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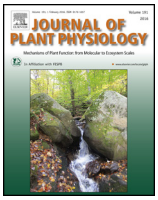

Changes in growth, physiological parameters and the hormonal status of *Myrtus communis* L. plants irrigated with water with different chemical compositions

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ABSTRACT

Myrtus communis, an important Mediterranean ornamental shrub, was used to study the effect of irrigation water with different chemical compositions in the plant response. A treatment with NaCl was used to establish the plant resistance to high salinity at long term. Plants were subjected to four irrigation treatments with drainage for three months: Control (0.8 dS m^{-1}); two treatments using reclaimed water (RWs): RW1 (2.0 dS m^{-1}) and RW2 (5.0 dS m^{-1}); and NaCl (10.0 dS m^{-1}). High levels of electric conductivity of RWs not affected plant growth, while NaCl decreased leaf dry weight. Coinciding with the accumulation of Na$^+$ and Cl$^-$ in the roots, soil water potential decreased, which hinders the mobilization of water to the leaves, decreasing leaf water potential. The osmotic adjustment in the NaCl treatment was due to Na$^+$ and Cl$^-$ ions, although the proline could contribute as an Osmo compatible solute, increasing the turgor plants. Also changes in cell walls rigidity minimize the negative effects on the water balance; however, a higher lipid peroxidation was observed in these plants. Stomatal closure was associated with a decrease in K$^+$ and an increase in abscisic acid. NaCl produced an increase in salicylic acid and did not affect jasmonic acid contents at the end of the experiment. Similar behavior in soil and leaf water potentials, although less pronounced than in NaCl, was shown in RW2 plants. The abscisic acid increased in the RW2 with respect to the control and a decrease in stomatal conductance was observed at the end of the experiment. Plants irrigated with RW1 behaved similarly to the control.

1. Introduction

Regions with a Mediterranean climate suffer a permanent scarcity of conventional water resources. This situation poses a double challenge, i.e., whether to use less freshwater for irrigation and urban needs or to use unconventional alternative water resources in order to preserve natural fresh water (Fereres and Connor, 2004; Pedrero et al., 2012). In this respect, reclaimed water (RW) are an example of an effective alternative to increasing exploitation of natural resources (Yermiyahu et al., 2008). Reclaimed water (RW), characterized by a high nutrient load (Ca^{2+}, K$^+$, Mg^{2+}, P and S) and a high concentration of phytotoxic ions (Na$^+$, Cl$^-$ and B^{3+}), have been used in several recent studies (Acosta-Motos et al., 2014a,b; Gómez-Bellot et al., 2014, 2015a,b). However, this type of water requires fundamental disinfection processes before it can be used, including tertiary treatments to eliminate the presence of certain pathogenic microorganisms. These treatments are considered

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Abbreviations: ABA, abscisic acid; DW, dry weight; EC, electrical conductivity; FW, fresh weight; g_s, stomatal conductance; HPLC, high performance liquid chromatography; IAA, indoleacetic acid; J, absorption rate of ions by roots; JA, jasmonic acid; LP, lipid peroxidation; MDA, malondialdehyde; NETD, noise equivalent temperature difference; PAR, photosynthetically active radiation; P_n, net photosynthetic rate; RH, relative humidity; RW, reclaimed water; RWC$_{tlp}$, relative water content at the turgor loss point; SA, salicylic acid; T, leaf temperature; TBA, thiobarbituric acid; TBARS, thiobarbituric acid-reactive-substances; TCA, trichloroacetic acid; WFC, weight at field capacity; Ψ_r, soil water potential at the root surface; Ψ_1, leaf water potential; Ψ_s, leaf osmotic potential; Ψ_t, leaf turgor potential; Ψ_{100s}, leaf osmotic potential at full turgor; Ψ_{tlp}, leaf water potential at the turgor loss point; ε, ulk modulus of elasticity.

