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Evaluation and improvement of post-harvest performance of cut *Viburnum tinus* inflorescence

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ABSTRACT

Post-harvest performance of cut viburnum inflorescences was examined in the present study. Harvesting viburnum at three developmental stages resulted in significant differences on flower opening rate (FOR) and flower abscission rate (FAR), but not on vase life. Harvesting at Stage III (>50% open flowers) resulted in highest flower opening percentage, whereas harvesting at Stage I (10–30% open flowers) in significantly lower flower abscission percentage. Pulsing with 20 or 40 mg/l $AgNO_3$ for 24 h extended vase life by 1.6 and 1.9 days, respectively, compared to the controls. Furthermore, flower abscission was significantly reduced after 20 or 40 mg/l $AgNO_3$ treatments by 51 and 62%, respectively, compared to the controls. In contrast, vase solutions containing 100 mg/l DICA or 100 and 200 mg/l methanol did not extend vase life of cut viburnum inflorescences, but significantly reduced flower abscission. Vase solutions containing 1 or 2% (w/v) sucrose negatively affected vase life, flower opening and flower abscission of viburnum inflorescence. Post-harvest treatments with 1-MCP at 10 μl/l in an ethylene-free environment resulted in extension of vase life and in significant reduction of FAR and respiration rates compared to the controls. Vase life of 1-MCP treated inflorescences was increased by 4.2 days compared to the controls. FAR of 1-MCP treated inflorescences remained significantly lower from the second to the eighth day of the vase life period.

1. Introduction

Viburnum (*Viburnum tinus*) is an evergreen perennial shrub native to Mediterranean regions that belongs to the Caprifoliaceae family. Viburnum is mainly used in landscape architecture exploiting its winter and early spring flowering. Viburnum leaves are single, dark green, borne in opposite pairs, 4–10 cm long and 2–4 cm broad, with an entire margin (Gilmar, 1999). Its flowers are white, lightly scented and produced in dense cymes of 5–10 cm diameter. Dark, blue-black 5–7 mm diameter fruits with significant ornamental value are produced after flower pollination. In the USA, viburnum species are commercially cultivated for their inflorescences, which are mainly used as bouquet fillers (Armitage and Laushman, 2003).

Post-harvest performance of specialty cut flowers has been evaluated in recent years. Most of these species are cultivated in small scale and used in flower arrangements. Most specialty cut flowers retain a high price off-season increasing grower's profits (Armitage and Laushman, 2003). Species such as Eucalyptus (*Eucalyptus tetragona, Eucalyptus youngiana*) (Delaporte et al., 2000), Santonia (*Sandersonia aurantica x Littonia modesta*) (Eason et al., 2001), Achillea (*Achillea filipendulina*), Buddleia (*Buddleia davidii*), Celosia (*Celosia argentea*), Cercis (*Cercis canadensis*), Cosmos (*Cosmos bipinnatus*), Echinacea (*Echinacea purpurea*), Helianthus (*Helianthus maximilianii*), and Weigelia (*Weigelia* sp.) (Redman et al., 2002) inflorescences have been examined for their post-harvest performance at different storage conditions or in response to various vase solutions. In most cases, vase life of specialty cut flowers is relatively short (i.e. 4–10 days) (Armitage and Laushman, 2003). However, their performance can often be prolonged by anti-microbial compounds in vase solutions [e.g. dichloroisocyanuric acid sodium salt dihydrate (DICA); Knee, 2000] or anti-ethylene agents [e.g. 1-methylcyclopropene (1-MCP); Bosma and Dole, 2002].

No research was found on the post-harvest behaviour of cut viburnum inflorescences. The objectives of the study were to determine the optimal harvest stage of viburnum inflorescences, increase its short vase life by using anti-microbial (i.e. methanol, DICA or $AgNO_3$) or anti-ethylene compounds (i.e. 1-MCP) and improve post-harvest flower opening by using sucrose in vase solutions.

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2. Materials and methods

2.1. Plant material

Viburnum tinus inflorescences were harvested in February–March 2008 from 5- or 6-year-old plants cultivated at the Agricultural University of Athens, Greece (37°59′01″N, 23°42′10″E). Inflorescences were harvested at three developmental stages (Stage I: 10–30% open flowers, Stage II: 30–50% open flowers and Stage III: >50% open flowers). All inflorescences were processed in the laboratory immediately after harvest. Basal leaves were removed so that all inflorescences maintained four leaves per inflorescence. The base (0.5–2 cm) of all stems was re-cut under water so that all inflorescences were 25 cm of length and uniform. Each inflorescence was stood individually into 200 ml glass vase containing 150 ml of each solution. Each glass vase was covered with a plastic (PVC) film, held by a rubber band to eliminate solution evaporation. Three individual experiments were carried out twice.

2.2. Chemical and sucrose treatments

In experiment 1, sucrose solutions were tested. One and 2% (w/v) sucrose (99.5%, Fluka, Steinheim, Germany) solutions were prepared by adding appropriate quantities in distilled water. Distilled water was used as the control. Ten-replicate viburnum inflorescences were harvested at Stage I, II or III and placed in glass vases (45 in total) containing distilled water (control), 1 or 2% (w/v) sucrose solutions.

