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Designing greener cities with water use efficient medicinal and aromatic plants

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Abstract

In the Mediterranean urban environment, plants have to face several abiotic conditions (e.g. air pollution, water scarcity, soil contamination) that can represent sources of stress, compromising their growth and aesthetic qualities.
Medicinal and aromatic plants (MAPs) have generally limited water and nutritional needs and high tolerance to contaminants, such as heavy metals. These low maintenance requirements, together with a high aesthetic value, make MAPs more and more used in urban green areas. *Salvia* spp. and *Helichrysum* spp. with abundant and long lasting blooms and grey foliage, are widely employed as ground cover, traffic divider, borders, road slopes and roundabouts and for vertical gardens. In terms of increasing biodiversity more generally, MAPs can also represent a sink of abundant nectar for pollinating insects even in the urban environment.
In the present study, we analysed some of the most important MAPs used in urban green areas, highlighting their water needs.

Keywords: green urban area, *Helichrysum*, MAPs, *Salvia* spp., water stress

INTRODUCTION

Several species are commonly used in the design of green cities (Arslan and Yanmaz, 2010). The main strategies of choice are currently based on the use of plants with low running costs. Among the usable herbs, medicinal and aromatic plants (MAPs) play an important role due to their growth and ornamental qualities but, above all, because of the limited water and nutritional need and high tolerance to contaminants (Jeliazkova et al., 1998; Arslan and Yanmaz, 2010).

In the Mediterranean urban environment, the main limiting factors for plant growth are the low availability of water resources and the heavy metal pollution. In addition, the decrease of water contributes to the increase in soil salinity, resulting in further limited productivity and growth of cultivated plants (Caser et al., 2013a,b). Urban soil is also characterized by a high heterogeneity in terms of composition. This is the result of repeated mixing of debris, filling materials and foundry remains, as well as the consequence of multiple contaminations due to anthropic activities (Craul, 1992; Larcher et al., 2012).

All these conditions of abiotic nature are sources of stress for plants in the urban environment and can compromise their growth and aesthetic qualities. It is obvious, therefore, that the design and management of a green city should be carried out professionally and can not ignore specific knowledge about plant and *ad hoc* cultivation.

Due to the sessile life cycle, plants have evolved mechanisms to respond and adapt to adverse environmental stresses during their development and growth. Plant growth is impaired by drought stress due to a decrease in stomatal opening, which limits CO_2 uptake and hence reduces photosynthetic activity. It is therefore essential to understand the various regulatory mechanisms that control and enhance adaptive responses to stress in different plant species. As indicated by Farahani et al. (2009), the decrease in the water regime has been used to reduce the size of *Calendula* plants. Aliabadi et al. (2009) describes how water stress conditions reduces the production of dry matter in *Melissa*.

MATERIALS AND METHODS

Here, a pilot study was conducted by analysing the physiological responses of *Salvia dolomitica*, *Salvia sinaloensis* and *Helicrhysum petiolare* plants to full (12 plants each) or no irrigation (12 plants each). Plants were cultivated as indicated in Caser et al. (2016) and maintained in an unheated greenhouse with photoperiod of 12h (300 PAR) located in Grugliasco (TO, Italy).

The physiological measurements were conducted at 10–12 a.m. Midday leaf water potentials (MLWP, MPa), measurement of the internal CO_2 concentration (*Ci*), the transpiration rate (*E*), the stomatal conductance (GH_2O), and the net photosynthetic rate (*A*) and relative statistical analyses were performed as previously indicated in Caser et al. (2016; 2017).

RESULTS AND DISCUSSION

Recently, Caser et al. (2012; 2016), studied morphological and eco-physiological responses to different irrigation levels of *S. dolomitica*, *S. sinaloensis* and *H. petiolare* plants. The studied species were generally able to withstand the water stress, each of them acting a specific behaviour to grow and maintain their ornamental quality, thus being suitable for use in Mediterranean green areas with limited water availability.

Here, additional physiological studies were conducted to determine the minimal water needs of the previously listed species and results are reported in Figure 1, 2 and 3.

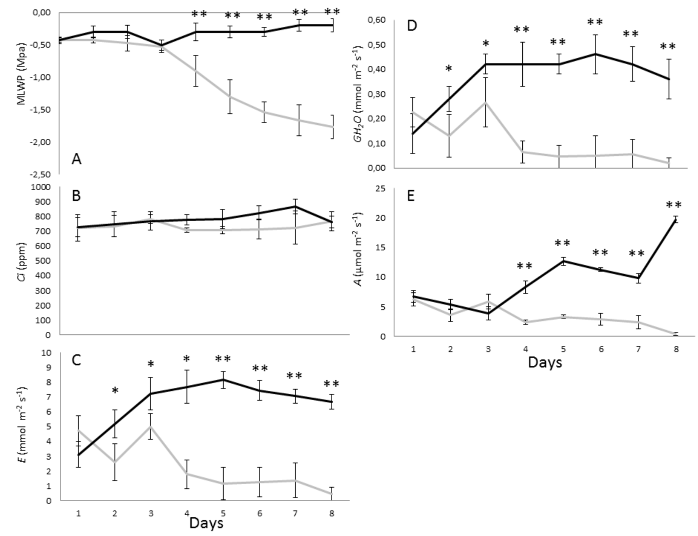

Figure 1. Dynamics of midday leaf water potential (MLWP, MPa) (A); internal CO_2 concentration (*Ci*) (B); transpiration rate (*E*) (C); stomatal conductance (GH_2O) (D); and net photosynthetic rate (*A*) (E) in *Salvia dolomitica* plants subjected to full irrigation (solid black line) or no irrigation (solid grey line). Each time point represents the mean values of twelve replicas and the vertical bars indicate standard errors. The statistical relevance of 'Between-Subjects Effects' tests (*P ≤ 0.05, **≤0.001) was evaluated.

