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The Effects of Thymol, Menthol and Eugenol on Quality and Vase-life of Chrysanthemum Cut Flowers

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ABSTRACT- Chrysanthemum (*Dendranthema grandiflorum*) is one of the most important ornamental plants used as cut flower, flowering pot plant and groundcover worldwide. In this research, the effects of preservative solutions containing thymol (75 and 125 mg $^{-L}$), menthol (75 and 125 mg L^{-1}) and eugenol (75 and 125 mg L^{-1}) on the quality and vase-life of chrysanthemum cut flowers at 3±1ºC and 75-80% RH were evaluated. 4% Sucrose was added to all solutions and distilled water+4% Sucrose was considered as the control treatment. The highest vase-life (59.58 days) was obtained by thymol 125 mg L^{-1}, followed by thymol 75 mg L^{-1} (59.17 days), compared to the control (31.08 days). Compared to the control and other treatments, thymol (75 and 125 mg L^{-1}) decreased petal wilting and increased preservative solution uptake, flower relative weight, flower TSS, leaf membrane stability, flower diameter and vase-life. Thus, thymol is suggested as the best treatment.

Keywords: Essential oils, Microorganism, Petal wilting, Preservative solution, Vascular blockage

INTRODUCTION

Chrysanthemum (*Dendranthema grandiflorum*) belongs to the Asteraceae family. Due to the versatile color range and inflorescence shape, chrysanthemum is favored by many consumers at the flower market (13). Chrysanthemum cut flower is non-climacteric and

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its senescence occurs in response to carbohydrate changes (2). The formation of bubbles in the vascular tissue of this flower, results in flower quality reduction due to blockage of water ingress into the stem. Subsequently, hydraulic resistance increases, leading to severe water stress (37). Chrysanthemum vascular tissues are immediately blocked after cutting and this response occurs not only in flower stems which are directly put in water but also in those first kept in cold storage (36). The reduction in chrysanthemum cut flower quality is mainly due to leaf wilting; hence, delays in leaf wilting and senescence lead to increasing vase-life longevity (28). This reduction in freshness coincides with chlorophyll degradation, ultimately leading to leaf senescence before inflorescence. Inhibition of water uptake is also triggered by other factors including vascular blockage caused by the rapid growth of microorganisms in the holding solution (37).

Cut flower senescence is governed by hormonal regulation involving physical and biochemical changes in cell membranes, coinciding with sudden changes in the amount of phospholipids and proteins (7). Increase in the activities of hydrolytic enzymes results in the degradation of macromolecules, increase in respiration and reduction of membrane stability (12) and preservative absorption, flower wilting and death. One of the causes of flower senescence in plant tissues is the involvement of reactive oxygen species such as $\cdot O_2$ and H_2O_2 that have an additional electron and lead to flower senescence by degrading proteins, lipids and nucleic acids. These radicals result in lipid peroxidation of cell membrane fatty acids and hasten flower senescence (34). Meanwhile, the reaction of these chemically active radicals with membrane lipids leads to cell death (22). Ethylene also plays an important role in senescence regulation of flowers, and the final stage of wilting coincides with autocatalytic ethylene production (39). Furthermore, microorganisms such as bacteria, yeasts and molds which grow in the water of the containers are responsible for stem blockage and flower quality reduction. The negative effects of bacteria on vase-life are associated with the production of toxic compounds. On the other hand, microorganisms may trigger ethylene production, hence indirectly reducing flower vase-life and quality (1, 38). The application of 8-hydroxyquinolin citrate and silver thiosulfate reduces the growth of microorganisms and increases the vase-life of chrysanthemum (17). Although the application of these compounds reduces damages caused by microbial agents, their use has been limited due to their increasing side effects on the environment and the consumers preference for flowers without chemical residues.

Nowadays, non-chemical alternatives such plant essential oils are being applied (30). These are natural organic compounds which are safe for the environment and due to the antimicrobial characteristics related to their high levels of phenolic compounds, are used for the postharvest pathogen control of fruits (33, 8). Maksimovic et al. (2008) have shown that the essential oils of *Thymus pannonicus* possess remarkable *in vitro* antimicrobial activities against several medicinally important pathogens such as fungi, bacteria and yeasts. In another study, the antibacterial activity of thyme essential oil was tested against standard and clinical bacterial strains of *Acinetobacter* genus and the results showed that the oil from *T. vulgaris* exhibited an extremely strong activity against all clinical strains of *Acinetobacter*. Thyme oil demonstrated very good efficacy against the tested bacteria (25).

