One-off tillage options for water repellent gravel soils Tillage options for severely repellent sands – which methods work?

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Purpose:	Assessing practical soil management options for overcoming severe water repellence on sandy gravels in the West Midlands
Location:	Rowes Rd, Moora and Brand Hwy, Badgingarra
Soil Type:	Water repellent sandy gravel
Soil Test Results:	Very severe soil water repellence (MED test = 3.6) Soil pH: 0-10cm = 6.2; 10-20cm = 5.9; 20-30cm = 5.8
Rotation:	2013 volunteer pasture; 2014 Saia oats; 2015 volunteer pasture
Growing Season Rainfall (April- October 2015):	413mm

BACKGROUND SUMMARY

Strategic deep tillage can be used to ameliorate soil water repellence and subsoil constraints. In addition to subsoil constraints, such as acidity and compaction, severely repellent pale deep sands also have poor water holding and low fertility which further limits productivity so amelioration approaches need to be as cost effective as possible. There is renewed interest in deep ripping as a cost-effective method for overcoming soil constraints, but the impact of deep ripping on soil water repellence is not well understood. One-way disc ploughs have a low capital cost and are relatively cheap to modify into a simple but robust tool for partial soil inversion. In this demonstration one-way disc ploughing is compared to rotary spading, a proven amelioration option for repellent sands and a number of deep ripping approaches, including some of the newer very deep rippers.

TRIAL DESIGN

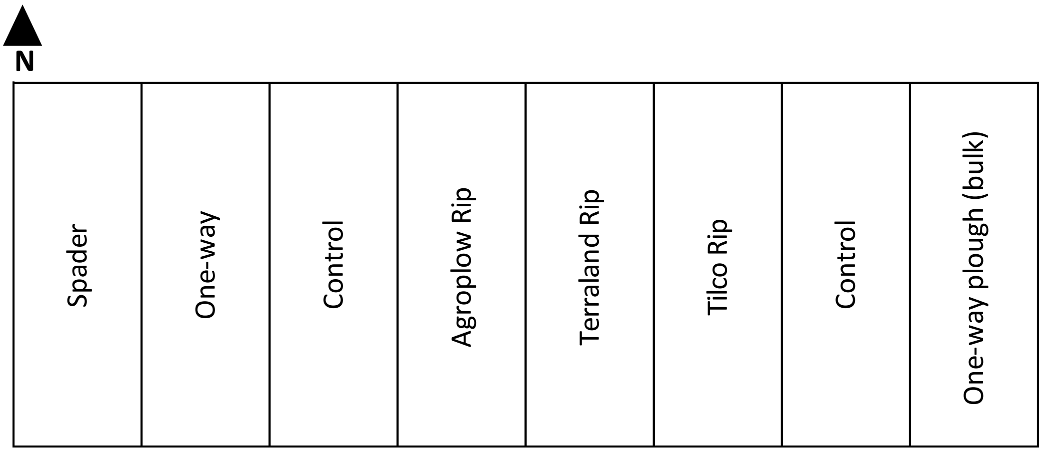
Strategic tillage treatments included in the trial are shown in Table 1.

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

Plot size: 12m x 1200m total (12m x 200m for yield)
Repetitions: Large scale demo
Crop type and varieties used: Mace wheat
Seeding rates and dates: 20 May at 83 kg/ha

TRIAL LAYOUT



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.

RESULTS and DISCUSSION

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 (data not shown). 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. 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).

Water infiltration

Deep rippers typically have narrow, deep working tines which break-up hard pans and apart from some surface roughening only result in minor topsoil changes. 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 topsoil impact 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. 1). In the untreated control moisture infiltration followed the typical pattern for repellent soils with preferential flow paths and large areas of ‘dry patch’ (Fig. 1), indicating by-pass flow. Preferential flow paths and large dry patches in the deep ripped treatments 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 in the extent of dry patch (Fig. 1). 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. 1).