Significant differences in MLWP were observed between full or not irrigated plants in all the species, starting from the day 4, 7 and 1 in *S. dolomitica*, *S. sinaloensis* and *H. petiolare*, respectively. A constant decrease occurred till the complete loss of the leaf turgor which happened at day 8, 11 and 11, respectively (MLWP = −1.77, -1.00 and -1.30 MPa, respectively; Fig. 1A; 2A; 3A), showing that these two lasts could be indicated as more resistant to water shortage.

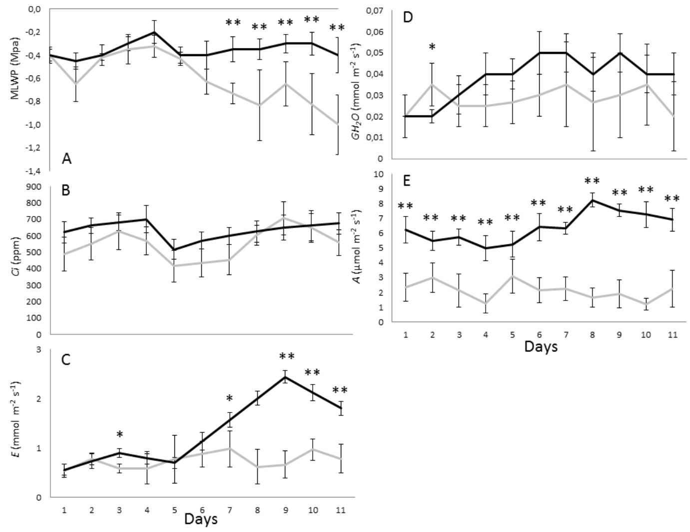

Figure 2. Dynamics of physiological parameters in *Salvia sinaloensis* plants subjected to full irrigation (solid black line) or no irrigation (solid grey line) were reported as in Figure 1. Statistical analyses were conducted as indicated in Figure 1.

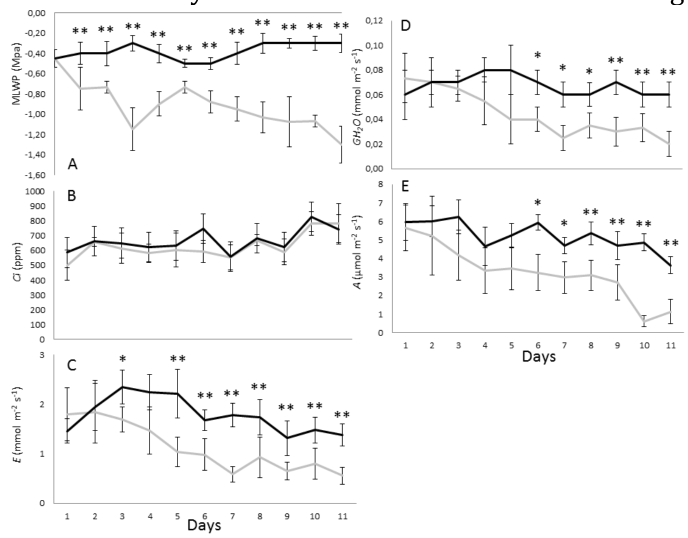

Figure 3. Dynamics of physiological parameters in *Helichrysum petiolare* plants subjected to full irrigation (solid black line) or no irrigation (solid grey line) were reported as in Figure 1. Statistical analyses were conducted as indicated in Figure 1.

No differences between full or not irrigated plants were observed in the content of *Ci* in all the studied species (Fig. 1B; 2B; 3B). Regarding parameters *E* and *A*, in all the studied species was observed a similar trend with a significant increase in fully irrigated plants starting from day 1 and 4 in *S. dolomitica*, 7 and 1 in *S. sinaloensis* and 5 and 6 in *H. petiolare*, respectively (Fig. 1C, E ; 2C, E; 3C, E). These findings highlighted how in all the treated plants, transpiration rate and photosynthesis were severely affected by water stress. In particular, both sages showed an early decrease in photosynthetic activity instead of *H. petiolare*. In *S. sinaloensis*, this happened already since the first day of treatment.

Regarding stomatal conductance, here, a stomatal limitation to photosynthesis occurred in *S. dolomitica* and *H. petiolare*, starting from day 2 and 6, respectively (Fig. 1D and 3D). Conversely, in *S. sinaloensis* (Fig. 2D) no statistical differences between treatment occurred, highlighting variability in physiological responses within the same genus. Stomatal limitation is the first major event that generally occurs in response to water stress

(Grassi and Magnani, 2005). The opening and closing of stomata is regulated by changes in turgor pressure in the guard cells that are present in epidermis and, hence, this process protects plants from the dehydration and death during fluctuating environmental conditions (Siddique et al., 2016). By the comparison of all the presented results with the previous studies (Caser et al., 2012; 2016), resulted that *S. sinaloensis* seems to tolerate moderate to severe drought conditions, without a complete stomatal closure and maintaining a minimal photosynthetic activity.

Overall, the tested species showed a general tolerance to drought stress with particular mention for *S. sinaloensis* and *H. petiolare*, thus their use in urban horticulture for low maintenance green areas appears feasible.

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