Improving Rooted Cuttings Quality of Pelargonium zonale cv. "Belmonte Red" after Planting and Cold Storage

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ABSTRACT

Pelargonium zonale cv. "Belmonte Red" is a popular as flowering pot plant with attractive flower heads, leaves and a wide range of floret color. The present investigation was carried out during two successive seasons of 2012 and 2013 at the Experimental Greenhouse and Post-Harvest Lab. of Ornamental Plants and Landscape Gardening Res. Dept., Hort. Res. Inst.; Giza, Egypt, to investigate the effect of spraying solutions of (GA3 and distilled water) on pelargonium rooted cuttings after planting (0- time) and cold storage in perforated and imperforated polyethylene bags for 4 and 8 days at 5°C and their interactions to maintain the quality during shipment. Results showed that all treatments significantly stimulated most of the studied characters compared to control in both 0-time and after cold storage. Spraying pelargonium rooted cuttings with GA3 at 200 mg/l significantly increased vegetative, flowering and root growth parameters in both 0-time and after cold storage. Also, the same treatment recorded higher values of both total chlorophylls and total carbohydrates and lower carotenoids contents in the leaves in both 0-time and after cold storage. Regarding rooted cuttings spraying with GA3 at 200 mg/l and stored for 4 days at 5°C, it was noticed that the pelargonium rooted cuttings stored for 4 days recorded significantly higher values of vegetative, flowering and root growth parameters than those stored for 8 days. In respect to packaging, it was noticed that the pelargonium rooted cuttings in imperforated polyethylene bags were better in all the studied characters than those stored in perforated polyethylene bags. Rooted cuttings sprayed with GA3 at 200 mg/l then stored for 4 days at 5°C decreased both weight loss, ethylene production, respiration rate and gray mold infection moreover, improved visual rating. The results of interaction showed that spraying rooted cuttings with GA3 at 200 mg/l and storing them for 4 days gave the lowest respiration rate and ethylene production. Moreover, the rooted cuttings sprayed with GA3 at 200 mg/l and stored for 4 days in imperforated polyethylene bags gave the significantly highest records of vegetative, flowering and root growth parameters and reduced the depletion of total carbohydrates and pigments contents in the leaves. Also, the same treatment gave the utmost decreasing in the decay caused by Botrytis cinerea and the least weight loss percentage which in turn increase quality.

Keywords: Pelargonium zonale cv. "Belmonte Red", rooted cuttings, storage periods, gibberellic acid spray, perforated and imperforated polyethylene bags.

INTRODUCTION

Pelargonium zonale known as horse-shoe pelargonium or wild malva in Afrikaans, is a wild species of Pelargonium native to southern Africa, belonging to Family Geraniaceae. It is one of the parents of the widely cultivated Pelargonium × hortorum plant, often called a "geranium", "zonale geranium" or "zonale pelargonium". Geraniums are popular flowering pot plants with attractive flower heads and leaves, and a wide range of floret colors. Postproduction quality of potted geraniums is limited by the rapid petal abscission induced by exposure to ethylene and postproduction leaf yellowing during shipping (Kim and Miller, 2009).

Gibberellins regulate stem elongation and have been implicated in a wide range of other developmental responses such as flowering, flower development, and root growth. Gibberellins also promote elongation almost exclusively in intact plants (Hopkins and Hüner, 2009). Also, gibberellic acid is used to regulating plant growth through increasing cell division and cell elongation on Ocimum basilicum (Abou-Leila et al., 1994). Application of gibberellic acid (GA3) to pelargonium cuttings before the dark treatment prevented chlorophyll breakdown and inhibited leaf senescence, probably not only by reducing reactive oxygen species (ROS) levels, but also by interfering with senescence regulation, through unknown mechanism yet Rosenvasser et al (2006). Application of GA retarded chlorophyll loss in leaves. GA can inhibit many processes, such as RNA and protein breakdown, that may be associated with senescence. GA may also delay senescence in petals and other plant parts such as petioles (Tabuchi et al., 2005).

Storage potential is limited at different temperatures by several factors including ethylene production, respiration rates, and carbohydrate depletion (Enfield, 2011). As a consequence, quality of the cuttings may be affected by time spent in transit and the subsequent stresses which they may be exposed to ethylene (Doyle et al., 2003). The delivery process from Africa to Europe can take between 4 to 7 days. However, during shipment, cuttings are exposed to adverse conditions of ethylene, water stress and darkness (Purer and Mayak, 1989), which induce leaf senescence (Behrens, 1988).

