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The effect of soil compaction on germination and early growth of *Eucalyptus albens* and an exotic annual grass

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Abstract Most agricultural land has been compacted to some degree by heavy machinery or livestock trampling. This legacy is expected to influence the success of tree seedling recruits in farmland areas where natural regeneration is being encouraged. We investigated the impact of soil compaction on seedlings of a woodland eucalypt (*Eucalyptus albens*) and an annual grass competitor (*Vulpia myuros*) in a laboratory experiment. Replicate soil cores were created at five bulk density levels; 1.0, 1.1, 1.2, 1.3 or 1.4 Mg m^{-3} with a soil water content of 20%. The depth of root penetration declined linearly with increasing bulk density, resulting in a decrease in root depth of around 75% in the most compacted soil compared with the least compacted soil for both species. Shoot length and primary root length did not vary between soil bulk density levels for either species, but seedlings responded to increasing levels of compaction with oblique (non-vertical) root growth. Results suggest that young seedlings of both *E. albens* and *V. myuros* will be more susceptible to surface drying in compacted than uncompacted soils and therefore face a greater risk of desiccation during the critical months following germination. Any competitive advantage that *V. myuros* may have over *E. albens* is not evident in differential response to soil compaction.

Key words: regeneration, root depth, seedling establishment, soil bulk density, woodland restoration.

INTRODUCTION

Soil compaction is prevalent in agricultural areas worldwide (Drewry *et al.* 2008). The impacts of soil compaction on crop and pasture growth are mostly adverse and are the subject of many reviews (Unger & Kaspar 1994; Greenwood & McKenzie 2001; Lipiec & Hatano 2003; Drewry *et al.* 2008). Remnant native vegetation and woody species used for re-afforestation can also be adversely affected by soil compaction. This has been demonstrated in laboratory studies of seedling growth for two New Zealand bushland species (Bassett *et al.* 2005) and the Northern American Douglas-fir (Heilman 1981), in forest stands of *Pinus* spp. subject to heavy machinery loads during harvesting (Kozlowski 1999), and in heavily grazed *Eucalyptus salmonophloia* woodlands in Western Australia (Yates *et al.* 2000a).

Soil compaction in agricultural areas can occur through use of heavy machinery, trampling by livestock, slumping/settling of soil, or exposure of surface soil to the elements following fire or heavy grazing (Håkansson & Voorhees 1998; Kozlowski 1999; Drewry *et al.* 2008; Prober *et al.* 2008). Compaction caused by livestock trampling is especially severe in stock camps, which are distinct areas within a field where animals are inclined to gather. Stock camps are typically near the shelter of remaining paddock trees; the zone to which tree recruitment from natural seedfall is mostly restricted.

Low levels or absence of tree recruitment is cited as a major threat to the persistence of remnant woodlands in many agricultural areas in Australia (Yates & Hobbs 1997). Climatic factors, competition from exotic species, grazing/trampling of seedlings by livestock, predation of seed and poor seed quality due to inbreeding of isolated trees are frequently cited as barriers to woodland regeneration (Nadolny 1995; Yates *et al.* 2000b; Semple & Koen 2001, 2003; Dorrough & Moxham 2005). The effects of soil compaction on tree recruitment in Australia are likely to be widespread, as most agricultural land has been affected by compaction to some degree (Greenwood & McKenzie 2001).

Compaction is characterized by increased soil bulk density, increased soil strength (mechanical resistance to penetration), increased soil water tension, and decreased air-filled porosity and infiltration. These effects may persist for years to decades after removal of the causal process (Braunack & Walker 1985; Greenwood & McKenzie 2001). The consequences of compaction for plant growth are reduced water, nutrient and oxygen availability (Kozlowski 1999), especially in early life stages (Smith *et al.* 2001; Bassett *et al.* 2005).

Plants differ in their tolerance of soil strength (Ferrero 1991; Smith *et al.* 2001; Williamson &

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