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Short communication

Combined preharvest and postharvest treatments affect rapid leaf wilting in *Bouvardia* cut flowers

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ABSTRACT

Bouvardia is an ornamental shrub, commercially cultivated as flowering stem. Occasionally, negative water balance, which leads to rapid leaf wilting, ends vase life immediately. This work studies the effect of preharvest and postharvest conditions on vase life, water uptake and transpiration. Stems grown at moderate RH show a significantly longer vase life, lower water uptake and transpiration rate compared to those grown at high RH. Postharvest treatments overcoming air emboli and wound response had a positive effect on vase life. One of the treatments to overcome air emboli, surfactant treatment, increased water uptake and transpiration rate compared to control. Higher water deficit was measured in stems that had reduced vase life. Stomata malfunction (not closing in response to closing stimuli) resulting from high air humidity during growth conditions is likely one cause for the negative water balance. A combination of high transpiration rate (due to high RH) and hindering of vase water uptake (due to air emboli and/or stem-wounding responses) is likely the main reason for early wilting of *Bouvardia* leaves and short vase life.

1. Introduction

Bouvardia is a genus of flowering shrubs in the *Rubiaceae* family native to Mexico and Central America, which contains about 30 species of shrubs. Each stem has a small inflorescence of flowers that can occur in various shades of pink, yellow, orange, red and white. *Bouvardia*, as a cut flower, currently does not have a large market, but this market is growing rapidly. Vase life of *Bouvardia* can reach between 10 and 14 days, but the problem of rapid leaf wilting often results in much shorter vase life, occasionally even less than one day (van Doorn et al., 1993; van Meeteren, 1990; Woltering and van Doorn, 1988).

The rapid leaf wilting disorder may be caused either by an inhibition of water uptake, or by a high transpiration rate of water through the stomata or by both. Water uptake of cut flowers can be blocked either by bacteria or by enzymatic wound responses that clog the xylem bundles, or by air emboli that inhibit water flow (van Meeteren, 1992; van Meeteren et al., 2006; van Meeteren and Schouten, 2013; Vaslier and van Doorn, 2003). In *Bouvardia*, rapid blockage of the xylem conduits causes premature wilting of the flowers and the leaves (Woltering and van Doorn, 1988). Van Meeteren (1990) found that air emboli were the main cause for rapid leaf wilting in *Bouvardia* and that adding surfactant to the vase water directly after harvest could restore this. High transpiration can also lead to rapid leaf wilting. The problem occurs mainly in winter, and varies between growers. It seems to have aggravated due to growing practices that emphasize energy saving strategies; which include closing the greenhouse as much as possible leading to high greenhouse air humidity (Gelder et al., 2012; Marcelis et al., 2014). Growing at high humidity can lead to stomata malfunction: stomata that do not close at low leaf water potential. This phenomenon occurs in many species, *e.g.* rose, spiderwort, bean and chrysanthemum, when air humidity is high during cultivation, even if it is only for a few days (Aliniaeifard and van Meeteren, 2013, 2016; Arve et al., 2013; Fanourakis et al., 2012; Rezaei Nejad and van Meeteren, 2005).

The unpredictable nature of the rapid leaf wilting may point to the involvement of multiple factors that do not always contribute equally. As far as we know, there has been little work done on the effect of preharvest and postharvest conditions combined. In this short communication, we demonstrate that a combination of high greenhouse air humidity (RH), air embolism and stem wound response is responsible for rapid leaf wilting in 'Daphne Fresco', a modern *Bouvardia* cultivar.

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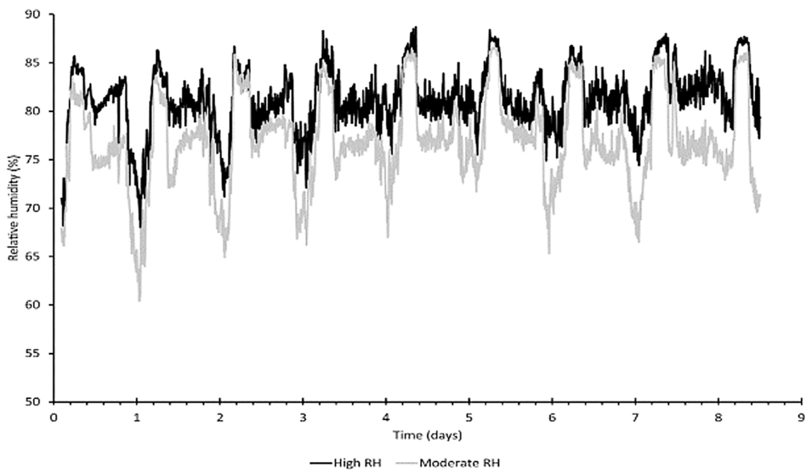

Fig. 1. Air humidity readings in the greenhouse plots. Measurements where performed from 16 to 25 January 2016; *i.e.* the last 8.5 days before harvesting.

