Cost-effectiveness of combinations of clay spreading and strategic tillage for management of repellent soils: first year results from a site in Moora, Western Australia

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Abstract

Clay spreading is a proven method for the amelioration of water repellent soils but it requires high initial capital investment and the outcomes can be quite variable. A field trial at Moora in Western Australia was established in early 2016 on a water repellent sand in order to identify the most cost-effective combination of clay spreading (at 0,100, 150 and 250 t/ha) and subsequent incorporation methods (off-set discs and rotary spader). Results from the first year of the trial showed that spading, on its own or in combination with claying, was the most effective method for reducing the severity of soil water repellence. Early plant establishment however was not significantly affected by the treatments, explained by a wetter than usual weather at seeding and during early plant growth. Nevertheless, clay spreading in combination with spading produced the highest grain yield, up to 1.5 t/ha above the untreated control. The difference in yields between the treatments was partly explained by frost damage. Clay spreading and, in particular, spading were found to significantly reduce frost induced sterility (FIS). Spading alone (without clay spreading) had the highest return on investment (ROI) in the first year thanks to its relative low cost, efficacy in reducing frost damage and good yield response. The trial will continue to be evaluated for a further three seasons (until 2019) in order to better assess the longevity and cost-effectiveness of all treatments in the medium to long term.

Keywords

Soil water repellence, clay spreading, tillage, frost damage.

Introduction

There is increased interest on clay spreading as an option for the management of water repellent soils in the WA wheat belt. Clay spreading is one of the most effective methods for the amelioration of water repellent soils but it requires high initial capital investments and the outcomes can be variable (Davenport et al 2011; Hall et al. 2010). Moreover, some evidence suggests that in medium-low rainfall areas there is a potential for negative outcomes following excessive applications of clay. The aim of this trial is to identify the best combination/s of clay application rate, subsequent clay incorporation method and deep ripping in a location where deep ripping alone has previously proven to increase crop productivity.

Methods

A field trial at Moora in Western Australia (-30.75603, 115.84921) was established in early 2016 on a water repellent deep yellow sand, typical of the area. The trial design included treatments consisting of a combination of four clay rates with three incorporation methods (tillage). Clay-rich subsoil was sourced from a nearby pit using an excavator and spread using a heavy duty multi-spreader. The rates of subsoil, applied were 0, 100, 150 and 250 t/ha. Two commonly available incorporation methods, off-set discs and rotary spader, were used to achieve different degrees of subsoil-clay incorporation and mixing in the topsoil. The offset discs incorporated the clay to a depth of 10-12cm and the rotary spader to depth of 30-35cm. An additional treatment with the rotary spader was added to the original trial design to further increase the degree of mixing. This was achieved by reducing operating speed to half its standard 5-6 km/h ("Spader ½ speed", Table 1). The reason for this was to study a wider range of soil mixing, from a "light" approach (such as with the off-set disc) to very aggressive (spader at ½ speed). This was based on evidence suggesting that the quantity and size of subsoil clay mixed with the sand can significantly affect several soil physical properties (Betti et al. 2016). The experimental design consisted of 16 treatment plots (17m x 18m each) replicated on three fully randomised blocks (each block had 8 extra control plots). After clay spreading and before incorporation the entire trial was deep ripped to depth of 40-42 cm in order to exclude (or at least reduce) the effect of subsoil compaction alleviation on plant growth. In this way differences in plant growth and yields between the treatments were mainly due to changes induced by the clay spreading and incorporation and their impact on soil water repellence. The trial was sown with LaTrobe barley on May the 16th in 2016. The costs of clay spreading at different rates for each individual treatment were estimates based on local information and are presented in Table 1. The effect of the treatments on the severity of water repellence was measured using the Molarity of Ethanol Droplet method (MED). Plant counts, tiller counts and NDVI were used to assess plant establishment. A tissue test for plant nutrient uptake was conducted on barley leaves collected in late July 2016. Grain yield and grain quality were obtained by field hand cuts and a small plot harvester. Statistical analyses were conducted using Genstat® software (18th Edn.; VSN International: Hemel Hempstead, UK). Field observations indicated that the trial was affected by frost. Samples of barley heads were collected after the frost events in early November 2016 from all the treatments (except spading at ½ speed) for the assessment of frost induced sterility (FIS= number of sterile florets / total number of florets). This paper presents the summary of the main results from the trial's first year.

