



Root Development Under Drought Stress

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INTRODUCTION

Serving as interfaces between plant and the soil, roots are much more exposed to drought stress than the upper plant parts. Therefore, the root system can be as affected, or even more affected, than the aerial parts of the plant for drought stress (Franco *et al.*, 2011). Nevertheless, the influence of this stress on root activity and development has been much less studied. Undoubtedly, this is due to limitations on accessibility for root observations; being studies on root system dynamics especially difficult because they require successive, non-destructive measurements (Franco and Abrisqueta, 1997; Franco *et al.*, 2002a).

ROOT DEVELOPMENT UNDER DROUGHT STRESS

Root development is strongly influenced by growing conditions such drought stress. However, root growth is usually less affected by drought stress than shoot growth. Thus, a decrease in shoot:root ratio is a common observation under drought-stress, which results either from an increase in root growth or from a relatively larger decrease in shoot growth than in root growth. This was so with *Lonicera implexa* (Navarro *et al.*, 2008), *Lotus creticus* (Franco *et al.*, 2001; Bañón *et al.*, 2004), *Myrtus communis* (Bañón *et al.*, 2002), *Nerium oleander* (Bañón *et al.*, 2006), *Rhamnus alaternus* (Bañón *et al.*, 2003), *Rosmarinus officinalis* (Sánchez-Blanco *et al.*, 2004) and *Silene vulgaris* (Arreola *et al.*, 2006; Franco *et al.*, 2008). In addition, in the review article by Franco *et al.* (2006), it is well-documented a reduction in the shoot:root ratio as a result of pre-conditioning deficit-irrigation processes during nursery period.

Not only the shoot:root ratio but also other root characteristics (root length, fresh weight –FW–, dry weight –DW–, diameter and surface area, deep rooting and cortex thickness) and behaviours (root turnover, metacutisation, hardening and hydraulic conductivity) may be strongly affected by drought.

Deep rooting is a critical factor influencing the ability of the plant to absorb water from the deeper layers of the soil (Franco *et al.*, 2006; 2011). Also, a greater percentage of fine roots, capable of penetrating smaller soil pores, presumably optimises the exploratory capabilities of the root system as a whole, and may have an important role for survival of plants to drought stress. Thinner roots compared with controls were reported for drought-stressed *Silene vulgaris* (Franco *et al.*, 2008). However, deficit-irrigation increased the percentage of thick roots, and reduced the percentage of medium and fine roots in *Myrtus communis* and *Nerium oleander* plants (Bañón *et al.*, 2002; 2006).

Branching of the roots and total root length of *Silene vulgaris* plants was increased under moderate drought-stress (Franco *et al.*, 2008). Likewise, root surface area of *Silene vulgaris* plants was increased under moderate drought-stress (Franco *et al.*, 2008). This can minimise localised water depletion around roots, thus minimising resistance to water transport to the root system (Franco *et al.*, 2006). Those plants had higher water-use efficiency (WUE) than well-watered plants. Studies by Fernández *et al.* (2006) in *Phillyrea angustifolia* also reported that WUE improved with limited water availability in different species.

The combined effect of deficit-irrigation and low air humidity during the nursery phase reduced the mortality rate of *Myrtus communis* (Bañón *et al.*, 2002) and *Nerium oleander* (Bañón *et al.*, 2006) seedlings after transplantation under



drought and heat conditions. Such behaviour was related to morphological changes observed in the roots (i.e., shorter, thicker, more dense and less ramified) and in the shoot:root ratio (i.e., reduced by approx. 60% in both species) of the pre-conditioned plants. This behaviour was related to the reordering of the assimilate gradient as the flow of solutes towards the roots intensified.

Hardening of roots, as revealed by an increased percentage of brown roots, is frequent in drought-stressed plants (Franco *et al.*, 2006). The change in the root colour from white to brown (and, for some species, roots showing beads) is associated with suberisation of the exodermis, and may reflect a metacutisation process (i.e., suberisation of one or more root-cap cell layers that result in a resting root that is protected against adverse environmental conditions, which is capable of regrowth when conditions ameliorate), which was correlated with the capacity to grow under drought conditions of *Limonium cossonianum* (Franco *et al.*, 2002b), *Lotus creticus* (Franco *et al.*, 2001) and *Silene vulgaris* plants (Franco *et al.*, 2008).

One indicator of plant capacity to absorb and transport water is the density of the xylematic vessels in the roots. Thus, a high vessel density would improve resistance to water-deficit situations. This was so with *Lotus creticus* in a study by Bañón *et al.* (2004), who reported that plants subjected to deficit-irrigation showed higher density of xylematic vessels in roots than well-watered plants.

Plants affected by drought can exhibit signs of tissue dehydration, evidenced by increasing their root DW:FW ratios (Franco *et al.*, 2011). This was reported in *Rosmarinus officinalis* by Sánchez-Blanco *et al.* (2004) and in *Nerium oleander* by Bañón *et al.* (2006). Consequently, a greater cortex thickness:root radius (C:R) ratio for *Silene vulgaris* plants grown under drought-stress, noted by Franco *et al.* (2008) in two experiments, is significant to improve resistance to dehydration. Thereby, tissues internal to the endodermis are relatively well protected against dehydration at the expense of the cortex. Therefore, changes in the C:R ratio of *Silene vulgaris* seedlings could influence plant capacity to obtain water and survive adverse conditions.

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