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

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ABSTRACT

*Pelargonium zonal*e 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 (GA_3 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 GA_3 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 GA_3 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 GA_3 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 GA_3 at 200 mg/l and storing them for 4 days gave the lowest respiration rate and ethylene production. Moreover, the rooted cuttings sprayed with GA_3 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 zonal*e 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 basillicum* (Abou-Leila *et al*, 1994). Application of gibberellic acid (GA_3) 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 (Saltveit, 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 O_2 and/or enriched CO_2 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 (O_2) and elevated carbon dioxide (CO_2) levels, which is beneficial for the extension of the storage period (Rudnicki *et al*, 1991). Postharvest treatment using modified atmosphere with low oxygen

(O_2) and/or high carbon dioxide (CO_2) concentrations lowered down the respiration rate, inhibited ethylene production that induces senescence of fruits (Arrebol *et al*, 2010).

The objective of this study was to investigate the effect of spraying solutions of GA_3 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 (GA_3) 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 was planted directly after spraying with gibberellic acid at 200 mg /l and distilled water (as control) to runoff only for one time in glasshouse 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 mμ thickness, area of each packet = 30 cm x 25 cm = 750 cm^2). 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 and 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 2ndExp. 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:

1- Plant height (cm). 2- Plant f.w. (g) 3- Plant d.w. (g).
4- Number of leaves/plant.
5- Number of inflorescences /plant.
6- Number of flowers/inflorescences.
7- Root f.w. (g). 8- Root d.w. (g).
9- 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).
10- Total chlorophyll and carotenoids content (mg/100g f. w.) in the leaves according to Saric *et al* (1976) at the end of the experiments.
11- 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 ($\mu l.l^{-1}$): was determined by gas chromatography according to Burg and Stolwijk, (1959).
4- Carbon dioxide (CO_2) and Oxygen (O_2) (%): determined by CO_2 and O_2 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 $P \geq 0.05$ 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 GA_3 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 inflorescences/plant and flowers/ inflorescence, data presented in Table (1) clearly indicate that the spray solution of GA_3 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 GA_3 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 GA_3 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 GA_3 at 200 mg/l as a spraying solutions on rooted cuttings of pelargonium recorded 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 GA_3 increased significantly total chlorophylls in *Balanites aegyptiaca* plants. Sardoei *et al* (2014) showed that the treatments of 200 mgl^{-1} GA_3 had higher reducing sugars than control in *Spathiphyllum wallisii* plant. Sardoei and Shahdadneghad (2014) showed that chlorophyll content was enhanced by increasing GA_3 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.

Spray solutions	Plant height (cm)	Plant f.w. (g)	Plant d.w. (g)	No. of leaves/ plant	No. of inflor./ plant	No. of flowers/ inflor.	Root f.w. (g)	Root d.w. (g)	Root w.c (g)
1st season									
Control	30.24b	36.70b	10.54b	13.33b	4.21b	17.10b	0.96b	0.38b	0.58b
GA_3 at 200 mg/l	44.30a	55.30a	22.57a	15.36a	6.85a	29.10a	2.29a	0.80a	1.49a
2nd season									
Control	30.11b	34.59b	10.45b	12.51b	4.17b	16.50b	0.97b	0.35b	0.62b
GA_3 at 200 mg/l	43.10a	54.21a	21.66a	15.24a	5.80a	28.20a	2.25a	0.79a	1.46a

