Understanding the impact of strategic tillage practices on crop performance and soil properties for a deep yellow sand at Goomalling. A 3-year study 2017-2019

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Key messages

1. In 2019 yield potential was very low due to spring drought conditions. Modified French-Schultz calculator crop yield estimates was limited to 1.07t/ha. At this site a comparably poor 0.66 t/ha top end yield outcome was achieved with 261mm of growing season rainfall.
2. Removing deep subsoil compaction is critical and for some soil types can dramatically improve access to deep soil moisture.
3. Yield increases in 2017 to 2019 were largely driven by very deep ripping to 700mm undertaken in 2017.Yield increases in 2019 were measured in response to very deep ripping at 53%, very deep ripping plus spading at 58%, very deep ripping with inclusion plates plus spading at 73%.
4. Despite average growing season rainfall lack of subsoil resource in the form of stronger soil types (i.e. minimal clay content to depth) may limit the ability of the crop to reach rainfall limited crop production potential.
5. Acid subsoil (below 30cm depth) and soluble Aluminium appear to be continuing to depress yields despite significant amendment of subsoil pH between 10-30cm depth in treatments that have mixed or inverted lime to this depth.

Aims

To compare and showcase the broad range of strategic tillage options for amelioration of yellow sandplain soils and to assess their effectiveness at overcoming a range of soil constraints including water repellent soil surface, compaction and subsoil acidity and increasing crop productivity over a period of 4-5 years.

Method

The Goomalling experiment is a randomised complete block design with 4 replications and has been established in 2017 on a deep yellow sand (Peartree sand) at Goomalling. The plots were established using the growers existing 12m seeding system. Plots are 4m wide and 22.5m long and are located in the wings, either side of the wheel tracks. The area between the wheel tracks has been left as an untreated buffer. The entire site is seeded and managed by the grower throughout the season but harvesting is undertaken with a small plot harvester so yield can be assessed on individual plots.

Table 1. Soil type, physical and chemical properties and growing season rainfall.

Soil Depth	Rainfall (mm)		Repellency rating	OC	EC	pH (CACl2)	Al (CaCl2)	Clay	Silt	Sand	Compaction (Severe)
	Average Annual	Growing Season	MED Test	%	ds m-1	Ph	mk kg-1	%	%	%	
0-10cm	365mm	261mm (2019)	1.5-1.9	0.8	0.02	5.8		3	3	94	2.5-4.2mpA
10-20cm				0.2	0.02	4.8	1.4	3	3	94	
20-30cm				0.2	0.01	4.3	5.5	6	2	92	
30-40cm				0.1	0.01	4.3	8	5	5	90	
40-50cm				0.1	0.01	4.3	10				

Machines used for the tillage treatments included an Agrowplow deep ripper, Heliripper very deep ripper, Farmax rotary spader, Alpler 5-furrow reversible mouldboard plough, a modified Chamberlain Plozza system one-way plough and a custom-built clay delver. All of the tillage treatments were applied and rolled prior to seeding and implemented in the first year (2017) only.

In 2019 the Goomalling site was sown to Chief Wheat at 80kg/ha on the 25th May using an Ausplow DBS with standard boots with 45kg/ha MAP and 15kg/ha Muriate of Potash banded under the seed and 80L/ha Maxam Flo banded to deliver total 27N, 10.1P, 6.24S, 7.5K. Pre emergent grass control was provided with 1.6L/ha Trifluralin 480

and post emergent grass control with at Prosulfocarb @ 2.5L/ha and Monza at 25gm/ha on the 14th July and follow up 500mls/ha Intervix Herbicide on the 31st July. Broadleaf weed control was achieved with 1.2L/ha Jaguar herbicide applied early post emergent.

Table 2. Experimental treatment details

No.	Treatment	Abbreviation	Effective Working Depth (cm)
1	Untreated control +/- 3t/ha Lime	CON	-
2	Deep rip +/- 3t/ha Lime	DR	32-34
3	Deep rip with topsoil inclusion +/- 3t/ha Lime	DRI	34-36
4	Deep rip + spading +/- 3t/ha Lime	DR+SP	33-35
5	Very deep rip +/- 3t/ha Lime	HR	65-68
6	Very deep rip with topsoil inclusion +/- 3t/ha Lime	HRI	62-65
7	Very deep rip + spading +/- 3t/ha Lime	HR+SP	62-65
8	Very deep rip + one-way plough +/- 3t/ha Lime	HR+OWP	62-65
9	Very deep rip with inclusion + spading +/- 3t/ha Lime	HRI+SP	62-65
10	One-way disc ploughing +/- 3t/ha Lime	OWP	30-35
11	Mouldboard plough (soil inversion) +/- 3t/ha Lime	MBP	34-36
12	Mouldboard plough + very deep ripping +/- 3t/ha Lime	MBP+HR	62-65
13	Delving + spading +/- 3t/ha Lime	DLV+SP	70+

Lime was applied at 3t/ha across the back half of each 45m plot and harvest results were taken separately from plus and minus limed plots creating 22.5m treatments.

