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Management to increase the depth of soft soil improves soil conditions and grapevine performance in an irrigated vineyard

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Abstract

Grapevine (*Vitis vinifera* L.) growth is limited by the hard-setting red duplex soils that occur in many major viticultural regions, including the Goulburn Valley, Victoria. Water often ponds on the soil surface and dense subsoils restrict drainage. An experiment was conducted to develop soil management that improved water infiltration, root growth and grapevine performance. The experiment was conducted from 1995 to 1998 in a vineyard block of Chardonnay on Ramsey rootstock planted at Rosbercon Vineyard, Picola in 1972. Three soil managements were compared over 3 years testing for improved soil physical properties, root growth and grapevine performance. Microjets irrigated the vine-line soil where randomised treatments of grown ryegrass (*Lolium multiforum*) (Autumn/Winter) or straw mulch (15 t/ha year round), gypsum application (12 t/ha) and slow (5 mm/h) or fast wetting (15 mm/h) were applied. Ryegrass growth maintained macropores (0.35 $cm^3/cm^3 > 30$ μm diameter) 33 months after tillage, kept the soil soft (<1 MPa) to a greater depth (134 mm) and had higher concentrations of grapevine roots (5.05 cm/cm^3 at 0–100 mm depth) compared with those of straw mulch (0.31 cm^3/cm^3 macropores, 73 mm depth soft soil and 3.35 cm/cm^3 root length density). Gypsum maintained the surface soil soft for a greater depth (120 mm) and improved water penetration to 250 mm depth compared with no gypsum application (87 mm depth soft soil). Ryegrass and gypsum improved water penetration to 450 mm depth compared with ryegrass and no gypsum application. Grapevine vegetative growth (pruning weight), reproductive performance (yield and bunch weight) and root growth were each directly dependent on the depth of soft soil (depth of soil less than 1 and/or 2 MPa). Grape yield and bunches per grapevine were also each directly dependent on the volumetric water content at field capacity of the surface soil. These results suggest that, to alleviate limitations of hard-setting red duplex soils to grapevine growth and performance, management should increase coagulation of clay particles and stabilisation of aggregates in order to maximize the depth of soft soil (<2 MPa). Moreover, the key soil parameter identified in this study that is most representative as an indicator of quality soil for winegrape production is depth of soft soil (<2 MPa) 24 h after irrigation.

Keywords: Gypsum; Ryegrass; Cover crop; Mulch; Soil strength; Macroporosity; Time domain reflectometry; Grapevine root growth

1. Introduction

Soil that is friable and permeable is crucial for water, applied as irrigation, to reach the grapevine rootzone. Inefficient use of water occurs when soils that are impermeable, due to hard and crusted surfaces, are irrigated. In these cases most water runs-off to the

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inter-row and is lost as surface drainage, evaporation or used by the cover crop.

Disturbed soil subjected to intensive irrigation or rain may slump and set hard. To avoid this structural degradation soil should be stabilised and watered at slow rates (<5 mm/h) (Lanyon et al., 2000). Soil aggregates that are water-stable may be structurally degraded (coalesced) if subjected to fast rates of water application (Ghezzehei and Or, 2000).

To maintain soft, friable and permeable soil that is optimal for root growth, management should aim to achieve stable soil aggregates. The addition of organic matter to soil can improve aggregate stability (Tisdall and Oades, 1979). Five years of grass cover crops on a degraded sandy clay loam in southern Nigeria increased organic carbon concentration by 28% over that of bare soil (Obi, 1999). The percentage of water-stable aggregates >1.0 mm was greater under grass or legume cover (79.3%) than bare soil (27.7%). Grass or legume cover also decreased the penetrometer resistance and increased infiltration and retention of water compared with bare soil.

