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# Evaluation of the Effects of 1-MCP (1-Methylcyclopropene) on Morphophysiological Indexes and Display Life of *Primula sinensis* L.

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Abstract

The effects of 1-MCP on some morphophysiological traits and display life of primrose were investigated in a factorial experiment based on a completely randomized design composed of two factors including 1-MCP at six levels (0, 50, 75, 100, 150, and 200 nl $l^{-1}$) applied in three periods (18, 21, and 24 hours) in three replications, amounting to 54 experimental plots and 270 primrose plants. The experiment was conducted in the post-harvest room of the Faculty of Agriculture, Islamic Azad University, Rasht Branch with an ambient temperature of 20 ± 2°C, relative humidity of 60 to 70%, a light intensity of 15 to 20 µmol $s^{-1}$ $m^{-2}$, and a day length of 12 hours. In this study, ethylene production, dry matter percentage, display life of primrose, protein content in the petals, chlorophyll a and b indices, total chlorophyll, and the ratio of open florets to closed florets were measured. The results of the analysis of variance showed that the effect of duration was significant only on ethylene production and the amount of petal protein, but the concentration of 1- MCP was significant on all traits except for the display life. The interactive effect of duration and concentration of 1-MCP was statistically significant on the display life at the 5% level so that the T3C5 treatment (24 hours + 150 nl $l^{-1}$ 1-MCP) increased the display life by 1.2 days compared to the control.

**Keywords:** Display life, Dry matter percentage, Ethylene, Petal protein content.

## INTRODUCTION

Primrose, which is scientifically named *Primula sinensis* L., belongs to the Primulaceae family. In Iran, due to its dry weather, the cultivation of this species outside greenhouses is limited to the coastal areas of the Caspian Sea (Khalighi, 2008). Potted flowers have a higher chance of survival than cut flowers because they are always in their planting bed as long as they live. However, these flowers are affected by environmental factors and gases in the air, and their optimal life is reduced (Memaran Kashani and Naderi, 1996).

One of the most important criteria for consumers in choosing these flowers is their longevity, so it is necessary to implement a correct and appropriate program to maintain the quality of potted flowers for a longer period of time (Ruin and Hassanpour Asil, 2011). The most negative effects of air around the plant are related to ethylene. In pure and unpolluted air, the concentration of ethylene is 3-5 mg $L^{-1}$, which is usually higher in autumn and winter (Chamani, 2005).

The amount of internal ethylene increases not only under water stress but also in response to mechanical tissue wounds, air pollution, pathogens, insect damage, waterlogging, and anaerobic conditions (Kafi *et al*., 2006). Flower pollination also stimulates ethylene production and accelerates wilting so that the first signs of wilting appear after pollination in petals (Chamani, 2005). Primrose is one of the most sensitive plants to ethylene and its aging progression increases this sensitivity. This sensitivity depends on the presence of specific receptors in the plant tissue (Chamani, 2005). Excessive concentrations of ethylene cause symptoms of poisoning in plants, including deformed flowers, petal blackening, plant shoot drying including leaves and flowers, pedicel (peduncle) dryness, bud recession, leaf yellowing and aging, bud deformation, and accelerated aging (Chamani, 2005; Mostofi and Shafi'i, 2003).

One of the most important methods to stand the destructive effects of ethylene in reducing the post-harvest life of horticultural crops, especially cut flowers, is the use of chemicals that inhibit or slow down the synthesis and activity of this hormone that plays an important role in promoting aging in plants. The researchers have found the positive effect of 1-methylcyclopropene (1-MCP) on reducing the harmful effects of ethylene. 1-MCP is a gaseous substance that inhibits the action of ethylene, which is used to control or delay ethylene-dependent postharvest effects in a range of horticultural crops (Burns, 2008). In potted flowering plants, the concentration increase from 0 to 5.8 nl/l in *Begonia* × *elatior hybrid* reduced the amount of bud and flower fall, and its increase from 0 to 10 nl/l in *Kalanchoe* 'Tropicana' and in rose 'Victor Parade' reduced flower and leaf fall, respectively (Serek *et al*., 1994a; 1995a).