To increase the vase-life of cut flowers, it is necessary to provide consumers with new preservatives (32). This study was undertaken to evaluate the possibility of replacing chemical treatments with natural preservatives and to assess the effects of

thymol, menthol and eugenol on *Dendranthema grandiflorum* cv. Mohandesi-e-Zard, in cold storage.

MATERIALS AND METHODS

Plant Materials

This study was designed as a factorial experiment with 7 treatments and 4 replications. Cut flowers provided from a commercial greenhouse were transferred to the laboratory soon after harvest. The flower stems were cut to 45 cm and the leaves of the lower 10 cm were trimmed. The treatments (500 ml) included thymol (75 and 125 mgL^{-1}), menthol (75 and 125 mgL^{-1}) and eugenol (75 and 125 mgL^{-1}) along with distilled water as control. 4% sucrose was also used for all treatments. The containers were sterilized for 2 hrs with 0.5% sodium hypochlorite before starting the treatments. Each experimental unit contained 3 cut flowers kept at 3±1 ºC and an RH between 70-80%. Light was provided by two inflorescence lamps for 12 hrs.

Parameters

During the experiment, parameters such as uptake of the preservative solution, flower relative fresh weight, flower and flower stem diameter (digital calipers) reduction and petal wilting were measured. Leaf wilting and yellowing (chlorosis) were evaluated based on visual quality indexing using a scoring system as follows: 0= without wilting symptoms, 1= 20% wilting, 2= 40% wilting, 3= 60% wilting, 4= 80% wilting and 5= 100% wilting. The above-mentioned parameters were measured at 3-day intervals. The amount of petal soluble solids, leaf membrane stability, chlorophyll a, chlorophyll b, pH of the preservative solution, number of microorganisms in container and flower vase-life were measured at the end of experiment when shelf life was over according to visual appearances. The time between the transfer of flowers to the preservative solutions and 60% of petal wilting was considered as the vase-life duration.

Preservative solution uptake was calculated according to the following equation (9):

Preservative solution uptake = $(w_{t=0}-w_t)$,
where $W_{t=0}$= Erlen total weight at day 0
and W_t= Erlen total weight at storage time.

Flower relative fresh weight was calculated according to the following equation (20):

Flower relative fresh weight = $\left(\frac{Wt}{Wt=0}\right) \times 100$,
where W_t= flower weight at storage time
and $W_{t=0}$= flower weight at day 0.

Membrane stability index was calculated using the electrical conductivity of leaf discs at 40 and 100˚C according to the following equation (14):

Membrane stability = $[1 - (\frac{C1}{C2})] \times 100$,

where C_1=electrical conductivity of leaf discs at 40˚C
and C_2= electrical conductivity of leaf discs at 100˚C.

To measure petal TSS, the extract of mixed petals was pulled out in a mortar and 1-2 drops were placed on the Rafractometer prism. Total soluble solids were represented as ^{o}Brix (3). At the end of the experiment, the pH of the preserving solution was measured by a pH meter directly (20).
Chl a and Chl b contents were determined according to Lichtenthaler (1987) method. The extract was prepared from fresh leaves (0.3 gr) by grinding in a cold mortar and pestling with 30 ml of 80% aqueous acetone. After filtering, the absorbance of centrifuged extracts was measured at 663 and 645 nm using a spectrophotometer (*U-2000, Hitachi Instruments,* Tokyo, Japan).

Chloropyll a (mg/l) = [12.7 (OD_{663}) 2.69 (OD_{645})] × V/10×1000

Chloropyll b (mg/l) = [22.9 (OD_{645}) - 2.69 (OD_{663})] × V/10×1000

Total Chloropyll (mg/l) = [20.2 (OD_{645}) + 8.02 (OD_{663})] × V/10×1000,

where, OD= Absorbance of specific wave length

and V= Final volume of chlorophyll in 80% acetone.