Ethylene is known to have an effect on stored plants at very low concentrations and can result in an alteration of the natural processes of plant development which in some cases can result in plant senescence (Salveit, 1999). Modified atmosphere packaging (MAP) is an effective tool used in the fresh-cut industry to extend shelf life by altering the gases in the package to produce a composition different from that of the air (Al-Ati and Joseph, 2002). Depleted O2 and/or enriched CO2 levels reduce respiration, decrease ethylene production, delay enzymatic reactions, alleviate physiological disorders and preserve the product from quality losses and growth of microorganisms (Day, 1994). Usually, during the dry cold storage, flowers are packed in gas-tight bags or boxes. Inside such packages respiration of flowers creates modified atmosphere of reduced oxygen (O2) and elevated carbon dioxide (CO2) levels, which is beneficial for the extension of the storage period (Rudnicki et al., 1991). Postharvest treatment using modified atmosphere with low oxygen
(O₂) and/or high carbon dioxide (CO₂) concentrations lowered down the respiration rate, inhibited ethylene production that induces senescence of fruits (Arrebolt et al, 2010).

The objective of this study was to investigate the effect of spraying solutions of GA₃ and distilled water on pelargonium rooted cuttings (Pelargonium zonale cv. "Belmonte Red") after planting and cold storage in perforated and imperforated polyethylene bags for 4 and 8 days at 5°C and their interactions to maintain the quality during shipment.

MATERIALS AND METHODS

The present investigation was carried out during two successive seasons of 2012 and 2013 at the Experimental Greenhouse and Post-Harvest Lab. of Ornamental Plants and Landscape Gardening Res. Dept., Hort. Res. Inst.; Giza, Egypt, to investigate the effect of spraying gibberellic acid (GA₃) on pelargonium rooted cuttings (Pelargonium zonale cv. "Belmonte Red") after planting and cold storage in perforated and imperforated polyethylene bags for 4 and 8 days at 5°C and their interactions to maintain the quality during shipment.

Plant material and experimental design:

All uniform rooted cuttings (6 cm length and 4 leaves) were planted in the hydroponic system under saran house conditions and were taken in the early morning on 1st February 2012 and 2013, respectively. The rooted cuttings were divided to:

1st Experiment: Experiment was planted directly after spraying with gibberellic acid at 200 mg/l and distilled water (as control) to runoff only for one time in greenhouse in plastic pots of 14 cm diameter filled with peat moss and sand as 1:1 [v/v]. During growth stage the plants were fertilized with 2 g / pot NPK 19:19:19 every 15 days and irrigated every three days.

2nd Experiment: Root cuttings were placed in perforated and imperforated polyethylene bags (130 μm thickness, area of each packet = 30 cm x 25 cm = 750 cm²). Perforated (20 holes / side/packet, diameter of each hole by punch paper = 0.4 cm) and the top of the bag was tightly sealed after spraying with gibberellic acid at 200 mg/l and distilled water (as control). Then they were randomly packed into boxes and stored at 5°C for 85-90 % RH in darkness for 4 and 8 days to simulate transport conditions. After the end of cold storage periods, the rooted cuttings were planted under the same previous condition.

The layout of 1st Exp.: was complete randomized design, 2 treatments (spray solution) x 3 rep. x 32 pot plants/replicate = 192 plants.

As for the 2nd Exp. was complete randomized design in factorial experiment, 8 treatments (2 spray solutions x 2 storage periods x 2 packages) x 3 rep. x 8 pot plants/replicate = 192 plants.

A. Data recorded at the end of season include:

- Vegetative, flowering, and root growth parameters:
  - Number of flowers/inflorences.
  - Root f.w. (g).
  - Root d.w. (g).
  - Root water content (r.w.c) (g): Root water content was determined by subtracting root dry weights from their corresponding fresh weights. Root water content is a measure of freshness of roots (Mutui et al, 2008).
  - Total chlorophyll and carotenoids content (mg/100g f. w.) in the leaves according to Saric et al (1976) at the end of the experiments.
  - Total carbohydrates (%) in the leaves according to Dubois et al (1956).

B. Data were measured at the end of the cold storage periods for 4 and 8 days at 5°C as follows:

1- Weight loss (%).
2- Visual rating: (1) very poor quality, severe leaf necrosis, leaf yellowing, not acceptable, (2) poor quality, large areas of leaf necrosis, leaf yellowing, not acceptable, (3) fair quality, small areas of leaf necrosis, leaf yellowing, marginal acceptability, (4) good quality, very little leaf necrosis, no yellowing, acceptable and (5) excellent quality, no leaf necrosis, no yellowing, acceptable according to Rajapakse et al, (1996).
3- Ethylene (μL/L): was determined by gas chromatography according to Burg and Stolwijk, (1959).
4- Carbon dioxide (CO₂) and Oxygen (O₂) (%): determined by CO₂ and O₂ analyzer Model 902, according to Vleck, (1987).
5- Botrytis cinerea infection % causing gray mold: % infection = Number of infection rooted cuttings/ Total number of rooted cuttings x 100.

Statistical analysis:

All data were subjected to statistical analysis by using MSTAT-C. The results were subjected to analysis of variance (ANOVA) and the means were compared by Duncan’s Multiple Rang Test at P≥ 0.05 as described by Waller and Duncan (1969) to verify differences among means of various treatments.