In most experiments, the duration of treatment was between 12 and 24 hours, which is sufficient for the effect of the substance. The treatment for 6 hours at concentrations of 0.45 µl $l^{-1}$ was not suitable for stimulating respiration or altering ethylene production in avocado (Jiang and Joyce, 2002). The main reason for the repeated use of 1-MCP or the invention of the 1-MCP slow release method is that despite the stable bond that 1-MCP creates with existing receptors during treatment, new sites and receptors are regenerated (Pesis *et al*., 2002). 1-MCP prevents the damage of external ethylene in some potted plants including the inhibition of flower fall in tuberous begonia (*Begonia* × *tuberhybrida*) cv. 'Nonstop', *Himalayan begonia* cv. 'Nayada' and cv. 'Rosa'. Also, aging retardation in *Kalanchoe* cv. Tropicana and prevention of leaf and bud fall in rose cv. 'Victor Parade' were observed for 5 to 12 days in comparison with the control, these plants did not receive any ethylene until 26 to 35 days later (Serek *et al*., 1994; 1995). 1-MCP delays pigment degradation and various types of color changes in many products (Porat *et al*., 1995). 1- MCP delays the degradation of chlorophyll in croton in the presence of ethylene and prevents the degradation of proteins in the old leaves (Jiang and Joyce, 2002). In an ethylene-free environment, 1-MCP increases display life, fresh weight, and total protein compared to control (Serek *et al*., 1995).

This study was performed to evaluate the effect of consumption time and different concen-

trations of 1-MCP for the evaluation of morphophysiological traits and display life of *Primula sinensis* L.

## MATERIALS AND METHODS

The primrose flowers were obtained from a greenhouse located in Amol. The flowers were purchased at closed or semi-open bud stages. The selected flowers had similar colors and plant sizes. The selected flowers, which were in the form of flowering plants, were immediately transported in the early morning to the postharvest laboratory of the Faculty of Agriculture, Islamic Azad University of Rasht.

Before the treatment, all flowering plants were transferred from the planting box into 450-cc containers as pots. Eighteen (18) uniform boxes of the same size were placed in three rows (54 plots in total) on the floor of the postharvest room. Five vases containing yellow primrose were placed in each box. Then, a plastic container was wrapped around the box so that the flowers were completely surrounded by plastic and all the inlet and outlet compartments were completely closed.

Then, a dot with a marked label was marked on a piece of plastic in all the boxes to fix the injection site and make it easily visible. A drop of aquarium glue was poured on the label to automatically block the hole after the injection. After performing the above steps, different amounts of 1-MCP were injected as per the experimental design on 15:00 and then 7 cc of ethylene gas was added to each box with a separate syringe.

After 18 hours, the plastic cover of the $T_1$ treatments was opened and the flowers were exposed to the room. After 21 and 24 hours, the covers of $T_2$ and $T_3$ treatments were also opened. The volume of the plastic cover was 18480 $cm^3$. This study was performed as a factorial experiment based on the randomized complete block design with three replications. The duration of exposure to 1-MCP included 18, 21, and 24 hours ($T_1$, $T_2$, and $T_3$, respectively), and 1-MCP concentration treatments included 0 (control), 50, 75, 100 and 150 and 200 nl $l^{-1}$ ($C_0$, $C_1$, $C_2$, $C_3$, $C_4$, and $C_5$, respectively). There were a total of 54 experimental plots.

### Trait Assessment

#### Ethylene

After 1-MCP treatment and opening of the plastic cover, one of the flowers with its container was placed in a jar equipped with a septum. After 24 hours, these jars were sampled with double-headed needles and venojects. Then, the gas sample inside the jar was transferred into vacuum (venoject) glass. After sampling from the whole experimental plots, the venojects containing ethylene gas were stored in a refrigerator at 4°C and transferred to the Horticultural Laboratory of Tehran University. The amount of ethylene produced was measured with a Shimadzu GC-8AIT Japan (Mostofi and Najafi, 2005).

