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Nutrient deprivation improves field performance of woody seedlings in a degraded semi-arid shrubland

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ABSTRACT

The performance of planted seedlings in drylands is affected by seedling morphological and physiological traits. Recent studies support a positive relationship between seedling size and field performance. However, exceptions to this paradigm suggest that this relationship may be dependent on species and degree of stress. To test the hypothesis that small seedlings would be favored under harsh semi-arid conditions over large seedlings, we produced seedlings of five Mediterranean woody species (*Pistacia lentiscus*, *Quercus coccifera*, *Rhamnus lycioides*, *Rhamnus alaternus* and *Tetraclinis articulata*) under contrasted fertilization regimes, and evaluated their performance after planting in a semi-arid area. Seedlings were cultivated under full sunlight and received either slow release fertilizer or bi-weekly applications of complete nutrient solution, diluted fertirrigation, or nutrient solutions containing no nitrogen or no phosphorus. Fertilization had a strong effect on nutrient status, above and belowground biomass accumulation, and biomass allocation patterns. Root: shoot ratio was higher in nitrogen- and phosphorus-deficient seedlings than in seedlings receiving complete nutrient solution or slow-release fertilizer. One year after planting, seedling survival was negatively correlated with plant size for all species. The effect of nutritional regime on field survival decreased over the 2 following years. Our results show that nutrient-deprived seedlings are more likely to establish under semi-arid conditions than well-fertilized seedlings, suggesting that morphological and functional characteristics associated with nutrient deficiency may outbalance the scarcity of nutrient reserves in seedling tissues.

1. Introduction

In arid and semi-arid areas, woody species frequently act as keystone species (*sensu* Hulbert, 1997), because they are positively associated with ecosystem functioning and community diversity whereas their cover is scarce (Whitford, 2002; Maestre and Cortina, 2004). Woody species have been intensely harvested, grazed and cleared in drylands worldwide, resulting in an overall reduction in cover (Le Houérou, 1986; Maestre and Cortina, 2003). Seedling recruitment, once anthropogenic pressure has stopped, is frequently too slow or absent (Martínez-Mena et al., 2002; Bonet and Pausas, 2004), increasing the risk of further land degradation. In degraded environments, planting seedlings of sprouting woody species represents a suitable alternative to foster succession and restore ecosystem integrity (Whisenant, 1999; Cortina et al., 2004).

The performance of planted seedlings is affected by various factors, such as environmental conditions, biotic interactions, and morpho-physiological traits (South and Smith, 2000; Palacios et al., 2009). These factors are particularly important in drylands, as adverse environmental conditions exert a strong filter for seedling establishment (Maestre et al., 2003; Cortina et al., 2006). Morpho-physiological traits are partly controlled by genetic origin (Van Andel, 1998), but they can be modified by cultural practices such as sowing density, container size, irrigation and fertilization regimes (Vilagrosa et al., 2003a; Luis et al., 2004; Chirino et al., 2008). Nevertheless, there is currently no consensus on the optimum traits defining seedling quality in drylands (Cortina et al., 2006). In mesic environments, larger plants frequently show higher survival and growth in the field than smaller plants (Kormanik et al., 1997). The pattern may be similar in drylands (Oliet et al., 2005; Luis et al., 2009), but the literature shows several examples of neutral and negative relationships between seedling size and field performance, particularly under semi-arid conditions (Tuttle et al., 1988; Rose et al., 1993; Seva et al., 2000; Trubat et al., 2008).

Fertilization is a common nursery technique that strongly influences plant growth and modifies seedling morphological and

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