Journal of Plant Nutrition, 31: 91–101, 2008

ISSN: 0190-4167 print / 1532-4087 online
DOI: 10.1080/01904160701741958

Taylor & Francis
Taylor & Francis Group

Response of Gerbera to Calcium in Hydroponics

R. Albino-Garduño,[1] H. A. Zavaleta-Mancera,[1] L. M. Ruiz-Posadas,[1] M. Sandoval-Villa,[2] and A. Castillo-Morales[3]

[1]Programa de Botánica, IRENAT, Colegio de Postgraduados, Montecillo Estado de México, México
[2]Programa de Edafología. IRENAT, Colegio de Postgraduados, Montecillo Estado de México, México
[3]Departamento de Matemáticas, Universidad Autónoma Metropolitana, Iztapalapa, Distrito Federal, México

ABSTRACT

The aim of this work, was to explore the potential of hydroponics system in *Gerbera jamesonii* cultivation ('Amaretto' and 'Darling' varieties), using the Steiner nutrient solution that contains 9 meq L^{-1} of calcium (Ca^{2+}) plus two modified nutrient solutions with 6, and 12 meq $Ca^{2+}\cdot L^{-1}$ on a red volcanic rock substrate known in Mexico as "tezontle",. Physiological and productivity parameters, and quality of inflorescence produced during 91 d were analyzed. Additionally, calcium in leaves, scapes, and capitula was quantified. The results showed the importance of calcium in gerbera cultivation. Calcium concentration in leaves indicated that ion assimilation was proportional to that supplied in the nutrient solution. It was found that calcium level of 6 meq Ca^{2+} L^{-1} reduced leaf area, plant dry weight, and the number of inflorescences produced per plant during 91 d by 74% in 'Amaretto' and 61% in 'Darling' varieties with respect to the control. Likewise, this dose had effect on quality; reducing the diameter of the capitulum and scape length with respect to 9 and 12 meq $Ca^{2+}\cdot L^{-1}$ The best calcium dose for 'Amaretto' was 12 meq $L^{-1}Ca^{2+}$, and for 'Darling' 9 meq $Ca^{2+}\cdot L^{-1}$, which showed the greatest dry mass weight, flower production, and quality of the inflorescence, related to high CO_2 net assimilation rates.

Keywords: calcium, Gerbera, hydroponics, inflorescence quality, photosynthesis, productivity, transpiration

Received 11 January 2006; accepted 15 May 2007.

Address correspondence to H.A Zavaleta-Mancera, Programa de Botánica, Colegio de Postgraduados en Ciencias Agrícolas, Km. 36.5 Carretera México Texcoco, Montecillo, Estado de México 56230, México. E-mail: arazavaleta@colpos.mx.

INTRODUCTION

Gerbera (*Gerbera jamesonii* H. Bolus ex Hook. f.) is a species of the Asteraceae family, whose development as a cultivar dates from the 19th century, when it was introduced from Africa to Europe and the United States, where the selection and improvement generated more vigorous plants, adapted to temperate climate, with longer flower stalks, and a wide range of color shades (Oszkinis and Lisiecka, 1990; Arias et al., 1993; Tourjee et al., 1995). Traditionally, gerbera cultivation has been in soil, however, the introduction of hydroponics systems promises economic and nutritional advantages over the cultivation of flowers and vegetables in soil. The term hydroponics is utilized to describe plant cultivation in absence of soil, where nutrients are provided in solution (Resh, 1997). Several authors suggest the use of hydroponics system in gerbera production (Pisanu et al., 1994; Maloupa and Gerasopoulos, 1999), which improves inflorescence quality (Maloupa et al., 1993) and profitability (Mattas et al., 2000) through economical use of water and space (Cadahía et al., 2000). Nevertheless, these studies focus the attention on the comparison of substrates and recycling of nutrient solutions than on the search of optimal nutritional conditions for gerbera cultivation. Some authors informed about the effect of different nitrogen (N), phosphorus (P), and potassium (K) levels on gerbera cultivation in soil (Dufault et al., 1990). Calcium (Ca^{2+}) is an essential macronutrient element for normal plant development, which participates in numerous physiological and biosynthesis processes. The Ca^{2+}ion is a cofactor of important enzymes (amylases, ATPases, etc.), essential component of the cell wall, mainly of the middle lamella; it is related to stability and mechanical strength of the cell wall (Demarty et al., 1984), associated to cell division, required for normal functioning of membranes, and involved as a secondary messenger in various plant responses to hormonal and environmental signals (Carafoli and Klee, 1999; Roberts and Harmon, 1992). Calcium deficiency yields meristem necrosis and growth alterations (Jones, 1998; Taiz and Zeiger, 1998). Numerous studies have stated the importance of the calcium ion in the regulation of stomata closing, which in turn modifies the patterns of gas exchange (Atkinson et al., 1992; Ruíz et al., 1992). Agronomically, calcium is associated to fruit firmness (Conway et al., 1995), to senescence delay in flowers (Torre et al., 1999) and to the increase vase life of gerbera, maintaining the scape firmness (Gerasopoulos and Chebli, 1999). Given the well-known advantages of hydroponics systems and the importance of calcium in different metabolic and growth processes, the present study explores the potential of a hydroponics system enriched with calcium (Ca^{2+}) in gerbera cultivation, analyzing plant transpiration, carbon dioxide (CO_2) assimilation rate, stomatal conductance, productivity and inflorescence quality in the gerbera varieties 'Amaretto' and 'Darling'.