RESULTS AND DISCUSSION

1-1st Experiment: Effect of spray solutions at 0-time on vegetative, flowering and root growth parameters of Pelargonium zonale cv. "Belmonte Red" rooted cuttings during 2012 and 2013 seasons:

The results presented in Table (1) show that the spray solution of GA₃ at 200 mg/l significantly increased plant height, fresh and dry weights, No. of leaves/plant and root w.c., fresh and dry weights plant⁻¹ in both seasons. Concerning number of inflorences/plant and flowers/ inflorescence, data presented in Table (1) clearly indicate that the spray solution of GA₃ at 200 mg/l significantly exhibited better influence than the control. These results are in accordance with those of Attia (2004) on Zantedeschia aethiopica, Abou El-Elela (2007) on Acanthus mollis and Mostafa and Abou Alhamd (2011) on Balanites aegyptiaca plants who found that spraying plants with GA₃ enhanced vegetative growth measurements. In
addition, Ibrahim (2005) on jojoba plant concluded that gibberellic acid is used to regulate plant growth through increasing cell division and cell elongation. In this respect, application of GA3 at 100 ppm gave significantly heavier root fresh and dry weights in Bougainvillea (Fagge and Manga, 2011).

As shown in Fig. (1) data indicate that GA3 at 200 mg/l as a spraying solutions on rooted cuttings of pelargonium recorded significantly higher values of both total chlorophylls (mg/100g f.w.), total carbohydrates (%) and lower carotenoids (mg/100g f.w.) contents than those of control in the two seasons. Similar results were obtained by Mostafa and Abou Alhamd (2011) who found that all concentrations of GA3 increased significantly total chlorophylls in Balanites aegyptiaca plants. Sardoei et al (2014) showed that the treatments of 200 mg l⁻¹ GA3 had higher reducing sugars than control in Spathiphyllum wallisii plant. Sardoei and Shahdadneghad (2014) showed that chlorophyll content was enhanced by increasing GA3 concentration up to 250 mgL⁻¹ of pot marigold (Calendula officinalis L.).

Table 1. Effect of the spray solutions at 0-time on the vegetative, flowering and root growth parameters of Pelargonium zonale cv. ”Belmonte Red” rooted cuttings during 2012and 2013.

<table>
<thead>
<tr>
<th>Spray solutions</th>
<th>Plant height (cm)</th>
<th>Plant fresh weight (g)</th>
<th>Plant dry weight (g)</th>
<th>No. of flowers/inflor. / plant</th>
<th>No. of leaves/plant</th>
<th>Root width (mm)</th>
<th>Root dry weight (g)</th>
<th>Root wet weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st season</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>30.24b</td>
<td>36.70b</td>
<td>10.54b</td>
<td>13.33b</td>
<td>4.21b</td>
<td>17.10b</td>
<td>0.96b</td>
<td>0.38b</td>
</tr>
<tr>
<td>GA3 at 200 mg/l</td>
<td>44.30a</td>
<td>55.30a</td>
<td>22.57a</td>
<td>15.36a</td>
<td>6.85a</td>
<td>29.10a</td>
<td>2.29a</td>
<td>0.80a</td>
</tr>
<tr>
<td></td>
<td>2nd season</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>30.11b</td>
<td>34.59b</td>
<td>10.45b</td>
<td>12.51b</td>
<td>4.17b</td>
<td>16.50b</td>
<td>0.97b</td>
<td>0.35b</td>
</tr>
<tr>
<td>GA3 at 200 mg/l</td>
<td>43.10a</td>
<td>54.21a</td>
<td>21.66a</td>
<td>15.24a</td>
<td>5.80a</td>
<td>28.20a</td>
<td>2.25a</td>
<td>0.79a</td>
</tr>
</tbody>
</table>

*Means within a column or row having the same letters are not significantly different according to Duncan’s Multiple Range Test at 5% level.

Fig. 1. Effect of the spray solutions at 0-time on total chlorophylls, carotenoids (mg/100g f. w.) and total carbohydrates (%) of Pelargonium zonale cv. ”Belmonte Red” rooted cuttings during 2012 and 2013.

2- 2nd Experiment:
Main effect of the spray solutions, storage periods and packaging on vegetative, flowering and root growth parameters of Pelargonium zonale cv. ”Belmonte Red” rooted cuttings during 2012 and 2013 seasons:

Data presented in Table (2) show that plant height, fresh and dry weights, No. leaves, inflorescence / plant and flowers/ inflorescence and root w.c., fresh and dry weights plant⁻¹ were significantly increased over control as a result of spraying Pelargonium zonale cv. “Belmonte Red” rooted cuttings with GA3 at 200 mg/l in the first and second season.

It is evident from data presented in Table (2) that the significantly higher values of plant height, fresh and dry weights, No.of leaves, inflorescence / plant and No. of flowers/ inflorescence, root f.w., d.w. and w.c. resulted from stored pelargonium rooted cuttings for 4 days, whereas lower values resulted from storing them for 8 days in both seasons.

