Clay delving for the amelioration of water repellent soils: first year results from a site near Esperance

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Key messages

1. A trial was established to evaluate two depths of clay delving and four incorporation methods on a water repellent texture-contrast soil (Sodosol) near Esperance (WA). To our knowledge, this trial is the first of its kind.

2. The depth of clay delving and the tillage methods affect both the quantity and distribution of the subsoil clay through the topsoil. Increasing the amount of subsoil clay in the topsoil decreased the severity of soil water repellency.

3. Uneven seeding depth in newly renovated soils contributed to poor early plant establishment in the clay delved and tilled treatments. Nevertheless, by the end of the growing season all clay delved and tillage treatments significantly increased barley grain yields up to 1.5 t/ha and up to 1 t/ha respectively in comparison to the control.

Aims

The aim of this experiment is to study the effects of clay delving on water repellent texture-contrast soil by comparing over a period of 4 years different clay delving approaches (based on amount of clay and method for topsoil incorporation) in one single trial. Ultimately, our objective is to evaluate the cost-effectiveness of different clay delving treatments and produce practical guidelines for farmers in the Southern region of WA.

The uneven soil profile wettability in water repellent texture-contrast soils (Betti et al., 2015) is a primary reason of poor crop establishment and reduced productivity. The high soil strength of the clay subsoil is also the cause of constrained root growth at depth. The Southern Region of WA presents great potential for clay delving, which is an effective soil modification for the amelioration of water repellent soils with shallow clay subsoils, such as the texture-contrast soils (DAFWA 2009, Davenport et al. 2011). Nevertheless, clay delving is an expensive exercise and yield improvements have not always been achieved.

One of the main challenges when studying clay delving is the difficulty to set apart and compare the factors contributing to its overall effect on crop yield. The most important factors are considered: i) the amount and type of clay brought to the surface by the delver; ii) how the subsoil clay is subsequently incorporated (degree of mixing) in the topsoil. Both factors determine the extent of mitigation of soil water repellency and laboratory experiments have shown that they significantly affect other important soil physical properties (Betti et al. 2016).

Results from past trials are somewhat difficult to compare, due to the variability of soil types and depth of the subsoil and depth of delving between and within the trials. All of these factors directly influence the amount of subsoil clay brought to surface. Moreover, incorporation methods are often different.

Method

The clay delving trial was established on a farm at Beaumont (S33.313, E123.068) near Esperance. The soil type was a texture-contrast one, characterised by a sandy topsoil with bleached A2 horizon over a sodic clay-rich subsoil and it was classified as Sodosol (Australia soil classification, Isbell 2002). Soil samples were collected at different depths and the main soil chemical and physical properties measured (Table 1). The site for the experiment was carefully chosen in an area of the paddock with subsoil consistently at a depth of approximately 0.2-0.25m. By having a constant depth of subsoil, we were able to create two clay delving treatments (based on different amounts of subsoil clay brought to surface) by simply setting the delver tines to two different depths (0.4 m or 0.6 m). This approach also allowed us to compare the effects of two depths of delving on plant root growth.

For the incorporation of the subsoil clay in the topsoil, four tillage treatments were combined with the two delving treatments: single run with rotary spader, single run with Grizzly off-set disc, two runs of rotary spader and two runs with Grizzly off-set disc. The aim was to compare different distribution of subsoil clay in the profile (spader vs off-set disc) and different degree of mixing (single run vs two runs). In order to better separate the effect of clay delving and tillage on plant growth, the tillage treatments were repeated on undelved soil. A control treatment (undelved and no-tillage) was also included, making a total of 13 treatments (Table 2) replicated in three randomised blocks.

Table 1. Soil properties of the Sodosol (texture-contrast soil) at Beaumont, WA.

