Longer term effects of spading, mouldboard ploughing and claying on the south coast of WA.

David Hall[1], Tom Edwards[1], Stephen Davies[2], Richard Bell[4], Imma Farre[3], Liz Petersen[3] and David Dodge[1]

[1]Department of Primary Industry and Regional Development, Esperance
[2]Department of Primary Industry and Regional Development, Geraldton.
[3]Department of Primary Industry and Regional Development, South Perth
[4] School of Veterinary and Life Sciences, Murdoch University.

Key messages

- Spading+Clay, Mouldboard ploughing and Spading alone reduced non wetting compared to the Control and all other seeding and wetting agent treatments.
- Soil strength was reduced by spading and mouldboard ploughing to 350mm only, however the improvements in soil strength diminished with time.
- Crop yields were increased by mouldboard ploughing, claying and spading by 3.5 – 4 t/ha over six seasons when compared to the Control.
- Mouldboard ploughing has been the most profitable treatment over the past six cropping seasons.

Aims

Sand plain soils typically have multiple constraints that limit crop production. These constraints include compaction, non-wetting and subsoil acidity. In the past farmers have tended to tackle each of these issues sequentially. For instance on-row seeding, use of wetting agents and paired-row seeding have been shown to help improve crop establishment in non-wetting soils (Kerr et. al. 2017; Davies et. al. 2016). However with the advent of tillage systems that can mix and invert these soils (e.g. spading and mouldboard ploughing) it is possible that multiple limitations can be ameliorated with a single tillage pass. Mixing and inverting non-wetting sands has been shown to be effective in burying and diluting organic materials that render sands hydrophobic and in reducing soil strength (Davies et al. 2012, 2013) while also mixing in soil amendments, such as clay and lime. Claying has also been found to increase crop production as a result of reduced non-wetting and increased access to nutrients (Hall et al. 2015); however such treatments have not always led to increased yields in lower rainfall regions. The aim of this research was to compare the longer term effects (2012 – 2017) of these sandplain soil management systems and specifically investigate changes in soil properties, crop yields and profitability associated with these treatments.

Background

A field experiment was established at Esperance Downs Research Station (S33.608º, E121.785º) in June 2012 on a water-repellent pale deep sand overlying clay at a depth of 80 cm. Eighteen treatments were imposed at the trial site. They consisted of nine main treatments and two lime sub treatments in four randomised blocks. Each plot was 20 m by 4.5 m in area.

1.	Control (Knife points)	(Control)	± Lime 2 t/ha
2.	Wetting agent (8 L/ha)	(Wetter)	± Lime 2 t/ha
3.	Seeding boot - Stiletto paired row	(Stiletto)	± Lime 2 t/ha
4.	Seeding boot - Winged point (Super seeder)	(WingP)	± Lime 2 t/ha
5.	Seeding boot - Disc seeder	(Disc)	± Lime 2 t/ha
6.	Spader (Farmax) to 35 cm	(Sp_35)	± Lime 2 t/ha
7.	Mouldboard plough (JD 995) to 35 cm	(Mbd_35)	± Lime 2 t/ha
8.	Spader 15 cm + Clay 170 t/ha	(Clay_15)	± Lime 2 t/ha
9.	Spader 35 cm + Clay 170 t/ha	Clay_35)	± Lime 2 t/ha

Clay-rich subsoil (clay) and lime were spread at the trial site in June 2012. The initial pH_{Ca} ranged from 5.5 at the surface to 4.8 in the subsoil. The spading (Sp) and mouldboard ploughed (Mbd) treatments were subsequently applied once at the end of June 2012. The seeding boot and wetting agent treatments were re-applied each year. Seeding and harvest were done with a cone seeder (3 passes per plot) and plot header (2 passes per plot), respectively. Knife points were used to seed the Sp and Mbd treatments. All plots were managed identically in terms of inputs including seeding rates, fertilizer and pesticides. Crops grown, cultivars, seeding rates, seeding and harvest dates, and rainfall are given in Table 1. The degree of non-wetting measured on soil samples using the molarity of ethanol droplet (MED) test to a depth of 10 cm at 5 locations in each plot. Soil strength was measured annually with a Rimik recording penetrometer at nine points within each plot. Simulations of crop yield responses to differing root elongation rates were done using APSIM. Economic data is presented as net present values ($/ha) which includes initial and ongoing input costs discounted at 5% per annum.