In experiment 2, anti-microbial compounds were tested. Twenty or 40 mg/l $AgNO_3$ (99.5%, Fluka, Buchs, UK), 100 or 200 ml/l methanol (MeOH; 99.8%, Fluka, Seelze, Germany) and 100 mg/l DICA (dichloroisocyanuric acid sodium salt dihydrate 98%, Fluka, Steinheim, Germany) were used. Fourteen-replicate viburnum inflorescences harvested at Stage I were placed in glass vases (42 in total) with solutions of 20 or 40 mg/l $AgNO_3$, 100 or 200 ml/l MeOH for 24 h at 22 °C as pulse treatment (Joyce, 1988). Vases containing $AgNO_3$ were covered with aluminium foil to prevent degradation of Ag^+ by light (Pompodakis et al., 2004). After pulsing all inflorescences were placed in distilled water. Another set of fourteen-replicate inflorescences were harvested at Stage I and placed in 100 mg/l DICA solution. Control inflorescences were placed in distilled water.

In experiment 3, 60 viburnum inflorescences were harvested at Stage I. Inflorescences were separated into two groups. Three inflorescences of the first group were put into a vase containing distilled water and then placed inside a 20 l sealed container. Ten sealed containers were used from the first group of inflorescences as the control treatment. Likewise, 10 sealed containers with three inflorescences each were used for 1-MCP treatment. The three inflorescences in each container were treated with 10 μl/l 1-MCP for 24 h at 20 °C. After exposure to 1-MCP, each set of three (totally 30 inflorescences from 10 containers) inflorescences per container was placed in glass jars at 20 °C in the dark. The jars were sealed for 1 h each day and the concentration of O_2 was determined by a portable PBI Dansensor A/S (checkpoint O_2/CO_2, DK-4100 Ringste 1, Denmark).

2.3. Handling and experimental design

Following sucrose and anti-microbial treatments (i.e. experiments 1 and 2), viburnum inflorescences were placed inside a controlled environment chamber running at 20 ± 1 °C, 60 ± 10% R.H. and 12-h photoperiod provided by fluorescent lamps (18 μmol/m^2/s fluorescent light) in a randomised complete block design with sucrose concentration and harvest stage as the two experimental factors (experiment 1) or in a completely randomised design with chemical treatments as the only experimental factor (experiments 2 and 3). Assessments were taken every day (experiments 1 and 2) or every 2 days (experiment 3) from the time inflorescences were placed in the vase solutions (day-0).

2.4. Vase life assessments

Vase life (e.g. the longevity of flowers) was recorded as days from the time that inflorescences were placed into vases (day-0). The end of vase life was considered when >50% of flowers were dropped down or abscised. Inflorescences fresh weight (F.W.; calculated as the percentage of the initial value) was measured by weighing the stems with a digital balance (Kern, & Sohn Gmbh, Balingen, Germany; Joyce and Jones, 1992). The base of the stem was wiped to dry before weighing. Vase solution uptake (calculated as ml/g/day in a F.W. basis) was measured by weighing the vases (vase + content) with a digital balance (Kern, & Sohn Gmbh, Balingen, Germany; Joyce and Jones, 1992).

Flower opening rate (FOR) or flower opening (FO) was expressed as a percentage (%) calculated by the number of open flowers per total flower number per day (FOR = open/total flowers/day*100) or for the total number of days from day-0 to day-6 (FO = open/total flowers*100). Flower abscission rate (FAR) or flower abscission (FA) was expressed as a percentage (%) calculated by the number of abscised flowers per total flower number per day (FAR = abscised/total flowers/day*100) or for the total number of days from day-0 to day-6 (FA; abscised/total flowers). Percentage data were transformed ($\sqrt{x}/100$) to obtain approximately normally distributed data sets for ANOVA (Little, 1985).

Respiration rate was expressed as milliliters of consumed O_2 per kg of inflorescence fresh weight per hour (mg O_2/kg F.W./h) and recorded every second day from day-0 to day-8 with a portable PBI Dansensor A/S.

2.5. Statistical analysis

Experiments were factorial of two- (experiment 1) or one-factor (experiments 2 and 3) designs. Experiment 1 was subjected to univariate ANOVA and experiments 2 and 3 to one-way ANOVA. Means were separated using Duncan's multiple range test at $P = 0.05$. Statistical analysis was performed using SPSS version 11 software (SPSS Inc., Chicago, IL, USA) for Windows.

3. Results

3.1. Effect of harvest stage and sucrose solution

Harvesting viburnum at three developmental stages significantly ($P < 0.05$) affected flower opening and flower abscission, inflorescences fresh weight and vase solution uptake, but not vase life (Table 1). Harvesting at Stage II or III flower opening, but also flower abscission percentage significantly ($P < 0.05$) increased compared to Stage I (Table 1). Inflorescences harvested at Stage I retained fresh weight higher compared to inflorescences harvested at Stage III (Table 1).

FOR of inflorescences harvested at Stage III remained higher ($P < 0.05$) from day-0 to day-3 compared to those harvested at Stage I or II (Fig. 1A). FAR of inflorescences harvested at Stage II was higher ($P > 0.05$) from day-0 to day-4 compared to inflorescences harvested at Stage I or III (Fig. 1B).

Sucrose solutions negatively affected vase life, flower opening and flower abscission percentages (Table 1). In detail, 1 or 2% (w/v) sucrose solutions significantly ($P < 0.05$) reduced vase life, flower opening and increased flower abscission percentages (Table 1). Flower abscission of control inflorescences was greater by 2-fold,