Soil depth (cm)	% Clay	% Sand	% Silt	EC (dS/m)	pH ($CaCl_2$)	Exc. Al	Exc. Ca	Exc. Mg	Exc. K	Exc. Na	eCEC	ESP
0-10	4.4	95.1	0.5	0.1775	5.45	0.0635	1.83	0.61	0.1	0.595	**3.2**	**19%**
10-20	3.9	95.6	0.5	0.069	6.6	0.0535	0.96	0.325	0.09	0.295	**1.7**	**18%**
20-30	22.7	74.9	2.4	0.238	7.95	0.1915	3.635	3.46	0.995	2.47	**10.8**	**23%**
30-40	28.2	68.0	3.8	0.3665	8.3	0.1745	5.59	4.095	1.27	3.96	**15.1**	**27%**

The trial was sown with La Trobe barley the 16th of May 2016. Crops were assessed for plant establishment (plant counts, tiller counts and NDVI) and grain yield and quality. The effect of the treatments on the severity of water repellency was measured using the MED method (Molarity of Ethanol Droplets). Soil resistance to penetration was assessed in wet winter conditions (June 2016) with a digital field penetrometer, sampling on the delving lines and off the delving lines. In order to measure the quantity of subsoil clay incorporated in the treatments and its degree of mixing (size of clay clods), large 0.1x0.1 m undisturbed cores were taken at 0-0.1m and 0.1-0.2m depths in the delved/tilled treatments (to date, only from the single run of tillage treatments). From each sample, we measured mean clay content and the distribution by weight of subsoil clay aggregates of different size by sieving the soil samples trough sieves with six different nominal apertures (2, 4, 4.75, 6.7, 12.5 and 20 mm).

The results presented below are a summary of the results from the first year of the trial.

Table 2. Summary of the treatments established in the trial.

Clay delving options		Combined with →	Tillage options (post delving incorporation)*	
A.	Undelved	→	1. 2. 3. 4. 5.	No incorporation Spader Grizzly off-set Spader x 2 runs Grizzly off-set x 2 runs
B.	Delved to 0.4 m depth	→	6. 7. 8. 9.	Spader Grizzly off-set Spader x 2 runs Grizzly off-set x 2 runs
C.	Delved to 0.6 m depth	→	10. 11. 12. 13.	Spader Grizzly off-set Spader x 2 runs Grizzly off-set x 2 runs

Results

Effects of the treatments on soil properties

Soil particle analysis on the sample collected from the clay delved treatments showed that clay delving increased the mean clay content of the top soil (0-0.1m depth). Delving at 0.4 m depth increased the clay content in the top 0.1m from 4.4% for the original soil (Table 1) to 5.4% (note: 5% of clay is generally considered the minimum amount to overcome water repellency). As expected, delving at 0.6 m depth further increased the clay content of the top soil to 7%.