MATERIALS AND METHODS

Plant Material and Hydroponics System

Seedlings of 'Amaretto' and 'Darling' varieties were obtained from 'Shreurs', Amsterdam, Holland. The seedling, with 6 exposed leaves were transplanted, individually to 15 L black polyethylene bags with red volcanic rock (tezontle) of 0.5 cm diameter as an inert substrate. The plants were distributed in rows at 30 cm distance from one another. The experiments were performed in the period of 287 to 487 d after transplant (dat) from May to November in a greenhouse at Montecillo, State of Mexico (19.46 N, 98.91 W). Nutrients were supplied through Steiner Universal Solution (1961) in the following concentrations meq L^{-1}: 9 Ca^{2+}, 15 nitrate (NO_3^-), 1 phosphate (H_2PO_4), 7 sulfate (SO_4^{2-}), 10 $K^+ \cdot L^{-1}$, 4 magnesium (Mg^{2+}) and micronutrients according to Arnon (1938). In order to obtain the other two treatments, Ca^{2+}concentration was modified to 6 and 12 meq $Ca^{2+}L^{-1}$ with calcium nitrate [$Ca(NO_3)_2$].

The solutions were prepared using distilled water, pH adjusted to 5.8 with sulfuric acid (H_2SO_4) 0.1N, the osmotic potential ranged from -0.082 to -0.090 MPa. A total volume 483 mL day^{-1} of the nutrient solution, distributed in three irrigation events (10:00, 13:00, and 17:00 h), was apply using an automatic drip irrigation system. The plants were shaded with a 30% screen in order to obtain a photo-synthetically active radiation (PAR) of 447 μmol $\cdot m^{-2}s^{-1}$ and a maximum temperature of $33 \pm 2^{\circ}$C, reached at noon, and minimum of $10 \pm 5^{\circ}$C during the night. According to the cultural practices recommended for the species (Sciortino and Roxas, 1986; Oszkinis and Lisiecka, 1990), the flower buds appeared during the first 91 d after transplant (dat) were removed and all senescent leaves were also removed, every 20 d, during the all period of the experiment. All experimental determinations were performed from 287–487(dat). This setting defines a completely randomized design with ten replications and a factorial arrangement of treatments; two varieties and three calcium levels.

Gas Exchange

Transpiration rate, stomatal conductance, and carbon dioxide (CO_2) assimilation rate were measured with a portable system of gas analysis in the infrared spectrum (IRGA, CIRAS-1 PP SYSTEMS). Measurement was done in the middle part of 10 completely expanded young leaves of 10 plants per treatment at 11 different dates during a period of 100 d (287–388 dat), making a total of 110 measurements per treatment. The variables were monitored from 12:00 to 13:30 h, the mean temperature at the moment of measuring was 29.19°C in the chamber, and 26.94°C in the leaf.