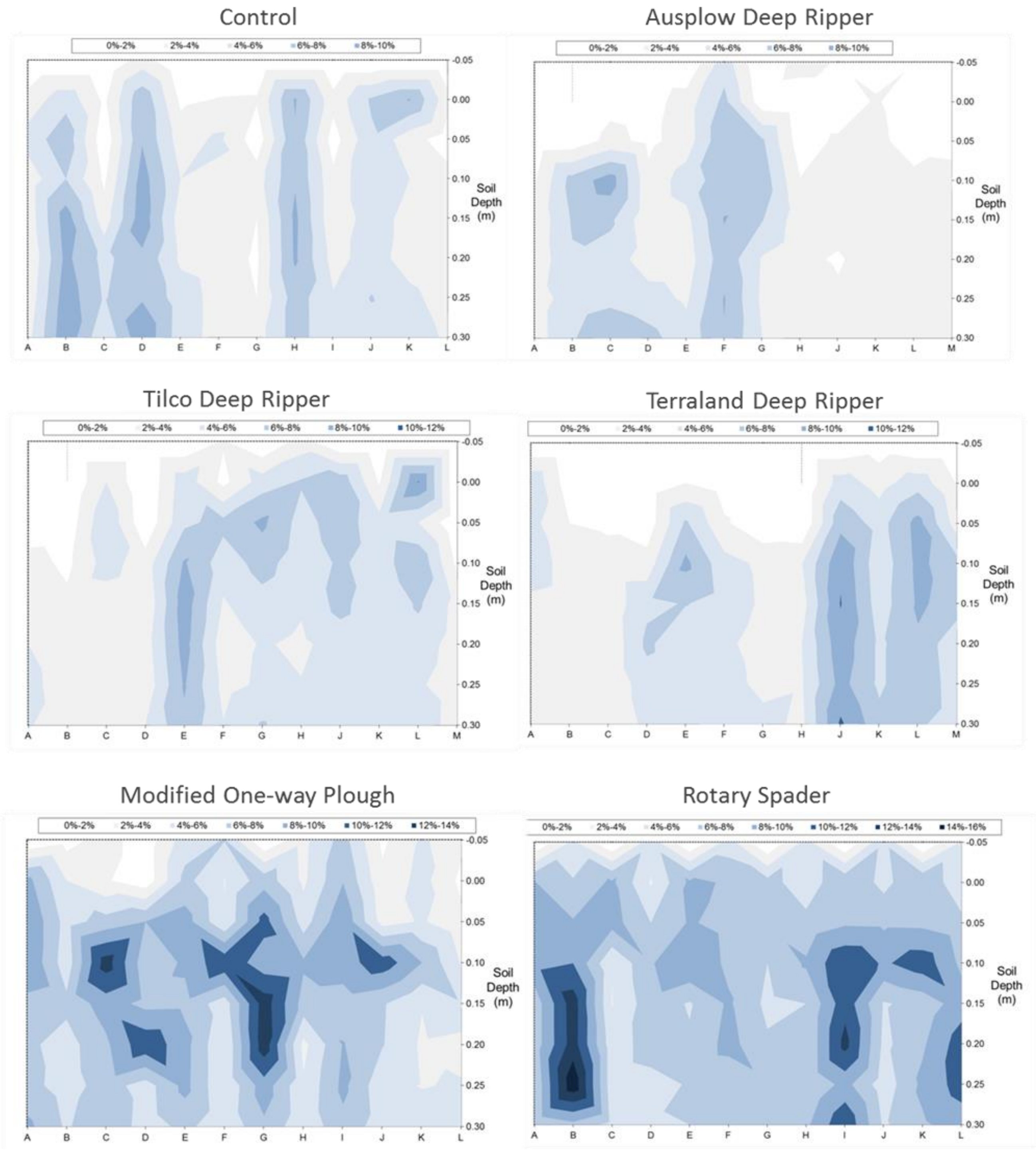


Figure 1. Volumetric soil moisture (%) on soil pit faces treated with various strategic soil tillage methods for severely repellent pale deep sand at Irwin following 50mm of rain over 4 days. Pits were 140cm wide and 30cm deep. Darker shading is indicative of higher soil moisture content.

Overall average volumetric soil moisture on 25 May 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. The deep rippers did not have a significant effect on average soil moisture compared to the control (data not shown).

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. 2). 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. 2). 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.

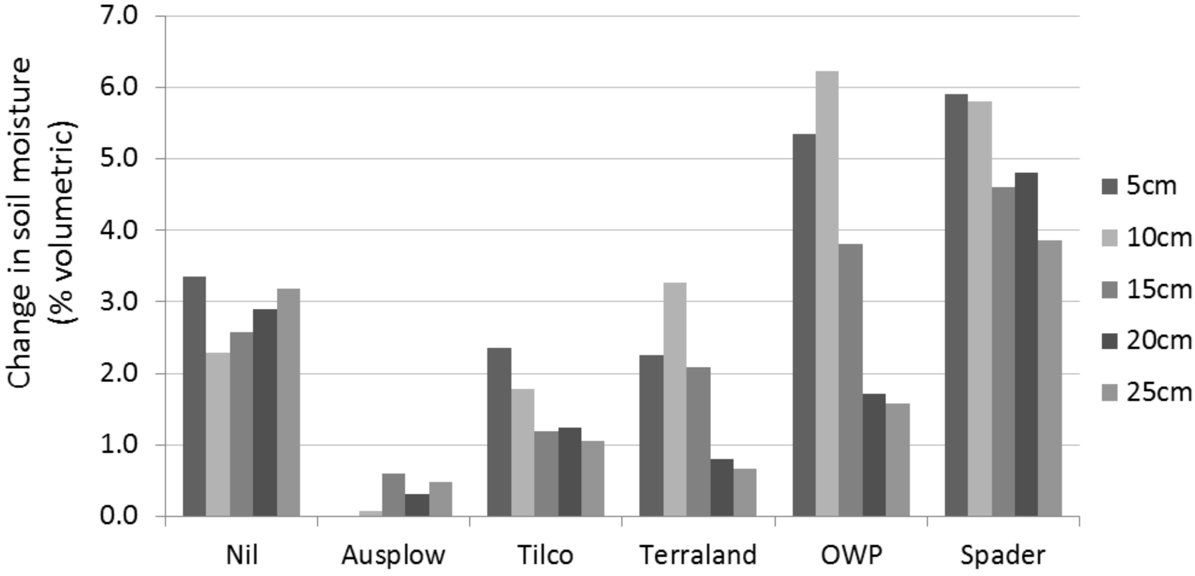


Figure 2. Increase in average volumetric soil moisture % down the profile for untreated repellent pale deep sand at Irwin compared with tillage treatments. Measurements were based on average water contents measured before and after 50mm of rainfall at the site from 21-24 May 2016 (Note: OWP = modified one-way plough)

Crop response

Because the site was an replicated demonstration and there were large confounding effects 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. Crop emergence was 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. The 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 a reduced but still significant weed burden would have reduced the yield potential. A neighboring 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 in the spaded treatment reflects the better weed control, a consistent seedbed and effective overcoming of soil water repellence.

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 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.

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