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Effects of pre-cooling and chlorine on post-harvest quality of cut roses (*Rosa hybrida* L.)

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ABSTRACT: The aim of this study was to quantify the vase-life and water relations of cut roses in response to pre-cooling and different concentrations of chlorine in the hydration solution. Cut 'Valentine' roses were stored dry at 4 ^{o}C or 25 ^{o}C for 24 h immediately after harvest and then placed in vase-solutions containing 0, 50, 100 or 150 µl l^{-1} chlorine provided as sodium hypochlorite. The results showed significantly higher water loss in cut flowers dry stored at 25 °C in the first 24 h after harvest compared with that in cut flowers dry stored at 4 °C. A combination of dry storage at 4 ^{o}C and inclusion of 50 µl l^{-1} chlorine in the vase-solution extended vase-life by 6.1 d over the control (25 ^{o}C and 0 µl l^{-1} chlorine). Vase-solutions containing chlorine showed reduced microbial counts compared with control. Results suggest that vase-life improvements are achieved through (1) a reduction in water loss from cut stems and leaves during pre-cooling and (2) a reduction in bacterial populations present in the vase-solution. This was associated with an increase in water uptake and relative fresh weight of cut stems without any toxicity to leaves. The results also revealed that only two of eight rose cultivars showed toxicity to leaves in response to 50 µl l^{-1} chlorine, suggesting that toxicity in response to effective chlorine concentration is cultivar dependent.
Keywords: Bacterial proliferation, Vase-life, Water relation.

INTRODUCTION

The vase-life of cut rose flowers is affected by various factors such as pre-harvest growing conditions and post-harvest handling, storage and transportation (Reid, 2001; Torre and Fjeld, 2001). All these factors may result in a negative water balance (water loss >water uptake) causing wilting and bent neck. Physiologically, a negative water balance could be due to: (1) poor water uptake as a result of vascular occlusion, which inhibits water supply to the flowers (Mayaket al., 1974; De Stigter, 1980; van Doorn, 1997; Ichimuraet al., 1999; Jin et al., 2006; Robinson et al., 2009) and/or (2) a high water loss via transpiration trough stomata (Torre and Fjeld**,** 2001; Rezaei Nejad and van Meeteren, 2005).

The majority of fresh cut flowers sold in Iran are produced in the northern parts of the country. It generally takes 24 h or longer, to commercially distribute these flowers to retailers throughout the country via truck transport without any temperature control. It has been shown that commercial cut flowers are often exposed to damaging high temperatures (Maxie et al. 1973; Thompson and Reid, 1994). Poor temperature management during transport of cut flowers is largely the result of inadequate pre-cooling and transport under non-refrigerated conditions. Leonard et al. (2011) showed that temperatures during the 24-hour transport system increased steadily and temperatures were at or above 10 ^{o}C for 18 h, with half of that time above 15 ^{o}C for all shipments. There are some reports on negative effects of improper storage temperatures on vase-life of a range of cut flowers (Cevallos and Reid, 2000; Cevallos and Reid, 2001). Maxie et al. (1973) exposed 'Improved White Sim' carnation for various lengths of time to typical packing temperatures and found that holding flowers for 24 h at 20 ^{o}C reduced vase life by 25% compared with holding at 0 ^{o}C. By contrast, a short retail simulation display of 2 d found no difference in vase life of gerbera when kept at 2, 6, 10, and 21 ^{o}C (Nell et al., 2009). It has been reported that reduction of cut flower vase-life during storage is highly correlated with respiration at the storage temperature (Cevallos and Reid, 2000; Celikel and Reid, 2002). However, it is not clear to what extent high temperatures after harvest during 24h dry storage of cut flowers correlate with changes in water relation characteristics.