Also, it is clear from packaging pelargonium rooted cuttings in imperforated polyethylene bags significantly increased plant height, fresh and dry weights, No. of leaves, inflorescence / plant and flowers/ inflorescence, and root f.w., d.w. and w.c. than those stored in perforated polyethylene bags in the first and second seasons. The above mentioned results are in agreement with those of Mostafa and Abou Alhamd (2011) who showed that GA3 at 50 ppm gave the best results by increasing the growth of Balanites aegyptiaca plants.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>height (cm)</th>
<th>Plant f.w. (g)</th>
<th>d.w. (g)</th>
<th>leaves/plant</th>
<th>No. of inflor./plant</th>
<th>flowers/inflor.</th>
<th>f.w. (g)</th>
<th>Root d.w. (g)</th>
<th>w.c. (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray solutions</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>22.76</td>
<td>25.95</td>
<td>8.53</td>
<td>9.51b</td>
<td>3.12b</td>
<td>13.15b</td>
<td>0.59b</td>
<td>0.16b</td>
<td>0.43b</td>
</tr>
<tr>
<td>GA3 at 200 mg/l</td>
<td>31.37a</td>
<td>45.87a</td>
<td>13.89a</td>
<td>11.61a</td>
<td>4.44a</td>
<td>25.32a</td>
<td>1.45a</td>
<td>0.49a</td>
<td>0.96a</td>
</tr>
<tr>
<td>Storage periods at 5°C</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>4 days</td>
<td>32.76a</td>
<td>39.98a</td>
<td>12.57a</td>
<td>11.67a</td>
<td>4.34a</td>
<td>21.30a</td>
<td>1.36a</td>
<td>0.36a</td>
<td>1.00a</td>
</tr>
<tr>
<td>8 days</td>
<td>21.38b</td>
<td>31.84b</td>
<td>9.85b</td>
<td>9.46b</td>
<td>3.22b</td>
<td>17.17b</td>
<td>0.68b</td>
<td>0.29b</td>
<td>0.39b</td>
</tr>
<tr>
<td>Packaging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Perforated</td>
<td>24.82b</td>
<td>34.23b</td>
<td>10.35b</td>
<td>9.94b</td>
<td>3.59b</td>
<td>18.55b</td>
<td>0.96b</td>
<td>0.28b</td>
<td>0.68b</td>
</tr>
<tr>
<td>Imperforated</td>
<td>29.31a</td>
<td>37.59a</td>
<td>12.06a</td>
<td>11.19a</td>
<td>3.97a</td>
<td>19.93a</td>
<td>1.08a</td>
<td>0.37a</td>
<td>0.71a</td>
</tr>
</tbody>
</table>

*Treatments* within a column or row having the same letters are not significantly different according to Duncan’s Multiple Range Test at 5% level.

The effect of interaction between the spray solutions and storage periods (day) on the vegetative, flowering and root growth parameters of Pelargonium zonale cv. "Belmonte Red" rooted cuttings during 2012 and 2013 seasons:

The results presented in Table (3) clear that spraying rooted cuttings with GA3 at 200 mg/l and stored for 4 days significantly increased the vegetative, flowering and root growth parameters [plant height, fresh and dry weights, No. of leaves, inflorescence / plant, flowers/inflorescence, root f.w., d.w. and w.c.] when compared to all other treatments in both seasons. These results are in agreement with those of Pinto et al. (2007) who reported that using pulsing with GA (500 mg/l) for Calathea louisae showed significantly higher leaf relative water content, and significantly smaller loss of accumulated fresh mass percentage compared to control. Hashemabadi and Zarchini (2010) showed that the effect of different levels of gibberellic acid (150, 200, 250 and 300 mg 1) at pre-harvest stage have been significant on fresh weight in cut rose (Rosa hybrida Poisson). Khenizy et al (2009b) indicated that Moluccella cut spikes stored for 7 days exhibited more loss in weight than cut flowers stored for 3 days. Also, Khenizy and Zaky (2008) showed that increasing storage duration from 3 up to 5 days decreased vase life and flower quality in tuberose cut flowers.