Table 1. Estimated costs of the clay spreading and tillage treatments.

Subsoil clay (t/ha)*	Estimated cost for clay spreading ($/ha)	Combined with→	Incorporation method (tillage)	Cost of Incorporation Method ($/ha)	Total cost of claying and incorporation ($/ha)
0	0	→	1. No incorporation	0	0
			2. Off-set disc	15-25	15-25
			3. Spader	85-110	85-110
			4. Spader (½ speed)	150-200	150-200
100 (50)	270	→	1. No incorporation	0	270
			2. Off-set disc	15-25	285-295
			3. Spader	85-110	355-380
			4. Spader (½ speed)	150-200	420-470
150 (74)	410	→	1. No incorporation	0	410
			2. Off-set disc	15-25	425-435
			3. Spader	85-110	495-520
			4. Spader (½ speed)	150-200	560-610
250 (123)	720	→	1. No incorporation	0	720
			2. Off-set disc	15-25	735-745
			3. Spader	85-110	805-830
			4. Spader (½ speed)	150-200	870-920

* Values in brackets after the rates of subsoil clay represent the mean quantity of actual clay (t/ha) incorporated in the soil, based on the mean clay content of the subsoil (31.0%). Crop in 2016: La Trobe Barley. Direct costs, including seeding treatments and harvest were estimated at 500$/ha (personal communication).

Results

The topsoil sand at Moora was severely repellent, as measured by MED (MED>2.2, King 1981; Figure 1a). Clay spreading, tillage and their combination significantly ($p<0.001$) reduced the severity of water repellence. When the subsoil clay was not incorporated by tillage or was incorporated using an off-set disc, the soil water repellency generally decreased with an increasing amount of subsoil clay. However, only at rates over 150 t/ha of subsoil the repellence became low. In contrast, spading (standard or at half speed) was the most effective method for the alleviation of soil water repellence. The MED values in these treatments were reduced to zero (non-repellent soil) and, most importantly, this was achieved independently from the presence, or not, of clay-rich subsoil. Surprisingly, the significant reduction of soil water repellence did not convert into significant differences in plant establishment measured five weeks after sowing (Figure 1b,). The above-average rainfall recorded during April-May 2016 (over 100 mm between 11th April and 25th May; source DAFWA) is likely to have reduced the impact of the soil water repellence on plant establishment. Issues with seeding depth on the newly renovated soils were not observed but they may have had a small effect on reducing the number of plants in the treatments with off-set discs and, in particular, those with the rotary spader. Five weeks after the plant counts, plant growth was assessed by tiller counts (data not shown). At this stage, treatments started to show differences in growth, with a significant ($p<0.05$) effect of tillage on the number of tillers. In particular, the spader treatments (standard and ½ speed) had the most tillers while the control had the fewest. This trend was repeated with the barley grain yields at harvest time (Figure 2a). Both tillage (Figure 2b) and rate of clay spreading (Figure 2c), significantly ($p<0.001$) improved grain yield in comparison to the control treatments (no clay and no tillage). The lowest yields were recorded in the control treatments and in the off-set tillage only (no clay) with an average of 1.41 t/ha and 1.36 t/ha, respectively. In general, the shallow tillage (or incorporation) of the off-set discs did not yield significantly different from the treatments with no incorporation at any given rate of subsoil clay. Clay spreading at 250 t/ha followed by spading at standard speed produced the highest yield on average (2.93 t/ha). Nonetheless, all treatments with spading (standard and ½ speed) were able to yield over 2.5 t/ha, even without the addition of subsoil clay (Figure 2a and b).