Table 1. Crop species, varieties, seeding rates, fertilizer applications, seeding and harvest dates, annual rainfall (AR) and rainfall decile for the experimental site between 2012 and 2017.

	2012	2013	2014	2015	2016	2017
Crop	Wheat	Canola	Barley	Canola	Wheat	Barley
Variety	Mace	Henty	Bass	Wahoo	Mace	LaTrobe
Seeding date	5 July	13 May	27 May	5 May	20 May	16 May
Seeding kg/ha	90	5	103	5	90	90
N:P:K:S kg/ha	39:14:0:9	63:10:29:10	32:9:0:13	116:9:60:20	56:14:0:43	53:8:34:12
Harvest date	4 Dec	15 Nov	21 Nov	16 Nov	10 Dec	24 Nov
AR mm (decile)	511 (6)	626 (10)	410 (2)	470 (4)	539 (7)	592 (8)

Results

1) Non-wetting and crop emergence

Soil water repellence at the site was rated as severe to very severe with MED values for the control treatment ranging from 2.8 – 3.6 (Figure 1) in the years measured. Soil water repellence was significantly (*P*<0.05) reduced by spading, mouldboard ploughing, and the spading and claying treatments when compared to the control. Spading alone retained a moderate level of repellence which was significantly higher than the mouldboard ploughed and clayed treatments. The wetting agent and the seeding point treatments did not result in any differences in water repellence when compared to the control when the measurements were made in March in each year. Lime had no effect on water repellence with a difference of only 0.2 – 0.3 MED between the sub treatments (data not presented). Treatment effects on non-wetting were quite consistent across years.

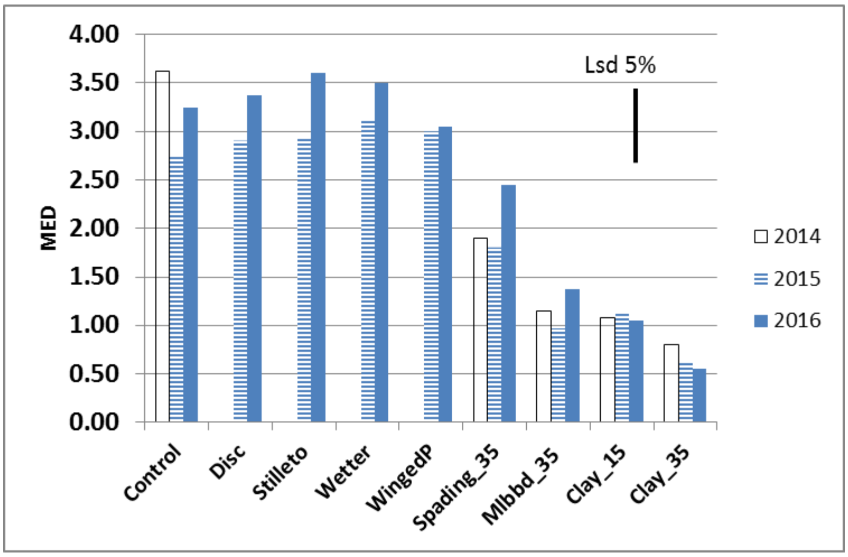

Figure 1. Effect of tillage treatments on water repellence as measured by the molarity of ethanol droplet (MED) test on soils collected to a depth of 0.1m. Measurements made during 2014, 2015 and 2016. The LSD 5% shown is the maximum value measured over the three years.

Treatment effects on crop emergence were not consistent. Plant numbers exceeded 115 for cereals and 35 plants/m^2 for canola in each year irrespective of the treatments. The claying+spading and spading treatments increased crop establishment in 2 and 1 of the six years respectively, while the mouldboard treatment never increased crop establishment over 6 years. Weed populations measured in 2013 were halved by the Mbd_35 and Sp_35 (5 weeds/m^2) treatments when compared with the Control (10 weeds/m^2).