Plant Productivity and Flower Quality

Plant productivity was evaluated by total foliar area, dry weight of leaves and stems, and the number of inflorescences per plant and flower quality was evaluated by the capitulum diameter and scape length, of the inflorescence, produced during 90 d. The leaves of 5 plants were rinsed with running water and the total foliar area per plant was measured using a leaf area integrator (LI-COR-MOD LI-3100) . Subsequently, stems and leaves were dried in an oven (LC-Oven LAB-LINE) at 70°C during approximately 48 h, until obtaining a constant weight of the sample with a pair of digital scales (ACCULAB VI-3mg). The number of inflorescences per plant, generated during 90 d (313–403 dat), were counted, procedure previously used to evaluate Gerbera production (Lin and French, 1985; D'Agliano et al., 1994; Farina and Volpi, 1989, Maloupa and Gerasopoulos, 1999). The inflorescences produced during this period were cut from the base of the scape, when the capitulum presented two rows of male flowers opened, according to the standard cut index for the species (Abdel and Rogers, 1986). Additionally, the capitulum diameter and scape length were measured as quality parameters.

Calcium Concentration in Tissue

Calcium was determined in triplicate of homogeneous samples of: a) 10 leaves of 5 plants per treatment at 427 dat; b) 10 capitula at cut maturity per treatment; and c) 10 scape segments of 5 cm, taken at 5 cm below the capitulum of the inflorescences sampled between 313–403 dat, because this region is considered to be the one presenting postharvest curvature (Marousky, 1986). Mineralization of the vegetal tissue was made with a digestion of nitric acid in samples of 0.5 g of dry vegetal tissue, according to the methodology of Alcántar and Sandoval (1999). The extracts were read in an equipment of spectrophotometry of Induction Coupled Plasma (ICP-AES Varian^{TM}).

Statistical Analysis

Analysis of data was made through comparison of means (Analysis of variance and Tukey-Kramer and LSD, $\alpha = 0.05$ and correlation tests (r–Pearson, $\alpha = 0.05$) with the statistical package Number Cruncher Statistical System: NCSS 2001 (Hintze, 2001).

RESULTS

Gas Exchange

Stomatal conductance observed in 'Amaretto' var. was not modified by the Ca^{2+} concentrations used (treatments). 'Darling' var. cultivated with 12 meq

$Ca^{2+}L^{-1}$ presented significant reduction of 16% with respect to those obtained with 6 meq Ca^{2+} L^{-1}, without showing differences between 9 and 12 meq $Ca^{2+}L^{-1}$ (Table 1).

The CO_2 assimilation rate observed in 'Darling' var. was not modified by calcium concentration, in contrast, in 'Amaretto' var. with 6 meq $Ca^{2+}L^{-1}$, it was reduced significantly by 22% with respect to 9 meq $Ca^{2+}L^{-1}$whereas the CO_2 assimilation rate was not modified between 9 and 12 meq $Ca^{2+}L^{-1}$. The transpiration net rates of 'Amaretto' and 'Darling' with 6 meq Ca^{2+} L^{-1} were reduced significantly by 13% and 12% with respect to the control (9 meq $Ca^{2+}L^{-1}$), significant difference between 9 and 12 meq $Ca^{2+}L^{-1}$ was observed in 'Darling' but not in 'Amaretto' (Table 1).

Productivity and Quality

Dry weight of leaves and stems of 'Darling' decreased remarkably with 6 meq $Ca^{2+}L^{-1}$. In 'Amaretto', these parameters were not affected by Ca^{2+} (Table 2). Inflorescence production, measured by the number of flowers produced per plant, diminished considerably in both varieties, when they were cultivated with 6 meq $Ca^{2+}L^{-1}$. The production decreased by 74% in 'Amaretto' and 61% in 'Darling' with respect to the control; differences between 9 and 12 meq $Ca^{2+}L^{-1}$were not observed (Table 2). As for flower quality, 'Amaretto' generated a capitulum diameter 11% and 9% larger when cultivated with 9 and

Table 1
Gas exchange; stomatal conductance, transpiration and CO_2 assimilation net rates in 'Amaretto' and 'Darling' plants grown with different concentrations of calcium in the nutrient solution

Treatments (me $Ca^{2+}\cdot L^{-1}$)	Stomatal conductance (μmol H_2O m^{-2} s^{-1})	Transpiration net rate (mmolm^{-2} s^{-1})	CO_2 assimilation net rate (μmolm^{-2} s^{-1})
		'Amaretto'	
6	225.05 ± 12.86 a[z]	6.00 ± 0.19 a	5.62 ± 0.36 a
9	254.17 ± 13.44 a	6.94 ± 0.20 b	7.42 ± 0.39 b
12	221.15 ± 12.92 a	6.62 ± 0.19 ab	7.54 ± 0.37 b
		'Darling'	
6	242.50 ± 11.16 a	6.03 ± 0.19 a	6.19 ± 0.35 a
9	237.00 ± 11.1 ab	6.92 ± 0.17 b	7.22 ± 0.34 a
12	202.07 ± 11.88 b	6.30 ± 0.17 a	6.79 ± 0.37 a

[z]Means with the same letter within the columns are equal according to the Tukey Kramer test with $P \leq 0.05$. Average 110 (measurements in 10 plants per treatment, on 11 dates) ±ES, during the period 287–388 d after transplant.