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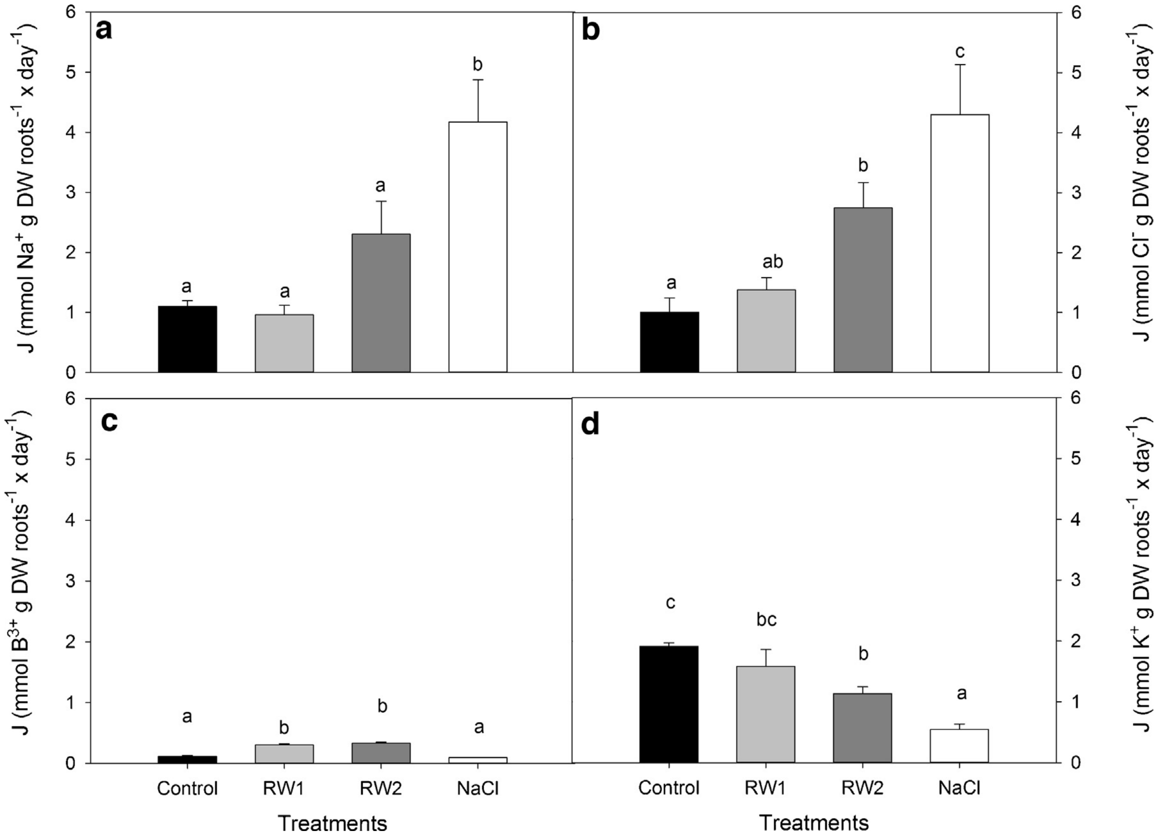

Fig. 1. Effect of the different irrigation treatments on the absorption rates of Na$^+$ (a), Cl$^-$ (b), B^{3+} (c) and K$^+$ (d) ions in *M. communis* plants at the end of the experimental period. Data are means of 6 calculations ± standard error (SE). Different letters in each column denote significant differences at $P < 0.05$ according to Duncan's Multiple Range Test.

necessary but are not so important when reclaimed water is used for the irrigation of ornamental plants whose visual appearance is the most important criterion to be considered (Gori et al., 2000; Álvarez et al., 2013).

Furthermore, it is known that about a third of cultivated lands are affected by salinity. In coastal areas or semiarid environments, this problem is accentuated by the high demand for high quality water for urban uses (Cassaniti et al., 2009). Therefore, in regions without adequate infrastructure to produce regenerated water, the use of marginal water still containing salts could be a solution for ornamental plant irrigation (Chartzoulakis et al., 2002; Acosta-Motos et al., 2015a,b). Moreover, using salt tolerant plants in landscaping and xeriscaping projects and in public areas would reduce the problem even further (Navarro et al., 2007). Among the species that can be used, myrtle plants are of particular interest because they show tolerance to different abiotic stresses, as described in Acosta-Motos et al. (2014a,b, 2015a), Navarro et al. (2009).

The responses to salinity in several ornamental plants studied vary, as has been observed with reclaimed water (RW) (Acosta-Motos et al., 2014a,b; Gómez-Bellot et al., 2014, 2015a,b) or saline water (NaCl) (Álvarez and Sánchez-Blanco, 2014; Acosta-Motos et al., 2015a,b). Salt stress is known to produce nutritional disorders, which affect the availability of nutrients through absorption and transport within the plant, changing the quality of vegetative organs (Grattan and Grieve, 1994, 1999a,b). High salt concentrations produce alterations in water relations and gas exchange, and mineral distribution (Cassaniti et al., 2009). Depending on the composition of the salt solution, ionic toxicity or nutritional deficiencies may occur due to competition between cations and anions (Shannon and Grieve, 1999). In reclaimed water used for irrigation, the presence of nutrients can offset or reduce the incidence of damage caused by salt (Pedrero et al., 2012; Acosta-Motos et al., 2014a,b; Gómez-Bellot et al., 2014, 2015a,b). In addition, the use of drainage, leaching the accumulated salts, may minimize the negative effects of salinity. As is known, another factor to consider is the time of exposure to salinity. Early responses to salt stress on several ornamental species showed that it appeared to be tolerant to high salt concentrations. While, for long periods, salinity could delay their recovery and even cause permanent damage (Álvarez and Sánchez-Blanco, 2014). In the case of myrtle plants, previous research results indicated that these plants subjected to solutions of NaCl (4 and 8 dS m^{-1}) for up to 30 days accumulated toxic ions in roots in order to avoid leaf toxicity, and keep their water status and stomata regulation in order to limit water loss (Acosta-Motos et al., 2015a). Nevertheless, the response to NaCl solutions with high electrical conductivity has not yet been studied in this plant at long-term.

Moreover, in response to situations of high salinity, changes in gene expression may be mediated by plant hormones such as abscisic acid (ABA), salicylic acid (SA), jasmonic acid (JA) and indole acetic acid (IAA). Assays on the ecophysiological response and induction of phytohormones in plant species under different conditions of abiotic stress have been described by several authors (Albacete et al., 2008; Arbona and Gómez-Cadenas, 2008; Ghanem et al., 2008; De Ollas et al., 2015; Gómez-Cadenas et al., 2015; Puértolas et al., 2015).

In this study, the response of myrtle plants to watering with two reclaimed water was evaluated under controlled environmental conditions to check if under such conditions the components of these water could be of benefit to these plants, despite the high salinity. In addition, the physiological response to salinity was