Impact of strategic tillage methods on water infiltration into repellent sands

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Key messages

- Deep ripping alone may not overcome topsoil water repellence and improve water infiltration in severely repellent sands.
- Overcoming soil water repellence through deeper subsoil mixing using a rotary spader or modified one-way disc plough improved water infiltration, the evenness of soil wetting and weed control.

Aims

The aim of this work was to compare the impact of soil rotary spading, a proven soil amelioration method on repellent sands, with newer amelioration approaches including modified one-way disc ploughing and very deep ripping, below 450mm, on soil water infiltration.

Method

An on-farm demonstration site was established on severely repellent pale deep sand at Irwin in 2016. Tillage treatments (Table 1) were all implemented on 18 April, and the site was rolled with a rubber-tyred roller post treatment. Tillage treatments were implemented as 12m wide strips running the length of the paddock, approximately 1200m. Mace wheat was sown on 20 May at a seeding rate of 83 kg/ha. The site was assessed for soil compaction by measuring penetration resistance using a Rimik CP40 cone penetrometer on 31 May. Soil moisture was measured using a Delta-T HH2 soil moisture probe to measure volumetric soil moisture on soil pit faces excavated by hand. Water infiltration measurements were taken on 19 and 25 May with 50mm of rain falling over 21-24 May. This was just after seeding prior to crop emergence so was indicative of the soil moisture during germination. Crop establishment was assessed on the 9 June. Grain yield was assessed on 12m x 200m strips using the growers harvester and a weigh trailer.

Table 1. Tillage methods used, approximate effective working depth (based on penetrometer measurements) and indicative cost for amelioration demonstration on severely repellent pale deep sand at Irwin, 2016.

Strategic tillage treatment	Approximate effective working depth (cm)	Indicative estimated cost ($/ha)
Nil (Control)	-	-
Ausplow deep ripper	38	40-50
Terraland deep ripper	48	70-80
Tilco deep ripper	58	70-80
Shearer modified one-way disc plough	36	80-90
Farmax rotary spader	30	150

Results and Discussion

Subsoil compaction

The paddock where the site was located has only been sporadically cropped and mostly left to volunteer pasture due to the severe repellence and poor water and nutrient holding capacity of the soil. Prior to 2016 the site was last cropped in 2014 to Saia oats. Despite limited cropping and machinery traffic, the subsoil compaction at the site was severe (>2.5MPa) from 22cm and extreme (>3.5MPa) from 30cm (Fig. 1A). The Tilco deep ripper effectively loosened the soil to 58cm, the Terraland ripper to 48cm, the Ausplow ripper to 38cm, the one-way plough to 36cm and the spader to 30cm (Fig. 1A). Soil acidity was not a constraint at the site with average soil pH's ($CaCl_2$) of 6.2 at 0-10cm; 5.9 at 10-20cm and 5.8 at 20-30cm (data not shown).