#### Percentage of dry matter of flowering plants at the end of display life

For this purpose, after the end of flowers display life, the aerial parts of the plant (flowers, leaves, stems, and buds) were cut and weighed with digital scales. Then, the weighed organs were placed in an oven at 105°C for 24 hours to estimate the dry weight of the aerial parts. Then, the dry percentage was calculated based on the following equation:

Dry matter (%): Dry weight / Fresh weight ×100

#### Display life

The main criteria to evaluate the display life of flowers were flower and leaf wilting, loss of marketable and commercial shape, and flower appearance. Therefore, the longevity of the plants in each box was measured, and the average was recorded as the display life of the treatment.

**Measuring the amount of protein in the petals**

As soon as the signs of wilting were seen in the postharvest room, one flower was sampled from each plant. Then, about 0.3 g of the petals were removed and poured into a 50-cc volumetric flask. A solution of 1 N sulfuric acid was added in addition to 1 N salicylic acid and after cooling, 2 ml was added to each volumetric flask. After mixing the acid with the petals, a black liquid was obtained, which should be kept with open door for 24 hours. After that, 1 ml of hydrogen peroxide was added to the volumetric flask and then boiled again. This process was repeated several times until the previous black liquid became clear and yellow. After cooling, the liquid was poured into small polyethylene cans and adjusted to 50 cc with distilled water. After 24 hours, the last step should be done. At this stage, using a pipette, 5 cc of the extract was poured into a 50 cc digestion balloon with 12 cc of distilled water and 3 cc of 1 N NaOH. In the next step, the colored liquid that was the reagent must be made. So, 10 cc of normal boric acid was taken and poured into a small flat bottom balloon, and 12 drops of methyl blue dye were added to give a red liquid.

The above 2 balloons were embedded in the British-made Branstad Kjeldahl and the distillation interface pipes were also connected. The temperature of the device was first set at 6°C and increased every 10 minutes. The extracted liquid was boiled and the drops of evaporated liquid were added to the colored liquid of the balloon. This process continued until about 30 minutes later, the reagent color turned golden. The golden liquid was titrated under the titration burette and 1 drop of 1 N sulfuric acid was added. The acid was also added until the liquid turned pink. In the end, all the acid consumption was read in the titration column and placed in the following formula to obtain the nitrogen content of the petal extract:

$$N = 0.56 \times t \times (a-b) \times V/W$$

in which t represents the concentration of the acid used for titration (mol/liter), a represents the concentration of the acid used for sample (ml), b represents the concentration of the acid used for control (ml), V represents the volume of the extract from digestion, and W represents the weight of the sample for digestion. Now, the obtained number was multiplied by a fixed number of 6.25 to yield the amount of petal protein.

**Leaf chlorophyll**

To measure chlorophyll content, as soon as the signs of wilting appeared in the postharvest room, 1 g of leaf tissue was sampled from each plant mixed with liquid nitrogen in a mortar and mixed and homogenized with 5 ml of 80% acetone. The resulting solution was filtered through Whatman No. 40 filter paper and then the volume of the solution was increased to 10 ml with acetone. Its absorption intensity was then read at 663 and 645 nm using a spectrophotometer. The concentrations of chlorophyll *a*, chlorophyll *b*, and total chlorophyll contents were calculated using the following formulas (Lichtenthder, 1987):

$$\text{Chl. a} = 12.5\ A_{663} - 2.79_{A645}$$
$$\text{Chl. b} = 21.51\ A_{645} - 5.1\ A_{663}$$
$$\text{Chl. Total} = \text{Chl. a} + \text{Chl. b}$$

**The ratio of open flowers to closed flowers**

To measure this trait, the number of open flowers and closed flowers were counted and recorded daily. The last open flowers were counted at the end of the display life. After adjusting the data, the corresponding numbers were obtained. The number of open flowers on the second day compared to the first day, the third day compared to the second day, the fourth day compared to the third day, etc. were the basis of the ratios. The same procedure was repeated for the buds.

