Controlled Traffic Delivers Soil Structure Benefits at Depth in Cracking Clay Soils

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KEY MESSAGES

- In cracking clay soils, controlled traffic alone could lead to soil structure changes at depth in the profile
- Not all cracking clays behave in the same manner in response to controlled traffic and/or raised beds
- A 10-20mm increase in plant available water in the top 40cm of soil of raised beds was a significant outcome for raised bed crops that frequently encounter water deficits during grain fill. The additional water could deliver yield stability across sub-optimal rainfall years,

INTRODUCTION

Significant land use change from perennial pasture to grain crop production, accompanied by rising productivity, has occurred on a diverse range of soils in high rainfall South-West Victoria (SFS, 2000). This change has occurred partly because farmers have adopted raised beds to overcome waterlogging. Despite well-distributed growing season rainfall, the low permeability of most SW Victorian soils can frequently restrict root growth and water movement, and can cause a severe perched water table (Belford *et al*., 1992).

The work reported here was conducted on two cracking clay soils, classified as Vertisols (Isbell, 1996), that were known to behave differently from each other (Adcock, 1998) both in response to waterlogging and in their crop and pasture productivity. One of them was a black, friable cracking clay (Gnarwarre A) and the other was a mottled olive clay with increasing sodicity at depth (Gnarwarre B). Gnarwarre B was considered to be more hostile to crop growth than Gnarwarre A due to its higher bulk density at depth and low porosity. These characteristics contribute to this soil being more prone to a perched water table under average rainfall conditions. Raised beds were installed on these soils and three crop and pasture systems were managed to best practice over a six year period. Physical characterisation of the soil in the beds was undertaken in the third and fifth years of the experiment.

By design, controlled traffic and minimum tillage are essential components of a raised bed farming system. All the crops and pastures were sown with a single bed seeder fitted with knife points and press wheels, with tractor and machinery wheels travelling only in the furrows. Other than these seeding passes the beds were not renovated or disturbed throughout the experimentation period, despite some compaction by sheep during the pasture phases of the rotations.

Three different rotations were used. They were continuous cropping, two years of crops followed by two years of pasture, and four years of crops followed by four years of pasture.

RESULTS AND DISCUSSION

In 2002 (three years after the commencement of the trial) and in 2004, (five years after commencement) the bulk density, soil porosity and the drained upper limit (field capacity) of soils under the raised beds were assessed and compared with flat, unimproved perennial pasture areas adjoining the beds. This was done in order to understand and describe the root zone that the crops and pastures on raised beds were experiencing.

Results show some of the changes and improvements in the soil measured in, and under, the raised beds. A lower number for bulk density (in grams per cubic centimetre of soil) is better than a higher (heavier) number. If a certain volume (in this case a cubic centimetre or cc) of a soil is heavier than the same volume of another soil, the soil with the higher bulk density is probably more compacted, containing less air spaces (lower porosity) and less able to hold water for plants to use.

The results presented here show that one of the main reasons why farmers should try to improve the soil is that the improvement may increase soil macro-porosity, thus enabling the soil to hold more plant available water. This should improve crop growth and grain fill.

Results suggest that the soil bulk density experienced by crops and pastures was lower on raised beds compared to the flat pasture. The bulk density of the Gnarwarre A soil appeared to improve more than the Gnarwarre B (Figure 1).

(In Figure 1, the soil bulk density on the flat soil is represented by the value zero and the improvements (reductions in bulk density) are shown by the horizontal bars for each soil type under raised beds. For example, the top grey bar shows that at the 0 – 10 cm soil depth, the Gnarwarre A soil under beds had, after 5 years, a bulk density a little over 0.2 grams lower [better] than it did under nearby flat pasture).