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

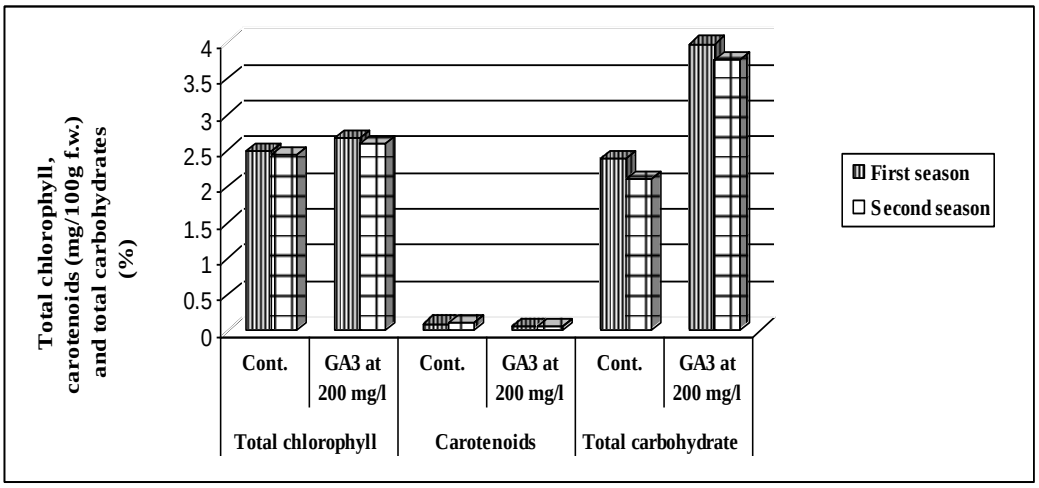

Fig. 1. Effect of the spray solutions at 0-time on total chlorophylls, carotenoids (mg/100g f. w.) and total carbohydrates (%) of *Pelargonium zonale* cv. ″Belmonte Red″ rooted cuttings during 2012 and 2013.

2- 2nd Experiment:

Main effect of the spray solutions, storage periods and packaging on vegetative, flowering and root growth parameters of *Pelargonium zonal*e 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 GA_3 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 GA_3 at 50 ppm gave the best results by increasing the growth of *Balanites aegyptiaca* plants.

Table 2. Main effect of the 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.

Treatments		Plant height (cm)	Plant f.w. (g)	Plant d.w. (g)	No. of leaves/ plant	No. of inflor./ plant	flowers/ inflor.	Root f.w. (g)	Root d.w. (g)	Root w.c. (g)
1st season										
Spray solutions	Control	22.76b	25.95b	8.53b	9.51b	3.12b	13.15b	0.59b	0.16b	0.43b
	GA_3 at 200 mg /l	31.37a	45.87a	13.89a	11.61a	4.44a	25.32a	1.45a	0.49a	0.96a
Storage periods at 5°C	4 days	32.76a	39.98a	12.57a	11.67a	4.34a	21.30a	1.36a	0.36a	1.00a
	8 days	21.38b	31.84b	9.85b	9.46b	3.22b	17.17b	0.68b	0.29b	0.39b
Packaging	Perforated	24.82b	34.23b	10.35b	9.94b	3.59b	18.55b	0.96b	0.28b	0.68b
	Imperforated	29.31a	37.59a	12.06a	11.19a	3.97a	19.93a	1.08a	0.37a	0.71a
2nd season										
Spray solutions	Control	21.73b	25.26b	8.20b	8.82b	3.01b	12.58b	0.55b	0.14b	0.41b
	GA_3 at 200 mg /l	29.80a	44.37a	13.37a	10.85a	4.29a	24.60a	1.38a	0.48a	0.90a
Storage periods at 5°C	4 days	31.55a	38.67a	12.09a	10.88a	4.12a	20.51a	1.28a	0.35a	0.93a
	8 days	20.15b	30.96b	9.48b	8.80b	3.18b	16.66b	0.65b	0.27b	0.38b
Packaging	Perforated	23.76b	33.24b	9.95b	9.12b	3.43b	17.91b	0.90b	0.27b	0.63b
	Imperforated	27.94a	36.39a	11.61a	10.56a	3.87a	19.26a	1.03a	0.35a	0.68a

***Means 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 GA_3 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 $mg.l^{-1}$) 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 l^{-1}) at pre-harvest stage have been significant on fresh weight in cut rose (*Rosa hybrida* 'Poison'). 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 of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

Treatments		Plant			No. of			Root		
Spray solutions	Storage periods at 5°C	height (cm)	f.w. (g)	d.w. (g)	leaves/ plant	inflor./ plant	flowers/ inflor.	f.w. (g)	d.w. (g)	w.c. (g)
1st season										
Control	4 days	25.27b	29.94c	8.89c	10.10b	3.39c	15.35c	0.69c	0.17c	0.52b
	8 days	20.25d	21.97d	8.16c	8.92d	2.86d	10.95d	0.49d	0.15c	0.34b
GA_3 at 200 mg /l	4 days	40.24a	50.02a	16.24a	13.24a	5.30a	27.25a	2.03a	0.55a	1.48a
	8 days	22.50c	41.72b	11.54b	9.99c	3.58b	23.39b	0.88b	0.44b	0.44b
2nd season										
Control	4 days	24.55b	29.02c	8.74c	9.10b	3.21c	14.43c	0.65bc	0.16c	0.50b
	8 days	18.90d	21.50d	7.65c	8.54c	2.81d	10.73d	0.46c	0.13c	0.33b
GA_3 at 200 mg /l	4 days	38.56a	48.33a	15.44a	12.65a	5.04a	26.60a	1.91a	0.55a	1.37a
	8 days	21.40c	40.42b	11.30b	9.05b	3.55b	22.60b	0.85b	0.42b	0.43b

***Means 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 GA_3 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 GA_3 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 GA_3 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 gladiolus.