In order to measure the population of microorganisms in the preservative solution, microbial culture was conducted by using 4 grams per liter of nutrient agar media. 1 ml of the preservative solution was placed on the agar media and distributed equally around the petri dish. The number of grown colonies was counted after 24 hours by a colony meter (6). 60% wilting petals was considered to be the end of vase life and the days between the start of the experiment until this time were calculated to evaluate vase life.

Statistical Analysis

The traits measured during storage were analyzed as split plot, considering dates of measurement as a factor; as for the characteristics measured at the end of experiment, data were analyzed as a completely randomized design. Data normalization was performed using MINITAB (Release 14) software. Data analysis was performed using MSTATC Ver. 1.42 software and the means were compared using DMRT at 1 and 5% probability. Graphs were drawn using Microsoft Excel software, 2007.

RESULTS AND DISCUSSION

According to the results, there was no significant difference among the treatments until 24 days of storage; hence, the results presented here do not include the first 24 days. During the storage period, the amount of water uptake, and petal and leaf wilting increased but flower relative fresh weight decreased from the 30th day onwards with a fixed trend. Flower diameter and stem diameter changes showed a steady trend till the end of experiment (Fig. 1).

Preservative Solution Uptake

The interaction of treatment and storage period on the preservative solution uptake was significant (Table 1). Tymol at 75 and 125 mgL^{-1} increased the uptake of the preservatives significantly compared to the control and other treatments.

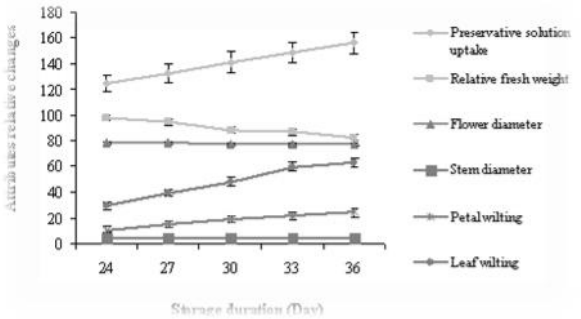

Fig. 1. Relative changes of measured characteristics of chrysanthemum cut flowers during storage at 3±1 ºC. Data are means ± S. E

Table 1- Analysis of variance of the measured traits during the storage of cut chrysanthemum at 3±1 ºC.

		Mean Square			
Source	**Degrees of Freedom**	**Preservative solution uptake**	**Relative fresh weight**	**Petal wilting**	**Leaf wilting**
Treatment	**6**	**18534.261****	**1282.23***	**3842.241****	**3313.81****
Error	**21**	**4740.962**	**408.827**	**279.396**	**495.331**
Time	**4**	**4454.471****	**1033.138****	**834.915****	**5394.291****
Treatment×Time	**24**	**46.985****	**26.445***	**53.992****	**150.684****
Error	**84**	**12.172**	**15.883**	**26.719**	**35.29**
CV(%)	**-**	**2.49**	**4.43**	**27.84**	**12.37**

****, * represent significance at the 0.01 and 0.05 levels respectively**

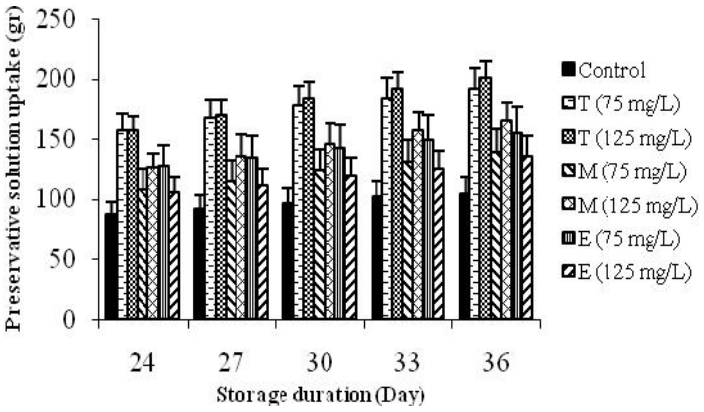

Fig. 2. Effects of thymol (T), menthol (M) and eugenol (E) on preservative solution uptake of chrysanthemum during storage at 3±1 ºC. Data are means ± S. E

