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Effects of 1-MCP on the vase life and ethylene response of cut flowers

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Abstract

Pretreatment for 6 h with low concentrations of 1-MCP (1-Methylcyclopropene, formerly designated as SIS-X), a cyclic ethylene analog, inhibits the normal wilting response of cut carnations exposed continuously to 0.4 $\mu l \cdot l^{-1}$ ethylene. The response to 1-MCP was a function of treatment concentration and time. Treatment with 1-MCP was as effective in inhibiting ethylene effects as treatment with the anionic silver thiosulfate complex (STS), the standard commercial treatment. Other ethylene-sensitive cut flowers responded similarly to carnations. In the presence of 1 $\mu l \cdot l^{-1}$ ethylene, the vase life of 1-MCP-treated flowers was up to 4 times that of the controls.

Abbreviations: 1-MCP = 1-Methylcyclopropene; STS = silver thiosulfate.

1. Introduction

The inhibition of ethylene action by pulse pretreatment with STS has become an important commercial technique for improving the life of ethylene-sensitive flowers, especially when they are to be handled in ethylene-contaminated environments such as supermarkets. Despite the minute amounts of silver applied to each flower in this treatment, there has been concern about potential environmental contamination resulting from STS treatments, principally in relation to disposal of waste treatment solutions [1]. We have been exploring possible substitutes for STS, particularly gaseous ethylene analogues that appear to inactivate the ethylene binding site irreversibly. Diazocyclopentadiene (DACP), one such material, is effective in overcoming the action of ethylene in rose [2]. Unfortunately, this promising material is unlikely to be commercialized because of the difficulties inherent in handling an unstable and potentially explosive chemical. 1-MCP, a cyclic olefine analogous to the photodecomposition product of DACP, has a similar action to that of DACP (Sisler, unpublished), appears to be non-toxic, and is quite stable under normal conditions. This material proved an effective inhibitor of ethylene effects in potted flowering plants [3]. We report here a study of the efficacy of 1-MCP as an inhibitor of ethylene action in ethylene-sensitive cut flowers.

2. Materials and methods

A range of ethylene-sensitive cut flowers were used in the experiments:

Alstroemeria L.,
Antirrhinum majus L.,
Consolida ambigua L.,
Dianthus barbartus L.,
Dianthus caryophyllus L. 'Sandra',
Matthiola incana Stock.,
Penstemon hartwegii Benth. × *P. cobaea* Nutt. 'Firebird'.

The flowers were harvested locally, and used in experiments immediately after transport to UC Davis.

2.1 *1-MCP treatment*

Flowers were placed with their bases in water in sealed glass chambers at 20 °C, and aliquots of 1-MCP calculated to provide a total concentration of 1 to 20 $nl \cdot l^{-1}$ were injected into the chambers. The chambers normally remained sealed for six hours. Control flowers were sealed in air in identical chambers. The flowers were then placed in a vase-life room, or were exposed to low concentrations (normally 1 $\mu l \cdot l^{-1}$) of ethylene.

2.2 *STS treatment*

Flowers were pulse-treated for 2 h with 1 m*M* STS prepared as described by Reid *et al.* [4].

2.3 *Ethylene treatment*

Flowers were enclosed in glass chambers ventilated (40 $l \cdot h^{-1}$) with air containing ethylene at 0.4 or 1.0 $\mu l \cdot l^{-1}$. The ethylene concentration was monitored daily by gas chromatography, using a gas chromatograph fitted with a flame ionization detector (Carle AGC 111, and HNU PI-51). Flower longevity was recorded as days to loss of all open florets, or days to flower wilting.

2.4 *Vase life*

The longevity of tested and control flowers placed in the vase-life room (20 °C, 60% RH, 12 h per day of light (15 $\mu mol \cdot m^{-2}s^{-1}$) from cool white fluorescent tubes) was also determined.

2.5 *Binding measurements*

Binding measurements were carried out essentially as previously described [2]. Petals were removed from the plant and allowed to stand overnight to allow wound ethylene to subside. Binding was carried out on 3 g petals of *Dianthus caryophyllus* 'Sandra'. The petals were exposed to 0.5 μCi of ^{14}C-ethylene and 1-MCP in 2.5 l dessicators for 0.75 h. They were then ventilated (45 seconds for rose and 2 min for carnation), and placed in 250 ml jars with a vial containing 0.3 ml mercury perchlorate on a piece of fiber glass filter to increase the surface area. After about 12 h the vials were removed, scintillation fluid was added, and the radioactivity was counted.