Previous studies have also shown that blockage of xylem vessels by micro-organisms that accumulate in the vase-solution, or in the vessels themselves, is a major cause of deterioration in cut flowers (Zagory and

Reid, 1986; Knee, 2000). Stem blockage and continuous evapo-transpiration disrupts the water relations of cut flowers (Knee, 2000) and consequently reduces vase-life (Halevy, 1976). Therefore, application of antimicrobial compounds in the water may prolong the vase-life of cut flowers (Marousky**,** 1976; van Doorn, 1997**;** Jowkar, 2006; Solgi et al., 2009**)**. A number of these compounds, however, are toxic to flowers, dangerous to human health and/or pollute environment (Damunpola and Joyce, 2006).Sodium hypochlorite as a source of chlorine is a cheap, environment friendly agent that can be used in the vase-solutions. Though it is widely used by researchers (Cellavos and Reid, 2001), a detailed study has not been carried out on the effects of this agent on flower vase-life. van Doorn et al. (1990) reported that when the concentration of the antimicrobial compound containing chlorine was high enough to reduce the number of bacteria in stems to below the detection limit, the roses (cv. Sonia) showed severe leaf chlorosis and leaf abscission. However the effect on other rose cultivars is unknown.

In the present study, we aimed to elucidate the effects of chlorine on the vase and leaf life of cut rose 'Valentine'. Moreover, we sought to examine the effects of high temperature on vase-life and water relations of cut rose flowers during 24 h of dry storage after harvest, simulating conditions before and during transportation in Iran.

MATERIAL AND METHODS

Plant material and experimental conditions

Cut rose flowers (*Rosa hybrida* L.'Valentine') were obtained from a local commercial grower in Iran. Flower stems were harvested at normal harvest maturity (sepal starting to reflex) early in the morning, wrapped in newspaper and transported to the laboratory of Lorestan University (a distance of 5 km). The weight of the cut flowers was recorded and half of the cut flowers were then placed in a cold room at 4 ± 1 ^{o}C (Treatment 2) and the other half were placed in the test room at 25 ± 1^{o}C (Treatment 1) for 24 h. All cut flowers were wrapped in newspaper and covered with black plastic bags during storage. After storage, flower stems were weighed again to calculate the water loss during the first 24 h. The stems were then re-cut under water to a stem-length of 45 cm and all leaves except for the upper three were removed. Single flower stems were kept in 500 ml conical flasks, each containing 400 ml vase-solutions of 0, 50, 100 or 150 µl l^{-1} chlorine using sodium hypochlorite (13% active chlorine, Acros Organics N.V., NJ). Distilled water was used for vase-solution preparations. The mouths of the flasks were covered with aluminum foil to prevent evaporative water loss. The experimental conditions were a temperature of 25 ± 2^{o}C, 60% relative humidity, and a 12-h photoperiod under 10 µmolm^{-2}s^{-1} irradiance provided by cool-white fluorescence lamps.

Measurements of vase-life, leaf-life and water relation parameters

The fresh weight of cut flowers and the amount of water uptake were measured daily. Longevity of flowers and leaves was recorded as vase-life and leaf-life (in d), from the time the cut flowers were placed in conical flasks (day-0). Flowers were considered to be at the end of their vase-life when the whole flower wilted (Pompodakis and Joyce, 2003; Kumar et al., 2008). The leaf-life was considered to be at the end when two of the three leaves on each stem wilted, dried or abscised.

Bacteria enumeration

At 2 d intervals, sampling from each vase-solution was carried out until day-6 of the experiment. After serial dilutions, samples of vase-solution were plated onto nutrient agar and incubated for 48 h at 30°C. The number of micro-organisms was counted by the standard plate counting method to determine the number of Colony Forming Units ml^{-1} (CFU ml^{-1}) (Jowkar, 2006).

Cultivar differences in response to sodium hypochlorite

To test the response of different rose cultivars to sodium hypochlorite, in a separate experiment, eight cut rose cultivars, namely 'Valentine', 'King Pride', 'Prima Donna', 'Black Baccara', 'Victory', 'Papagayo', 'Royal Baccara' and 'Yellow Island' were obtained from the same company as used above and transported to the laboratory. Flower stems were placed in tap water and used for experiments within one hour after harvest. Flower stems were re-cut under water to a stem-length of 45 cm and all leaves except for the upper three leaves were removed. Single flower stems were kept in 500 ml conical flasks, each containing a 400 ml vase-solution of 50 µl l^{-1} chlorine provided as sodium hypochlorite. Distilled water was used for vase-solution preparation. The abovementioned conditions were applied and leaf-life was recorded.

Data collection and statistical analysis

Storage of cut flowers at 4 °C and 25 °C during the first 24 h after harvest and inclusion of four concentrations of chlorine using sodium hypochlorite (0, 50, 100 and 150 µl l^{-1}) in the vase-solutions was combined factorially based on a randomised complete block design (RCBD) with four replications. The