Two years of a mowed sod (tall fescue, *Fescue arundinacea*) as row management in a peach orchard (*Prunus persica*) on a silty loam in West Virginia, maintained the percentage of soil organic matter (2.7%) beyond that of sod removed by tillage (2.0%) or by residual herbicide (2.2%) (Welker and Glenn, 1988). After 4 years of a mowed sod, the percentage of stable aggregates (between 5 and 8 mm diameter) in the surface 50 mm was greater (83.7%) than that under tillage (53.4%) or residual herbicide (57.3%). Infiltration of water into the soil was greatest under killed sod than that under mowed sod and residual herbicide. The percentage of pores >1 mm diameter at 10 mm depth decreased in the order: mowed sod > killed sod > resi-residual herbicide and tillage.

For clay to coagulate and soil to remain in an aggregated state, a threshold electrolyte concentration in the soil solution is required. Likewise, a high exchangeable sodium percentage (ESP) (>6%) can be detrimental to soil aggregation. Shainberg et al. (1981) related the salt concentration of the soil solution to ESP of soil in the range 0–30%, and measured the resultant saturated hydraulic conductivity (K_{sat}) and clay dispersion. When the concentration of salt in the soil extract ($EC_{1:5}$) was 0.3 dS/m, K_{sat} was decreased but clay dispersed only if ESP of the soil exceeded 12%. Conversely, a salt concentration of 0.05 dS/m in the soil extract led to clay dispersion and decreased K_{sat} at ESP values as low as 1 or 2%. The findings of Shainberg et al. (1981) emphasise that even for soils with low ESP, that are leached periodically with rainwater, K_{sat} can be substantially decreased and a surface crust formed.

The infiltration rate of 2.5 mm/h of sandy loam in a mature navel orange (*Citrus sinensis*) orchard was doubled when gypsum was applied weekly to the soil surface (Peacock et al., 1989). Calcium (Ca^{2+}) added as calcium acetate to the irrigation water (0.4 dS/m) more than doubled infiltration rates compared with those of untreated water (0.1 dS/m).

Irrigation strategies such as partial rootzone drying (PRD) and regulated deficit irrigation (RDI) are encouraged in the winegrape industry to improve water use efficiency and composition of fruit (Kriedemann and Goodwin, 2003). Both PRD and RDI assume that water from irrigation drippers reaches the roots. This may not occur if impermeable soil limits water infiltration and redistribution.

The depth of soil amenable for root growth has a large influence on performance of woody perennial crops. The depth of soil horizons of red duplex soils, particularly the A horizon, limits the production of deciduous fruit (Cockroft and Wallbrink, 1966). An A horizon less than 150 mm deep limits tree size. When the depth of the A horizon is around 250 mm or more, soil depth is not as important for tree growth as the mechanical composition of the A horizon. The use of raised beds (1.24 m wide at base, 0.45 m on top of subsoil) to increase the growth of young grapevines (*Vitis vinifera* L.), provided a greater depth of surface soil and improved soil physical and hydraulic properties that optimised root and shoot growth of Chardonnay (Eastham et al., 1996). Two-year-old Chenin Blanc on 99 Richter rootstock grown on raised beds at least 1.5 m wide and 0.4 m high and irrigated by microsprinkler, significantly increased vegetative growth and yield compared with those grown on flat unripped soil (Myburgh, 1994). In the raised beds the majority of the fine roots were active due to improved drainage and aeration (Myburgh and Moolman, 1991), whilst fine roots found in cracks in flat beds were dead due to waterlogging. Depth (<0.4 m) and irrigation, plus a surface cover are critical to the success of raised beds, particularly for young grapevines. Careful management of raised beds, surface covers and irrigation can sustain the soil physical fertility.

In this study, we assessed changes in soil properties, root growth, grapevine performance and water infiltration of a hard-setting red duplex soil in northern Victoria after increasing the depth of surface soil, then stabilising it with additions of gypsum, straw mulch, ryegrass growth or changes in wetting rate. The aim of the study was to: (a) develop soil management that