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.

Treatments		1st season								
		Plant			No. of			Root		
Spray solutions	Packaging	height (cm)	f.w. (g)	d.w. (g)	leaves/ plant	inflor./ plant	flowers/ inflor.	f.w. (g)	d.w. (g)	w.c. (g)
Control	Perforated bags	20.31d	24.38d	8.12c	8.89d	3.02d	12.75d	0.53d	0.12d	0.42b
	Imperforated bags	25.22c	27.53c	8.93c	10.13c	3.23c	13.55c	0.65c	0.20c	0.45b
GA_3 at 200 mg/l	Perforated bags	29.34b	44.08b	12.59b	10.98b	4.15b	24.34b	1.39b	0.45b	0.94a
	Imperforated bags	33.40a	47.66a	15.19a	12.25a	4.72a	26.30a	1.52a	0.54a	0.98a
		2nd season								
Control	Perforated bags	19.60d	23.98d	7.60c	8.05d	2.96d	12.23d	0.49b	0.11d	0.39c
	Imperforated bags	23.85c	26.54c	8.79c	9.59c	3.06c	12.93c	0.62b	0.18c	0.44bc
GA_3 at 200mg/l	Perforated bags	27.92b	42.51b	12.30b	10.18b	3.91b	23.60b	1.31a	0.44b	0.87ab
	Imperforated bags	32.04a	46.24a	14.44a	11.52a	4.67a	25.60a	1.45a	0.53a	0.93a

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

The effect of interaction between 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:

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 GA_3 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. 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 GA_3 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 GA_3 (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 GA_3 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 GA_3 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 5. Effect of the interaction between storage periods and packaging on the vegetative, flowering and root growth parameters of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

Treatments		1st season								
		Plant			No. of			Root		
Storage periods at 5°C	Packaging	height (cm)	f.w. (g)	d.w. (g)	leaves/ plant	inflor./ plant	flowers/ inflor.	f.w. (g)	d.w. (g)	w.c. (g)
4 days	Perforated bags	30.30b	38.48b	11.29b	10.78b	4.04b	20.75b	1.29a	0.31bc	0.98a
	Imperforated bags	35.22a	41.48a	13.84a	12.56a	4.65a	21.85a	1.44a	0.41a	1.03a
8 days	Perforated bags	19.35d	29.98d	9.42c	9.09d	3.13d	16.34d	0.63b	0.25c	0.38b
	Imperforated bags	23.40c	33.71c	10.28bc	9.82c	3.30c	18.00c	0.73b	0.33b	0.40b
		2nd season								
4 days	Perforated bags	29.16b	37.25b	11.00b	9.90b	3.79b	20.07b	1.20a	0.31b	0.89a
	Imperforated bags	33.95a	40.10a	13.18a	11.85a	4.46a	20.96a	1.37a	0.40a	0.97a
8 days	Perforated bags	18.36d	29.24d	8.90c	8.33d	3.08d	15.76d	0.60b	0.24c	0.37b
	Imperforated bags	21.94c	32.68c	10.05bc	9.26c	3.28c	17.57c	0.70b	0.31b	0.39b

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

Table 6. Effect of the 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.

