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Quercus ilex root growth in response to heterogeneous conditions of soil bulk density and soil NH_4-N content

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ABSTRACT

A greenhouse study examined the effects of heterogeneous conditions of soil bulk density and soil NH_4-N content on the growth of holm oak (*Quercus ilex* L.) seedlings over an 8-month period. Heterogeneity of soil was produced inside 150 cm depth pots, by applying manual compaction or enriching different soil layers with NH_4 (vertical heterogeneity) and, by splitting the root system into two columns with differing soil bulk density or NH_4 conditions (horizontal heterogeneity). Root distribution patterns were assessed by collecting roots within layers, each 10 cm depth, and by recording both the fine (diameter <2 mm) and the coarse (diameter ≥2 mm) root biomass. Root systems significantly responded to the vertical gradients of soil bulk density, decreasing their maximum depth and showing lower values of fine root densities at the layers with a dry bulk density of 1.62 Mg m ^{3}. The split-root system showed that maximum rooting depth of the axis with a dry bulk density of 1.38 Mg m ^{3} was limited by the reduced rooting depth of the adjacent more compacted axis. Root systems were less dense in the NH_4 soil treatment than in the control soil treatment (34 mg dm ^{3} vs. 212 mg dm ^{3}), even at the lowest rate used (0.1 g NH_4 L_{soil}^{1}). This high sensitivity to NH_4 conducted to a significant decrease of shoot height and root depth (50 and 43%, respectively). The split-root system showed that unfavourable conditions of NH_4 content have local consequences on the rooting depth and systemic consequences on the fine root density. The implications of root growth restrictions for *Q. ilex* natural regeneration, seedling survival, and decline are discussed.

1. Introduction

In the western European Mediterranean countries, holm oak (*Quercus ilex* L.) is the most abundant forest tree and dominates the landscape in an estimated 4.1 million ha of open woodland. In these oak woodlands, the landscape is a mosaic of trees and patches of cultivated and grazed ecosystems. Since the early 1980s there has been a great concern about the severe decline of *Q. ilex* trees in Spain and Portugal (Brasier, 1996). Severe drought episodes, flooding and rapid fluctuations in soil water content have been reported as predisposing factors favouring tree invasion by bark borer insects and/or opportunistic fungi (Brasier, 1996; Sánchez et al., 2002). Additional decline-inducing factors suggested include rangeland practices generated by the changes in the traditional management of oak open woodlands, such as the use of heavy machinery for forage production, the increase of stocking rates, and the excess of N supply (Sánchez et al., 2002; Thomas et al., 2002). The effects of these recent management practices on *Q. ilex* health and root development have not yet been studied.

Overuse of machinery, intensive cropping and trampling by grazing livestock decrease soil macropore spaces, resulting in soil compaction (Hamza and Anderson, 2005; Sánchez-Andrés et al., 2006). Soil compaction decreases infiltration and leads to reduced root growth and plant survival (Jordan et al., 2003; Mósena and Dillenburg, 2004; Watson and Kelsey, 2006). In *Q. ilex* open woodland cultivated soils, dense compact subsoils frequently underlie the loosened topsoil (Sánchez-Andrés et al., 2006) whereas the opposite situation occurs in areas with high grazing pressure (Coelho et al., 2004). As tillage methods changed from full width and/or uniformly applied soil disturbance to more strip-type soil manipulation, soil physical and chemical conditions became less homogeneous. Spatial patterns of physical and/or chemical properties may develop in those fields managed with controlled wheel traffic and/or localized fertilizer placement. Livestock grazing alters nutrient dynamics because large amounts of N are transferred to the soil in the excreta of animals. As the intensity of

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