Flower Relative Fresh Weight

The interaction of treatments and storage period on flower relative fresh weight was significant at 5% (Table 1). A comparison of means indicated that on the 24th day of storage, thymol (75 and 125 mg L^{-1}) and eugenol (125 mg^{-L}) had higher flower relative fresh weight compared to the control (91.41) and from the 24th day onwards, in almost all treatments, flower relative fresh weight decreased. However, 125 mg^{-L} thymol had a higher flower relative fresh weight at all dates and menthol (125 mg^{-L}) had lower flower relative fresh weight compared to the control and other treatments (Fig. 3).

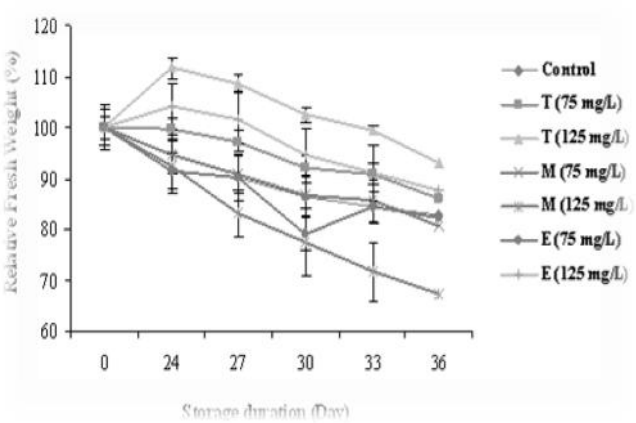

Fig. 3. Effects of thymol (T), menthol (M) and eugenol (E) on flower relative fresh weight of chrysanthemum during storage at 3±1 ºC. Data are means ± S.E

Flower and Flower Stem Diameter

The effect of thymol on flower diameter indicated that thymol (75 and 125 mg L^{-1}) not only increased preservative solution uptake but also enhanced the flower diameter compared to the control (Table 2). Flower stem diameter significantly increased when treated with menthol (125 mg^{-L}) and eugenol (75 mg L^{-1}) (Table 2).

Table 2. Effects of different treatments on flower and stem diameter of chrysanthemum during storage at 3±1 ºC

Treatments	Flower diameter (mm)	Stem diameter (mm)
Control	71.7±0.54 ^{c†}	4.03±0.04 ^{b}
Thymol (75 mg/L)	82.32±0.42 ^{ab}	4.98±0.08 ^{ab}
Thymol (125 mg/L)	84.85±0.51 ^{a}	4.66±0.04 ^{ab}
Menthol (75 mg/L)	76.36±1.23 ^{bc}	4.67±0.15 ^{ab}
Menthol (125 mg/L)	77.34±0.58 ^{abc}	5.29±0.07 ^{a}
Eugenol (75 mg/L)	75.58±0.94 ^{bc}	5.45±0.08 ^{a}
Eugenol (125 mg/L)	76.15±0.99 ^{bc}	4.75±0.11 ^{ab}

† In each column, means with the same letter(s) are not significantly different ($p < 0.01$) Data are means ± S.E

Petal Wilting

Petal wilting in chrysanthemum cut flowers was evaluated based on curling and desiccation of petal edges. The interaction effect of treatment and storage period indicated that petal wilting symptoms appeared later in thymol (125 mg L^{-1}) compared to other treatments and no symptom of wilting was observed until day 30. During the storage period, all treatments showed less wilting in comparison to the control but flowers treated with thymol (75 and 125 mg L^{-1}) showed less wilting (11.66% and 11.67%, respectively) compared to the control and other treatments (Fig. 4).