Treatments			Plant			No. of			Root		
Spray solutions	Storage periods at 5°C	Packaging	height (cm)	f.w. (g)	d.w. (g)	leaves/ plant	inflor./ plant	flowers/ inflor.	f.w. (g)	d.w. (g)	w.c. (g)
1st season											
Control	4 days	Perforated bags	22.21e	28.33f	8.33e	9.45f	3.29e	15.20e	0.61f	0.12de	0.49b
		Imperforated bags	28.33c	31.55e	9.45de	10.75c	3.50d	15.50e	0.77e	0.22d	0.55b
	8 days	Perforated bags	18.40g	20.42h	7.91e	8.33g	2.76g	10.30g	0.45h	0.11e	0.34b
		Imperforated bags	22.10e	23.51g	8.41e	9.51f	2.95f	11.60f	0.52g	0.18de	0.34b
GA_3 at 200 mg/l	4 days	Perforated bags	38.38b	48.62b	14.25b	12.11b	4.80b	26.30b	1.96b	0.50ab	1.46a
		Imperforated bags	42.10a	51.41a	18.23a	14.36a	5.79a	28.20a	2.10a	0.60a	1.50a
	8 days	Perforated bags	20.30f	39.54d	10.92cd	9.85e	3.50d	22.38d	0.81d	0.39c	0.42b
		Imperforated bags	24.70d	43.90c	12.15c	10.13d	3.65c	24.40c	0.94c	0.48bc	0.46b
2nd season											
Control	4 days	Perforated bags	21.70e	27.58f	8.25ef	8.35g	3.25d	14.33e	0.57f	0.11e	0.46b
		Imperforated bags	27.40c	30.45e	9.23de	9.85c	3.17d	14.52e	0.73e	0.20d	0.53b
	8 days	Perforated bags	17.50h	20.37h	6.95f	7.75h	2.66f	10.12g	0.41h	0.10e	0.31b
		Imperforated bags	20.30f	22.63g	8.35ef	9.33d	2.95e	11.33f	0.50g	0.16de	0.34b
GA_3 at 200 mg/l	4 days	Perforated bags	36.61b	46.91b	13.75b	11.45b	4.33b	25.80b	1.82b	0.50b	1.32a
		Imperforated bags	40.50a	49.75a	17.12a	13.85a	5.74a	27.40a	2.00a	0.59a	1.41a
	8 days	Perforated bags	19.22g	38.11d	10.85cd	8.91f	3.49c	21.40d	0.79d	0.37c	0.42b
		Imperforated bags	23.57d	42.72c	11.75c	9.19e	3.60c	23.80c	0.90c	0.46b	0.44b

***Means within a column or row having the same letters are not significantly different according to Dancan'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 GA_3 (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 CO_2. The main effect of using polyethylene bags is to raise CO_2 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 GA_3 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 CO_2 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 CO_2. They added that the main effect of using polyethylene bags is to raise CO_2 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 CO_2 and poorer in O_2 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 $mg \cdot l^{-1}$ of GA_3 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 GA_3 before a 4-week period of cold storage and in leaves treated after chlorosis had initiated.

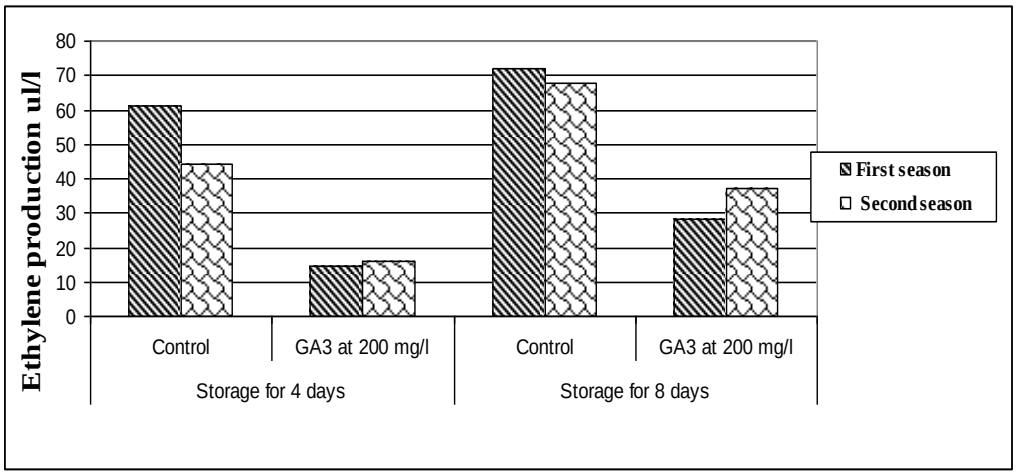

Fig. 2. Effect of the interaction between spray solutions and storage periods in imperforated polyethylene bags on ethylene production µl/l of *Pelargonium zonale* cv. ″Red″ rooted cuttings during 2012 and 2013.

