been a response to climatic conditions, especially average ambient temperature. Temperatures varied from 13.9 ºC to 27.5 ºC (Figure 3). During the winter months the average temperatures were below 20 ºC and along that period a mean reduction in flower stalks was about 65% (Figure 2A). Also a reduction of 25% in stalk length (Figure 2B), of 18% in stalk diameter (Figure 2C) and of 13% in the diameter of the capitulum (Figure 2D) were determined. That result is confirmed by some significant positive correlations ($p < 0.05$) in between temperature and flower production in every month (r = 0.87), in between temperature and length of floral stalk (r = 0.74), temperature and diameter of the stalk (r = 0.77) and temperature and the capitulum diameter (r = 0.75). Guiselini et al. (2010) concluded that the ambient exerts great influence on gerbera plants and the air temperature has a direct effect on the emission and leaf growth and precocity of the flowering period. The author also informs that gerbera plants require a temperature in the range of 20 ºC and 25 ºC. Muniz et al. (2013) determined a variation in the parameters of floral stalks in response to harvest periods and justify that there could have been a response to the climatic conditions, especially of the air temperature in the weeks when the average temperature was 17.5 ºC. Potential productivity of a crop is dependent on the energy available associated to other climatic variables, as air temperature and Guiselini et al. (2010) concluded that gerbera plants in an ambient with higher amounts of energy and with more elevated average air temperatures adequate to the requirements of the species have the settings for the species for higher total photosynthesis resulting in a higher net photosynthesis rate.

The lower yield of flowers, mainly, in the winter months is probably a result of a combined effect of low solar radiation and low ambient temperature, common in that season of the year and resulting in lower metabolic rates. With regard to relative humidity (RH), Mercurio (2002) recommends that the ideal span is from 75% to 90%. The RH in the majority of the time was in that range (Figure 3).

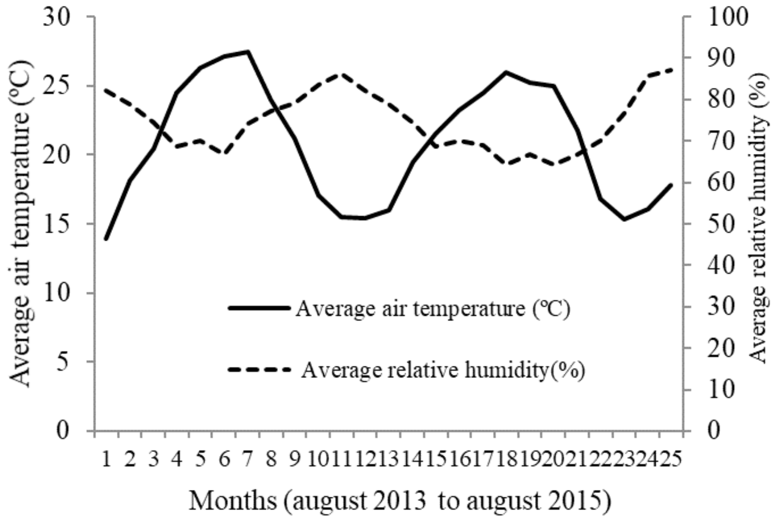

Figure 3. Average ambient temperature (ºC) and relative humidity (%) inside the protected cultivation system for gerberas.

In general, there was an increase production and quality of the floral stalks with increases in air temperatures. However, in January and February, that condition was not confirmed (Figure 2), probably because of the occurrence of some days with temperatures beyond 35 ºC (Figure 3), which is the maximum temperature for gerberas according to Infoagro (2017).

The analysis of the main effect of N doses on flower yields over time, independently of Ca doses and evaluation months, indicate that the data fitted to a quadratic polynomial response. The maximum flower yield of 0.9 flower stalks plant^{-1} month^{-1} was determined at a dose of 0.14 g N L^{-1} substrate applied every 15 days (Figure 4A).