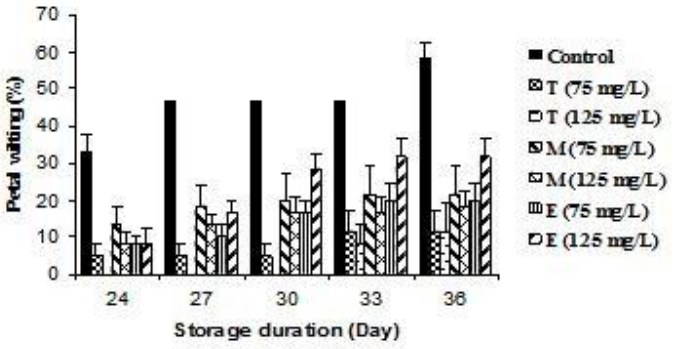

Fig. 4. Effects of thymol (T), menthol (M) and eugenol (E) on chrysanthemum petal wilting of chrysanthemum during storage at 3±1 ºC. Data are means ± S.E

Leaf wilting and yellowing

Leaf wilting and yellowing was more severe than petal wilting (Fig. 4) at the end of storage. A comparison of means indicated that all treatments had less wilting during the storage period compared to the control. According to Fig. 5, the lowest value of wilting and yellowing was observed in menthol 125 mgL^{-1} on the 24^{th} and 36^{th} days of storage.

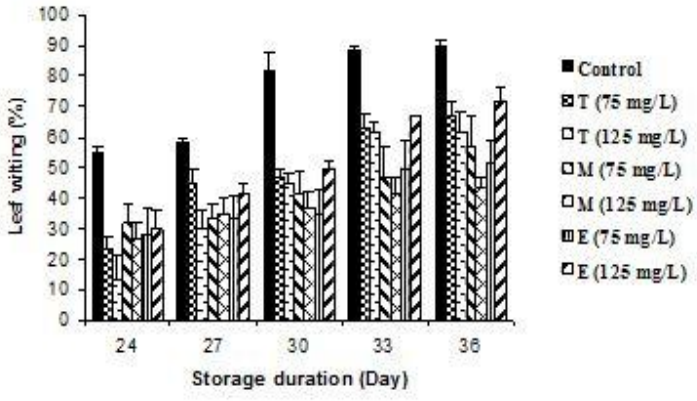

Fig. 5. Effect of thymol (T), menthol (M) and eugenol (E) on chrysanthemum leaf wilting during storage at 3±1 ºC. Data are means ± S.E

Petal soluble solids

In the present study, the content of petal soluble solids increased with storage time. Therefore, the effects of treatment on petal soluble solids indicated that menthol (75 mg L^{-1}) and eugenol (125 mg L^{-1}) had the lowest (9.65 and 9.6, respectively) petal soluble solids and no significant difference was observed among the other treatments. Nevertheless, as Fig. 6 shows, thymol (125 mg L^{-1}) and menthol (125 mg L^{-1}) had higher petal soluble solids (13.45 and 13.4, respectively).

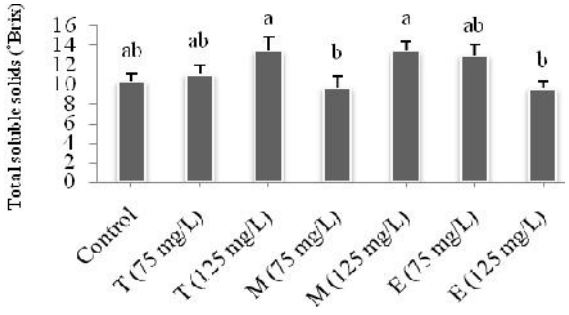

Fig. 6. Effects of thymol (T), menthol (M) and eugenol (E) on petal soluble solids of chrysanthemum at 3±1 ºC. Data are means ± S.E
Means with the same letter(s) are not significantly different (p < 0.01)

Leaf Membrane Stability

All treatments significantly increased leaf membrane stability compared to the control. Menthol (75 mg L^{-1}) showed the highest leaf membrane stability, which was not significant compared to the other treatments (Table 3).