Measurements at the site in 2019 included:

- Re-assessment of full site pH change under amelioration treatments
- Plant establishment counts
- Tiller counts
- Grain yield and quality

Results and Discussion

Rainfall

The wheat crop was dry sown on the 25th May with the opening and crop establishing rain occurring on 7th June with a fall of 11.9mm and follow up rain of 16.2mm and 21mm on the 10th and 11th June respectively. The Goomalling site for 2019 season proved very tough, with only 41.2mm summer rain received from January to April inclusive and a total of 261mm growing season rainfall (Table 1) benefiting the crop development with no significant rainfall after the 2nd September.

A significant period of spring moisture stress again occurred in 2019 during the critical periods of flowering and grain fill, with less than 12mm of rainfall occurring in September and less than 10mm in October.

Despite the investment in grass weed herbicides the site and subsequent yield was impacted by annual ryegrass and early crop competition from the previous years' cereal crop volunteers.

Soil Constraints

Revisiting the soil tillage treatments in the year of trial establishment in 2017 the effective working depth of the tillage treatments varied from 30cm to more than 70cm (Table 2). All of the treatments reduced the soil strength of the top 30cm of soil to a penetration resistance less than 2000kPa (Figure 1). All of the very deep ripping (including Ripping via Delver) treatments removed severe compaction to their working depth of below 60cm with a soil penetration resistance of less than 2500 kPa throughout the profile.

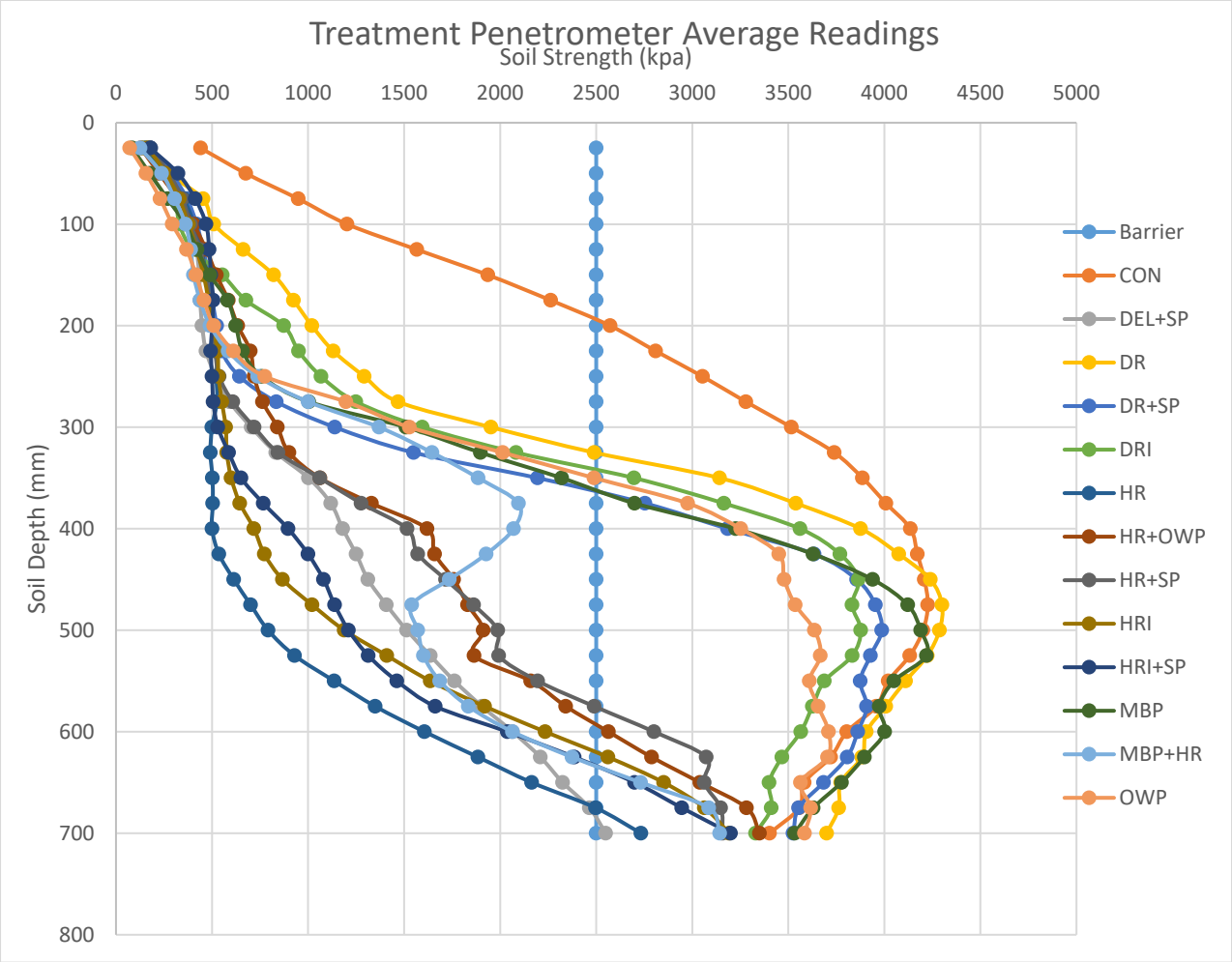

Figure 1. Soil strength measured in kPa comparing tillage treatments as measured by a RIMIK data logging Penetrometer in August of 2017 when soils reached moisture field capacity.