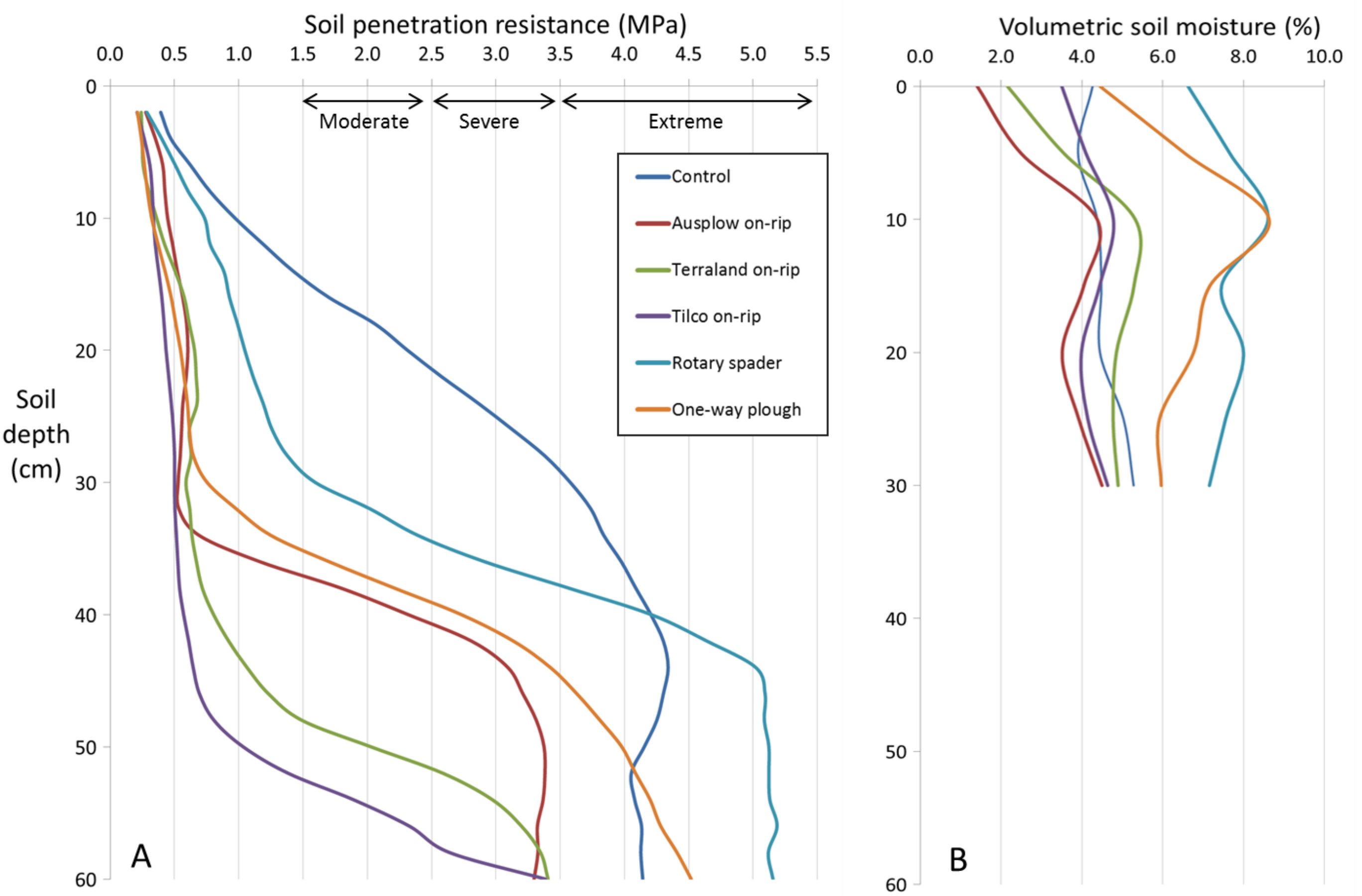

Figure 1. A) Soil penetration resistance measured 31st May, and B) average volumetric soil moisture measured 25th May, in response to soil amelioration treatments for severely repellent pale deep sand at Irwin, 2016. Note: Soil strength ratings (A) based on published reductions in cereal root growth rate, with severe reducing root growth rate by up to 75% and extreme preventing root growth except in pre-existing soil biopores and fractures.

Water infiltration

Deep rippers tend to have narrow, deep working tines which break-up hard pans and apart from some surface roughening only result in minor alterations of the topsoil. In contrast one-way ploughs and rotary spader substantially alter the topsoil. Modified one-way disc ploughs partially invert the soil bringing to the surface wettable subsoil. The action of a rotary spader tends to bury about two-thirds of the topsoil with the remaining third being mixed and diluted through the topsoil. These differences in impacts on the topsoil translate to significant differences in water infiltration on severely repellent soils.