Table 2
Productivity and quality indicators in inflorescences from 'Amaretto' and 'Darling' plants grown on different concentrations of calcium in the nutrient solution

Treatments (me $Ca^{2+}L^{-1}$)	Productivity			Quality	
	Inflorescences / plant (90 días^{-1}) [z,y]	Foliar area/plant (cm^2) [x]	Dry weight of leaves and stems (g) [x]	Capitulum diameter (cm) [w]	Scape length (cm) [w]
			'Amaretto'		
6	1.60 ± 0.73 a	1135.8 ± 518.38 a	33.92 ± 13.13a	8.90 ± 0.28 a	31.78 ± 1.46 a
9	6.20 ± 0.73 b	1692.31 ± 448.93 a	39.92 ± 9.28 a	10.06 ± 0.14 b	34.97 ± 0.75 a
12	6.28 ± 0.87 b	2285.61 ± 401.64 a	46.01 ± 8.30 a	9.84 ± 0.16 ab	32.99 ± 0.87 a
			'Darling'		
6	2.44 ± 0.93 a	1521.52 ± 322.18 a	30.96 ± 6.53 a	8.82 ± 0.22 a	31.84 ± 1.95 a
9	6.30 ± 0.88 b	2608.89 ± 298.28 a	57.52 ± 6.05 b	9.57 ± 0.10 b	38.12 ± 1.02 b
12	4.27 ± 0.84 ab	2258.74 ± 352.93 a	55.12 ± 7.15 ab	9.60 ± 0.12 b	37.44 ± 1.24 b

[z]Means with the same letters within the columns are equal to the Tukey Kramer test with $P \leq 0.05$, [y]$n = 10$, [x]$n = 5$,
[W]All flowers produced during 90 d per treatment ($n = 18 – 59$ observations in 'Amaretto' and 'Darling') ± ES.

12 meq $Ca^{2+}\cdot L^{-1}$, related to those produced with 6 meq Ca^{2+}; in 'Darling' the diameters were 7% and 8% larger in the same doses (Table 2). Scape length of 'Darling' was greater by 16% and 14% in 9 and 12 meq $Ca^{2+}\cdot L^{-1}$ with respect to the one obtained with 6 meq $Ca^{2+}.L^{-1}$ .In 'Amaretto' the greatest scape length was obtained with 9 meq $Ca^{2+}\cdot L^{-1}$, being by 9% greater than the length generated with 6 meq $Ca^{2+}\cdot L^{-1}$.

Calcium

Comparing Ca^{2+}concentrations in the leaves of the two varieties, it was observed that the Ca^{2+}content increases remarkably in relation to the dose of calcium administered in the nutrient solution in 'Amaretto' and in 'Darling'. This tendency, however, was not observed in the capitula of 'Amaretto' and 'Darling'.

The Ca^{2+}concentrations in the scapes of 'Darling' cultivated with 9 and 12 meq $Ca^{2+}\cdot L^{-1}$were significantly higher than those produced with 6 meq $Ca^{2+}\cdot L^{-1}$ but this tendency was not observed in 'Amaretto' (Table 3).

DISCUSSION

Stomata are the plants sensors which respond to any ambient changes, it has been accepted that the size of the stomatal pore is an indicative of the physiological state of the plant. Furthermore, it has been recognized for many years that calcium is involved in the stomatal movements, since an increase of its

Table 3
Calcium concentrations (%) in leaves, capitula and scapes of cv. 'Amaretto' and 'Darling' grown with different calcium levels in the nutrient solution