Table 3. Effect of the interaction between spray solutions and storage periods (day) on the vegetative, flowering and root growth parameters of Pelargonium zonale cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>height (cm)</th>
<th>Plant f.w. (g)</th>
<th>d.w. (g)</th>
<th>leaves/plant</th>
<th>No. of inflor./plant</th>
<th>flowers/inflor.</th>
<th>f.w. (g)</th>
<th>Root d.w. (g)</th>
<th>w.c. (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray solutions</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Control</td>
<td>25.27b</td>
<td>29.94c</td>
<td>8.99c</td>
<td>10.10c</td>
<td>3.39c</td>
<td>15.35c</td>
<td>0.69c</td>
<td>0.17c</td>
<td>0.52b</td>
</tr>
<tr>
<td>GA3 at 200 mg/l</td>
<td>20.25d</td>
<td>21.97d</td>
<td>8.16c</td>
<td>8.92d</td>
<td>2.86d</td>
<td>10.95d</td>
<td>0.49d</td>
<td>0.15c</td>
<td>0.34b</td>
</tr>
<tr>
<td>Storage periods at 5°C</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 days</td>
<td>40.24a</td>
<td>50.02a</td>
<td>16.24a</td>
<td>13.24a</td>
<td>5.30a</td>
<td>27.25a</td>
<td>2.03a</td>
<td>0.55a</td>
<td>1.48a</td>
</tr>
<tr>
<td>8 days</td>
<td>22.50c</td>
<td>41.72b</td>
<td>11.54b</td>
<td>9.99c</td>
<td>3.59b</td>
<td>23.39b</td>
<td>0.88b</td>
<td>0.44b</td>
<td>0.44b</td>
</tr>
</tbody>
</table>

*Treatments* within a column or row having the same letters are not significantly different according to Duncan’s Multiple Range Test at 5% level.

The effect of interaction between spray solutions and packaging on the vegetative, flowering and root growth parameters of Pelargonium zonale cv. "Belmonte Red" rooted cuttings during 2012 and 2013 seasons:

As shown in Table (4) data indicate that the interaction between the spray solution with GA3 at 200 mg/l and packaging in imperforated bags had significant effects on increasing plant height, fresh and dry weights, No. of leaves, inflorescence / plant, flowers/inflorescence, root f.w. and d.w. followed by rooted cuttings sprayed with GA3 at 200 mg/l and packaged in perforated bags compared to those sprayed with distilled water and packaged in both perforated and imperforated bags in the two seasons. However, the rooted cuttings sprayed with GA3 at 200 mg/l and packaged in either perforated or imperforated polyethylene bags gave the highest values of r.w.c compared with those sprayed with distilled water (control) and packaged in either perforated or imperforated bags in the first and second seasons. In this respect, Kumar and Gupta (2014) showed that foliar spray of gibberellic acid at 100 ppm gave more number of florets per cut spike of gladilus.
The effect of interaction between spray solutions and packaging on the vegetative, flowering and root growth of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013 seasons:

It is quite clear from the data presented in Table (5) that the higher values of plant height, fresh and dry weights, No. of leaves, inflorescence / plant, flowers/inflorescence, root f.w., d.w. and w.c. were obtained from storing rooted cuttings for 4 days in imperforated polyethylene bags followed by those stored for 4 days in perforated bags as compared with those stored in both imperforated and perforated polyethylene bags for 8 days in the two seasons. In this concern, ethylene reduced root water content in *Pelargonium zonale* cuttings. (Mutui et al., 2010).

The effect of interaction between spray solutions, storage periods and packaging on the vegetative, flowering and root growth parameters of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013 seasons:

Data presented in Table (6) show that rooted cuttings sprayed with GA₃ at 200 mg/l and stored for 4 days in imperforated polyethylene bags gave the significantly highest records of vegetative, flowering and root growth parameters: plant height, fresh and dry weights, No. of leaves, inflorescence / plant and flowers/inflorescence, and root f.w., d.w. and w.c. compared with all other treatments in the two seasons. However, the second category was occupied by cuttings sprayed with GA₃ at 200 mg/l and stored for 4 days in perforated polyethylene bags in both seasons. In this respect Zaky et al. (2008) indicated that spraying cut *Fatsia japonica* leaves with GA₃ (100 ppm) and storing for 1 week at 5°C increased the percentage of leaves fresh weight compared to 2 weeks.

The effect of interaction between spray solutions and storage periods on ethylene production μl/l, carbon dioxide and oxygen percentage of *pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013 seasons:

As shown data in Fig. (2) illustrate that spraying rooted cuttings with GA₃ at 200 mg/l and storing for both 4 and 8 days exhibited lower values of ethylene production as compared to the control. Also, the results clear that spraying rooted cuttings with GA₃ at 200 mg/l and storing for 4 days gave the lowest rate of ethylene production as compared with other treatments in both seasons. These results are in harmony with those of Mutui et al., (2005 & 2010) and Rapaka et al. (2008) that ethylene reduced fresh root mass in *Pelargonium zonale* cuttings. Also, they added that undesirable shipping conditions increased ethylene generation in geranium cuttings, which caused lower-leaf senescence during propagation. Calegario et al. (2001) showed that respiration and ethylene production are important indicators of physiological state and/or senescence in fresh products. Regular air (RA) cold storage is widely used to extend the storage life of fruit and vegetables.