2) *Soil strength*

Soil strength (penetration resistance) increased with depth, achieving maximum strength at 0.3 m. In each year, soil strength in the Control treatment exceeded 2500 kPa at 190 mm depth and 3000 kPa at 220 mm depth. Soil strength was significantly reduced as a result of the Spading (± Clay) and Mbd_35 ploughed treatments when compared to the Control (Figure 2). The reductions in soil strength occurred within the 50 – 320 mm zone in the initial year and in later years between the depths of 100 and 320 mm. In 2013 and 2014, soil strength was reduced in the order; Control > Clay_Sp15 > Mbd_35> Clay_Sp35 = Sp35. However by 2017 the order in which the treatments reduced soil strength had changed to Control = Clay_Sp15 > Mbd_35 = Sp_35 = Clay_Sp35.

The differences between the Control and the spaded and mouldboard ploughed treatments diminished with time (Figure 3). Initially the Control had soil strength values up to 2000 kPa higher than the Sp_35 treatment in 2013 at a depth of 280 mm. However by 2016 the corresponding difference was 1000 kPa. There were no differences between the limed and unlimed treatments. Also there were no consistent differences in soil strength between the Control, Wetter, WingP and Stiletto treatments (data not presented).

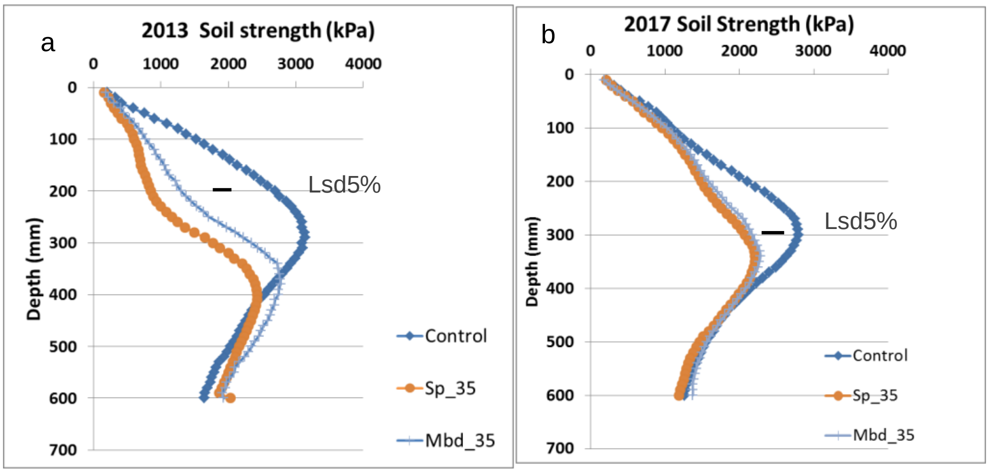

Figure 2 Soil strength as affected by the Control, spaded (±clay (Sp_35)) and mouldboard ploughed (Mbd_35) treatments. Measurements recorded during the winter months of 2013 (a) and 2017 (b).

The high subsoil strengths and periodic waterlogging almost certainly restricted root growth. Few roots were observed and measured below 40 cm depth at the trial site in any treatment (data not shown). Soil water extraction profiles showed almost no water extraction below 70 cm depth regardless of treatment. Analysis of the effect of root depth on crop yields was done at this site using the APSIM model calibrated for the trial site. Restricting roots to the depth of 70, 60 and 50 cm reduced predicted yields to 83, 75 and 67% of the water-limited potential in any given season. This suggests that root depth is important even in higher rainfall environments and that the spaded and mouldboard ploughed treatments may not be de-compacting the soil to the depths required to achieve yield potential.

3) *Crop yields and economics*

Total production over the five years was increased significantly by the spading (± clay) and mouldboard ploughing treatments by 3.3 – 4.0 t/ha when compared to the Control (Figure 3a). The spading with clay treatments (Clay_Sp15 and Clay_Sp35) had significantly higher grain yields than the Control in five of the six years. The Sp_35 and Mbd_35 treatments resulted in yield increases over the Control in three and two of the five years, respectively. The grain yields in all of the other treatments (Disc, Stiletto, Wetter, WingP) did not differ significantly to the Control in any year. Grain yields for the Sp_35 and Clay_Sp35 treatments were statistically similar in each year. There was no significant interaction between the tillage main treatments and lime in any year.

