Flower longevity and quality attributes of gerbera cut flower affected by different nutrient solutions

Mohammad Ali Khalaj¹ and Mehran Kanani²*

¹Department of Soil Sciences, the National Institute of Ornamental Plants (NIOP), HSIR, AREEO, Iran. +989188664220. ²Department of Horticulture, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardabil 56199-11367, Iran. *E-mail: kanani.mehran@gmail.com

Abstract

Nutrition is the cornerstone of plant production. Here, efforts have been made to study the effect of different nutrient solutions from the Netherlands floriculture companies (S1; Schreurs, S2; Florist, and S3; Research Station for Floriculture and Greenhouse Vegetables (RSFGV)) on two gerbera cultivars (‘Stanza’ and ‘Double Dutch’). Total chlorophyll index (SPAD), flower harvest per plant, flower stem height, disk diameter, total carbohydrate, lignin, and cell membrane stability were significantly affected by treatments. The highest number of cut flowers was harvested in RSFGV solution which was about 24% and 50% more than Florist and Schreurs solutions, respectively. Schreurs’s solution showed the best impact on cell membrane stability, total carbohydrate, and lignin production. Flowers stem height, disk diameter, and hemi-cellulose content were significantly increased by RSFGV solution. The cultivar ‘Double Dutch’ showed the highest cell membrane stability, total carbohydrate, hemi-cellulose, lignin, and vase life. Flower stem height was highest in the cultivar ‘Stanza’. The interaction of nutrient solution and cultivar affected the studied parameters significantly, and the highest vase life was obtained in the cultivar ‘Double Dutch’ fertigated with Schreurs solution (11.4 d). Results indicated that Schreurs and RSFGV solutions could be the proper solutions for producing high-quality cut gerberas commercially.

Key words: Cellulose, Double Dutch, gerbera vase life, hydroponics, lignin, Stanza

Introduction

Gerbera cut flower (Gerbera jamesonii Bolus ex. Hook f.) is a popular flower in family Asteraceae, which consists of a terminal composite head (capitulum) and a flower stem called scape (Perik et al., 2012). Gerbera cut flower longevity is limited and in most cases terminates by stem bending (Van Meeteren, 1978) and petal wilting (Gerasopoulos and Chebli, 1998). Soilless cultivation system uses advanced technology, is highly productive, conserves water and nutrients, protects environment, and is an intensive cultivation system and provides a medium to roots have unlimited access to water and nutrient elements, consequently plants grow up 10 times faster and healthier than soil grown plants (Wahome et al., 2011). Efficient nutrition, availability of cultivation in nonarable lands, and higher density planting leads to increase in yields per unit area in hydroponically grown plants (Resh, 2012). Additionally, different plants and cultivars have different nutrient elements need. Moreover, crop yield and quality is a result of the interaction between plant genetic traits and production condition management (Diacono et al., 2012).

Mineral nutrition affects gas exchange in leaves by influencing stomatal behaviour and the water relations (Neocleous and Savvas, 2015). Therefore, changes in nutrient solution composition influences growth and productivity of plants. Şirin (2011) studied five different nutrient solutions on gerbera and reported that the highest flower quantity and quality was obtained in Colakoğlu-2 solution. Additionally, different nutrient solutions (e.g., Hoagland, Hewitt, and Steiner) showed different effects on growth of fig trees (Kilinc et al., 2007). This study was set up to evaluate the effect of different nutrient solutions on productivity and quality of cut gerbera flowers, which is a very popular cut flower in many parts of the world.

Material and methods

This experiment was conducted in the national institute of ornamental plants (NIOP), Mahallat, Iran, 2016. A factorial experiment based on completely randomized design with three replicates (5 plants per replicate) was performed. Different nutrient solutions procured from the Netherlands companies (S1; Schreurs, S2; Florist, and S3; Research Station for Floriculture and Greenhouse Vegetables; (RSFGV)) and two gerbera cultivars (‘Stanza’ and ‘Double Dutch’) were studied. Cultivation medium was a volume mixture of Peat: Perlite: Expanded clay (70:25:5 V/V) respectively. Gerbera seedling were cultivated in pots (3L), irrigated with tap water (Table 1). The greenhouse condition (day/night temp: 25/18±1°C; RH: 65%) was controlled accurately.

Plants were irrigated with full concentration of nutrient solutions (Table 2) with pH 5.5-5.8.