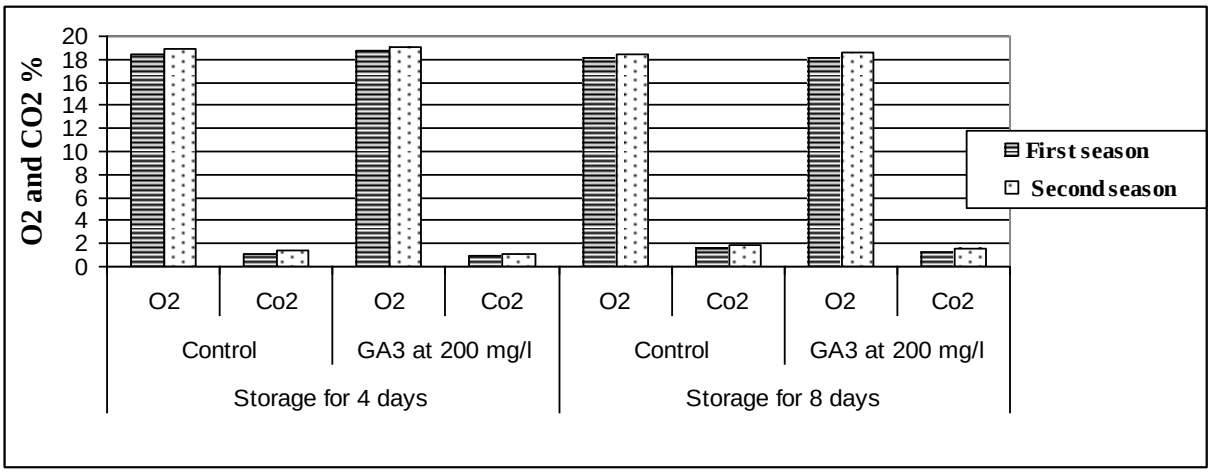

Fig. 3. Effect of the interaction between spray solutions and storage periods in imperforated polyethylene bags on respiration rate percentage of *Pelargonium zonale* cv. ″Belmonte Red″ rooted cuttings during 2012 and 2013.

The effect of interaction between spray solutions, storage periods and packaging on gray mold, weight loss, visual ratting, 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 seasons:

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.

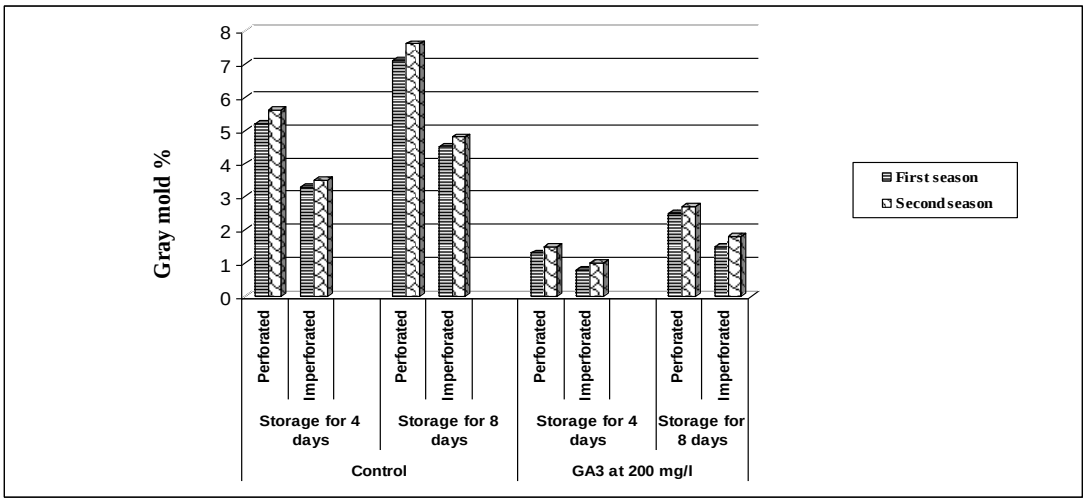

Fig. 4. Effect of the interaction between spray solutions, storage periods and packaging on gray mold % of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

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.

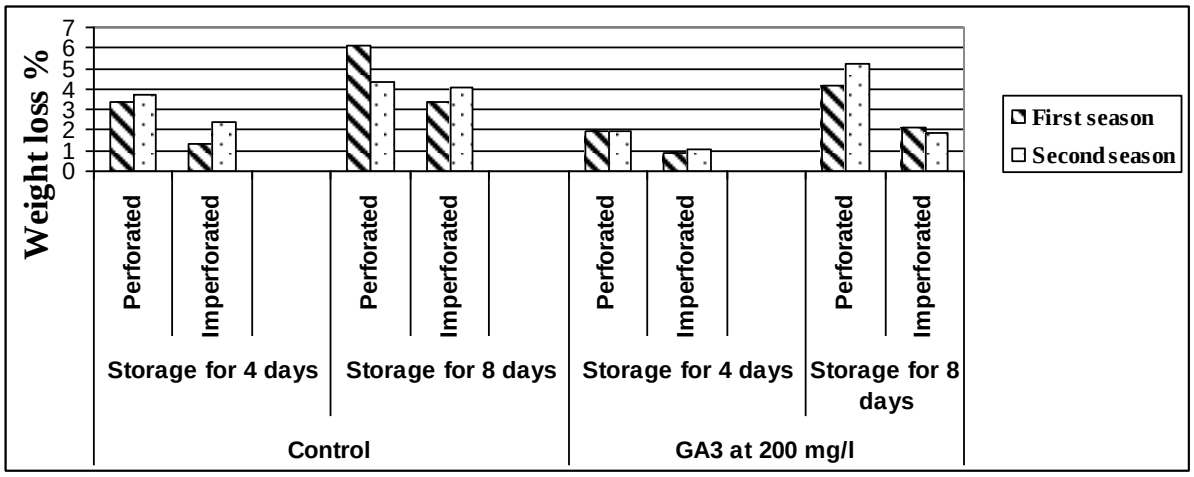

Fig. 5. Effect of interaction between spray solutions, storage periods and packaging on weight loss percentage of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