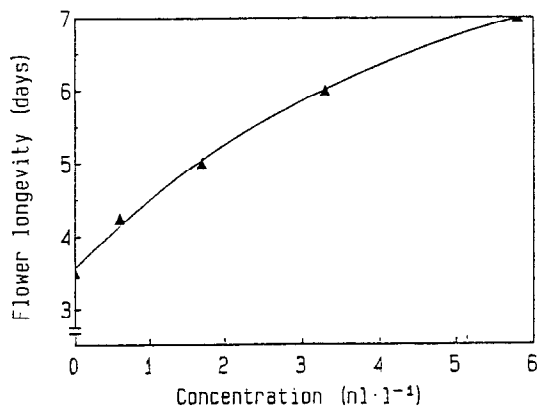

Fig. 1. Longevity of *Dianthus caryophyllus* L. 'Sandra' flowers pretreated with 0, 0.6, 1.7, 3.3 or 5.8 $nl \cdot l^{-1}$ 1-MCP (6 h). Control flowers (0 $nl \cdot l^{-1}$ 1-MCP) were placed in air, in identical tanks to those used for 1-MCP treatment. After treatment all plants were exposed continuously to 0.4 $\mu l \cdot l^{-1}$ ethylene.

Source of variation:	
Control vs other 1-MCP trts	***
Among 1-MCP trts	***
1-MCP linear	***
1-MCP quadratic	ns

(ns, ***) Nonsignificant or significant at P = 0.001.

2.6 *Binding constants*

These were determined by competition measurement between 1-MCP and 14C-ethylene. Values were obtained from Scatchard Plots and corrected for the presence of ethylene by the method of Cheng and Prusoff [5] and Prescan *et al.* [6].

2.7 *Statistics*

Statistical procedures were performed using the PC–SAS software package. Differences between means were determined using orthogonal comparisons or Student T-test.

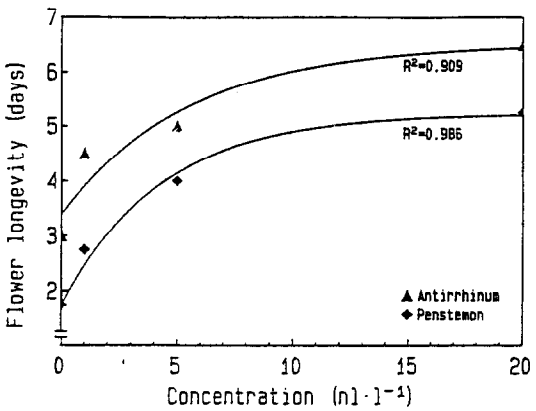

Fig. 2. Longevity of flowers of *Antirrhinum majus* L. and *Penstemon hartwegii* Benth × *P. cobaea* Nutt. 'Firebird' pretreated with 0, 1, 5 or 20 nl·l^{-1} 1-MCP (6 h). Control flowers (0 nl·l^{-1} 1-MCP) were placed in air, in identical tanks to those used for 1-MCP treatment. After treatment all plants were exposed to 1 μl·l^{-1} ethylene.

Source of variation:[4pt]	*Antirrhinum*	*Penstemon*
Control vs other 1-MCP trts	***	***
Among 1-MCP trts	**	***
1-MCP linear	***	***
1-MCP quadratic	*	**

(***, **, *) Significantly at $p = 0.001, 0.01$ or 0.05, respectively.

3. Results

3.1 *Effects of 1-MCP concentration on the ethylene response of cut flowers*

The longevity in 0.4 μl·l^{-1} ethylene of cut carnations pre-treated with 1-MCP increased with increasing pre-treatment concentration (Fig. 1). Calculation of the asymptote of the curve indicated that 90% of possible longevity would be achieved with a pre-treatment of 10–20 nl·l^{-1}. Pre-treatment of snapdragon and penstemon flowers with 1-MCP up to 20 nl·l^{-1} confirmed this hypothesis (Fig. 2). The inhibitory effect of 1-MCP appeared to plateau at a pre-treatment concentration of 20 nl·l^{-1}.