Water infiltration measured after 50mm of rain over 4 days was significantly improved by rotary spading and one-way ploughing with higher and more even soil moisture contents down the soil profile (Fig. 2). In the untreated control moisture infiltration followed the typical pattern for repellent soils with preferential flow paths and large areas of 'dry patch' (Fig. 2) indicating bypass flow. In the deep ripped treatment preferential flow paths and large dry patches indicated no improvement in moisture infiltration and soil wetting. Rotary spading and one-way ploughing did bury some of the repellent topsoil resulting in more even water infiltration and a reduction the extent of dry patch (Fig. 2). Higher water content areas within the 15-30cm layers of these treatments are evidence of higher water retention in patches of buried organic topsoil (Fig. 2).

Average volumetric soil moisture on 25 May (Fig. 1B) in the one-way plough and spader treatments were 100% higher that of the control at 10cm, 50-80% higher at 20cm and 10-40% higher at 30cm (Fig. 1B). The deep rippers did not have a significant effect on average soil moisture compared to the control (Fig. 1B).

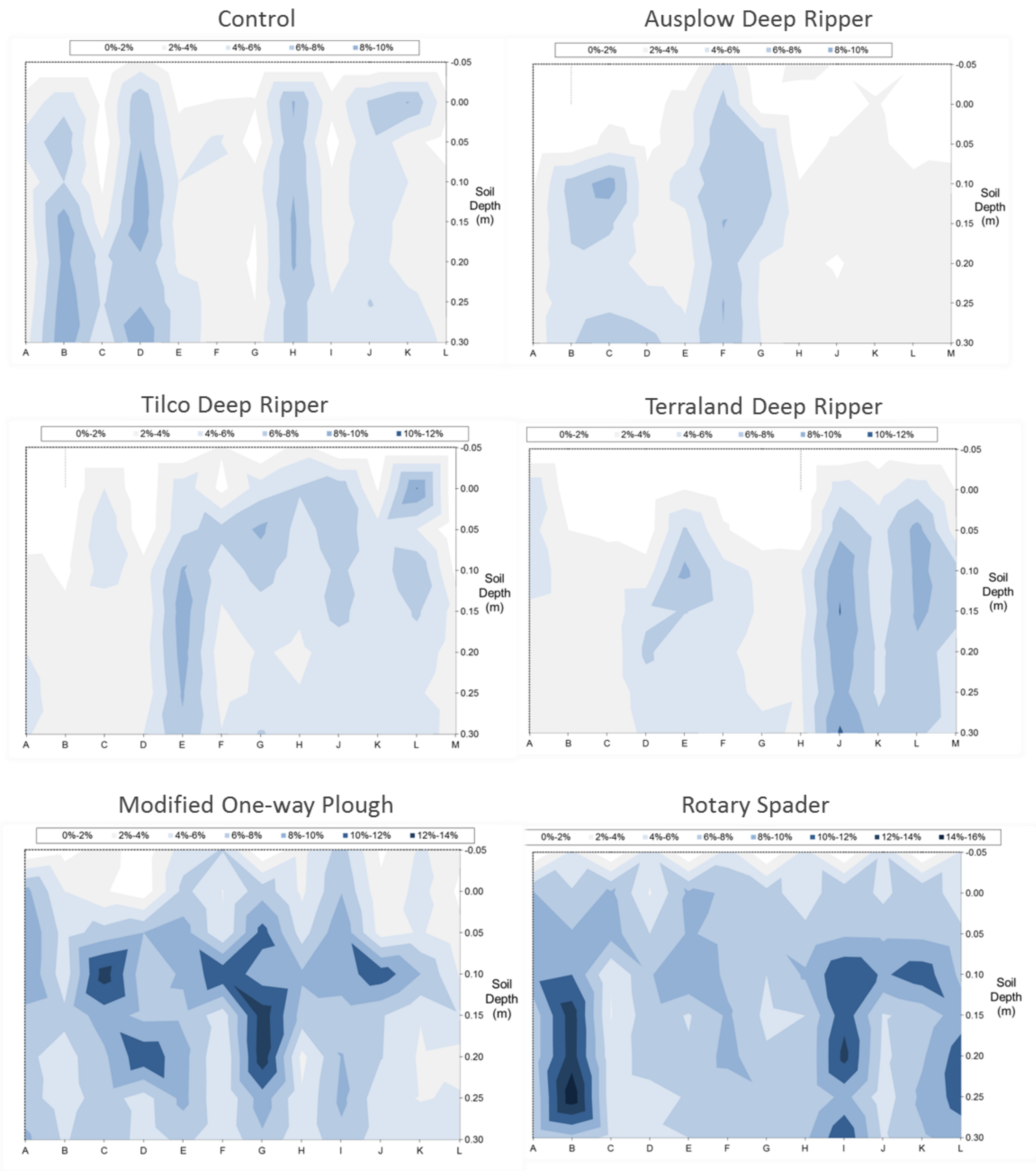

