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Identification of ornamental shrubs tolerant to saline aerosol for coastal urban and peri-urban greening

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ABSTRACT

Salt spray can be an important abiotic stress that strongly influences plant survival and species distribution. Much of the research conducted on salinity tolerance concerns saline soil or saline irrigation, but little research focuses on plant exposure to salt spray in the absence of saline irrigation conditions. The aim of this study was to investigate the effects of seawater aerosol on fifteen ornamental shrubs diffuse in the Mediterranean environment. Plants of the fifteen ornamental shrubs were subjected to twice a week nebulisation treatments with synthetic seawater solution for eight weeks. Among the 15 species studied, four were selected as models, one as a sensitive species (*Viburnum tinus*), two as intermediate species (*Murraya paniculata* and *Polygala myrtifolia*), and one as a tolerant species (*Raphiolepis umbellata*). The following morphological parameters were monitored: the fresh and dry weight of shoots and roots, leaf area, leaf number, leaf damage, specific leaf area (SLA), chlorophyll content and ion content. The relative water content (RWC), leaf gas exchange and chlorophyll *a* fluorescence were monitored during the entire experimental period. The species exposed to the seawater solution showed different physiological and morphological responses. The treatment led to a decrease of biomass, leaf area and number in *M. paniculata*. The gas exchanges were affected by the stress conditions, indicating the defence mechanism activated against the salt stress. The leaf damage increased with the exposure to the seawater aerosol and the greatest damage was found in *V. tinus*. In *P. myrtifolia*, a decrease in the chlorophyll a fluorescence was observed. The salt spray treatments enhanced the correlation between chlorophyll *a* fluorescence and WUE.

1. Introduction

Woody perennials planted in streets, public recreation areas and car parks are selected primarily on their aesthetic qualities (flowers, bark, berries, leaf colour); however, little information is available about their foliar salt tolerance (Percival, 2005). The widespread use of green spaces along coastal areas has led to considerable interest in the identification of salt-tolerance species (Cassaniti et al., 2012), especially where it is difficult to obtain water for irrigation in which case, wastewater containing high concentrations of sodium and chloride are used (Jordan et al., 2001). The problem of salinity, especially in ornamental species, can be controlled with functional irrigation management and/or with the identification of species or cultivars with salinity tolerance (Torrecillas et al., 2003), especially when the plants are close to the coast. A number of ornamental species are very interesting options for use in landscaping and gardening projects in coastal regions, but their ability to tolerate sea aerosols differs among the species (Elshatshat, 2010) and sometimes among the cultivars (Torrecillas et al., 2003). Ornamental plants along the touristic coastal areas are very important and have a positive effect on the attractiveness of the areas for tourism. Therefore, the identification of ornamental plants tolerant to sea aerosol represents an important nursery issue to guarantee high-quality vegetation in green areas and private gardens (Ferrante et al., 2011).

In coastal environments, plants face multiple stresses that can be of natural (drought, high radiation intensity, heat and frost, sea spray, soil salinity, low nutrient) or anthropogenic (ozone, soil salinization, NO_x, SO_2, heavy metals) (Mereu et al., 2011) origin. In fact, in coastal environments, plants may have to cope with a special complexity of available water sources over space and time, such as rainwater, water table, seawater or their mixtures (Sternberg

Abbreviations: A, net photosynthetic rate; *E*, transpiration rate; *Fv*, variable fluorescence; *Fm*, maximum fluorescence; G_s, stomatal conductance; *RWC*, Relative Water Content; *SLA*, Specific Leaf Area; *WUE*, Water Use Efficiency.

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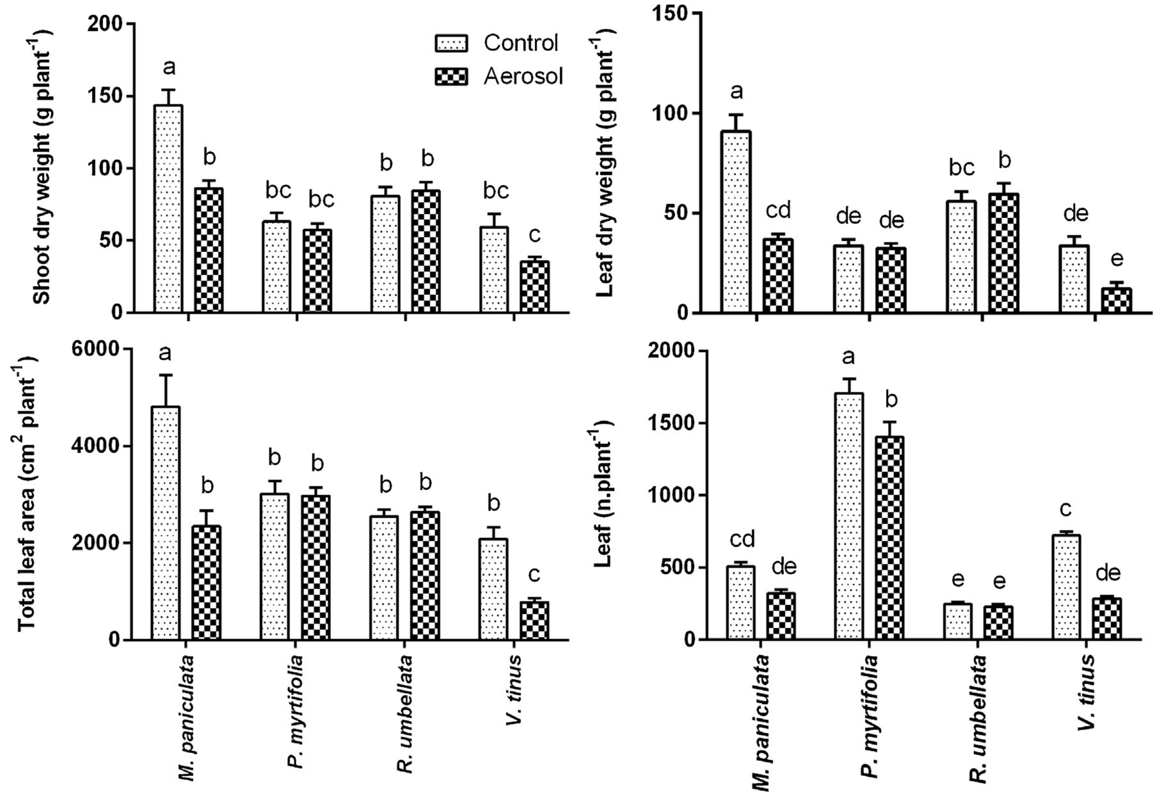