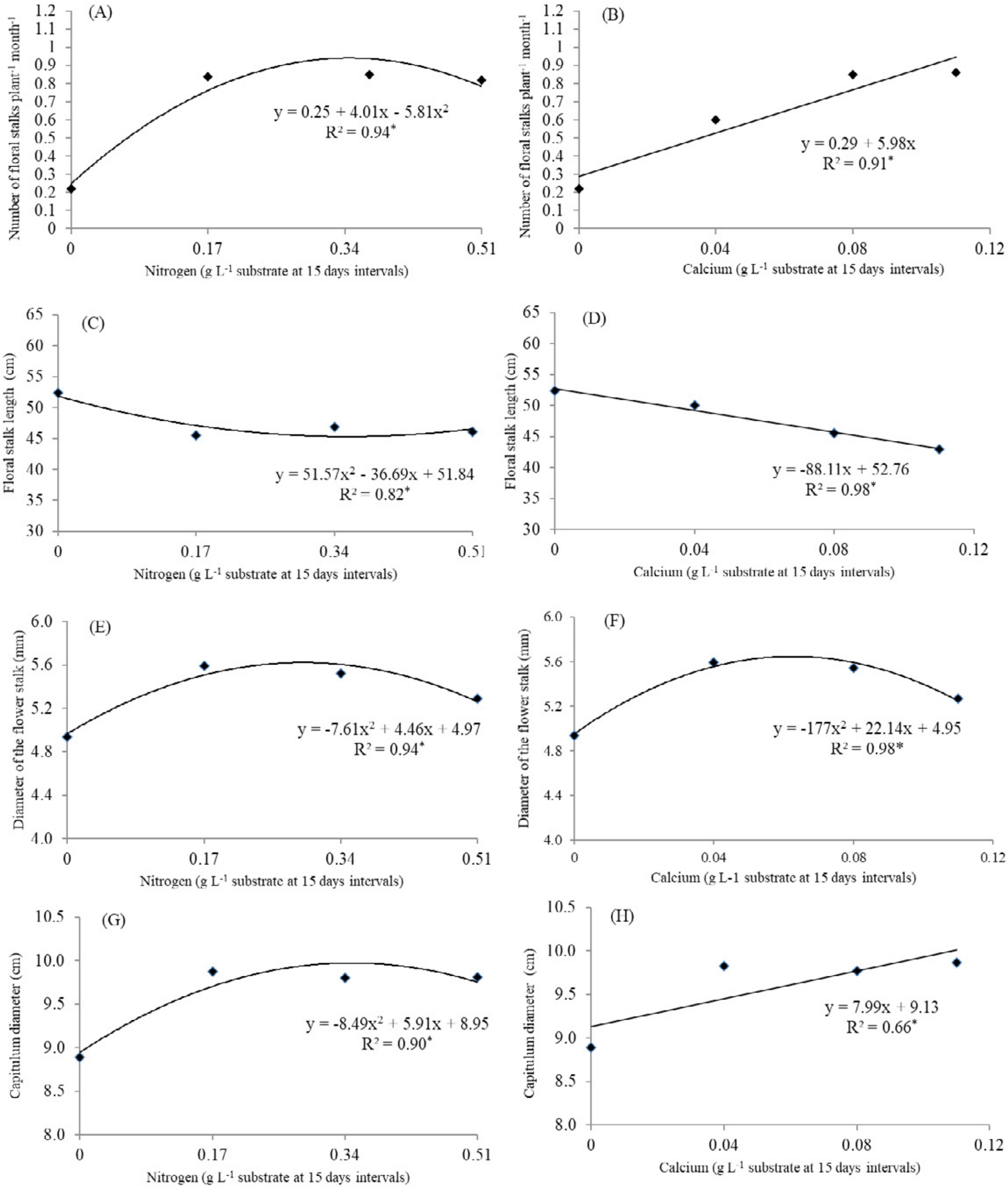

Figure 4. Gerbera plants cv. Dino cultivated on substrate with different doses of nitrogen (g L^{-1} substrate) and calcium (g L^{-1} substrate) applied every 15 days: number of floral stalks $plant^{-1}$ $month^{-1}$ for N doses (A) and calcium doses (B); floral stalk length (cm) for the different doses of nitrogen (C) and calcium (D); diameter of the flower stalk (mm) in response to different doses of nitrogen (E) and doses of calcium (F) and capitulum diameter of gerberas (cm) in response to different doses of nitrogen (G) and doses of calcium (H). *Significant at $p < 0.05$.