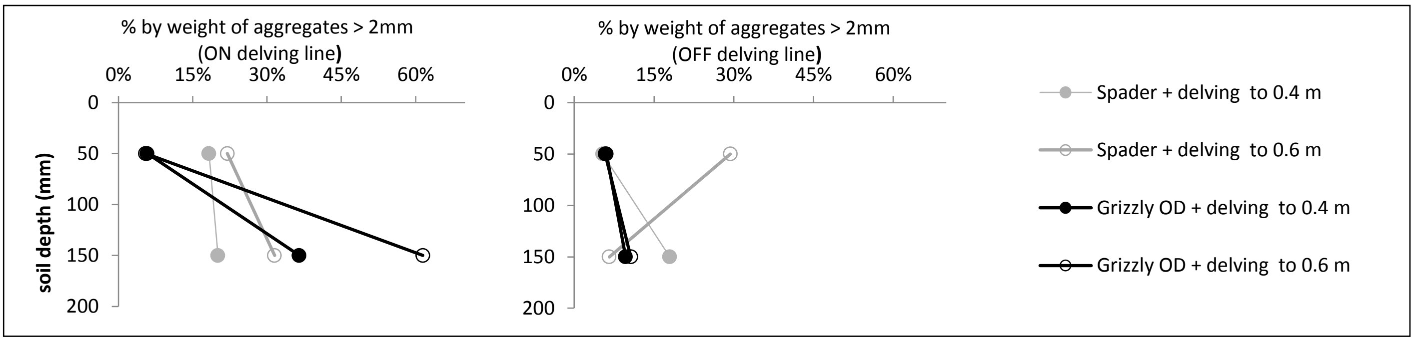

Fig 1. Effect of tillage and depth of clay delving on the distribution of clay aggregates (larger than 2mm) on the delving line **(left)** or off the delving line (**right**).

Obvious differences between the incorporation methods (spading and Grizzly off-set single run only) were marked by the analysis of the distribution of the clay aggregates throughout the profile (Figure 1). On the delving line (**figure 1, left**), where most of the susbsoil clay is found after the soil is clay delved, the spader effectivelly broke up and redistributed the clay aggregates (diameter >2mm) through the topsoil; unlike the off-set disc, which was more effective in breaking up the clay aggretates near surface but less effective in either breaking up or lifting up the clay aggregates below 0.1m depth.

Spading was also more effective in distributing clay aggregates between the delving lines (or off-line) when compared to the off-set disc (Figure 1, right) but this was more evident when more susboil was brought up by the delver, such as in the case of delving to the depth of 0.6 m.

The mean MED value in the control treatment was 1.73, which is considered moderate repellency (King, 1981). Nevertheless, the MED values were highly variable in the control plots, ranging from a minimum of 0.8 (low repellency) to over 3 (severe repellency). All tillage treatments and clay delving+ tillage treatments were highly effective in reducing the MED values to <1 (low repellency) (Figure 2, left). The treatments with a single run of spading were the most effective in reducing water repellency, independently from their combination or not with clay delving. As expected, the MED values decreased with increasing amount of subsoil clay added to the topsoil (i.e. increased depth of delving). On the other hand, no clear differences were observed between treatments with one or two runs of tillage.

The mean values for soil resistance to penetration measured with the field penetrometer are shown in Figure 2 (right). All treatments had little effect on the topsoil strength (0-0.2 m depth) while the deep ripping effect of clay delving had an obvious and significant effect in reducing the subsoil strength along the delving lines. Surprisingly, there was not significant difference between delving at 0.4 m or 0.6 m depth. Visual observation of the soil profiles suggested that the increased depth of delving did not necessarily translate in more topsoil sand replacing the subsoil at depth greater than 0.4 m.