Table 3. Effects of different treatments on chrysanthemum leaf membrane stability and vase-life at 3±1 ºC

Treatments	Membrane stability index (%)	Vase-life (days)
Control	36.68±4.15[b]	31.08 ± 0.71[b]
Thymol (75 mg/L)	52.11±2.32[a]	59.17±3.7[a]
Thymol (125 mg/L)	51.65±1.66[a]	59.58±2.28[a]
Menthol (75 mg/L)	54.16±1.85[a]	50.92±3.46[a]
Menthol (125 mg/L)	48.15±2.76[a]	52.25±0.52[a]
Eugenol (75 mg/L)	53/97±1.66[a]	57.96±5.49[a]
Eugenol (125 mg/L)	52.53±3.42[a]	51.54±6.91[a]

† Means with the same letter(s) are not significantly different (p < 0.01). Data are means ± S.E

Vase-Life

The application of thymol, menthol and eugenol in preservative solutions significantly increased vase-life in comparison with the control (31.08 day). Among the treatments,

thymol (125 mg L^{-1}) caused the highest vase-life (59.58 day) but no significant difference was observed between different concentrations of this treatment with other preservatives (Table 3).

Preservative Solution pH

The mean comparison of preservative solution treatments indicated that those having menthol (75 mg L^{-1} and 125 mg L^{-1}) and eugenol (125 mg L^{-1}) had lower pH (4.75, 4.7 and 5.06, respectively) at the end of the experiment. No significant difference was found among the other treatments and the control (Fig. 7).

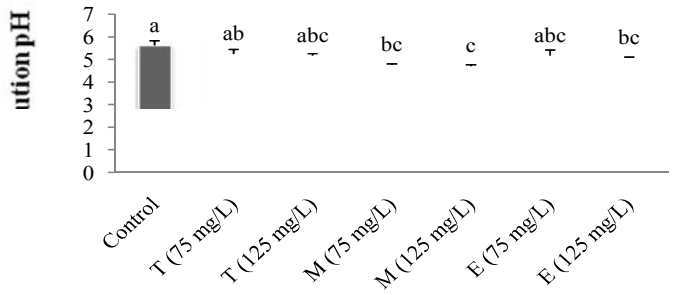

Fig.7. Effects of thymol (T), menthol (M) and eugenol (E) on preservative solution pH of chrysanthemum at 3±1 ºC. Data are means ± S.E
Means with the same letter(s) are not significantly different ($p < 0.01$)

Leaf Pigments

Analyses revealed that pigments were affected by essential oils (Table 4). Mean comparisons indicated that during storage period, menthol (75 mg L^{-1}) and eugenol (75 mg L^{-1}) showed the highest value of chlorophyll a, chlorophyll b and total chlorophyll in the leaves of cut chrysanthemum flowers. There was no significant difference between the other treatments and the control.

Microbial Activity in Preservative Solutions

The effects of the treatments on microorganism colonies grown in preservative solutions indicated that menthol (75 and 125 mg L^{-1}) significantly decreased the growth of microorganisms in preservative solutions with 5.82 and 6.03 CFU respectively, (based on a logarithmic scale) compared to the control (6.63 CFU) (Fig. 8). Although insignificantly, other treatments decreased the number of colonies as compared to the control (Fig. 8).

Table 4. Effects of different treatments on chlorophyll a, chlorophyll b and total chlorophyll of chrysanthemum at 3±1 ºC

Treatments	Chlorophyll a (mg 100g^{-1} F.W)	Chlorophyll b (mg 100g^{-1} F.W)	Total Chlorophyll (mg 100g^{-1} F.W)
Control	10.42±1.5 ^{b}	3.7±1.07 ^{b}	13.94±1.07 ^{b}
Thymol (75 mg/L)	9.97±1.37 ^{b}	3.66±0.94 ^{b}	13.66±0.94 ^{b}
Thymol (125 mg/L)	10.21±3.57 ^{b}	3.55±2.27 ^{b}	13.35±2.27 ^{b}
Menthol (75 mg/L)	33.14±10.88 ^{a}	6.57±4.29 ^{a}	23.94±4.29 ^{a}
Menthol (125 mg/L)	21.51±5.29 ^{ab}	6.17±2.45 ^{a}	19.84±2.45 ^{ab}
Eugenol (75 mg/L)	30.01±6.4 ^{a}	6.29±2.51 ^{a}	23.46±2.51 ^{a}
Eugenol (125 mg/L)	20.10±4.13^{ab}	5.15±2.18^{ab}	19.16±2.18^{ab}