3.2 *Effects of 1-MCP on longevity of cut carnations held in air*

The longevity in an ethylene-free environment of 'White Sim' carnations pretreated with 20 nl·l^{-1} 1-MCP was compared with that of untreated flowers (Fig. 3). The control wilted 4 days after the start of the experiment, and flowers treated with 20 nl·l^{-1} 1-MCP lasted for 7 days.

Fig. 3. Cut 'White Sim' carnation flowers pretreated with 20 nl·l^{-1} 1-MCP for 6 h. After treatment treated and control (Di) flowers were held for 4 days in an ethylene-free interior environment.

3.3 *Comparison of inhibition of ethylene effects by 1-MCP and STS pre-treatments*

The longevity, in the presence of 1 μl·l^{-1} ethylene, of a range of cut flower species (Table 1) was significantly enhanced by pre-treatment with STS (1 m*M*, 2 h) or 1-MCP (20 nl·l^{-1}, 6 h). There was no significant difference in the efficacy of the two inhibitory treatments. Both prevented accelerated flower or petal abscission, and floret wilting (Fig. 4).

3.4 *Effect of exposure time and concentration*

The surface interrelationship between 1-MCP pre-treatment concentration, treatment time, and flower longevity in the presence of ethylene (Fig. 5) indi-

Table 1. Longevity of different cut flowers pretreated with 20 $nl \cdot l^{-1}$ 1-MCP (6 h), 1 m*M* STS (2 h) or DI. Control (DI) and STS treated flowers were placed in air, in identical tanks to those used for 1-MCP treatment. After treatment all flowers were exposed continuously to 1 $\mu l \cdot l^{-1}$ ethylene

Species	Treatment	Flower longevity (days)
Alstroemeria	Control	5.0b[x]
	STS	6.8a
	1-MCP	6.8a
Matthiola	Control	2.3b
	STS	5.0a
	1-MCP	5.0a
Consolida	Control	1.5b
	STS	5.8a
	1-MCP	5.8a
Dianthus	Control	2.3b
	STS	5.3a
	1-MCP	5.8a
Penstemon	Control	1.8b
	STS	5.3a
	1-MCP	5.3a
Antirrhinum	Control	3.0b
	STS	6.3a
	1-MCP	6.5a

[x] Numbers followed by different letters in a column are statistically different at $p = 0.05$ by T-test probability values for the hypothesis H_o: LSM(i) = LSM(j).

cates an interaction between treatment concentration and time. Lower treatment concentrations may be as effective as higher concentrations if the treatment time is extended.

3.5 *Effect of pre-treatment temperature*

Penstemon flowers treated at 2 °C were not protected from the effects of ethylene by 1-MCP treatments that were very effective when applied at 20 °C. Exposure to 1 $\mu l \cdot l^{-1}$ ethylene of spikes treated with 5 or 20 $nl \cdot l^{-1}$ 1-MCP for 6 h at 2 °C resulted in loss of all the florets within 1 day. Florets remained on spikes treated similarly, but at room temperature, for three days (data not shown).

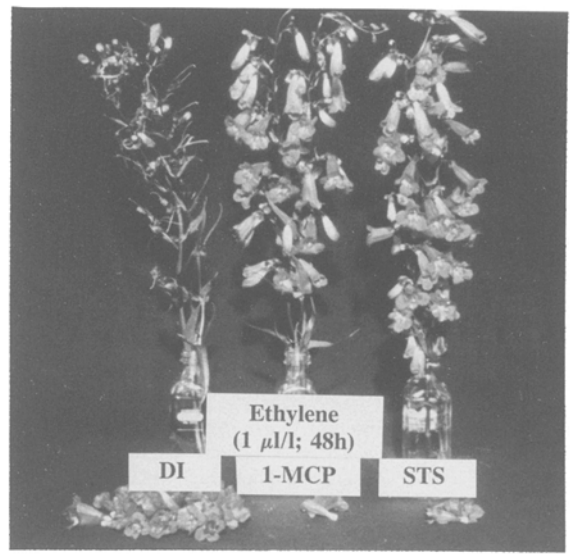

Fig. 4. Effects on ethylene-stimulated flower drop in *Penstemon hartwegii* Benth. × *P. cobaea* Nutt. 'Firebird' of pretreatment with 20 $nl \cdot l^{-1}$ 1-MCP (6 h) or 1 m*M* STS. Treated and control flowers were exposed for 48 h to 1 $\mu l \cdot l^{-1}$ ethylene.