Treatment (me $Ca^{2+}.L^{-1}$)	Leaves	Capitula	Scapes
		'Amaretto'	
6	0.57 ± 0.08 (a)[z]	0.17 ± 0.09 (a)	0.10 ± 0.01 (a)
9	0.84 ± 0.11 (b)	0.18 ± 0.12 (a)	0.09 ± 0.01 (a)
12	0.89 ± 0.06 (b)	0.14 ± 0.02 (a)	0.19 ± 0.09 (a)
		'Darling'	
6	0.71 ± 0.03 (a)	0.17 ± 0.02 (a)	0.08 ± 0.01 (a)
9	0.80 ± 0.04 (ab)	0.12 ± 0.01 (a)	0.10 ± 0.01 (b)
12	1.18 ± 0.17 (b)	0.15 ± 0.02 (a)	0.11 ± 0.01 (b)

[z]Means with the same letter within the columns are equal according to the LSD test with $P \leq 0.05$. $n = 3 \pm ES$.

concentration in the apoplast of the guard cells unchain a series of events that produce lost of turgor within the cells and as consequence, stomata closing (Mansfield et al., 1990). 'Amaretto' and 'Darling' plants cultivated with 12 meq $Ca^{2+}\cdot L^{-1}$ presented a significant increase in calcium concentration measured in leaves, this fact was related to the diminution of 14% in stomatal conductivity in 'Darling'; however, 'Amaretto' did not showed any significant change (Table 1). The tendencies observed in Darling was consistent with the observations of Atkinson (1991) and Ruíz et al. (1992) in plants of *Commelina communis* L. (8 mol m^{-3} Ca^{-3}) and *Lupinus luteus* (15 mol m^{-3} Ca^{-3}), which showed diminution of stomatal conductance in the highest tested Ca^{2+} levels. It is well-known that stomatal conductance is directly proportional to plant transpiration (Salisbury and Ross, 1994); however in gerbera, there was no considerable correlation between Ca^{2+}concentration in leaves and transpiration rate, but the difference among treatments was reflected in the transpiration analysis. On the other hand, it was observed that 'Amaretto' was more sensitive to the low calcium concentration, since the plants cultivated with 6 meq $Ca^{2+}\cdot L^{-1}$significantly reduced their transpiration and assimilation rates with respect to the control (9 meq $L^{-1}Ca^{2+}$), by 13% and 22% respectively (Table 1). At this respect, Atkinson's experiments (1991), carried out in vitro with plants of *Commelina communis* L., indicated that low calcium doses (4 meq $L^{-1}Ca^{2+}$) reduce transpiration rate by 21% compared to supplements of 16 meq $Ca^{2+}\cdot L^{-1}$. Comparing the values obtained in this work with those found in literature, it can be observed that the highest values in CO_2 assimilation rate, registered in 'Darling' and 'Amaretto', were lower than the maximum values obtained in other gerbera varieties such as 'Cyprus' and 'Heart Breaker' (10 μmol $m^{-2}s^{-1}$), cultivated with 6.49 meq $L^{-1}Ca^{2+}$ (D'Agliano et al., 1994; Issa et al., 2001); these differences may be attributed to the genotype.

The production of inflorescence per plant was related to the CO_2 net assimilation rates, where the highest rates values, observed in 'Amaretto' with 12 meq $Ca^{2+}\cdot L^{-1}\cdot$, and in 'Darling' with 9 meq Ca^{2+} L^{-1}, produced the largest number of inflorescences per plant (Table 2). The varieties studied in the present research, 'Darling' and 'Amaretto' developed lower CO_2 net assimilation values (Table 1) than the observed in Cyprus" and "Heart Breaker" var. (10 μmol $m^{-2}s^{-1}$), cultivated with 6.49 $Ca^{2+}\cdot$(D'Agliano et al., 1994; Issa et al., 2001); these differences may be attributed to the genotype.

It is worth mentioning that the calcium concentrations measured in the different parts of the studied plants were within the ranges reported in literature (Kirkby and Pilbeam, 1984; Oszkinis and Lisiecka, 1990; Baas et al., 1995; Gerasopoulos and Chebli, 1999). The results of production and quality indicated that the low Ca^{2+}concentrations (6 meq $Ca^{2+}\cdot L^{-1}$) reduced the number of inflorescences produced, in both varieties, between 60% and 70%. The plants cultivated with concentrations of 9 and 12 meq $Ca^{2+}\cdot L^{-1}$produced the largest number of inflorescences per plant. The plants cultivated in 6 meq $Ca^{2+}\cdot L^{-1}$ did not showed any e symptoms of Ca^{2+}deficiency, such as death of the apical