### Table 4. Effect of the interaction between spray solutions and packaging on the vegetative, flowering and root growth of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Packaging</th>
<th>Plant height (cm)</th>
<th>F.w. (g)</th>
<th>D.w. (g)</th>
<th>Leaves/Plant</th>
<th>Flowers/Infloresc.</th>
<th>F.w. (g)</th>
<th>D.w. (g)</th>
<th>W.c. (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st season</td>
<td>Control</td>
<td>Perforated bags</td>
<td>20.31d</td>
<td>24.38d</td>
<td>8.12c</td>
<td>8.93c</td>
<td>10.13c</td>
<td>12.75d</td>
<td>0.53d</td>
</tr>
<tr>
<td></td>
<td>GA₃ at 200 mg/l</td>
<td>Perforated bags</td>
<td>29.34b</td>
<td>44.08b</td>
<td>12.59b</td>
<td>10.98b</td>
<td>4.15b</td>
<td>24.34b</td>
<td>1.39b</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Imperforated bags</td>
<td>33.40a</td>
<td>47.66a</td>
<td>15.19a</td>
<td>12.25a</td>
<td>4.72a</td>
<td>26.30a</td>
<td>1.52a</td>
</tr>
<tr>
<td></td>
<td>GA₃ at 200 mg/l</td>
<td>Imperforated bags</td>
<td>32.04a</td>
<td>46.24a</td>
<td>14.44a</td>
<td>11.52a</td>
<td>4.67a</td>
<td>25.60a</td>
<td>1.45a</td>
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</table>

*Means within a column or row having the same letters are not significantly different according to Duncan’s Multiple Range Test at 5% level.*

<table>
<thead>
<tr>
<th>Spray solutions</th>
<th>Treatments</th>
<th>Storage periods at 5°C</th>
<th>Packaging</th>
<th>Plant height (cm)</th>
<th>f.w. (g)</th>
<th>d.w. (g)</th>
<th>leaves/plant</th>
<th>inflor./plant</th>
<th>flowers/florish</th>
<th>f.w. (g)</th>
<th>d.w. (g)</th>
<th>w.c. (g)</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
<td>4 days</td>
<td>Perforated bags</td>
<td>22.21e</td>
<td>28.33f</td>
<td>8.33e</td>
<td>9.45f</td>
<td>3.29e</td>
<td>15.20e</td>
<td>0.61f</td>
<td>0.12de</td>
<td>0.49b</td>
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<tr>
<td></td>
<td>8 days</td>
<td>Imperforated bags</td>
<td>28.33c</td>
<td>31.55e</td>
<td>9.45de</td>
<td>10.75c</td>
<td>3.50d</td>
<td>15.50c</td>
<td>0.77c</td>
<td>0.22d</td>
<td>0.55b</td>
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<td>Perforated bags</td>
<td>18.40g</td>
<td>20.42h</td>
<td>7.91e</td>
<td>8.33g</td>
<td>2.76g</td>
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<td>0.45h</td>
<td>0.11e</td>
<td>0.34b</td>
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<tr>
<td></td>
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<td>Imperforated bags</td>
<td>23.10e</td>
<td>23.51g</td>
<td>8.41e</td>
<td>9.51f</td>
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<td>GA3 at 200 mg/l</td>
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<td>Perforated bags</td>
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<td>48.62b</td>
<td>14.25b</td>
<td>12.11b</td>
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<td>14.36a</td>
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<td>0.94c</td>
<td>0.48bc</td>
<td>0.46b</td>
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</tbody>
</table>

*Means within a column or row having the same letters are not significantly different according to Duncan’s Multiple Range Test at 5% level.

Chilled RA storage contributes to the quality maintenance and nutrient retention by reducing the rates of respiration and other metabolic processes of the product. Key benefits of RA storage are that it can be readily implemented in any cool store, is cheap and is easy to manage compared to controlled atmosphere (CA) storage, it requires less experienced staff and has fewer safety issues. Postharvest dips in GA3 (50 and 100 ppm) inhibited the decay development of stored lemon fruit and exerted inhibitory activity against common postharvest pathogens (Thamarath, 2009). CA storage may be used to maintain the quality of fresh produce when refrigeration alone is insufficient to achieve the required storage time (Vigneault et al., 2004). Khenizy et al., (2009a) showed that chrysanthemum cut flowers wrapped in polyethylene gave the highest value of CO2. The main effect of using polyethylene bags is to raise CO2 concentration around flowers in order to prevent ethylene action and maintain flowers quality.