3.6 *Binding constants*

Binding constants for 1-MCP in *Dianthus caryophyllus* 'Sandra' were: C 50(K'd) 2.8 $nl \cdot l^{-1}$ and Kd 2.1 $nl \cdot l^{-1}$. Kd was calculated from K'd using the formula K'd = Kd(1 + S/Ks) where S and Ks refer to the concentration and dissociation constant for ethylene. The values reported here for K'd and Kd are the first direct measurements of the effect of concentration of a compound which interacts permanently with the ethylene binding components. Although the values obtained are not strictly valid from a kinetic standpoint because the reaction is not reversible (or is extremely slow), they are values obtained in competition with ethylene and since the treatment time used was minimal, they should approximate the correct value. The values show that very low amounts of 1-MCP are needed to inactivate the receptor, and are; higher than the minimum required for a physiological effect in the absence of ethylene competition. DACP shows similar kinetics, but with DACP the measurements [2] are based on the original compound (DACP) rather than the active component and are therefore much higher. The active DACP photolysis product would probably act at a concentration close to that found for 1-MCP.

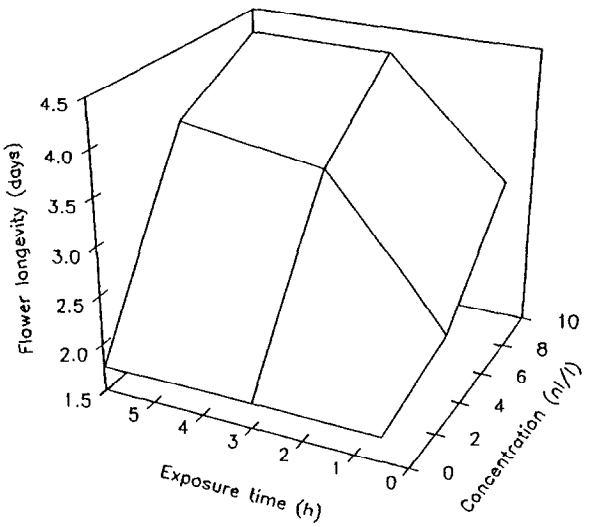

Fig. 5. Longevity of *Penstemon hartwegii* Benth. × *P. cobaea* Nutt. 'Firebird' flowers exposed to 0, 5 or 10 $nl \cdot l^{-1}$ 1-MCP for 0.5, 3 or 6 h. Flowers exposed for 0.5 or 3 h were placed after 1-MCP treatment in air, in identical tanks to those used for 1-MCP treatment, for 5.5 or 3 h, respectively. After treatment all flowers were exposed continuously to 1 $\mu l \cdot l^{-1}$ ethylene.

Source of variation:	
0.5 h vs 3 h	***
0.5 h vs 6 h	***
3 h vs 6 h	ns
Time linear	***
Time quadratic	*

(ns, ***, *) Nonsignificant or significant at $p = 0.001$, or 0.05, respectively.

4. Discussion

Our data show that 1-MCP is a very effective alternative to STS as a pretreatment for ethylene-sensitive flowers. At very low concentrations, this material is as effective as STS, not only in preventing the effects of exogenous ethylene (Table 1), but also in delaying senescence of flowers whose natural senescence is mediated by a rise in endogenous ethylene production (Fig. 3). If 1-MCP can be registered for use with cut flowers, it will have exciting commercial possibilities. 1-MCP treatment does not have the heavy metal implications of STS treatment, and there should be no waste disposal problem. Since the material is a gas, its use would obviate the need for placing flowers in additional treatment solutions, which is labor intensive. The development of a practicable system for treating flowers with 1-MCP will depend on data such as those reported here. The interrelationship that we found between treatment time and concentration (Fig. 5) clearly indicates that appropriate treatment conditions can be developed for a range of possible treatment regimes.

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