It was noticed from data illustrated in Fig. (7) that spraying rooted cuttings of *Pelargonium zonal* 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/100g 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 GA_3 retarded chlorophyll loss in the leaves. GA_3 can inhibit many processes, such as RNA and protein breakdown, that may be associated with senescence. GA_3 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 GA_3 (50 ppm) gave the best results by increasing the phytochemical composition in *Balanites aegyptiaca* plants.

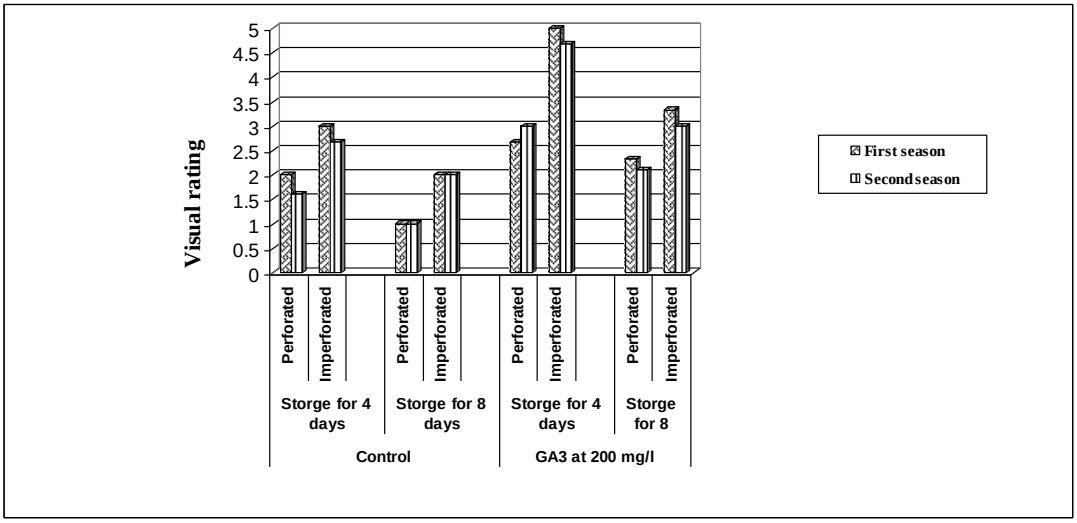

Fig. 6. Effect of interaction between spray solutions, storage periods and packaging on visual ratting of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