† In each column, means with the same letter(s) are not significantly different ($p < 0.01$)
Data are means ± S.E

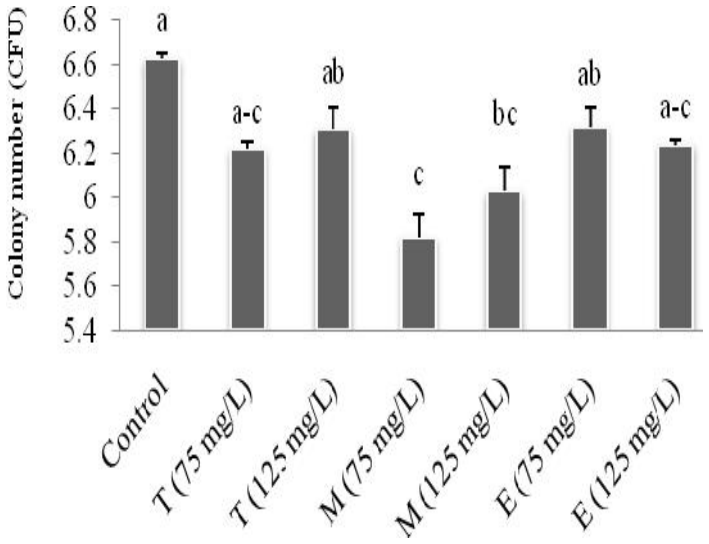

Fig. 8. Effects of thymol (T), menthol (M) and eugenol (E) on colony number in preservative solutions of chrysanthemum at 3±1 ºC. Data are means ± S.E
Means with the same letter(s) are not significantly different ($p < 0.01$)

Water balance is the main factor influencing quality and vase-life of cut flowers. The ability of cut flowers to uptake water and transpire results in a balance between these two processes (11). When transpiration is higher than water uptake, the cut flower is subjected to water deficit and flower wilting develops (16). The inability to uptake water is one of the reasons for wilting which may result from the growth of microorganisms in the cambial tissues of the stem (18).

In the present research, the highest preservative solution uptake and vase-life was obtained by thymol (75 and 125 mg L^{-1}) These treatments increased the vase-life up to about 59.17 and 59.58 days respectively compared to the control (31.08 days), a finding

which is in accordance with those of Solgi *et al*. (31), who reported that preservative solutions containing thymol (100 mg L^{-1}) and carvacrol (50 and 100 mg L^{-1}) significantly increased the vase-life of gerbera compared to the control. The antimicrobial activity of plant extracts and essential oils has also been shown in different studies. Lysakowska *et al* (25) reported that thyme essential oils have a very good efficacy against some strains of bacteria and that these compounds could be considered as excellent alternatives for synthetic preparations. In another study, the *in vitro* antifungal activity of essential oils of *Nepetartanjensis* was investigated. The results showed that the conidia germination of *Cladosporium cladosporioides*, *Trichodermaviride* and two *Alternaria* species was inhibited by essential oils (15). It seems that essential oils could maintain water balance of cut flowers by inhibiting vessel blockage of the stems and hence increasing the vase-life and visual parameters of flowers.

The role of essential oils in increasing vase-life in chrysanthemum could be associated with the anti-microbial activities of thymol, menthol and eugenol. These effects have already been reported by Serrano *et al.* (29) who reported that the application of eugenol, thymol, menthol and eucalyptol in a controlled atmosphere package during the storage of sweet cherries greatly decreased the growth of microbial agents. In another study, the use of essential oils such as eugenol, thymol and menthol in modified atmosphere packaging considerably decreased the growth of microbial agents during 35 days of grape storage (35). Basil essential oil has also been reported to be effective in controlling the growth of *Rhizopus stolonifer* in peaches (40). Essential oil of *Eucalyptus citriodora* was effective in controlling *Botrytis cinerea* in apple fruits (23). Bagamboula *et al*. (4) studied the antifungal effects of thyme and basil essential oils on the postharvest growth of fungi in lettuce and reported positive effects. All these results suggest the high antimicrobial potential of essential oils to control microorganisms.