Photosynthetic capacity: Leaf number was measured at the end of experiment. Plants chlorophyll was measured using leaf Porometer (CCM-200; USA). To measure the photosynthetic pigments (Chl a, b, carotenoids, and total Chl), fully expanded mature leaves were sampled and dissolved in acetone (80%) and centrifuged, followed by measurement of the absorbance of each sample using a spectrophotometer (Perkin Elmer, Lambda 25, UV/VIS Spectrophotometer) at wavelengths of 663.2, 646.8 and 470 nm. The amount of pigments was calculated based on...
Flower longevity and quality attributes of gerbera cut flower

Total carbohydrate: Irigoyen et al (1992) method with some modifications was applied to measure total carbohydrate content. Briefly, 0.1 g of stem (10 cm below the capitulum), was weighed and ground in a porcelain mortar with 95% ethanol. The upper extract was put in a falcon and the residue was ground again with 10 mL of 70% ethanol and the obtained mixture was centrifuged at 3500 rpm for 10 minutes. Afterwards, 0.1 mL of the extract and 3 mL of fresh anthrone (100 mg anthrone+100 mL 72% sulfuric acid) was transferred into the test tube and the samples were put in hot water bath for 10 minutes. Samples were cooled down and the amount of absorption at 630 nm wavelength was measured using spectrophotometer (Perkin Elmer, Lambda 25,UV/VIS Spectrophotometer). Total carbohydrate content was determined by comparing to standard curve.

Lignin: The lignin content of gerbera flower stem was determined by the thiglycolic acid (TGA) method (Bruce and West, 1989). The proximal and distal end of the flower stem at fully opened stage (3 g, 10 days after harvest) was homogenized in 6 mL of 99.5% ethanol (Sigma–Aldrich; Germany) and the crude extract was centrifuged at 10,000 X g for 15 min. The pellet was transferred to a glass Petri dish, and air-dried overnight. 30 mg of the dried residue was placed in a screw-cap tube to which 5 mL of concentrated HCl was added and the samples were put in hot water bath for 10 minutes. Afterwards, 0.1 mL of the extract and 3 mL of 70% ethanol and the obtained mixture was centrifuged at 12,000 x g for 45 min. After cooling, the mixture was centrifuged at 12,000 x g for 45 min at 4 °C. The pellet was washed with 2.5 mL of water and then resuspended in 5 mL of 0.5 N NaOH. The solution was agitated gently at 25 °C for 24 h. After centrifugation at 12,000 X g for 30 min, the supernatant was transferred to a new tube. One microliter of concentrated HCl was added to the test tube and the lignin thiglycolate was allowed to precipitate at 48°C for 6 h. After centrifugation at 10,000 X g for 30 min, the pellet was dissolved in 1 mL of 0.5 N NaOH. The absorbance was measured against a NaOH blank at 280 nm using spectrophotometer (Perkin Elmer, UV/VIS, Lambda 25). The amount of lignin was calculated from a linear calibration curve with commercial alkali lignin (Sigma–Aldrich; Germany).

Cellulose and Hemi-Cellulose: Cellulose was isolated for GLC analysis by an extraction procedure based on Udpegraft, (1969) with some modifications. Finely ground samples (30-150 mg depending on the cellulose content) were weighed into 15 X 125 mm Teflon-lined screw-capped test tubes. Acetic-nitric acid

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**Table 1. Chemical composition of tap water used for irrigation of gerbera seedling**

<table>
<thead>
<tr>
<th>Water type</th>
<th>pH</th>
<th>EC (µS/m)</th>
<th>NO₃⁻</th>
<th>NH₄⁺</th>
<th>H₂PO₄⁻</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>HCO₃⁻</th>
<th>CO₃²⁻</th>
<th>Na⁺</th>
<th>Cl⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap water</td>
<td>5.7</td>
<td>363</td>
<td>20</td>
<td>32</td>
<td>12</td>
<td>70.15</td>
<td>0</td>
<td>16</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Elements concentration in applied nutrient solutions**

<table>
<thead>
<tr>
<th>Nutrient solution</th>
<th>NO₃⁻</th>
<th>NH₄⁺</th>
<th>H₂PO₄⁻</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>SO₄²⁻</th>
<th>NO₃⁻:NH₄⁺ ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>8.5</td>
<td>0.2</td>
<td>1.2</td>
<td>4.25</td>
<td>4</td>
<td>1</td>
<td>1.3</td>
<td>42.5</td>
</tr>
<tr>
<td>S₂</td>
<td>9.5</td>
<td>-</td>
<td>1.8</td>
<td>5.4</td>
<td>5.3</td>
<td>2</td>
<td>3</td>
<td>9.5</td>
</tr>
<tr>
<td>S₃</td>
<td>11.25</td>
<td>1.5</td>
<td>1.25</td>
<td>5.5</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.25</td>
</tr>
</tbody>
</table>

| Nutrient solutions | S₁: Schreurs, S₂: Florist, S₃: RSFGV |

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**Flower disk**: Flower disk diameter was measured by digital caliper.