The numbers obtained from the ratios were summed up and divided by the number of days for each treatment. The number obtained showed the number of days the flowers survived.

**Data analysis**

Data were analyzed using SPSS and MSTATC software, and the means were compared using LSD test.

## RESULTS AND DISCUSSION

**Ethylene**

Analysis of variance showed that the effect of treatment duration, 1-MCP concentration, and their interaction was significant ($P < 0.01$) on the rate of ethylene production (Table 1). Also, the comparison of the means revealed that among the different treatment durations, the 18-hour treatment was related to the highest ethylene production rate of 0.516 nl $l^{-1}$ $h^{-1}$ $g^{-1}$ F.W. The highest ethylene production was observed in the control treatment (without 1-MCP), in which it was 0.652 nl $l^{-1}$ $h^{-1}$ $g^{-1}$ F.W. All 1-MCP concentrations significantly reduced ethylene production. The lowest ethylene production was observed in $T_3C_5$ (duration of 24 hours × concentration of 150 nl $l^{-1}$ 1-MCP) at the rate of 0.212 nl $l^{-1}$ $h^{-1}$ $g^{-1}$ F.W. In this treatment, ethylene production was less than 25% compared to the control (Table 2).

Table 1. Analysis of variance for the effect of different treatments on the measured traits.

| S.o.V | df | Chlorophyll a | Chlorophyll b | Total chlorophyll | Display life | Ethylene production | Dry matter | Petal protein | Ratio of open/closed flowers |
|---|---|---|---|---|---|---|---|---|---|
| T (time) | 2 | 0.05 $^{ns}$ | 0.04$^{ns}$ | 15.956$^{ns}$ | 0.206$^{ns}$ | 0.156$^{**}$ | 165.70$^{ns}$ | 141.63$^{**}$ | 0.0$^{ns}$ |
| C (1-MCP) | 5 | 0.255$^{**}$ | 0.13$^{**}$ | 56.968$^{**}$ | 0.33 $^{ns}$ | 0.147$^{**}$ | 277.81$^{*}$ | 143.42$^{**}$ | 0.735$^{*}$ |
| T × C | 10 | 0.030$^{ns}$ | 0.023$^{**}$ | 8.285$^{ns}$ | 0.2$^{*}$ | 0.039$^{**}$ | 92.96$^{ns}$ | 143.80$^{**}$ | 0.178$^{ns}$ |
| Error | 36 | 0.037 | 0.021 | 8.284 | 0.2 | 0.007 | 78.64 | 16.33 | 0.22 |
| CV (%) | - | 92.92 | 65.49 | 57.4 | 8.352 | 20.98 | 27.36 | 24.05 | 39.71 |

$^{*}$, $^{**}$ and $^{ns}$: significant at $P < 0.05$, $P < 0.01$ and insignificant, respectively.

Flowers and ornamental plants have different sensitivities to ethylene. Primrose is a very ethylene-sensitive plant and the aging progress in the plant increases its sensitivity, which depends on the presence of specific receptors in the plant tissue. 1-MCP is highly capable of bonding to ethylene receptors, thereby preventing ethylene action. 1-MCP also inhibits the increase in pollen production due to ethylene production and inhibits the progression of aging in *Phalaenopsis* sp. cv. 'Herbert Hager' (Porat *et al*., 1995). It also inhibits the accumulation of mRNA associated with ethylene biosynthetic enzymes such as ACC synthase and ACC oxidase (Dong *et al*., 2002; Ownio *et al*., 2002). The active concentration of 1-MCP is very diverse and this can vary depending on the time, temperature, and method of application. Studies show that 1-MCP concentrations of 1 to 12 µl $L^{-1}$ have been very effective in blocking ethylene activity (Able *et al*., 2002).