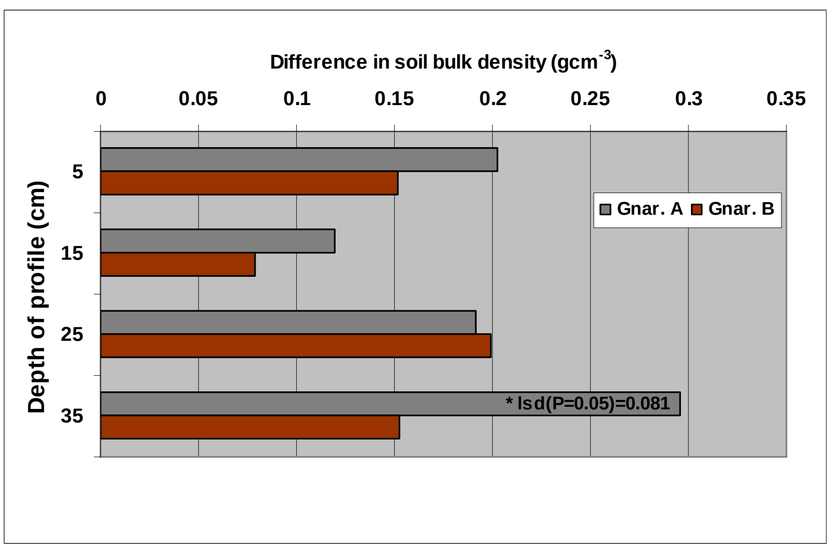

Figure 1. Bulk density of Gnarwarre A and Gnarwarre B soils after five years of raised beds, at four depths, relative to the bulk density of unimproved pastured on flat soil.

It is noteworthy that at the 30-40cm depth in the profile, the bulk density difference was significantly greater in Gnarwarre A compared to Gnarwarre B. The depth at which this difference was noted is below the depth of tillage. This suggests that, when controlled traffic is adopted, some soils may actually be able to reverse or repair compaction, or naturally dense constitution, through both physical and biological processes (McCallum *et al*., 2004).

It is difficult to separate the effects of the absence of compaction from those of biological drilling by plants roots and organisms in the subsoil. But there is wide consensus (Cresswell and Kirkegaard, 1995), that the absence of compaction may be essential for soil biological processes to continue uninterrupted. If this is so, then the fact that the raised beds abolished soil compaction and its harmful effects may be the primary reason for the differences in soil structure measured in this trial.

Greater shrinkage (Adcock, 1998, Loveday, 1972) of the black cracking clay (Gnarwarre A) is likely to have contributed to its significantly lower soil bulk density at depth compared to Gnarwarre B. The wetting and drying cycles in that soil cause a greater depth of aggregate formation (Sarmah et al., 1996) and this can result in a lower bulk density. This effect would have been enhanced by the absence of compaction.

Figures 2 and 3 show changes to soil water storage at depth in the two soils, measured in 2002 and 2004 respectively. The results are from a combined analysis of the different rotations managed on the raised beds since 1999.

(In Figures 2 & 3 the horizontal bars of the graphs indicate the measured difference of the water held by the soils in the raised beds, compared to the flat pasture, at "field capacity" [called the drained upper limit {DUL} in the graphs]. The water held is given in millimetres per each 20cm depth band of the soil. The "field capacity" of a soil is the maximum amount of water it can effectively hold, and is defined as "the amount of water held in the soil just after excess has drained away").

Figure 2 shows that in 2002, after three years of the rotations, the water holding capacity of Gnarwarre A (the black cracking soil) appeared to have decreased while that of Gnarwarre B increased. This was the result of extreme drying following wetting of soil, particularly at the surface layer, leading to the formation of a greater depth of aggregates.