The percentage increase in crop yields for the spaded (± clay) and mouldboard ploughed treatments declined markedly after the third year of the experiment. Initially, crop yield increases over the Control exceeded 40-60% however, by the fourth year the differences were generally less than 20% (Figure 3b).

A Net Present Value analysis using a discount rate of 5% was calculated over the life of the trial (6 years) and includes the initial treatment costs. The NPV ranged from $2500 to $3750/ha. The increase in NPV ($/ha) at this trial site when compared to the Control was, in order from lowest to highest: Wetter ($-517), WingP ($-292) , Clay_35 ($-61) , Clay_15 ($61) , Stiletto ($115) , Sp_35 ($517) and Mldb_35 ($715) .

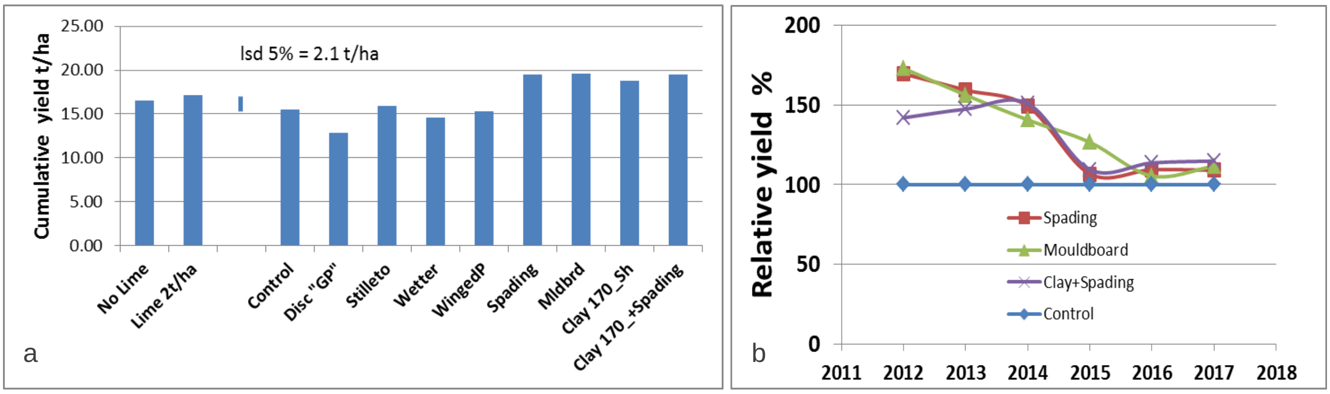

Figure 3. (a) Cumulative grain yield for the period 2012 – 2017 as affected by the soil management main treatments and (b) relative yield differences between the Control and spaded and mouldboard ploughed treatments for each year.

Conclusion

- Spading, mouldboard ploughing and clay reduced the degree of non-wetting when compared to the Control. Mouldboard ploughing was more effective in reducing non-wetting than Spading alone and as effective as Spading+Clay.
- Crop emergence was improved by the inversion tillage and clay treatments in some but not all years. In most years sufficient plants emerged to achieve yield potential irrespective of the treatment.
- Soil strength was markedly reduced to 350 mm as a result of the Spading and Mouldboard ploughing treatments. The benefits from the tillage diminished with time.
- High soil strength was found below 35 cm depth. Deep ripping prior to spading or mouldboard ploughing is practiced commercially and would seem to be justified based on the high soil strength below 45 cm depth presented here.
- Cumulative crop yields were increased by 3.3 to 4 t/ha by the mouldboard ploughed and spaded (± clay) treatments over 6 years.
- The Mouldboard ploughed and spaded alone treatments were most profitable, with discounted returns exceeding $500/ha.

Key words

Non-wetting, compaction, acidity, soil management, sandplain, mouldboard ploughing, spading, lime, wetting agent.

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