Soils: The Key Focus in Controlled Traffic Farming

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Abstract: Alleviation of soil compaction through controlled traffic farming (CTF) can lead to long-term improvement of many physical, chemical and biological processes that contribute to increased crop productivity. Results from a long-term trial on raised beds are used as an example of CTF to demonstrate the likely impact of the removal of compaction on soil and plant processes in the long-term. Since most of the cropping soils in question are inherently compacted or have undergone induced compaction through unsustainable farming practices, some form of initial tillage may be useful in restoring the lost porosity as a key to enhancing the beneficial soil processes, expected with the implementation of CTF.

INTRODUCTION

Crop performance in many farming systems in Australia and elsewhere are affected by dense subsoils. The high bulk density of soils can impact on rooting depth, water uptake and the storage of plant available water (PAW). Dense subsoils may be the result of an inherent soil characteristic, such as the case of volcanic soils where the process of weathering is slow and the large structural units are not easily broken down in the short-term. But equally important in the context of current farming systems is the induced compaction caused by overuse of machinery, intensive cropping, wet-weather grazing and inappropriate soil management practices. Controlled traffic farming (CTF) is considered to be one of the ways by which the impact of machinery on soil can be minimised. It also has the potential to assist other soil processes that in the long-term improve the physical, chemical and biological properties of soil.

It is estimated that soil compaction costs over $850m per year in lost production in agriculture (Walsh, 2002). Lowered production limits the addition of organic matter into soil, which is a key component in reducing the impact of compaction. The resulting low mineralisation can also increase the costs of crop nutrition. Increased compaction also increases the energy requirement in the use of agricultural implements. Therefore alleviation of compaction alone by CTF can lead to a range of benefits to the farmer. If a soil environment can be created for improved root proliferation, it may have the potential to ameliorate the subsoil through the process of biological drilling (Cresswell and Kirkegaard, 1995) by certain primer crops and the subsequent crops in the farming system are likely to exploit the additional porosity created by these primer crops (Elkins, 1985, Yunusa et al., 2002). The 'ideal' macroporosity of 15% for root growth and water infiltration (Cockroft and Olsson, 1997) is highly unlikely at depth in many agricultural soils in Australia and the conventional approach of improving macroporosity through tillage and ameliorants (Olsson et al., 1995) is often short-lived under conditions of indiscriminate trafficking. Controlled traffic farming therefore creates an enormous opportunity to explore root growth, soil structure, soil water movement and the role of primer plants under a completely different set of environmental circumstances that have evolved in recent times. This paper briefly examines some of the relevant work conducted in Victoria and elsewhere and explores possible amelioration options that could catalyse the soil processes under CTF when compaction is not a part of the equation.

SOIL PROCESSES IMPROVING PRODUCTIVITY

Soil structure and soil biology are both important components of a healthy soil. Therefore in the management of soils, our primary concern should be the facilitation of processes that lead to the creation and stabilization of the soil aggregates. In soils high in clay content, as is the case in most high rainfall zone (HRZ) soils in southern Victoria, the shrink-swell process plays a very important role in the creation of soil aggregates (Loveday, 1972; Sarmah et.al., 1996). This happens through the wetting-drying or freezing-thawing cycles that occur during climatic events. The stabilization of aggregates formed is, a process dependent on biological activity in the soil including those of roots, hyphae, bacteria and earthworms. Appropriate tillage also favours the creation and stabilization of soil aggregates (Oades, 1993) and may become a useful tool in dealing with soils that are severely compacted through long years of indiscriminate trafficking.

EVIDENCE OF 'BETTER' SOIL ENVIRONMENT

Raised beds as a form of CTF

Raised beds were developed by farmers in the HRZ to overcome the effects of waterlogging in a range of soils. By design, minimum tillage (MT) and controlled traffic (CT) are essential components of a raised bed farming system. In a farming systems trial conducted near Geelong in South-west Victoria, the hypothesis was tested that the crops on raised beds will experience a different root environment over time. A black self-mulching (BMV) Vertosol (Isbell, 1996) and a grey sodic Vertosol (GSV) behaved differently in response to MT, CT and the alleviation of waterlogging. Three years after the installation of beds, crops on raised beds experienced a lower bulk density and a consequent higher total porosity in the root zone compared to the flat (Table 1). These differences in soil structure were also detected below the depth of initial tillage (20cm) suggesting that processes other than the wetting-drying cycles were impacting on soil structure under the beds in the long-term. These processes may be explained in part by the processes that are triggered by the removal of compaction, compared to conventional farming practice (Holland, 2006). Three years after installation of raised beds, crops experienced an increase of 12 – 21% in the plant available water capacity (PAWC) to a depth of 40cm in the soil (Figure 1). Increases in PAWC of 34% associated with improved hydraulic conductivity below the depth of seeding have been reported by McHugh *et.al*., (2003) under CTF on Vertosols, which is consistent with our observations. The additional PAWC could result in a reduced impact on crop performance under conditions of below average rainfall.