Figure 2. Volumetric soil moisture (%) on soil pit faces treated with various strategic soil tillage methods for severely repellent pale deep sand at Irwin following 50mm of rain over 4 days. Pits were 140cm wide and 30cm deep. Darker shading is indicative of higher soil moisture content.

Using average water contents down the soil profile before and after the 50mm of rainfall between the 21-24 May it was possible to estimate the average increase in soil water content (Fig. 3). The results indicate that the change in soil moisture down the profile for the deep ripped treatments were the same as or even less than the control. By comparison one-way ploughing had larger increases in soil moisture from 5-15cm and rotary spading throughout the measured profile, from 5-25cm (Fig. 3). In the case of severely repellent sandplain soils deep ripping alone may not overcome the soil water repellence constraint. Deeper soil mixing or inversion, application of soil wetters or addition of soil amendments such as clay-rich subsoil may be required in cases of severe repellence.

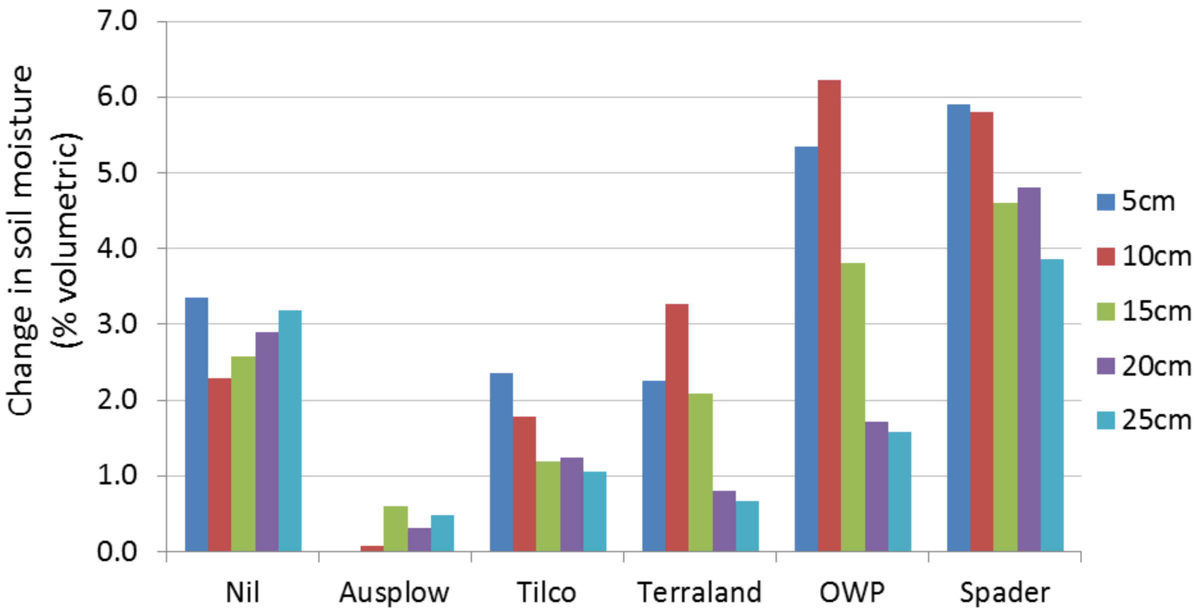

Figure 3. Increase in average volumetric soil moisture % down the profile for untreated repellent pale deep sand at Irwin compared with tillage treatments. Measurements were based on average water contents measured before and after 50mm of rainfall at the site from 21-24 May 2016. (Note: OWP = modified one-way plough).