Regarding the interaction treatments between spray solutions and storage periods on carbon dioxide and oxygen percentage of pelargonium zonale cv. "Belmonte Red" rooted cuttings, it is clear from data illustrated in Fig. (3) that spraying rooted cuttings with GA3 at 200 mg/l and storing for 4 days decreased the respiration rate as compared with the other treatments in the first and second seasons. The results are in accordance with those of Mutui et al., (2005) and Rapaka et al., (2008) they stated that undesirable shipping conditions increased respiration in geranium cuttings, which caused lower-leaf senescence during propagation. Doyle et al., (2003) suggested that Pelargonium cuttings may travel better under reduced oxygen conditions. A decrease in respiration rate during storage is usually beneficial to maintain quality (Calegario et al., 2001). This increased level of CO2 reduces the biosynthesis of ethylene and hence increased the flower longevity. Storage under such conditions is known as ‘modified atmosphere storage’. It is a cheaper method of flower storage as it does not require precise atmospheric conditions (Senapati et al., 2016). Khenizy et al., (2009a) showed that chrysanthemum cut flowers wrapped in polyethylene gave the highest value of CO2. They added that the main effect of using polyethylene bags is to raise CO2 concentration around flowers in order to reduce respiration rate, carbohydrates metabolism in flowers tissues, prevent ethylene action and maintain flowers quality. Antmann et al., (2008) indicated that modified atmospheres, richer in CO2 and poorer in O2 than air, are assumed to be able to reduce respiration rate, decay and physiological deteriorations of vegetables, which results in shelf- life extension. Franco and Han (1997) found that treating lily leaves with 500 mg-l-1 of GA3 lowered the respiration rates by one-third to one-half, and markedly delayed the respiratory rise. Similar effects on respiration were detected in leaves treated with GA3 before a 4-week period of cold storage and in leaves treated after chlorosis had initiated.
The effect of interaction between spray solutions, storage periods and packaging on gray mold, weight loss, visual rating, total chlorophylls (mg/100 g f.w.), carotenoids (mg/100 g f.w.) and total carbohydrates (%) of Pelargonium zonale cv. "Belmonte Red" rooted cuttings during 2012 and 2013

Data illustrated in Fig. (4) show that spraying rooted cuttings of Pelargonium zonale cv. "Belmonte Red" rooted cuttings with GA$_3$ at 200 mg/l and stored for either 4 or 8 days in both imperforated and perforated polyethylene bags reduced percentage of gray mold infection caused by Botrytis cinerea as compared with distilled water (control) in the two seasons. In this respect, the superiority was for spraying rooted cuttings with GA$_3$ at 200 mg/l and storing for 4 days in imperforated polyethylene bags, as this treatment gave the utmost decrease the decay caused by Botrytis cinerea as compared with the other treatments in both seasons. In this concern, Antmann et al., (2008) indicated that modified atmospheres, richer in CO$_2$ and poorer in O$_2$ than air, are assumed to be able to reduce decay and physiological deteriorations of vegetables.

Data illustrated in Fig. (5) show that the least weight loss percentage was obtained by spraying rooted cuttings with GA$_3$ at 200 mg/l and storing for 4 days in imperforated polyethylene bags compared with the other treatments in both seasons. This decrease in rooted cuttings weight percentage may be due to water loss during storage period.

In this connection, Danaee et al., (2012) found that GA$_3$ (50 mg/l) was the most effective treatments based on fresh weight of gerbera cut flowers. Chrysanthemum cut flowers wrapped in polyethylene bags had the least percentage of weight loss (Khenizy et al., 2009a). Yeole et al., (2008) found that average physiological weight losses were more in spinach stored in open condition (perforation) compared with those stored in polythene bags without perforation (WP). Abou El-Ghait et al., (2012) showed that GA$_3$ (20 ppm) as pulsing solution, increased change % in fresh weight of Dendranthema grandiflorum cut flowers.
Fig. 4. Effect of the interaction between spray solutions, storage periods and packaging on gray mold % of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

Data illustrated in Fig. (6) indicate that treating rooted cuttings with GA$_3$ at 200 mg/l as spraying solution, stored for either 4 or 8 days and packaging in imperforated polyethylene bags were the best treatments in maintaining visual rating of pelargonium rooted cuttings compared to the control in the two seasons. Moreover, rooted cuttings sprayed with GA$_3$ at 200 mg/l and stored for 4 days in imperforated polyethylene bags gave the highest quality compared with the other treatments, in the first and second seasons. Petal abscission in *Pelargonium x hortorum* was inhibited by a spray with an aqueous mixture of gibberellins A$_4$ and A$_7$ (Miranda and Carlson, 1982). Spray application of gibberellic acid (GA) at various stages in propagation reduced lower-leaf senescence in geraniums (Currey *et al.*, 2013). Kim and Miller (2009) showed that GA$_{4+7}$ increased higher visual qualities in geranium. These results suggest that leaf yellowing in pelargonium cuttings was due to stress-induced ethylene that occurs after dark storage. Storing pelargonium cuttings in the dark for 4 days decreased total leaf chlorophyll in all cultivars. Ethylene treatment reduced the ability of continued growth of regenerated roots (Mutui, 2005). Hashemabadi and Zarchini (2010) showed that the effect of different levels of gibberellic acid (150, 200, 250 and 300 mg l$^{-1}$) at pre-harvest stage has been significant on the quality in cut rose (*Rosa hybrida* 'Poison'). Khenizy *et al.*, (2009a) showed that chrysanthemum cut flowers wrapped in polyethylene gave the highest value of CO$_2$. The main effect of using polyethylene bags is to raise CO$_2$ concentration around flowers in order to maintain flowers quality. Zaky *et al.*, (2008) indicated that spraying cut *Fatsia japonica* leaves with GA$_3$ at 100 ppm and storing at 5° C for 1 week prevented leaf chlorosis compared to 2 weeks. Abou El-Ghait *et al.*, (2012) recorded that increasing the cold storage period from zero-time to 21-days decreased quality of *Dendranthema grandiflorum* cut flowers.