**Yield or flower harvested per plant**: Average of harvested cut flowers in three plants, during the cultivation period was considered as cut flower number.

**Petel ion leakage**: Petal ion leakage was measured based on Lutts et al (1996) with some modifications. Briefly, 1 g of the fresh petal tissue was transferred into a falcon containing 20 mL of deionized water. After 24 hours (25°C), the ionic leakage of the samples (Lₐ) was read by a conductivity meter (Aqualytic Sensodirect, CD24). Afterwards, samples were autoclaved for 20 min at 120°C. Samples were cooled down and the ionic leakage of the solution (Lₐ) was read. The petal ion leakage was calculated according to the following formula:

\[
\text{Ion leakage (‰)} = \frac{(L_a/L_a)}{100}
\]
reagent (3 mL of a mixture containing 150 mL of 80% acetic acid and 15 mL of concentrated nitric acid) was added slowly to each tube while the contents were being mixed. Each tube was tightly capped and heated for 30 min at 100°C, after which the tubes were cooled and centrifuged. The supernatant was removed and discarded. The fibrous precipitate was washed twice with the acetic-nitric acid reagent (3 ml) and twice with acetone 2 ml. Most of the residual acetone remaining after the last wash was removed by evaporation. The cellulosic residue was analyzed as described by Sloneker (1971).

**Longevity:** Average of three cut flowers in every plant was measured as day until flowers wilted and lost marketability (He et al., 2006).

**Statistical analysis:** Data analysis was performed using SAS V9.2 software. (SAS Institute Inc., Cary, NC, USA). Means were compared using Duncan’s multiple range test at *P*<0.01 and *P*<0.05.

**Results and discussion**

Cut gerbera ‘Stanza’ and ‘Double Dutch’ showed different morpho-physiological traits and their responses to the applied nutrition varied significantly. Nonetheless, the interactive effect of nutrient solution and cultivar did not show a significant effect on studied parameters.

**Photosynthetic capacity:** According to the results, neither treatments (Variety or Solution), nor their interactive effect (Variety × Solution) affect leaf number, chlorophyll a, and carotenoids significantly. SPAD index was significantly affected by treatments (Variety and Solution). Moreover, chlorophyll b content was significantly affected by variety. According to the results, the highest SPAD index was in RSFGV solution (57.9±0.79 a), Florist (57.3±0.96 a), and Schreurs (54.04±0.82 b) respectively (Fig. 1). Additionally, SPAD index (57.69±0.7 a) and Chl b (3.145±0.13 a) in cut gerbera ‘Stanza’ were higher than SPAD index (54.84±0.8 b) and Chl b (2.493±0.16 b) in ‘Double Dutch’ (Data not shown). Chlorophyll content was approximately proportional to leaf nitrogen content (Bojović and Marković, 2009). Probably, high content of total chlorophyll in plants fertigated with RSFGV solution is related to higher concentration of N in RSFGV solution compare to other solutions.

**Stalk length:** Stalk length is among the most important indexes of cut gerbera marketability. Cultivars showed a significant difference on stalk length. Moreover, the length of stalk was significantly affected by nutrient solution (Table 3). The highest stalk length was in cut gerbera ‘Stanza’ (Table 4). The difference between stalk length of studied gerbera cultivars was probably related to the genetic diversity among cultivars (Shammy et al. 2012). RSFGV nutrient solution increased length of stalks. Probably, increase of stalk length in RSFGV was related to nitrogen concentration in this solution, which was higher compare to Schreurs and Florist solutions. Adequate nitrogen supply in nutrient solution and its efficient uptake stimulated cell growth leading to increase in flower stem length (Singh, 2000). Additionally, Şirin (2011) studied the effect of five different nutrient solutions on quality and productivity of cut gerbera and reported that the highest stalk length was produced in Hewitt, 1966 nutrient solution.