Table 1. Measured differences in soil bulk density on controlled traffic raised beds under different farming systems and soil types relative to a flat perennial pasture. Negative values indicate a lower soil bulk density value in the corresponding depth under the raised bed system

Response area		Depth Interval / Soil bulk density (g cm^{-3})			
		0-10cm	**10-20cm**	**20-30cm**	**30-40cm**
Rotation					
	2x2	-0.15	-0.17	-0.25	-0.30
	4x4	-0.19	-0.13	-0.22	-0.23
	Continuous crops	-0.18	-0.02	-0.16	-0.23
Chi square probability **l.s.d. (P=0.05)**		**ns** **0.141**	**<0.05** **0.142**	**ns** **0.174**	**ns** **0.100**
Soil Group					
	Black Vertosol	-0.24	-0.18	-0.26	-0.37
	Brown sodic Vertosol	-0.11	-0.03	-0.16	-0.13
Chi square probability **l.s.d (P=0.05)**		**<0.05** **0.124**	**<0.05** **0.125**	**ns** **0.152**	**<0.001** **0.087**

The evidence suggests that depending on the inherent characteristics of the soil, the simple removal of long-term compaction alone could contribute towards the improvement of the hydraulic properties of the soil. The high soil BD would initially act as a deterrent to deep root penetration and to the access of soil water at depth. The roots would initially be confined to areas between the large structural units, not being able to exploit the volume of soil water trapped within. However, once compaction process is removed, root growth and the thorough exploitation of the profile for water would be facilitated by other processes such as wetting and drying taking place simultaneously in these clay soils (Oades, 1993; Whitebread *et.al*., 1998). If wetting and drying of the profile would occur regularly, it would be a trigger for aggregate formation and the general amelioration cycle to proceed, with plant roots gradually proliferating into the deeper layers of the soil. Because of the rapid drainage of excess water from the root zone, raised beds offer a good opportunity to set that wetting-drying cycle in motion.

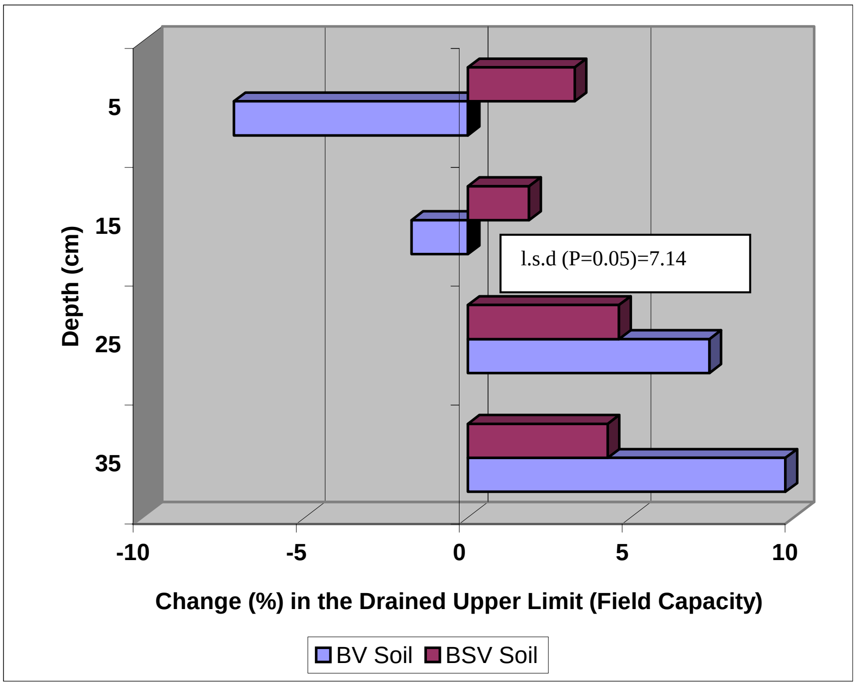

Figure 1. Measured differences in the upper level of plant available water (field capacity) in the black self-mulching Vertosol and the Grey sodic Vertosol to a depth of 40cm in the soil profile under CTF on raised beds.

TILLAGE OPTIONS IN CTF

As different soils behave differently, 'raising the bed' will not be the only solution to address inherent or induced compaction. However, 'controlled traffic bed farming' may still require the initial use of appropriate tillage to set the beneficial soil processes in motion in heavily compacted soils.

In agricultural situations where compaction is severe (bulk densities of 1.6 – 1.8 t m^{-3}) and soil organic matter is low, it is almost a necessity to create some disturbance at the surface to reopen the macropores between the large structural units of the soil. The soil disturbance must be sufficient to ensure that the displaced surfaces will not return to their initial position (Spoor, 2006) through swelling despite the absence of subsequent traffic. Such a disturbance of the soil referred to as a tensile disturbance (Hettiaratchi, 1987), can cause an overall reduction in soil density with little or no density change within the units themselves. In soils with low organic matter or in subsoils with high exchangeable sodium (sodic soils) addition of gypsum and/or organic matter may be useful in preventing the rapid return of soil into its original status (Hamza and Anderson, 2003). These ameliorants in the subsoil could contribute in several ways to the improvement of PAWC and the consequent higher harvest indices from crops both in the short and long-term.

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