**Percentage of dry matter of flowering plants at the end of display life**

The analysis of variance showed that the effect of different concentrations of 1-MCP was significant ($P < 0.05$) on the dry matter content of flowers, but the effect of time and the interaction of time and concentration of 1-MCP was not (Table 1). According to the comparison of the means,

Table 2. Comparison of the mean effects of duration and concentrations of 1- MCP on the studied traits in primrose.

| Treatments | Chl. a (mg $g^{-1}$ F.W.) | Chl. b (mg $g^{-1}$ F.W.) | Display life(day) | Ethylene production (nl $l^{-1}$ $h^{-1}$ $g^{-1}$ F.W.) | Dry matter (%) | Petal protein (%) | Open/closed flowers | Total Chl (mg $g^{-1}$ F.W.) |
|---|---|---|---|---|---|---|---|---|
| T1(18h) | 0.147a | 0.168a | 5.251a | 0.516a | 29.019a | 13.567b | 1.183a | 4.030a |
| T2(21h) | 0.239a | 0.258a | 5.462a | 0.377b | 33.328a | 18.583a | 1.186a | 5.107a |
| T3(24h) | 0.239a | 0.239a | 5.387a | 0.338b | 34.874a | 18.250a | 1.176a | 5.906a |
| C1(0nl/l) | 0.081c | 0.067c | 5.093a | 0.652a | 21.923b | 9.833c | 1.728a | 1.530d |
| C2(50nl/l) | 0.273b | 0.332a | 5.627a | 0.382bc | 35.422a | 20.633a | 0.933b | 6.679ab |
| C3(75nl/l) | 0.134bc | 0.135bc | 5.350a | 0.313c | 36.880a | 15.467b | 1.124b | 3.492cd |
| C4(100nl/l) | 0.081 c | 0.161bc | 5.258a | 0.341c | 30.558a | 20.433a | 1.237b | 4.134bcd |
| C5(150nl/l) | 0.521a | 0.369a | 5.533a | 0.327c | 35.127a | 17.967ab | 0.960b | 8.663a |
| C6(200nl/l) | 0.158bc | 0.266ab | 5.338a | 0.448b | 34.533a | 16.467b | 1.046b | 5.589bc |
| T1C1 | 0.047a | 0.057a | 4.953b | 0.883a | 21.346a | 8.800e | 1.720a | 0.970a |
| T1C2 | 0.211a | 0.182a | 5.340ab | 0.408d-g | 26.763a | 14.400de | 0.876a | 2.453a |
| T1C3 | 0.055a | 0.074a | 5.330ab | 0.348e-h | 36.663a | 17.500cd | 1.190a | 3.743a |
| T1C4 | 0.049a | 0.060a | 5.066b | 0.481b-e | 29.843a | 14.400de | 1.156a | 5.290a |
| T1C5 | 0.370a | 0.399a | 5.203ab | 0.441c-g | 29.576a | 11.900de | 1.200a | 6.120a |
| T1C6 | 0.151a | 0.297a | 5.613ab | 0.536bcd | 29.923a | 14.400de | 0.956a | 5.603a |
| T2C1 | 0.049a | 0.067a | 5.260ab | 0.465c-f | 22.293a | 11.900de | 1.720a | 1.343a |
| T2C2 | 0.440a | 0.450a | 5.933a | 0.263h | 45.00a | 30.00a | 0.900a | 10.280a |
| T2C3 | 0.117a | 0.173a | 5.396ab | 0.349h | 38.243a | 17.00cd | 1.453a | 3.006a |
| T2C4 | 0.058a | 0.290a | 5.513ab | 0.304gh | 30.040a | 17.500cd | 1.100a | 1.349a |
| T2C5 | 0.695a | 0.268a | 5.396ab | 0.329fgh | 28.803a | 12.00de | 0.993a | 8.590a |
| T2C6 | 0.076a | 0.301a | 5.273ab | 0.556bc | 35.586a | 23.10bc | 0.950a | 6.073a |
| T3C1 | 0.149a | 0.077a | 5.066b | 0.609b | 22.130a | 8.800e | 1.746a | 2.276a |
| T3C2 | 0.168a | 0.364a | 5.610ab | 0.474b-e | 34.503a | 17.500cd | 1.203a | 7.303a |
| T3C3 | 0.232a | 0.159a | 5.323ab | 0.242h | 35.733a | 11.900de | 0.730a | 3.726a |
| T3C4 | 0.138a | 0.134a | 5.196ab | 0.240h | 31.379a | 29.400ab | 1.456a | 5.761a |
| T3C5 | 0.500a | 0.500a | 6.00a | 0.212h | 47.00a | 30.00a | 0.686a | 11.280a |
| T3C6 | 0.248a | 0.199a | 5.130ab | 0.254h | 38.090a | 11.900de | 1.233a | 5.089a |