**Flower diameter:** In this experiment, cultivars did not show significant difference on flower diameter, however, nutrient solution affected flower diameter significantly. The highest flower diameter was obtained in flowers supplied with RSFGV formula (12.02 cm) (Table 3) which was about 6 and 5% higher than Schreurs and Florist nutrient solutions, respectively. Probably, the differences between nutrients concentration, especially nitrogen and potassium, which are higher in RSFGV solution, have increased flower diameter size through affecting cell division and growth. Although, Dufault et al (1990) reported that gerbera flower diameter was not affected by application of nitrogen in soil cultivation (Fig. 2A).

**Yield (flower harvested/plant):** Flower harvested/plant
was significantly affected by cultivar and solution whereas the interactive effect of cultivar and solution did not show a significant effect on cut flower number. The highest number of cut flowers was harvested in RSFGV solution (291.17±19.94a) compared to Schreurs solution (193.5±1.23c) and Florist solution (234.5±14.6b) (Table 3). Additionally, the number of cut flowers harvested in ‘Stanza’ cultivar was about 21% higher than ‘Double Dutch’ (Table 4). There was a high correlation between N concentration and flower harvested/plant (Fig. 3), which supported the idea that N concentration affected productivity in gerbera cut flowers. Singh et al. (2015) reported that increase in N and K concentration led to higher productivity of cut carnation ‘Master’. Therefore, considering the high concentration of N and K in RSFGV solution compare to other solutions, probably the effect of N and K on higher productivity of cut flowers is related to increase in chlorophyll content and subsequently photosynthetic rate. Moreover, Şirin (2011) who studied the effect of five different nutrient solutions on cut gerbera productivity revealed that the highest cut flower number was obtained in Çolakoğlu-2 solution.

Petal ion leakage: According to the results, petal ion leakage was significantly affected by cultivar and nutrient solution. The highest cell membrane stability was in Schreurs solution (Table 3). Moreover, cut gerbera ‘Double Dutch’ showed the best cell membrane stability (Table 4). Ion leakage is a remarkable index of cell membrane stability and plays an important role in flower stem rigidity and cut flowers longevity. Nazarideljou et al (2011) in an experiment for screening cut gerbera cultivars reported that cut gerbera ‘Candela’, ‘Entourage’, ‘Derin’, ‘Onedin’, and ‘Popov’ showed the highest ion leakage, and ‘Sazo’, ‘Stanza’, ‘Dune’, and ‘Cabana’ showed the lowest ion leakage.

Total carbohydrate: The effect of cultivar and solution on total carbohydrate was significant. Schreurs solution led to the highest carbohydrate (14.94±0.41a) compare to Florist solution (13.15±0.15b) and RSFGV (13.07±0.25b), in cut gerbera stem (Fig. 4). Additionally, the content of carbohydrate in cut gerbera ‘Double Dutch’ was higher compare to ‘Stanza’ (Fig. 5). According to the results, total carbohydrate decreased as nitrogen supply in nutrient solution was increased. In this regard, the lowest carbohydrate was in RSFGV solution which supplied the highest nitrogen (11.25 mmol.L⁻¹ (NO₃⁻) + 1.5 mmol.L⁻¹ (NH₄⁺)) for plant. Druege et al. (2000) reported that increase in nitrogen supply, decreases carbohydrate content which is consistent with our finding.

Lignin: Lignin content was significantly affected by cultivar and solution treatments. Plants which were supplied by Schreurs nutrient solution produced higher lignin (Fig. 4). Furthermore, higher content of lignin was reported in ‘Double Dutch’ (Table 4). Concentration of N in nutrient solution led in reduction of lignin supply.
production in cut gerbera stem and there was a close correlation between these parameters (Fig. 6), subsequently high lignin production in plants fertigated with Schreurs solution is related to low N concentration in this solution compare to Florist and RSFGV solutions. Lignin is a determinative factor in gerbera vase life which influences structural function and defensive mechanisms. In plants, lignin is synthesized by catalytic activity of phenylalalnine ammonia-lyase (PAL), peroxidase (POD), and cinnamyl alcohol dehydrogenase (CAD), which converts phenylalalnine to hydroxy- and methoxy-cinnamyl alcohols (Boerjan et al., 2003; Vanholme et al., 2010). Hardening of few-flower wildrice (Zizania latifolia Turcz.) resulted from lignin deposition and cell wall fibration (Liu et al., 2010). Nazarideljou & Aziizi (2015) reported that cut gerbera ‘Aqua’ had higher lignin content compared to ‘Beaudine’ which reveals that different cultivars have different lignin content.