Fig. 5. Effect of interaction between spray solutions, storage periods and packaging on weight loss percentage of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

It was noticed from data illustrated in Fig. (7) that spraying rooted cuttings of *Pelargonium zonale* cv. "Belmonte Red" with GA$_3$ at 200 mg/l and storing for 4 days in imperforated polyethylene bags exhibited higher
contents of total chlorophyll (mg/100 g f.w.) in leaves followed by rooted cuttings stored for 4 days in perforated polyethylene bags compared with the other treatments in both seasons. In this regard, application of GA3 retarded chlorophyll loss in the leaves. GA3 can inhibit many processes, such as RNA and protein breakdown, that may be associated with senescence. GA3 may also delay senescence in petals and other plant parts such as petioles [Tabuchi et al., (2005), Rosenvasser et al., (2006) and Franco and Han (1997)]. Mostafa and Abou Alhamd (2011) showed that GA3 (50 ppm) gave the best results by increasing the phytochemical composition in Balanites aegyptiaca plants.

![Graph showing visual rating of Pelargonium zonal cv. "Belmonte Red" rooted cuttings during 2012 and 2013.](image)

**Fig. 6.** Effect of interaction between spray solutions, storage periods and packaging on visual rating of Pelargonium zonal cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

![Graph showing total chlorophyll (mg/100 g f.w.) of Pelargonium zonal cv. "Belmonte Red" rooted cuttings during 2012 and 2013.](image)

**Fig. 7.** Effect of the interaction between spray solutions, storage periods and packaging on total chlorophyll (mg/100 g f.w.) of Pelargonium zonal cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

Data illustrated in Fig. (8) show that spraying rooted cuttings of pelargonium with distilled water as control and packaging in perforated or imperforated polyethylene bags and storing for either 4 or 8 days gave the highest values of carotenoids compared with other treatments in the two seasons. However, spraying rooted cuttings with GA3 at 200 mg/l and storing for 4 days in imperforated polyethylene bags was the best treatment for obtaining the lowest value of carotenoids compared to other treatments in the two seasons. In this regard, Han (2001) mentioned that spraying leaves of Oriental and Asiatic lily with GA4+7 completely...
prevented postharvest leaf yellowing. Kim and Miller (2009) showed that GA$_{4+7}$ greatly reduced leaves yellowing in potted *Pelargonium zonale* during shipping and handling.

Data illustrated in Fig. (9) reveal that spraying rooted cuttings with GA$_3$ at 200 mg/l and storing for 4 days in both perforated and imperforated polyethylene bags were the best treatments for obtaining the highest values of the total carbohydrates % so as to reach their maximum records with the treatment of imperforated polyethylene bags compared to all the other treatments in both seasons. These results are in agreement with those of Mutui *et al.* (2005) and Rapaka *et al.* (2008) who found that undesirable shipping conditions reduced carbohydrates concentration, in geranium cuttings. Khenizy *et al.* (2009a) showed that wrapping chrysanthemum cut flowers in polyethylene recorded the highest increase in the percentage of total soluble sugars in petals. Abou El-Ghait *et al.* (2012) recorded that GA$_3$ (20 ppm) as pulsing solution increased total sugars content in *Dendranthema grandiflorum* cut flowers.

![Fig. 8](image1.png)

**Fig. 8.** Effect of interaction between spray solutions, storage periods and packaging on carotenoids (mg/100 g f.w.) of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

![Fig. 9](image2.png)

**Fig. 9.** Effect of the interaction between spray solutions, storage periods and packaging on total carbohydrates (%) of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

**CONCLUSION**

The best treatment to improve quality of *Pelargonium zonale* cv. "Belomnet Red" can be done by spraying rooted cuttings with GA$_3$ at 200 mg/l before planting (0-time) and storing for 4 days at 5°C in imperforated polyethylene bags. It showed improved vegetative, flowering and root growth parameters. Moreover, maintained chlorophyll, carbohydrates contents and reduced carotenoids content. Also, spraying rooted cuttings with GA$_3$ at 200 mg/l before storing for 4 days at 5°C in imperforated polyethylene bags reduced weight loss, ethylene production, gray
mold infection %, and respiration rate, also improved visual rating.

REFERENCES


Mutui, T. M. (2005). Physiological and molecular effects of thidiazuron and ethylene on leaf yellowing and rooting of Pelargonium (Pelargonium zonale)
hybrids cuttings. Doctoral dissertation, Fac. of Natural Sciences Univ. of Hanover. 128 pp.


الكلمات الدالة: عقل البار، جونيوم، روتات الجذر، فترات التخزين، الرش بحمض الجيرنيك، أكاس البولي شيلين المقاومة و العثور مثالية.