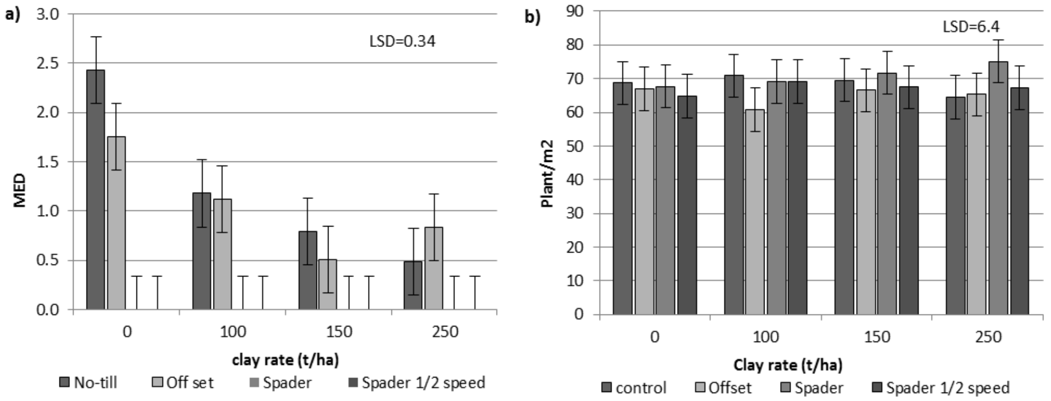

Figure 1. a) Effect of the treatments on the severity of soil water repellence as measured by the Molarity of Ethanol Droplet method (MED). Lower values of MED indicate less water repellence b) Effect of the treatments on early plant establishment. Error bars represent the least significant difference (LSD).

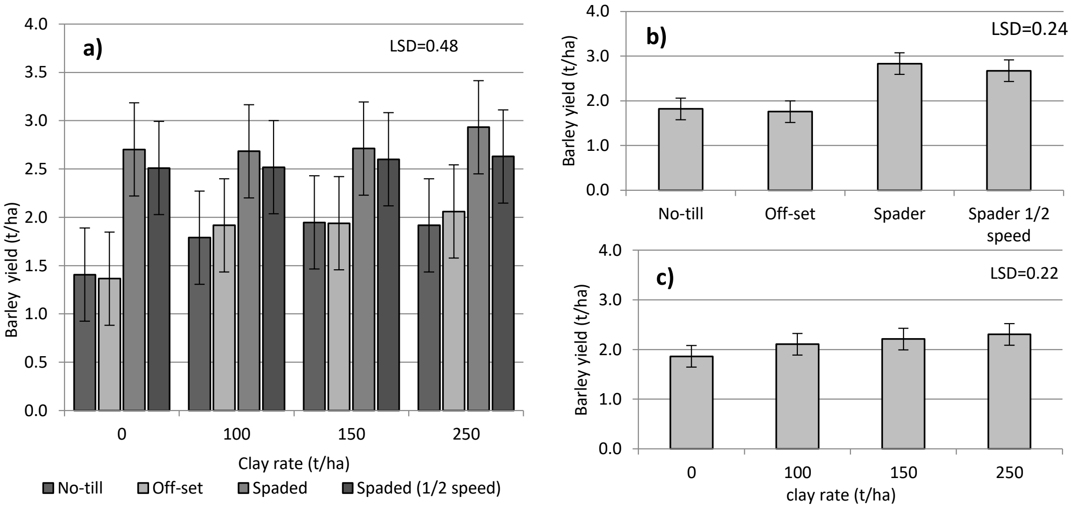

Figure 2. a) Effect of the treatments on grain yields. b) Mean effect of the incorporation methods (tillage) on grain yields. c) Mean effect of the subsoil clay rates on grain yields. Error bars represent the least significant difference (LSD).