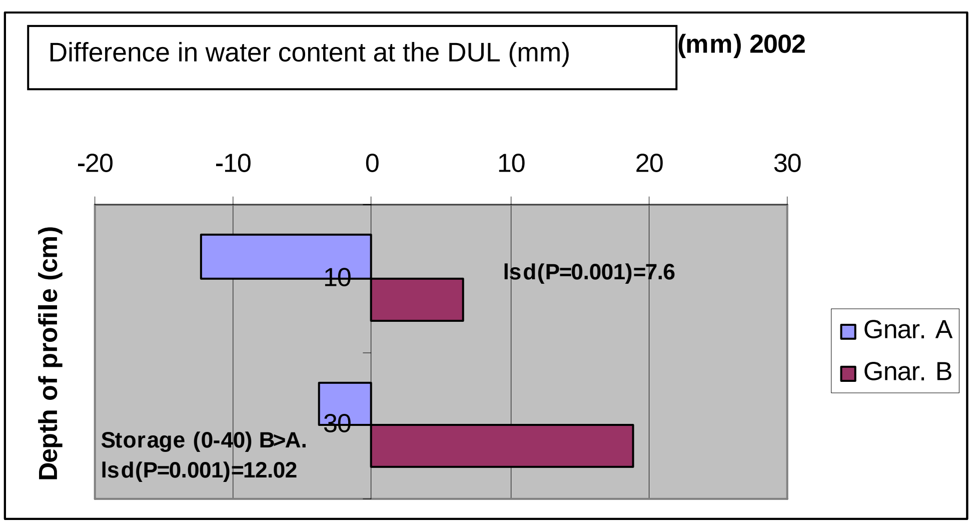

Figure 2. Comparison of the measured differences in soil water storage in the two soils in 2002

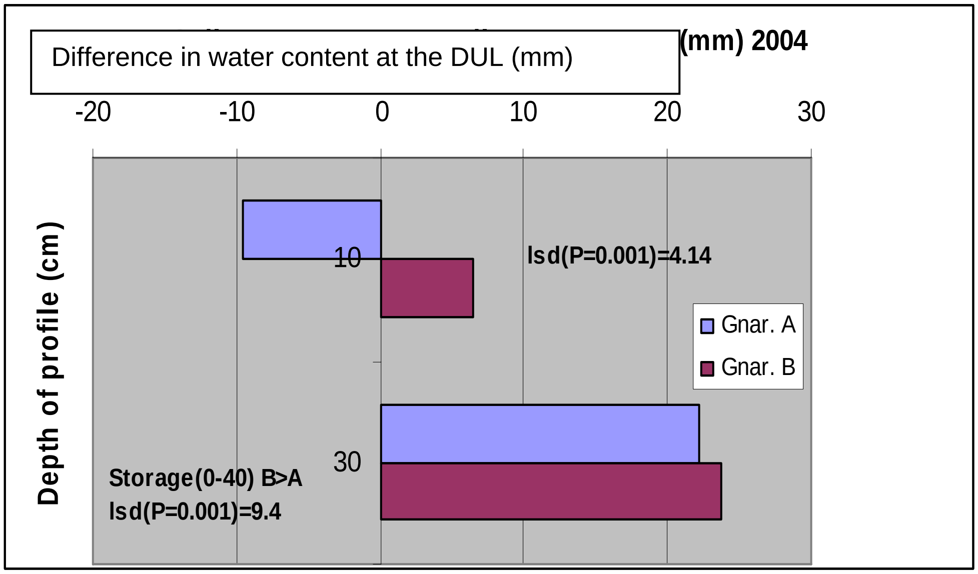

Figure 3. Comparison of the measured differences in soil water storage in the two soils in 2004

It seems that, despite the improvement in soil porosity, the loss of some pore connectivity may have resulted in the decrease of the Gnarwarre A soil's capability to hold water. In other words, the more open, friable nature of that improved Gnarwarre A soil may have made it easier for water to evaporate from it. The difference between the two soils suggests that not every heavy, cracking clay soil would respond similarly to raised beds. In this instance, perhaps controlled traffic alone, (abolishing the compaction without forming raised beds), might have led to a better outcome in the Gnarwarre A soil type.

The situation at the surface of the beds (0-20cm) had not changed much in 2004, three years later. However, below 20cm depth the situation reversed (Figure 3) and both soils appeared to improve their capacity to hold water, resulting in a smaller difference between them.

This is a good result, as crops frequently experience shortages of available water during grain fill. In this trial the crops on raised beds and controlled traffic had an increase in plant available water of 10-20mm, at depths down to 40cm, which is an important outcome.

CONCLUSIONS

Our results show a clear improvement in soil bulk density and plant available water capacity, at depths down to 40cm, in cracking clay Vertisols cropped using raised beds and controlled traffic. The two different soils responded differently to the raised beds and, in the case of the black cracking soil, some of the beneficial outcomes might have been obtained simply by controlled traffic alone. The mottled, olive clay Vertisol, which was considered comparatively more hostile prior to the adoption of raised beds and controlled traffic, appeared to improve more rapidly under the experimental conditions.

ACKNOWLEDGMENTS

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