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Effects of pot-in-pot production system on water consumption, stem diameter variations and photochemical efficiency of spindle tree irrigated with saline water

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ABSTRACT

Our aim was to determine whether the pot-in-pot (PIP) system can improve the salinity tolerance of spindle tree (*Euonymus japonicus*) compared to above-ground pot (AGP) systems in terms of water use efficiency (WUE), irrigation water evapotranspired (IWET), stem diameter variations and photochemical efficiency. The PIP system involves burying a "holder pot" in the ground up to the rim. A second, "cultivation pot" containing the growing plant is placed inside the holder pot, while AGP is the traditional above-ground pot production system. In the present experiment, the cultivation pots in both systems contained a mixture of white peat, coconut fibre and perlite (40/40/20, v/v/v). The following treatments were studied: AGP and PIP with control irrigation using water of 1.76 $dS\,m^{-1}$ (AGPc and PIPc); and AGP and PIP using saline irrigation water of 9.04 $dS\,m^{-1}$ (AGPs and PIPs). A soil moisture sensor-controlled irrigation system was used to irrigate all the treatments when AGPc reached a substrate volume water content (θ) of around 0.34 $m^3\,m^{-3}$. The θ of the saline treatments increased as the experiment progressed, particularly in PIP. The leaching fraction was 33% in AGPc, 41% in PIPc, 43% in AGPs and 54% in PIPs. PIPs produced the lowest amount of IWET (9.94 L) and AGPc the highest (13.20 L). Salinity reduced the plant dry weight (DW) in AGP (5.39 g), but not in PIP (10.2 g). AGPs led to the lowest WUE (0.52 $g\,DW\,L^{-1}$), while PIPs led to 1.23 $g\,DW\,L^{-1}$. Daily IWET per plant was related with the amount of photosynthetic light received each day (daily light integral, DLI) and age in the control treatments, while, under salinity, IWET was only related with DLI. Stem diameter growth was greater in PIPc (1278 μm) and lower in AGPs (60 μm). The discrepancy between the photosystem II efficiency and photosynthesis rate in AGPs pointed to an increasing rate of photorespiration.

1. Introduction

The favourable growing conditions of the Mediterranean coastal belt in Spain contrast sharply with the scarcity of good quality water, which has led to the overexploitation of aquifers and their salinization through seawater intrusion and fertilizer infiltration. This has forced growers to use water sources with moderate or high salt concentrations (Rubio et al., 2010), which may increase soil salinity and potentially damage plant growth. In such circumstances, it would be desirable to blend saline with fresh water as well as to grow selected salt-tolerant crops (Flowers et al., 2005). Niu et al. (2010a) reported that salt tolerance of plants depends on the species, climatic conditions, type of soil, and irrigation method. However, the management of other factors will also affect salt tolerance; for example, factors that affect humidity and temperature in the substrate can help produce good-quality plants. Thus, salt tolerance in plants should also be regarded in the context of the cultivation system used (Miralles et al., 2012a,b).

Pot-in-pot (PIP) production, introduced around 1990 (Parkerson, 1990) in the USA, is a nursery production method that combines some of the benefits of both field and container production. In a PIP system, a holder pot is permanently placed in the ground with the rim remaining above the surface. A potted plant is placed within the holder pot for the production cycle.

Abbreviations: AGP, above ground pot; AGPc, AGP with control irrigation; AGPs, AGP with saline irrigation; PIP, pot-in-pot; PIPc, PIP with control irrigation; PIPs, PIP with saline irrigation; DLI, daily light integral; WUE, water use efficiency; IWET, irrigation water evapotranspired; VPD, vapour pressure deficit; DAFI, days after first irrigation; SDV, stem diameter variations; MDS, maximum daily shrinkage; MXDS, maximum daily diameter value; SGR, stem growth rate; DW, dry weight; θ, substrate volume water content.

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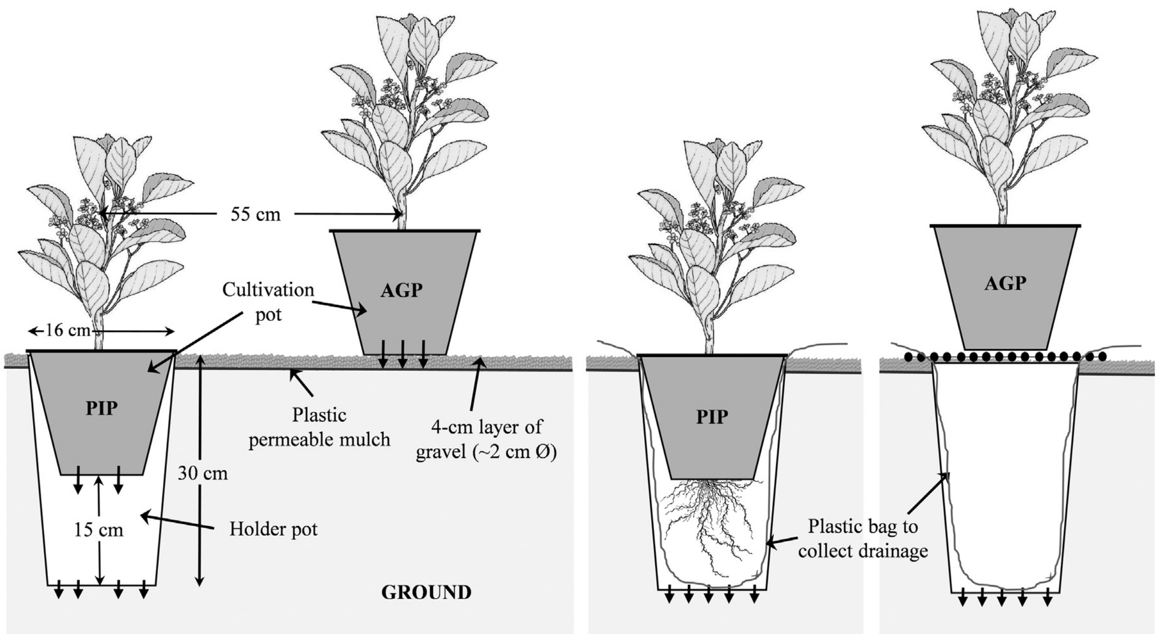

