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The influence of water stress and air velocity on growth of *Impatiens walleriana* and *Petunia* × *hybrid*

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ABSTRACT

Impatiens walleriana 'DeZire' and *Petunia* × *hybrid* 'Tidal Wave' were subjected to a combination of water stress and exposure to wind to evaluate the potential application of these treatments as an alternative to chemical growth retardation. Air velocities evaluated were 0.1, 0.2, 0.4, 0.8, 1.5, and 4.5 m s^{-1} and irrigation treatments were either control or 45% water stress based on irrigation occurring when the weight of the plant (plant, pot and peat) was reduced by 25% (control) or 45% (water stress) of the initial weight. The experiment was repeated twice; once in spring and once in summer.

Water stress did not significantly influence growth of *Impatiens* while increasing air velocity resulted in decreasing plant height, but the only significant effect was obtained at air velocity of 4.5 m s^{-1}. Air velocities at or over 0.8 m s^{-1} resulted in significantly lower fresh weight of the plants, while dry weight was significantly lower at air velocities higher than 0.1 m s^{-1}.

The plant height of *Petunia* was different in the two replicates and an interaction between water stress and air velocity was determined in the first replicate, in which air velocity did not influence plant height of water stressed plants. Water stressed plants of *Petunia* had significantly lower fresh weight of the plants and increased air velocity reduced the number of flower buds and fresh and dry weight of the plants.

1. Introduction

In the production of ornamental plants, chemical growth retardants are used to control plant height. From an environmental perspective, the use of chemical growth retardants should be minimised or eliminated. To do so, alternative methods should be developed that are environmentally friendly and that are able to control plant height to the same extend as chemical growth retardants.

Reduced fertilisation with phosphorus or reduced water availability reduces stem elongation, but not with same efficiency as chemical growth retardants (Petersen and Hansen, 2003; Hansen and Petersen, 2004). The reaction of bedding plants to irrigation level has been investigated with regard to compactness (Van Iersel and Nemali, 2004) and plant quality (Henson et al., 2006). Van Iersel and Nemali (2004) evaluated the effect of water content in the peat substrate and reported that plant height, shoot dry weight and leaf area of *Tagetes erecta* L. decreased with decreasing water content. Van Iersel and Nemali (2004) defined compactness as an increase in leaf area or dry weight per unit plant height. They concluded that the plants were not more compact with decreasing water content in the peat substrate, because shoot dry weight and leaf area per unit plant height decreased linearly with decreasing water content.

Petunia performed best and *Impatiens* poorest in a field experiment where the levels of irrigation were based on potential evapotranspiration (ET) (Henson et al., 2006). Petunia was able to maintain an acceptable ornamental value and biomass production at all irrigation level from 0 to 100% of ET. At an irrigation level of 75% of ET, *Impatiens* did not perform well and the ornamental value was reduced, together with a 50% reduction in biomass production (Henson et al., 2006). Unfortunately Henson et al. (2006) did not provide any information on soil tension, but only information on the amount of water applied.

Reduced plant height may be obtained by mechanical stress in the form of brushing the plant shoots and this method reduced stem elongation in tomato plants while the plants were still placed in plug trays (Garner and Björkman, 1996). The effect of brushing was dependant on the number of strokes and time of the day. In contradiction to this Garner and Langton (1997) did not find an effect of timing of the treatment, which was either 10 or 20 strokes per day, on *Viola tricolour* by brushing, but brushing reduced elongation of the petiole by 25–30%. Brushing reduced stem elongation in *Callistephus chinensis*, *Senecio bicolour* and *Petunia* × *hybrida* and a visible effect was realised after 20 days but time to visible effect

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was depending on the brushing duration (Autio et al., 1994). In the same experiment it was observed that two weeks after cessation of the brushing treatments the difference in plant height between brushed plants and unbrused was levelled out.

In nature, the effect of wind on plant growth is observed, e.g. biomass distribution (Coutand et al., 2008) and plant height (Meng et al., 2006), and a higher air velocity in a greenhouse can be established by the use of fans. Most often horizontal air flow is used in greenhouses but air velocity varies according to the distance from the fan and on average the air velocity observed in the greenhouse is approximately 1 m s^{-1} compared to 0.1 m s^{-1} without fans (Fernandez and Bailey, 1994).

In climate chambers with either horizontal or upward or downward air flow a higher plant dry weight, larger leaf area and shoot length of tomato seedlings was reported in an environment with upward or downward air flow as compared to horizontal airflow (Shibuya et al., 2006). The air velocity was not identical in the three treatments and the air velocity range was 0.12–0.27 m s^{-1} for the horizontal air flow and in the range of 0.03–0.11 m s^{-1} for the two other air flows.

In an experiment with humidity and air velocity Mortensen and Gislerød (1997) did not find any influence of air velocities at 0.08, 0.21 and 0.35 m s^{-1} on the growth of cut roses, except that flowering was delayed at the highest air velocity.