meristem and sometimes yellowing of leaf edges (Rogers and Tjia, 1990); the application of 6 meq $L^{-1}Ca^{2+}$, however, produced smaller leaves and lower dry biomass. The calcium content analysis showed that ion assimilation was proportional to the concentration administered in the nutrient solution only for the leaves, of both varieties. Calcium content in leaves was considerably higher than that found in capitula and scapes in both varieties. The calcium concentration measured in the 'Amaretto' leaves of plant grown with 9 meq $L^{-1}Ca^{2+}$ was 78% higher than that contained in capitula, and 89% higher than that of the scapes. This pattern could be attributed to the proximity of the leaves to the roots, which would explain the limited mobility of the ion, and that calcium translocation depends on the concentration in the solution and on transpiration, considering that the leaves are the organs that transpire most with regard to other structures (Salisbury and Ross, 1994; Kirkby and Pilbeam, 1984).

CONCLUSIONS

The results of the present study support the importance of calcium in gerbera cultivation under hydroponics system, and it is concluded that 6 meq L^{-1} of calcium, resulted in low calcium concentration in leaves, reduced the number of inflorescences produced per plant, foliar area, dry weight of the aerial part of the plant, capitulum diameter, and scape length. These tendencies were related to low CO_2 net assimilation rates. The best calcium doses for 'Amaretto' was 12 meq Ca^{2+} L^{-1}, and for 'Darling' 9 meq Ca^{2+} L^{-1}, which produced the largest number of inflorescences per plant, foliar area, dry weight of leaves and stems, capitulum diameter, and scape length. These tendencies were related to high CO_2 net assimilation rates.

ACKNOWLEDGMENTS

Thanks to the Consejo Nacional de Ciencia y Tecnología for financing the investigation of the first author, to the Colegio de Postgraduados, and to the Advisory Committee presiding over the research.

REFERENCES

Abdel, K. H., and N. M. Rogers. 1986. Postharvest treatment of *Gerbera jamesonii*. Acta Horticulturae 181:169–176.

Alcántar, G., and M. Sandoval. 1999. Manual de Análisis Químico de Tejido Vegetal, [Manual of Chemical Analysis of Vegetal Tissue] Chapingo, México: Publicación especial 10. Ed. Sociedad Mexicana del Suelo, A.C.

Arias, B. D., C. H. Romo, and G. G. Benavente. 1993. Gerbera, Lilium, Tulipan y Rosa [Gerbera, Lilium, Tulipa and Rose]. Madrid, España: Mundi Prensa. 120 p.

Arnon, D. I. 1938. Microelements in culture solution experiments with higher plants. American Journal of Botany 25: 322–325.

Atkinson, C. J. 1991. The flux and distribution of xylem sap calcium to adaxial and abaxial epidermal tissue in relation to stomatal behavior. *Journal of Experimental Botany* 42: 987–993.

Atkinson, C. J., L. P Ruiz, and T. A. Mansfield. 1992. Calcium in the xylem sap and the regulation of its delivery to the shoot. *Journal of Experimental Botany* 43: 1315–1324.

Baas, R., T. J. Nijssen, V. D. Berg, and M. G. Warmenhoven. 1995. Yield and quality of carnation (*Dianthus caryophyllus* L.) and gerbera (*Gerbera jamesonii* L.) in a closed nutrient system as affected by sodium chloride. *Scientia Horticulturae* 61: 273–284.

Cadahía, C. L., E. A. Eymar, M. J. Lucena, L. T. Montalvo, P. M. L Segura, B. M. Abad, P. N. Castilla, V. D. López, and M. P. Noguera. 2000. Fertirrigación: Cultivos Hortícolas y Ornamentales. Madrid España: 2ª ed. Mundi Prensa. 475 p.

Carafoli E., and C. B., Klee. 1999. Calcium as a cellular regulator. New York: Oxford University Press 656 p.

Conway, W. S., C. E. Sams, and A. E. Watada. 1995. Relationship between total and cell bound calcium in apples following postharvest pressure infiltration of calcium chloride. *Acta Horticulturae* 398: 31–39.

D'Agliano, G., C. Carrai, and G. Bigongiari. 1994. Preliminary evaluation of a hydroponic recirculating nutrient system for gerbera cultivation. *Acta Horticulturae* 361: 414–422.

Demarty, M., C. Morvan, and C. M. Thellier. 1984. Calcium and the cell wall. Plant Cell and Environment 7: 441–448.