* In each column, that numbers that have at least one similar letter are not significantly different according to the LSD test.

the treatment of 75 nl $l^{-1}$ l-MCP with 36.880 % dry matter showed a significant advantage over the control (Table 2). The reason for the increase in the percentage of dry matter compared to the control can be the prevention of the burning of sugars by the respiratory process, which indicates the positive effect of the treatments used. 1-MCP delays the aging of flowers by reducing protein degradation and respiration rate (Hashemabadi *et al.*, 2009).

**Display life**

The analysis of variance revealed that display life was not affected significantly by duration and concentration of 1- MCP, but their interaction was statistically significant at the 5% level (Table 1). However, in response to the $T_3C_5$ treatment (24 hours with 200 nl $l^{-1}$ 1-MCP), the flowers exhibited the longest display life of 6 days (Table 2). As 1-MCP blocks ethylene receptors, it can be said that the longer display life of the superior treatment is related to this feature. In examining the effect of concentrations of 0.5 and 5 µl $l^{-1}$ l-MCP on rose cv. 'First Red', it was concluded that all three concentrations were significantly ($P < 0.05$) superior to the control, but no significant difference was observed between the concentrations (Chamani, 2005). In an experiment, the effect of STS and 1-MCP on the vase life of cut freesia cv. 'Corolla' was investigated and it was reported that the longest flowering life was observed in spikes in the treatment 4 nl $l^{-1}$ 1-MCP for 3 hours.

The superior treatment showed 9.06 days versus 6.33 days of control treatment. 1-MCP prevented the destruction of proteins by disrupting SAM synthase (Zencirkirans Lab, 2010). In a study, it was found that 1-MCP prevented the breakdown of proteins in the leaves of old croton (Jiang and Joyce, 2002). As was mentioned, the presence of 1-MCP disrupts the activity of ethylene, which increases the display life. In potted flowering plants, the concentration increased from 5.8 nl $l^{-1}$ in *Begonia* × *elatior* hybrida to 10 nl $l^{-1}$ in Kalanchoe cv. 'Tropicana' and rose 'Victor Parade', the fall of buds and petals were reduced (Serek *et al*., 1994b; 1995).