Crop response

Because the site is an unreplicated demonstration and there was a large confounding effect of weeds crop performance measures need to be treated with caution. Crop establishment was affected by tillage, with the one-way plough having the most uneven seedbed, poor seeding depth control and poor establishment with just 78 plants/m^2 compared to 98-114 plants/m^2 for the other treatments (data not shown) as measured on 9 June. As is typical of repellent soils crop emergence is staggered so additional plants would have emerged over time though not counted in this demonstration.

Wheat grain yields for the untreated control and deep ripping treatments were low ranging from 0.7-0.9 t/ha (data not shown) and not indicative of the seasonal conditions. These low yields are most likely due to high weed competition (mostly ryegrass) and severe soil water repellence. In contrast grain yields were significantly higher for the one-way plough (1.6 t/ha) and rotary spading (2.3 t/ha; data not shown). For the one-way plough, poor crop establishment on an uneven seedbed and reduced but still significant weed burden would have reduced the yield potential. A neighbouring paddock that was one-way ploughed in 2015 had an average wheat yield of 1.8 t/ha in 2016 (Paul Kelly, personal communication). Weed control on repellent soils is notoriously difficult with staggered weed germination making control difficult. Much of the demonstration site area had to be cut for hay due to the high weed burden. The 2.3t/ha yield obtained in the spaded treatment reflects the better weed control achieved and consistent seedbed.

Conclusion

On deep sandy profiles subsoil compaction and acidity are major constraints. At this site the limited cropping history resulted in an expectation that the site would not be compacted but in fact compaction was severe, indicating how susceptible these pale sands can be to compaction. For many deep sands, liming followed by deep ripping with topsoil slotting may be one of the most economical ways of effectively overcoming subsoil compaction and acidity to depths of 40-60cm.

On severely repellent sands however, it may be that deep ripping alone is inadequate and options which overcome the repellence and assist with weed control while at the same time addressing subsoil compaction and acidity may be required to get sustained productivity benefits (Davies *et. al.* 2017). The impact of deep ripping on highly repellent soils is variable with anecdotal reports that ripping can sometimes worsen the expression of repellence and result in poorer crop establishment. Other reports indicate substantial productivity gains can also be achieved (Blackwell *et. al.* 2016). Deep ripping may help overcome soil water repellence by: 1) creating a rougher soil surface allowing water to pond and infiltrate over time; 2) loosening the dry topsoil making it a more effective mulch, reducing soil moisture loss from the subsurface soil; 3) delving some seams of subsoil to the surface which act as pathways for water entry, with some ripper tine designs and attachments facilitating this more than others. Conversely the negative effects of deep ripping can include: 1) enhanced drying of the repellent topsoil from the loosening action; 2) increased expression of the water repellence when the soil is ripped when it is quite dry. Repellence severity, or expression, is increased with these negative effects which was the case for this site. For other sites where repellence is more moderate any benefits of deep ripping may outweigh the negative impacts. The mixed effects of deep ripping on repellent soils needs further research to be better understood. It is likely that rippers with C-shaped or parabolic shaped tines with broader points and wider 'face' plates will achieve more subsoil delving into the topsoil. Some rippers can also be fitted with wings which can also increase the degree of soil mixing. A greater degree of subsoil delving could result in development of more effective infiltration paths and longer lasting reductions in topsoil water repellence.

In this study rotary spading and modified one-way ploughing were effective in improving water infiltration on severely repellent sand even if they did not remove the deeper compaction. Second-hand one-way disc ploughs have a relatively low capital and operating cost (Table 1) and are relatively cheap to modify into a simple but robust tool for partial soil inversion (Davies *et. al.* 2016), although good seed bed preparation is still essential.

Key words

Soil water repellence, deep ripping, strategic tillage, rotary spading, one-way ploughing, water infiltration

References

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