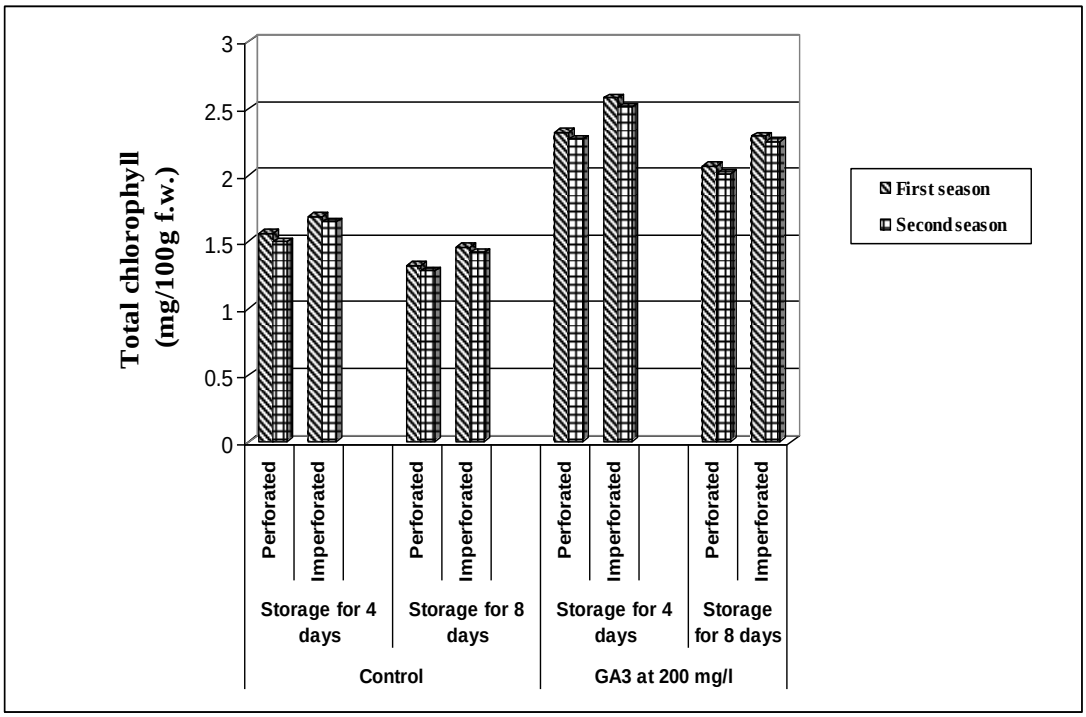

Fig. 7. Effect of the interaction between spray solutions, storage periods and packaging on total chlorophyll (mg/100 g f.w.) of *Pelargonium zonale* cv. "Belmonte Red" rooted cuttings during 2012 and 2013.

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 GA_3 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 GA_{4+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.

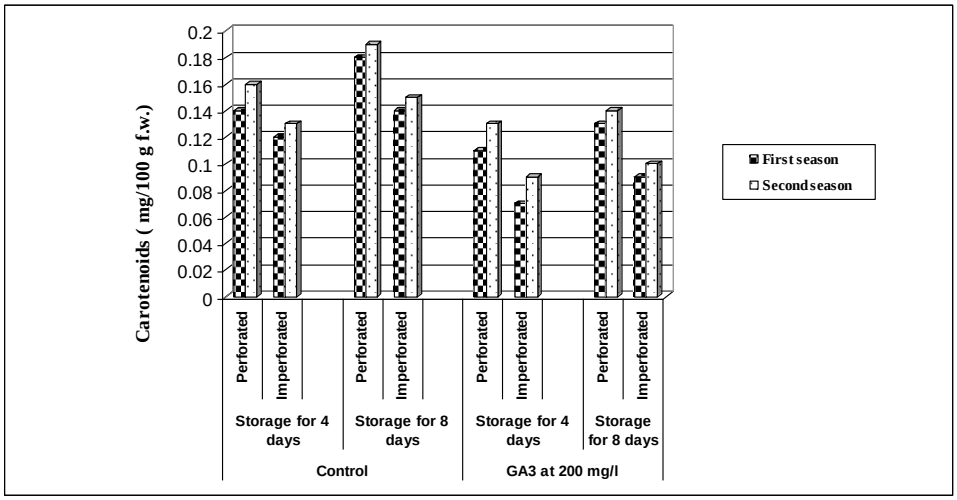

Fig. 8. Effect of interaction between spray solutions, storage periods and packaging on carotenoids (mg/100 g f.w.) of *Pelargonium zonale* cv. ″Belmonte Red″ rooted cuttings during 2012 and 2013.

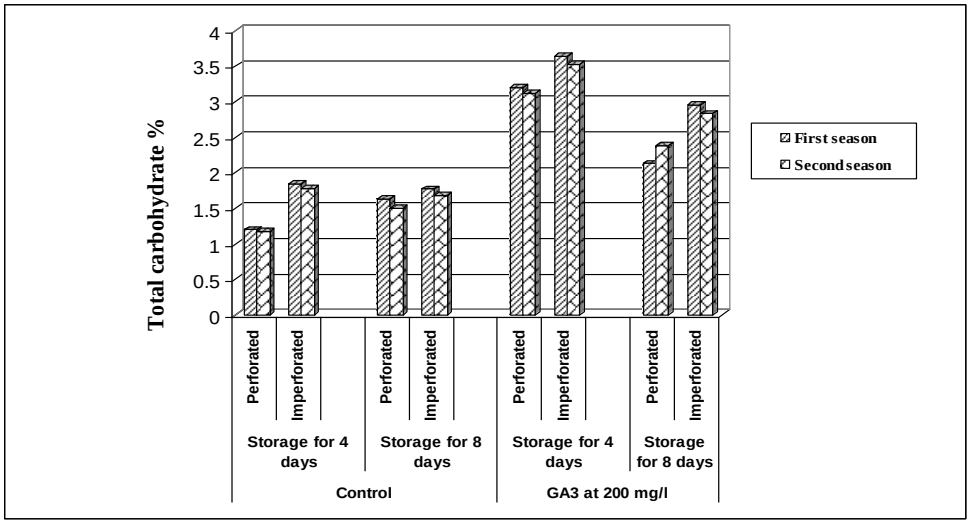

Fig. 9. Effect of the interaction between spray solutions, storage periods and packaging on total carbohydrates (%) of *Pelargonium zonale* cv. ″Belmonte Red″ rooted cuttings during 2012 and 2013.