**Petal protein content**

According to the analysis of variance, the effects of duration of treatment with 1-MCP, the concentration of this compound, and their interaction were significant ($P < 0.01$) on this trait (Table 1). Also, the comparison of means showed that the treatments of $T_2$ (21 hours) and $C_2$ (50 nl $L^{-1}$ 1- MCP) with 18.58 % and 20.633 % protein, respectively and the interactive treatments of $T_2C_2$ (21 hours and 75 nl $L^{-1}$ 1-MCP) and $T_3C_5$ (24 hours and 200 nl $L^{-1}$ (1-MCP) with 30% protein had a significant advantage over the other treatments (Table 2). A study on the effects of aging in *Brassica napus* found that during aging, key metabolites from the old organs were transferred back to the plant system and were used for the development of other organs. Protein breakdown has been shown to be an important part of this remobilization process. Thus, the activity of proteolytic enzymes is an essential element of aging (Buchanan-Wollaston and Ainsworth, 1997). 1-MCP in *Petunia* increases electrolyte leakage by preventing the induced effects of foreign ethylene and prevents the reduction of membrane proteins and lipid fluidity (Blankenship and Dole, 2003). 1-MCP increases electrolytic permeability by inhibiting the induction effect of foreign ethylene (1 to 12 µl $L^{-1}$), as well as inhibiting the reduction of membrane proteins and the reduction of the fluidity of lipids in *Petunia*. In an ethylene-free medium, 1-MCP increased display life, fresh weight, and total protein content compared to the control treatments (Serek *et al*., 1995).

**Leaf chlorophyll content**

As the analysis of variance revealed, the effect of 1-MCP concentration was significant ($P < 0.01$) leaf chlorophyll content, but the duration of 1-MCP treatment and the duration-concentration interaction were not significant (Table 1). The comparison of means showed that the treatment of C5 (150 nl $l^{-1}$1-MCP) with 0.521 mg $L^{-1}$ fresh chlorophyll *a* content was significantly different from the other treatments (Table 2). Also, the means comparison showed that in terms of the amount of chlorophyll *b*, the treatment of C5 (150 nl $l^{-1}$ l-MCP) with 0.369 mg $g^{-1}$ F.W. of chlorophyll *b* differed from the other treatments significantly (Table 2). In terms of total chlorophyll, the treatment of C5 (150 nl $l^{-1}$ 1-MCP) with 8.663 mg $g^{-1}$ chlorophyll was significantly different from the other treatments (Table 2). In fact, 1-MCP has improved the condition of flowers and increased their display life by preventing chlorophyll degradation (Hashemabadi, 2006). Preventing chlorophyll degradation in the above treatments may be due to the fact that the chlorophyllase enzyme could not degrade chlorophyll properly. Chlorophyllase is the first enzyme in the path of chlorophyll breakdown, the amount of which is higher in older leaves than in young leaves (Ferrante *et al*., 2002). 1-MCP prevents or delays chlorophyll degradation and various types of color changes in many products (Porat *et al*., 1995). This action, in turn, prolongs the life of the pot in the treated cultivars. One of the important side effects of ethylene is chlorophyll degradation and leaf yellowing in plants. 1-MCP delayed chlorophyll degradation in croton in the presence of ethylene (Jiang *et al*., 2002).

**Ratio of open to closed flowers**

The analysis of variance of data related to this trait showed that the effect of 1-MCP con-

centration was significant ($P < 0.01$), but 1-MCP duration and the interaction were not (Table 1). According to the comparison of means, the mean of the $C_1$ treatment (control) with a ratio of 1.728 accelerated the opening of primrose flowers (Table 2). It can be said that the control treatment causes the flowers to age, while the presence of 1-MCP keeps the plants in the bud state. Since flower opening requires the use of ATP and to provide the required ATP, sugar molecules need to be broken down during the respiration process, any factor that reduces the plant's respiration rate can delay the flower opening process. Numerous experiments have shown that 1-MCP can reduce or delay respiration. In a study on the effect of 1-MCP on packaged plums, it was concluded that 1-MCP drastically reduced upward breathing in this fruit (Valero *et al*., 2004).

## CONCLUSIONS

According to the results, among different durations tested, 1-MCP treatment of primrose flowers for 24 hours yielded the best results. The plants treated with 150 nl $l^{-1}$ 1-MCP, which exhibited the lowest production and the highest amount of chlorophyll a, chlorophyll b, and total chlorophyll and the lowest ratio of open to closed flowers, had the highest durability among different treatments. In addition, the interaction of these two treatments with the longest display life is recommended for primroses.

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