Fig. 1. Schematic diagram of PIP and AGP systems.

The advantages of PIP compared to AGP systems include reduced irrigation requirements, reduced heat stress to the roots, the elimination of pot blow-over and the minimization of root-zone temperature fluctuations (Ruter, 1998).

However, research to determine the potential benefits of PIP production using saline irrigation water is limited. Niu and Rodriguez (2006) reported that root zone salinity increased with time even though salinity levels of the irrigation water were kept constant. Salt accumulation in the root zone is affected by substrate properties, plant size, and environmental conditions, all of which influence substrate moisture and the cation exchange capacity in the root zone (Niu et al., 2010b). Previous research comparing PIP and above -ground pot (AGP) systems found that it reduces root zone temperature stress (Young and Bachman, 1996) and enhances efficient water use by decreasing container evapotranspiration (Martin et al., 1999). London et al. (1998) found temperature fluctuations and extremes to be greater in an AGP system than in a PIP system in South Carolina. Previous findings also describe how PIP reduced the salinity damage to spindle tree, the main effect being lower chloride ion uptake (Miralles et al., 2012b). Such factors can affect plant water consumption, photochemical behaviour, stem diameter growth and root development.

Spindle tree is a commercial woody perennial shrub, with pleasing aesthetic qualities and commonly planted in streets, public recreation areas and car parks. Percival (2005) determined that it was the second in order of salinity tolerance among 30 woody perennial species studied. Gómez-Bellot et al. (2013) suggested that potted spindle tree should not be irrigated for long periods with water with an EC value exceeding 4 dS m^{-1}, if the plant's aesthetic value was to remain undamaged. These authors focused their study on exchange gas, nutrient content and growth, but provided little information concerning the response of these species in terms of water consumption, trunk diameter growth and leaf chlorophyll fluorescence under saline irrigation conditions, especially when different pot cultivation systems were used.

The volume water content in the substrate (θ) can be automatically monitored by soil moisture sensors (Jones, 2004). This is important under saline irrigation conditions because leaching plays an important role in salt-tolerance and can be controlled more accurately with automated irrigation systems.

In the present work, trunk diameter growth was studied because several authors have suggested that this parameter is one of the most sensitive water indicators (Ortuño et al., 2010) and suitable for shrubs of small trunk diameter (Miralles et al., 2010a). Here, the stem diameter variations (SDV) originated by water changes in the trunk tissues were studied using a dendrometer. The high frequency measurements obtained with this instrument usually point to a maximum diameter value just before sunrise (MXDS) and a minimum value sometime during the afternoon. The difference between both measurements reflects the maximum daily shrinkage (MDS), and the difference between two consecutive MXDS measurements can be regarded as the stem growth rate (SGR). It has been suggested that both, MDS and the SGR are related with the plant water status (Ortuño et al., 2010), and so they could be sensitive to both salinity and the cultivation system used.

In this study spindle tree were grown in PIP and AGP systems and irrigated using fresh or saline water. The irrigation water evapotranspired (IWET) and water use efficiency (WUE) were quantified; and the effects on θ, stem dendrometry and photochemical efficiency were determined.

2. Material and methods

2.1. Plant material and crop conditions

One year old spindle tree (*Euonymus japonicus* var. Marieke) seedlings were transplanted from 96-plug trays (each plug 56 cm^3) into 2.5-L black plastic pots (16 cm Ø × 15 height) in January 2010. The substrate was a mixture of white peat, coconut fiber, and perlite (40/40/20, v/v/v) amended with 3 g L^{-1} of a slow release fertilizer (Osmocote plus 14-14-14; 14N-6.1P-11.6K; release time 2–3 months at 21 °C; The Scotts Company LLC, Marysville, OH). The plants were 5–7 cm in height at the beginning of the experiment. Fertilization was applied on 1 March and 1 June with 7.5 g per pot of slow-release fertilizer (described above). The experiment was conducted under field conditions, in an outside plot of 70 m^2 at the Experimental Agro-Food Station of the Polytechnic University of Cartagena (lat. 37°35′N, long. 0°59′W) starting on 6 March 2010 and ending on 24 August 2010. Day one was taken to be 6 March because it was when the first irrigation event took place.

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