CONCLUSION

The best treatment to improve quality of *Pelargonium zonale* cv. ″Belomet 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.

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تحسين جودة عقل الخبيزة الأفرنجى المجذرة صنف "بلمونت رد" بعد الزراعة والتخزين المبرد

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تعتبر نباتات الخبيزة الأفرنجى صنف "بلمونت رد" من نباتات الأصص المزهرة التى تمتلك أزهار و أوراق جذابة و مدى واسع من ألوان الأزهار. أجريت هذه الدراسة خلال موسمى ٢٠١٢ و ٢٠١٣ وتمت إجراؤها فى الصوبة الزجاجية و معمل ما بعد الحصاد فى قسم بحوث نباتات الزينة و تنسيق الحدائق - معهد بحوث البساتين. بهدف دراسة تأثير رش حمض الجبريليك بتركيز ٢٠٠ ملجم /لتر والماء المقطر على عقل الخبيزة الأفرنجى المجذرة صنف "بلمونت رد" بعد الزراعة مباشرة و الزراعة بعد الشحن المبرد فى أكياس من البولى إثيلين المثقبة و الغير مثقبة لفترات ٤ و ٨ أيام على درجة حرارة ٥ ° م و التفاعل بينهم للمحافظة على جودتها.و قد أوضحت النتائج : أن كل المعاملات أعطت زيادة معنوية لمعظم الصفات المدروسة مقارنة بالكونترول فى كل من العقل المزروعة مباشرة و العقل التى تم تخزينها تخزين مبرد. أدى رش عقل البلارجونيوم المجذرة بحمض الجبريليك بتركيز ٢٠٠ مليجرام / لتر إلى زيادة معنوية لكل من إرتفاع النبات و الوزن الطازج و الجاف للنبات و كذلك عدد كل من الأوراق و النورات الزهرية/النبات و عدد الأزهار/ النورات الزهرية و الوزن الطازج و الجاف للجذر و محتوى الجذر من الماء لكل من العقل المزروعة مباشرة و العقل التى تمت زراعتها بعد التخزين المبرد . وقد سجلت نفس المعاملة أعلى قيم فى محتوى الأوراق لكل من الكلوروفيلات الكلية (ملجم/١٠٠جرام وزن طازج) و الكربوهيدرات الكلية (%) و أقل قيم من الكاروتينيدات (ملجم/١٠٠جرام وزن طازج) فى كل من العقل المزروعة مباشرة بدون تخزين و العقل المخزنة تخزين مبرد . أعطت المعاملة بحمض الجبريليك بتركيز ٢٠٠ ملجم/ لتر و التخزين لمدة ٤ أيام على درجة ٥ ° م أعلى قيم معنوية لمعظم الصفات الخضرية و الزهرية و الجذرية مقارنة بالعقل التى عوملت بحمض الجبريليك و المخزنة لمدة ٨ أيام على درجة ٥° م. لوحظ أن العقل المعبأة فى أكياس البولى إثيلين الغير مثقبة كانت أحسن فى كل الصفات المدروسة عن العقل المعبأة فى أكياس البولى إثيلين المثقبة.أدت المعاملة بحمض الجبريليك بتركيز ٢٠٠ ملجم/لتر و التخزين لمدة ٤ أيام على ٥°م إلى نقص كل من معدل التنفس و إنتاج غاز الإثيلين. أدت معاملة التفاعل بين حمض الجبريليك بتركيز ٢٠٠ ملجم/لتر والمخزنة لمدة ٤ أيام فى أكياس البولى إثيلين الغير مثقبة إلى إختزال نسبة الإصابة بالعفن الرمادى المتسبب عن فطر البوتريتس سيناريا وقللت معدل الفقد فى الوزن الطازج و سجلت أعلى معنوية لكل من الصفات الخضرية و الزهرية و الجذرية و حافظت على مستوى الكربوهيدرات الكلية ومحتوى الصبغات فى الأوراق مما أدى إلى الحفاظ على جودة النباتات.

الكلمات الدالة: عقل البلارجونيوم زونال المجذرة، فترات التخزين، الرش بحمض الجبريليك، أكياس البولى إثيلين المثقبة و الغير مثقبة.