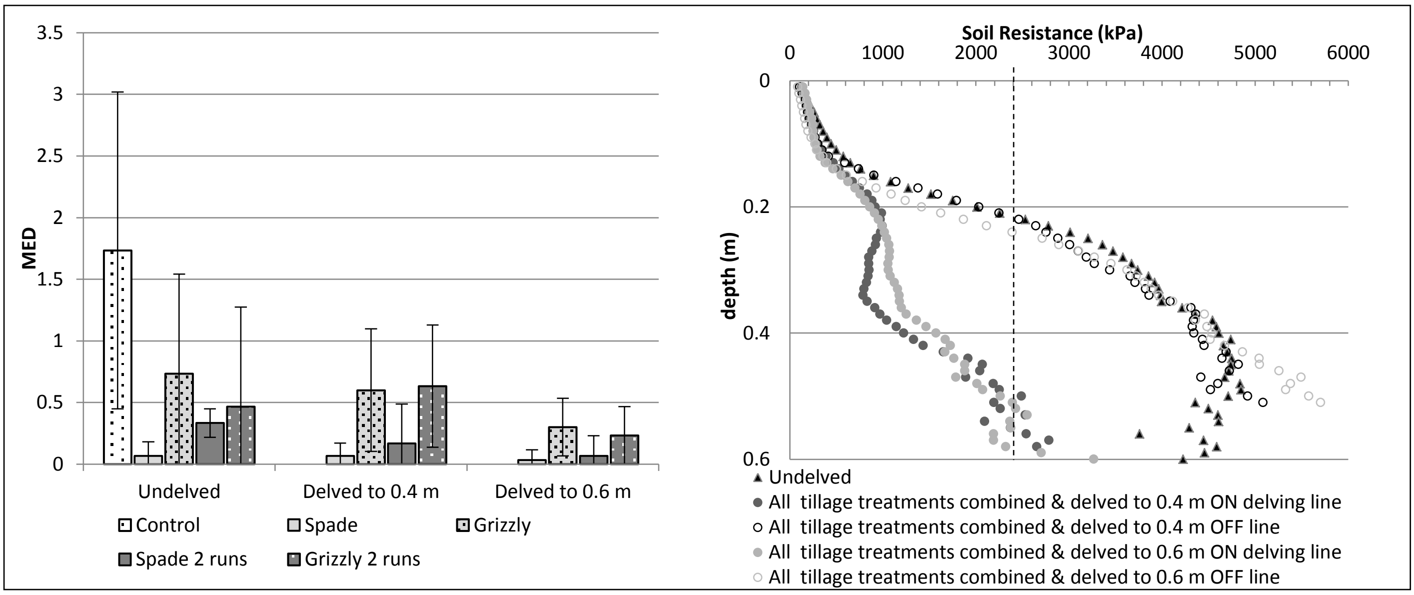

Fig 2. **Left**: effect of the treatments on the severity of soil water repellency as measured by the molarity of ethanol droplet method (MED). Lower values of MED indicate less water repellency. Error bars represent standard deviation of the means. **Right**: Effect of clay delving depth and tillage methods on soil resistance to penetration measured by digital field penetrometer. The vertical dashed line marks the 2500 KPa value after which plant growth is significantly reduced in most crops.

Effects of the treatments on crop establishment and yield

Poor early crop establishment was observed in most treatments, particularly those with clay delving and tillage combined. This was expected and explained by the difficulty in achieving the targeted seeding depth when sowing on a newly renovated soil with an uneven surface. Early poor crop establishment was confirmed by the plant counts recorded approximately two weeks after sowing (Figure 3, left). The number of plants per linear metre in the treatments was very variable and in most cases fewer than the control treatment. On the other hand, the good crop establishment in the control treatment was explained by a wetter than usual conditions in April-May, which most probably mitigated the severity of water repellency.

Nevertheless, field observation showed that the plants were eventually able to compensate for the early poor establishment and progressively the crops in the delved and tillage treatments started to grow better compared to the control treatments.

This was confirmed by the grain yield results, as shown in Figure 3 (right). Statistical analysis (Genstat®) showed that tillage and clay delving affected the grain yield of barley. On average, the harvest index increased due to the effect of delving and tillage by 10% and 15% in comparison to the control treatments. All tillage treatments, in combination or not with clay delving, outperformed the mean 2 t/ha of barley recorded in the control treatment. Spading and Grizzly off-set alone yielded on average 3.1 t/ha and 2.8 t/ha respectively with no significant differences between one or two runs. The higher yields were nonetheless achieved in the clay delved treatments. On average, all the clay delved treatments achieved 3.4-3.5 t/ha of barley. Surprisingly, no significant differences were found between all tilled treatments when delving either at 0.4 m depth or 0.6 m depth.

Field observation suggested the trial was subjected to frost sometime between flowering and harvest time but the clay delved and tillage treatments appeared less affected than the controls. This may have been a key factor influencing grain yields. However, no data are available in support of this hypothesis. Sampling for frost damage will be included next season.