The main effect of Ca on flower yield, also independent from N doses and evaluation period, adjusted significantly to a linear model (Figure 4B), which means that the higher the Ca dose applied the higher the number of flower stalks collected. With the highest Ca dose (0.04 g L^{-1} substrate) 11 flower stalks were harvested from one single gerbera plant in a one-year time frame or 0.9 flower stalks $plant^{-1}$ $month^{-1}$. Albino-Garduño et al. (2018) observed that the number of flowers stalks of gerberas cultivated in 15L-pots was 60% to 70% less when a low dose of Ca (120 mg L^{-1}) was applied.

The average number of gerbera flowers harvested from each plant in the present experiment is below the number of flowers harvested by Muniz et al. (2013). The authors collected on average, 1.75 gerbera flower stalks on every plant in every month. These numbers are even more contrasting when examining the number of flowers harvested from the control plants in the present experiment: on average, eight flowers less than the number of flowers harvested from the plants that received fertilizers (Figure 4 A and B).

Regression analysis for length of flower stalk in response do N doses indicate that the data fit significantly in a quadratic polynomial model. Increases in N supply diminished the number of flowers to be harvested until the dose of 0.14 g L^{-1} substrate at every 15 days. After that dose, the tendency was of an increment in the stalk length (Figure 4C). For Ca doses, a significant negative linear adjustment of the data was calculated, which means that the lowest length of flower stalks was determined at the highest Ca dose (Figure 4D).

The plants grown without N and Ca were the ones with longest stalk length: 51.84 cm and 52.76 cm, respectively. Those lengths are considered long stalks according to the criteria practiced by the Cooperativa Veiling Holambra for gerberas as cut flower since these lengths exceed 50 cm (Ibraflor, 2021). In all the other plants due to the fact that there is always more than one flower stalk in development there might have occurred competition for photoassimilates given that the distribution occurs largely due to the amount and the proximity of the source, the leaves, and the sink, the floral stalk (Taiz and Zeiger, 2017).

The diameter of floral stalks was significantly influenced by the N and Ca doses and presented a significant quadratic effect. The highest average value for gerbera flower stalks diameter of 5.64 mm was determined in plants that had been supplied with 0.12 g N L^{-1} substrate (Figure 4E) and 0.04 g Ca L^{-1} substrate (Figure 4F) applied at two week intervals.

For gerberas as cut flower it is essential to have an adequate correlation in between the length and the diameter of a flower stalk. Very long and thin stalks will have a higher propensity to lower mechanical resistance to bending and breakage reducing the aesthetic and market quality (Ludwig et al., 2011). Therefore, even when floral stalks of the control plants were longer, no increases in diameter were determined.

Regarding the diameter of the capitulum of gerberas, the plants that yield inflorescences of a diameter equal or higher than 10 cm are considered as of large size (Ibraflor, 2021). The analysis of data of that variable in the present experiment made evident a significant quadratic adjustment in response to N supplies. The largest average diameter was determined when 0.14 g N L^{-1} substrate (Figure 4G). Data of capitulum diameter for Ca doses presented a significant and positive linear adjustment. The plants supplied every 15 days with highest dose of Ca (0.04 g L^{-1} substrate) yielded the largest capitulum diameters: equal or beyond 10 cm (Figure 4H).

Conclusions

The monthly variations of flower yields and quality are independent from the different doses of nitrogen and calcium supplied every 15 days to gerbera plants cultivated in pots containing a commercial pine bark-based substrate. Along the cultivation period, in the winter months occurs a reduction in production and quality of gerbera flower stalks.

Author Contribution

MM: responsible for the implementation, conduct, evaluation of the experiment and writing of the scientific article; **EMP**: responsible for the implementation, conduct, evaluation of the experiment and writing of the scientific article; **WH**: responsible for the implementation, conduct, evaluation of the experiment and writing of the scientific article; **GS**: advisor, participating in the conception and planning of the experiment and in the correction of the scientific article; **SJL**: participation in the statistical analysis and writing of the scientific article; **RJB**: advisor, participating in the conception and planning of the experiment and in the correction of the scientific article.

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