The reduction of the cut flowers' fresh weight is one of the stages of flower senescence. The more the flowers progress towards senescence, the less their ability to uptake water becomes. Ultimately, they encounter decreased cellar turgidity (19). Thus, the measurement of water uptake after flower harvest is one of the most important factors determining flower durability (21). During the storage period, in all treatments the relative flower fresh weight was decreased, so that the lowest decrease in flower relative weight was obtained on the first measurement date (24^{th} day) and the highest was observed at the end of experiment. The reduction of flower relative weight (flower relative weight loss) may occur due to the reduction of preservative solution uptake or the increase in water loss (5). The present results confirmed the findings of Solgi *et al.* (31) who reported that the inclusion of carvacrol and thymol in preservative solutions significantly decreased relative flower weight loss compared to the control.

Essential oils (65% thymol, 5-10% carvacrol) derived from plants such as *T. vulgaris* are particularly valuable because of their antibacterial and antioxidant properties (25). Reactive oxygen species have a high tendency to attack cell membranes; it could thus be deduced that the reduction of membrane stability could most probably be associated with the increase in the activity of reactive oxygen species and a reduction in the activities of antioxidant enzymes (14, 10), Chanjirakul *et al* (10) reported that the application of natural compounds in some products, protect the cell's physical structure against oxidative damage caused by reactive oxygen species, by increasing the

antioxidant capacity of the products. Thus, cell membranes which are the main target of reactive oxygen species are also protected in this way. It is hence likely that in our study the applied essential oils including menthol, thymol and eugenol, protected membrane integrity by mechanism(s) suggested by Chanjirakul *et al*. (10), through the antioxidant activities of the essences. This finding, however, should be further clarified in future studies.

CONCLUSION

In conclusion, the application of various essential oils, including those used in this research, shows their usefulness in increasing cut flower vase-life, especially for chrysanthemum. As discussed above, some putative mechanisms have been proposed for the mode of action of essential oils, but further research will be needed to discover these modes of action regarding the inhibitory effects of essential oils on the growth of microorganisms in containers or flower stems at cellular, molecular and ultrastructural levels.

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اثرات تیمول، منتول و اوژنول بر کیفیت و عمر گل‌جایی گل بریده داودی

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چکیده- گل داودی یکی از مهم‌ترین گل‌ها می‌باشد که هم به صورت گلدانی و هم به صورت بریدنی در بازارهای جهانی داد و ستد می‌شود.در این پژوهش، اثرات محلول‌های نگهدارنده حاوی تیمول (۷۵ و ۱۲۵ میلی‌گرم در لیتر)، منتول (۷۵ و ۱۲۵ میلی‌گرم در لیتر) و اوژنول (۷۵ و ۱۲۵ میلی‌گرم در لیتر) روی حفظ کیفیت و افزایش عمرگل‌جایی گل بریده داودی در محیط سردخانه (دمای ۱±۳ درجه سانتی‌گراد و رطوبت نسبی ۸۰-۷۵ درصد) بررسی شد. ساکارز ۴ درصد به همه تیمارها اضافه شد و آب مقطر و ساکارز ۴٪ به عنوان تیمار شاهد استفاده شد. در مقایسه با شاهد (۳۱/۰۸ روز)، بیشترین عمر گل‌جایی در گل‌های تیمار شده با تیمول ۱۲۵ میلی‌گرم در لیتر (۵۹/۵۸ روز) و پس از آن تیمول ۷۵ میلی گرم در لیتر (۵۹/۱۷ روز) به دست آمد اگرچه تفاوت معنی‌داری با سایر محلول‌های نگهدارنده نداشتند. در بین تیمارها؛ تیمول ۷۵ و ۱۲۵ میلی‌گرم در لیتر در مقایسه با شاهد و سایر تیمارها، با کاهش پژمردگی گلبرگ و افزایش جذب محلول نگهدارنده، وزن تازه نسبی گل، مواد جامد محلول گلبرگ، پایداری غشاء برگ، قطر گل و عمر گل‌جایی به عنوان بهترین تیمار شناخته شد.

واژه های کلیدی: اسانس‌های گیاهی، بسته‌شدن آوندی، پژمردگی گلبرگ، محلول نگهدارنده، میکروارگانیزم

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