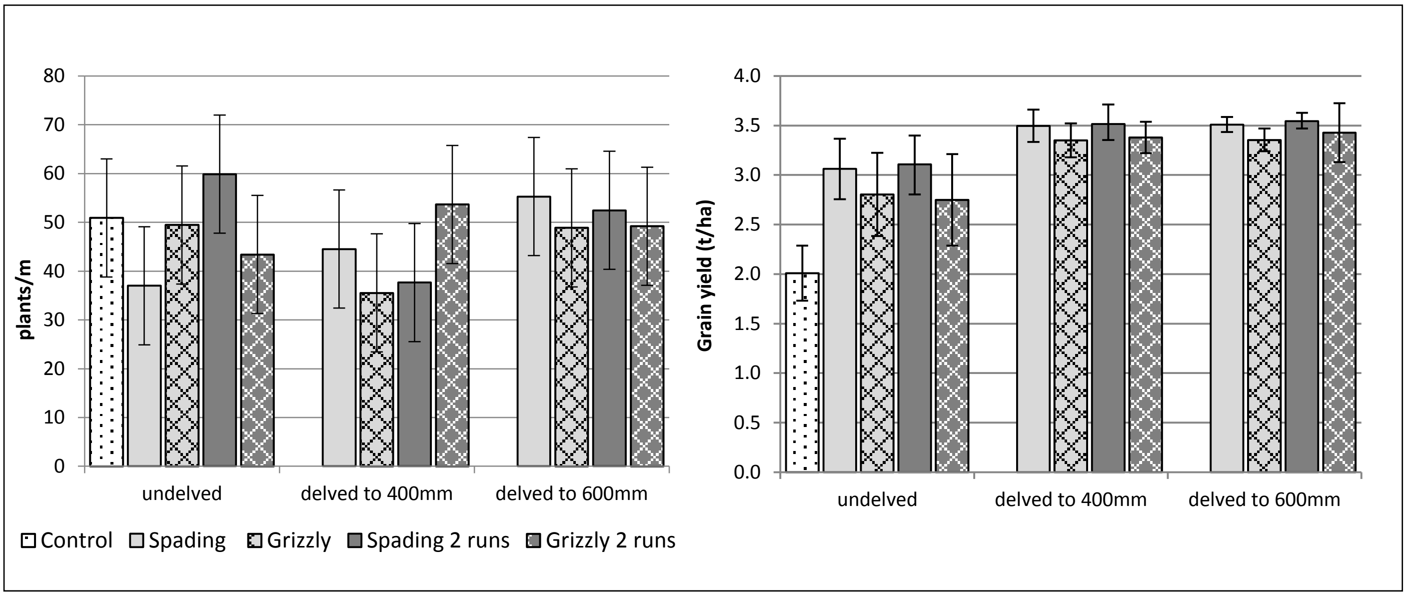

Fig 3. Effect of clay delving depth and tillage methods on early plant establishment (**Left**) and grain yield (**Right**) of La Trobe barley. Error bars represent standard deviation of the means.

Conclusion

Results from the first season trial showed that depth of clay delving and the tillage methods affect both quantity and distribution of the subsoil clay through the topsoil. All treatments were effective in reducing the severity of water repellence, in particular when an increasing amount of subsoil clay was incorporated in the topsoil (achieved by increasing the depth of delving). Uneven seeding depth in the newly modified soils affected early plant establishment. However, the treatments were eventually able to compensate for the poor establishment and the yields of La Trobe barley in all clay delving treatments outperformed the control treatment by about 1.5 t/ha. The tillage treatments in undelved soil also recorded higher yields up to 1 t/ha more than in the control treatment. No significant differences were found between delving to 0.4 m or 0.6 m and between the tillage methods. Field observation indicated that the clay delving and tillage treatments probably reduced the frost damage in the trial. Sampling for frost damage will be included next season in order to verify these observations.

The trial will continue for another three seasons. This will allow us to better understand the effects of the soil modifications on plant growth and develop a cost analysis of the treatment combinations for the medium-long term.

Key words

Texture-contrast soil, duplex soil, soil water repellency, clay delving, tillage

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