Fig. 1. Interactive effects of treatment and species on the shoot and the leaf dry weight, the total leaf areas (cm^2 $plant^{-1}$) and leaf numbers (n° $plant^{-1}$) in *Murraya paniculata*, *Polygala myrtifolia*, *Raphiolepis umbellata* and *Viburnum tinus*. Columns denoted with the same letters are not significantly different, as determined by Tukey's test ($P \leq 0.05$).

and Swart, 1987; Alessio et al., 2004). Plant compositions in coastal communities may be modified by the relationships between plants and water sources (Touchette et al., 2009). Salt spray can be an important abiotic factor that strongly influences plant survival and species composition (Griffiths and Orians, 2003). Several studies have shown that stress affects plant water balance (Munns, 1993), leads to a reduction in growth (Tominaga et al., 1991) and can cause necrosis or leaf abscission (Karschon, 1958). Exposure to water with high salt content reduces or inhibits plant growth (Marcum, 2001; Qian et al., 2001). Among the groups of plants of greatest interest for use in harsh environments, ornamental shrubs, particularly natives, appear suitable for their hardiness and adaptability to the most varied environmental conditions, thanks to their particular morphological and biological characteristics (De Herralde et al., 1998; Sánchez-Blanco et al., 1998; Cabot and Travesa, 2000; Franco et al., 2001; Martínez-Sánchez et al., 2003).

Much of the research conducted in salinity tolerance concerns saline soil or saline irrigation (Gulzar et al., 2003; Alshammary et al., 2004; Hunter and Wu, 2005; Marcum et al., 2005), but little research focuses on plant exposure to salt spray in the absence of saline irrigation conditions. In general, salt spray causes far more injury than do excess soil salts (Wu et al., 2001). Many authors did not specify whether the tolerance was to soil salts or salt spray, many plants that are tolerant to soil salts might not be tolerant to salt spray. Indeed, in a test conducted on several ecotypes of *Agrostis stolonifera*, it was found that these two factors were independent (Ashraf et al., 1986). Plants that are tolerant to elevated root salinities may be intolerant to foliar applications of seawater (e.g., *Senecio elegans* and *Austrofestuca littoralis*) (Sykes and Wilson, 1988). Foliar type can affect the stress tolerance. Sodium uptake from saline sprays has been related to leaf wettability in *Agrostis stolonifera* (Ahmad and Wainwright, 1976) and leaf morphology in *Festuca rubra* (Humphreys et al., 1986). The different behaviour of the species suggests that tolerance to the action of aerosols is the result of the strength of the structures protecting the leaf, and increases with schlerophyllia and with the thickness of the cuticle (Bussotti et al., 1995). Although the cuticle protects the leaf from external agents, the penetration of ions and the resulting osmotic and ionic stress cannot be avoided. The main cause of damage, in fact, is the accumulation of substances in the leaf tissues (Bussotti et al., 1984; Guidi et al., 1988; Grossoni et al., 1990). The damage always appears to be associated with the increase in the variation of osmotic pressure, which causes dehydration or desiccation of tissues and high quantities of specific ions (Na^+ and Cl^-), which alters the mineral nutrients balance (Hootman et al., 1994). These substances are absorbed through the stomata and cuticle, causing deterioration of the epistomatal wax structures and inducing alterations in the stomatal guard cell walls (Sánchez-Blanco et al., 2004). These changes may affect the efficiency of photosynthesis and gaseous exchange processes (Bussotti et al., 1997). Salt spray induces a decrease in stomatal conductance, photosynthesis and efficiency of photosystem II (PSII) (Tezara et al., 2003). The effects of salinity and drought on photosynthesis are attributed directly to the stomatal limitations for the diffusion of gases, which ultimately alters photosynthesis and mesophyll metabolism (Parida et al., 2005; Chaves et al., 2009).

Several studies have shown that the main symptoms seen in the leaves are discoloration, thickening of the leaf blade, which can be tough (Longstreth and Nobel, 1979; Nolan et al., 1982), and the presence of necrosis and burns, especially along the leaf margins, due to the direct action of the sodium accumulated in the mesophyll (Poliakoff-Mayber and Lerner, 1993). Additionally, premature defoliation is possible, as is the decay of buds and stems, and reduced shoot growth. More sensitive plants may also have metabolic alterations, such as increased stomatal resistance and resistance to water movement within the tissues (Maas and