2. Material and methods

2.1. Plant material and growth conditions

Bouvardia (*Bouvardia spp.*) plants were grown in a greenhouse of the flower nursery Chrywijk (Brakel, The Netherlands) as clones from 2-week-old cuttings. Temperature was set to 24 °C and *Bouvardia* were grown either at moderate, or high relative humidity (RH), the later was elevated by surrounding each plot of plants with light plastic cloth. Apart from these climate conditions, standard greenhouse conditions were applied. Greenhouse climate was measured using data loggers (KeyTag KTL-508, Leiderdorp, The Netherlands). Plants were grown for 8–9 weeks until harvest at the 25th of January 2016. Flowers were harvested when they had fully developed and coloured flower buds in the morning at 7:00, mechanically cut, and sleeved in plastic bags per ten stems afterward. Stems were stored dry at room temperature, sleeved in plastic bags per ten stems, before transport to the lab in Wageningen, which all took 4 h.

2.2. Postharvest treatments

Five postharvest treatments were applied to ten flowers from each greenhouse environment. Flowers were placed in the following treatments overnight before vase life evaluation. (1) Control: tap water, only mechanically cut at harvest. (2) Recut: tap water, 3 cm stem cut under tap water. (3) Surfactant: tap water with 0.1 g l^{-1} Triton X-100 [Fluka]), 3 cm stem cut under treatment solution. (4) Wound inhibitor: tap water with 2 mM hydroquinone (*tert*-Buthylhydroquinone [Fluka]) (Çelikel et al., 2011), 3 cm stem cut under treatment solution. (5) Cold: cold tap water (4 °C), 3 cm stem cut under tap water. Treatment 5 was kept at 4 °C overnight. The other treatments were placed overnight at room temperature. Stems were bundled in bushes of ten and wrapped in plastic to regain maximum fresh weight during the overnight application of the postharvest treatments. After overnight treatment, stems were rinsed and individually placed in Erlenmeyer flasks containing 300 ml tap water at standard vase life conditions.

2.3. Vase life, water uptake and transpiration rate

Starting fresh weight of individual flowering stems was measured after the stem was cut, before and after the overnight treatment. Each day, leaves of each stem were scored for wilting. Vase life ended when stems showed more than 50% of its leaves wilting. The weight of an Erlenmeyer flasks vase with and without flowering stem was determined on successive days between 11:00 and 13:00 to calculate water uptake and fresh weight. Water uptake and transpiration rate (in ml h^{-1} g^{-1}) were calculated using the difference in weight between two successive measurements, per number of hours during that interval and per g fresh weigh at the start of vase life (van Meeteren, 1992). Water balance was calculated by subtracting water uptake from transpiration.

2.4. Data analysis

End of vase life was determined for each individual stem. Vase life, water uptake and transpiration were analysed as function of the greenhouse environment and postharvest treatments applying 2-way ANOVA. Means were compared by the Tukey-Kramer multiple comparison test at $p = 0.05$.

3. Results

3.1. Greenhouse climate

During our experiment, the high RH was, on average, 5% higher than the moderate RH, and daily, the maximum difference is often larger than 10% (Fig. 1). Temperature was almost the same in both compartments, with a slightly lower average temperature (−0.1 °C) in the low RH treatment.

3.2. Vase life

Stems grown at moderate RH had an average vase life of 5.5 days and stems grown at high RH showed a significantly lower average vase life of 4.8 days ($p = 0.02$) over all postharvest treatments. For the postharvest treatments, highly significant differences were obtained ($p < 0.001$). Surfactant and cold treatment increased vase life significantly compared to control (Table 1). No significant interaction between RH and the postharvest treatments is present ($p = 0.293$).

The percentage of wilted stems on day 2 and day 4 was analysed to indicate vase life issues over time (Table 2). Already at day 2, and also after 4 days, most stems grown at high RH show a higher percentage ‘end of vase life’ than those grown at moderate RH. Wound inhibitor treatment seems to delay the wilting, but not as much as cold treatment or surfactant. (Table 2). Recutting hastened the wilting.

3.3. Water uptake and transpiration

At day 2, water uptake and transpiration rates show, both for RH ($p < 0.001$) and the postharvest treatments ($p = 0.007$) significant differences. Higher water uptake and transpiration was encountered at high RH. Higher water uptake and respiration for the surfactant treatment was found compared to control (Table 1). Our experimental set up did not show an interaction between RH and the postharvest treatments