**Cellulose and Hemi-Cellulose:** Treatments did not show any significant effect on cellulose content of cut gerbera ‘Double Dutch’ and ‘Stanza’, whereas hemi-cellulose content was significantly affected by treatments (Fig. 4).

The highest hemi-cellulose content was in plants supplied with Schreurs solution. Moreover, ‘Double Dutch’ produced higher level of hemi-cellulose while compared to ‘Stanza’ (Fig. 5). Cellulose is the most abundant natural polymeric material on earth (Ikeda et al., 2002). Lignin grows into the cellulose micro-fibrils and forms a three-dimensional polymer of p-hydroxyphenylpropane units, being much more rigid than cellulose (Yousif et al., 2007). This compound gives rigidity and strength to cell wall structure.

A few number of investigations describe significant cell wall modifications in flower petals which represented changes in texture during senescence (O’Donoghue et al., 2002), such as quantitative loss of hemicellulose in senescing cut carnation (de Vetten et al., 1991). Our results indicated that hemicellulose content was affected by changing nutrients supply in solution, especially the Schreurs solution, which had the lowest N supply and moderate level of calcium, produced the highest hemicellulose content, indicating that nutrients concentration and probably ratio is effective in metabolite synthesis in plant.

**Longevity:** Cut gerbera longevity was not affected significantly by nutrient solution, however, Schreurs solution extended vase life of cut gerbera ‘Double Dutch’ about 11% and 22% compared to Florist and RSFGV solutions, respectively (Fig. 2). Further, Schreurs solution extended longevity of cut gerbera ‘Stanza’ comparing Florist and RSFGV solutions. It seems that the high concentration of nitrogen in RSFGV solution (11.25 mmol.L⁻¹ (NO₃⁻) + 1.5 mmol.L⁻¹ (NH₄⁺)) compare to Florist (9.5 mmol.L⁻¹(NO₃⁻)) and Schreurs (8.5 mmol.L⁻¹(NO₃⁻) + 0.2 mmol.L⁻¹(NH₄⁺)) solutions s negatively affected cut gerbera longevity. Bernstein et al (2005) reported that Ranunculus asiaticus flowers grown under 50 ppm N application in a soilless system with perlite medium, characterized by almost double vase life duration compared to flowers grown under 100 ppm treatment.

On the other hand, calcium concentration in RSFGV solution was low (3 mmol.L⁻¹) compared to Florist (5.3 mmol.L⁻¹) and Schreurs (4 mmol.L⁻¹) solutions. The role of calcium in extending cut flowers longevity is probably related to the formation of crosslinks between carbohydrate xyloglycans chains found in middle lamella of cell wall (Shafiee et al., 2010). Calcium application increased longevity of gladiolus ‘Black Jack’ (Gowda and Gowda, 1990), cut gerberas ‘Campitano’, ‘Dino’, ‘Sangria’, and ‘Testarossa’ (Gerasopoulos and Chebli, 1999), cut gerbera ‘Carambole’ (Geshnizjany et al., 2014), and cut rose ‘Kiss’ (De Capdeville et al., 2005).

Cut gerbera longevity was affected significantly by cultivar (Table 4). Cut gerbera ‘Double Dutch’ (11.55 d) lasted longer compared to ‘Stanza’ (9.9 d). The increased longevity of ‘Double Dutch’ is probably related to better cell membrane stability, high lignin formation in flower stem (Table 4) as a factor in extending longevity of cut gerbera (Zamski et al., 1991), and higher carbohydrate (Fig. 4) as a source of energy (Acharya et al., 2010), which resulted in longer lasting of cut gerbera ‘Double Dutch’ compared to ‘Stanza’. Various external cues (e.g., relative humidity, temperature, and nutrition) and internal cues (e.g., genotype, carbohydrate, and nutrients uptake) affected vase life on cut gerbera (Acharya et al., 2010). De Jong & Garretsen, (1985) reported there is ample variation in vase life of gerbera. Nazarideljou et al. (2011, 2012) demonstrated that longevity of cut gerbera bears close relationship with cultivar. These results are consistent with Mahmood et al (2013), who reported a significant difference between gerbera cultivars. Ferrante et al (2007) in a screening experiment on gerbera cultivars reported that cut gerbera longevity varied between cultivars and ranged from 5 to 24 days.

Schreurs and RSFGV solutions produced stiffer stalks with high quality indexes of cut gerberas and could be the proper solutions for producing cut gerberas commercially.

**References**


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**Fig. 6.** Correlation between N concentration in nutrient solution and lignin production in cut gerbera stem. (n=3 for each point)