Field observations indicated that the trial was also affected by frost, which explained the lower than expected yields. Samples of heads were collected in early November 2016 from all the treatments (except spading at ½ speed) for the assessment of frost induced sterility (FIS= number of sterile florets / total number of florets) and the results are shown in Figure 3. The differences in FIS help explain the large differences in yields between treatments. The control treatments and the off-set treatment (no clay) had over 60% frost induced sterility. Although increasing amounts of subsoil clay significantly reduced FIS (Figure 3c), the treatments with no incorporation or with incorporation by off-set discs still recorded FIS values over 50%. Spading was the most effective treatment able to significantly reduce frost damage below 40%, independently of applied subsoil clay (Figure 3a and c). Some evidence from trials conducted in WA showed that improved potassium uptake can potentially alleviate frost damage in cereals (Bell and Ma 2017). Results from the tissue test showed that tillage (spading in particular) significantly ($p<0.001$) increased the K concentration in the barley leaves. A good correlation was also found when the K concentrations were plotted against the FIS data ($r^2=0.67$; data not shown), with decreasing frost damage at increasing K.

The combination of the high crop-specific costs with barley ($500/ha) and the yield reduction due to frost had also a major effect on the estimated return of investments (ROI) in the first year of the trial. Spading alone at standard speed was the only treatment that gave a positive ROI (+$0.4/ha), followed by negative ROI with spading at ½ speed (-$0.18/ha) and the control (-$0.35/ha).

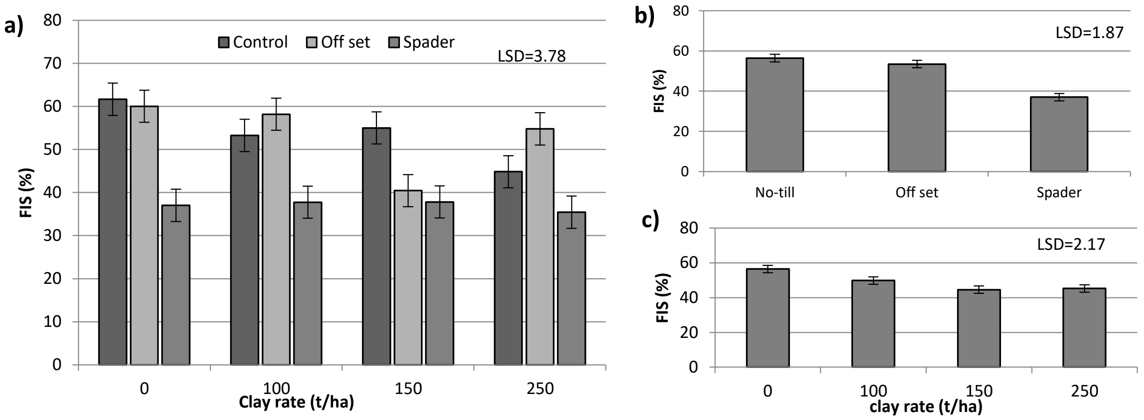

Figure 3. a) Effect of the treatments on frost induced sterility percentage (FIS). b) Mean effect of the incorporation methods (tillage) on FIS. c) Mean effect of the subsoil clay rates on FIS. Error bars represent the least significant difference (LSD).

Conclusion

The wetter than usual weather at seeding time (April-May 2016) reduced the impact of the soil water repellence on crop establishment. As a consequence, the effect of the treatments on reducing soil water repellence was less evident under these conditions. Nonetheless, significant effects of the treatments (rate of clay spreading or tillage and their combinations) were found at different stages of crop growth and at harvest. Spading (alone or with clay spreading) and increasing rates of clay spreading significantly reduced the severity of soil water repellence as measured by MED. Increasing rates of subsoil clay were associated with increased yields of barley, most probably due to reduced frost damage.

Nonetheless, spading was the most successful treatment in this first year of the trial and no significant differences were found when spading at standard or half operating speed. Most importantly, the spading treatments were able to produce the highest yields and significantly reduce the frost damage regardless of the addition of subsoil clay. This was particularly evident when estimating ROI as only the spading alone treatment (at standard speed) produced a positive ROI in the first year of the trial.

The trial will continue to be evaluated for a further three seasons (until 2019) in order to better assess the longevity and cost-effectiveness of all treatments in the medium to long term.

Acknowledgments

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