Air velocities of 2.2 and 6.0 m s^{-1} had a significant influence on plant height, number of leaves, leaf area and biomass of *Sinapis alba* compared to plants grown at an air velocity of 0.3 m s^{-1} (Retuero and Woodward, 1992). Van Gaal and Erwin (2005) found that stem elongation in tomato plants was inhibited at an air velocity of 8 m s^{-1} and that the largest effect was found when the plants were exposed to high air velocity continuously for 24 h a day.

Work on air velocity and transpiration has been carried out by Chu et al. (2009) on well-watered *Pachira macrocarpa*. The experiment was conducted in a wind tunnel with a single plant. Chu et al. (2009) found that the sap flow was lacking behind increasing air velocity and that it took approximately 30 min before a steady sap flow was reached. At air velocities higher than 8 m s^{-1} there was no additional increase in sap flow and the sap flow decreased rapidly when air velocity was decreased.

The influence of irrigation and air velocity on plant growth is seldom described however, Katsoulas et al. (2006) measured the change in leaf area index of cut roses over time for two different irrigation frequencies controlled by solar radiation. Irrigation levels of 0.2 and 0.4 mm evapotranspirated were used, and the amount of water applied was equal in the two treatments, because the half amount of water was given at 0.2 mm of evapotranspiration. No significant difference in leaf area index was found but there was a marked trend showing reduced development in leaf area. The irrigation method used exposes the plant to episodic drought because a replenishment of water occurs at irrigation and this could be a reason for the lack of effect.

The water content in peat rapidly declines to a tension of approximately 100 hPa, after which the decline is much slower and becomes more linear. The high amount of available water makes peat suitable as growing substrate for container grown plants, but it may be a disadvantage in relation to water stress, that the wilting point is very sharp.

To my knowledge, studies on the combination of water and increased air velocity for reduction of stem elongation have been used through the whole production, are not reported in the literature.

The objective of the experiment was to reduce stem elongation by a combination of environmental and mechanical stresses. Air velocity influences the water loss from the leaves, whereas water stress influences the water uptake by the root. The hypothesis is that water stress reduces stem elongation and that the stem elongation can be further reduced if air velocity in the greenhouse is increased.

2. Materials and methods

The heating set point was 15 °C and ventilation started at 20 °C. The aluminised shading screens has a shade factor of 60% were closed at 600 W m^{-2} and used during night for energy saving. The CO_2 concentration was kept at 600 ppm except during ventilation. The dew point temperature (HMT330, Vaisala, Finland) in the canopy was measured at an air velocity 1.5 m s^{-1}. Indoor air temperature was measured at plant height in an aspirated screen and outdoor air temperature was measured in a sensor shelter placed at 2 m height.

Impatiens walleriana 'DeZire' and *Petunia × hybrid* 'Tidal Wave' were seed propagated and the plants were transplanted three weeks after germination. Eight days after transplantation the treatments were started.

For the experiment all plants were grown on flood/drainage benches. The plants were irrigated when the weight of the plant (plant, pot and peat) was either reduced by 25% (control) or 45% (water stress) of the initial weight, equivalent to a soil moisture tension of approximately 100 and 600 hPa, respectively. Irrigation was initiated based on weight loss, when the weight of 3 out of 4 plants reached the minimum weight either 25 or 45% of the full irrigated weight. The weight of the pots was continuously measured by a load cell connected to a datalogger, for further details see Andersson (2001).

Water potential was determined by tensiometer, the percent moisture by volume in relation to tension was calculated based on information from Karlovich and Fonteno (1986).

Plants were exposed to air velocities of 0.1, 0.2, 0.4, 0.8, 1.5, and 4.5 m s^{-1}, where 0.1 m s^{-1} is the typical air velocity in greenhouse when the vents are closed and is designated as unexposed. The air velocity was increased by fans with horizontal air flow and the plants were exposed to increased air velocity in sequences of 5 min with the fans running and a 10 min break, running 24 h a day.

All climatic parameters (air velocity, air temperature, dew point temperature and solar radiation) were measured continuously throughout the experiment.

Eight plants per plot were used and the plot was repeated twice. The experimental design was a split-plot design with water stress as the whole plot factor and air velocity as the split-plot factor. The experiment was repeated twice in time (spring and summer) and data analysed with PROC MIXED (SAS Institute) with the repetition of the experiment and water stress as random factors. The advantage of a split plot design is the relatively high statistical power for the sub plot (air velocity) and the disadvantage is the more conservative degrees of freedom used in the test of the whole plot factor (water stress) and for the interaction between whole plot and sub plot factors. However, the environmental difference between the two irrigation levels could be documented by tensiometer measurements and climatic conditions.

The experiment was conducted from April 24 to May 25 in 2008 (spring trial: replicate 1) and July 9 to August 11 in 2008 (summer trial: replicate 2).

3. Results

3.1. Greenhouse climate

The average day temperature in the two replicates was very similar, whereas the average night temperature was approximately 3 °C higher in the second replicate (Table 1). This was due to a