Dufault, R. J., L. T. Phillips, and J. W. Kelly. 1990. Nitrogen and potassium fertility and plant population influence field production of gerbera. *HortScience* 25: 1599–1602.

Farina, E., and L. Volpi. 1989. Effect of GA_3 treatments on flowering of gerbera grown for winter production. *Acta Horticulturae* 246: 159–163.

Gerasopoulos, D., and B. Chebli. 1999. Effects of pre and postharvest calcium applications on the vase life of cut gerberas. *Journal of Horticutural Science* 74: 78–81.

Hintze, J. 2001. NCSS and PASS. Number Cruncher Statistical Systems, Software, Version 2001. Kaysville, Utah, U.S.A.

Issa, M., G. Ouzounidou, H. Maloupa, H. A. Isis, and A. Constantinidou. 2001. Seasonal and diurnal photosyntetic responses of two gerbera cultivars to different substrates and heating systems. *Scientia Horticulturae* 88: 215–234.

Jones, J. B. 1998. Plant nutrition manual. Boca Raton, FL: CRC Press,. 149 pp.

Kirkby, E., and J. D. Pilbeam. 1984. Calcium as a plant nutrient. *Plant Cell and Environment* 7: 397–405.

Lin, W. C., and C. J. French. 1985. Effect of supplementary lighting and soil warming on flowering of the three Gerbera cultivars. *HortScience* 20: 271–273.

Maloupa, E., A. Papadopoulos, and S. Bladenopoulos. 1993. Evapotranspiration and preliminary crop coefficient of gerbera soils culture grow in plastic greenhouse. *Acta Horticulturae* 335: 519–525.

Maloupa, E., and D. Gerasopoulos. 1999. Quality production of four cut gerberas in a hydroponics system of four substrates. *Acta Horticulturae* 491: 433–438.

Mansfield, T. A., A. M. Hetherington, and C. J. Atkinson. 1990. Some current aspects of stomatal physiology. *Annual Review of Plant Biology* 41: 55–75.

Marousky, F. J. 1986. Vascular structure of the gerbera scape. *Acta Horticulturae* 181: 399–405.

Mattas, K., E. Maloupa, I. Tzouramani, and K. Galanopoulos. 2000. An economic analysis of soiless culture in gerbera production. *Horticultural Science* 35: 300–303.

Oszkinis K., and A. Lisiecka. 1990. Gerbera. Estado de México, Mexico: EDAMEX.

Pisanu, A. B., G. M. Carletti, and S. Leoni, 1994. Gerbera jamesonii cultivation with different inert substrates. *Acta Horticulturae* 361:590–602.

Resh, H. M. 1997. Cultivos hidropónicos [Hydroponic crops]. 4ª ed. Mundi Prensa. España. 509 p.

Roberts, D. M., and A. C., Harmon. 1992. Calcium modulated proteins: targets of intracellular calcium signals in higher plants. *Annual Review Plant Physiology Plant Molecular Biology*. 43: 375–414.

Rogers M. N., and O. B. Tjia. 1990. Gerbera production for cut flowers and pot plants. *Portland, Oregon: Timber Press.* 170p.

Ruiz, L. P., J. C. Atkinson, and T. A. Mansfield. 1992. Calcium in the xylem and its influence on the behaviour of stomata. *Journal of Experimental Botany* 43: 1315–1324.

Salisbury, B. R., and C. W. Ross. 1994. Fisiología vegetal [Plant Physiology]. Grupo Editorial *Iberoamericana*. México. pp: 138–141.

Sciortino, A., and A. U. Roxas. 1986. Vegetative and productive behaviour of the gerberas grown on natural and artificial substrata. *Acta Horticulturae* 176: 133–142.

Steiner, A. A. 1961. A universal method for preparing nutrient solutions of a certain desired composition. *Plant Soil* 15: 134–154.

Taiz, L., and E. Zeiger. 1998. Plant Physiology. 2 ed. Sunderland, MA: Ed. Sinauer Associates, Inc., *Publishers*. 792 p.

Torre, S., A. Borochov, and A. Halevy. 1999. Calcium regulation of senescence in rose petals. *Physiolgia Plantarum* 107: 214–219.

Tourjee, R. K., J. Harding, and T. G. Byrne. 1995. Complex segregation analysis of Gerbera flower color. *Heredity* 74: 303–310.