Subsoil acidity was an issue for the Goomalling site with an average pH_{Ca} of 4.5 or lower in the 20-30cm, 30-40cm and 40-50cm depth increments when initially tested in 2017.

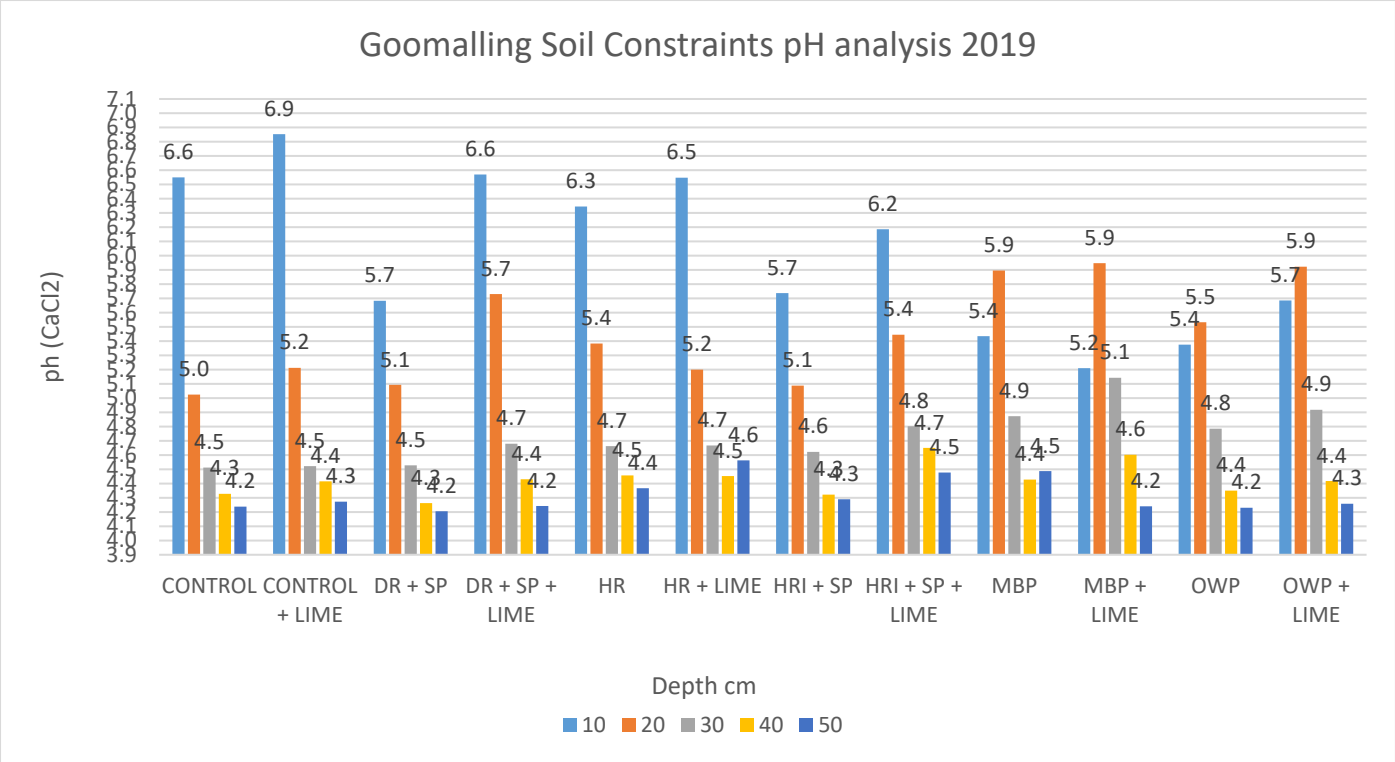

Figure 2. pH analysis in 10cm increments from 0-50cm, 2 years post lime application and tillage intervention (Measured March 2019)

The spading, one-way plough and mouldboard plough treatments can mix and bury the lime and less acid topsoil to the working depth. Follow up soil testing was completed in 2019, 2 years following the lime application and tillage interventions, to re-assess lime movement to depth under the different treatments. Margin of error of testing and laboratory analysis of pH is estimated at 0.2 units. pH increase in the control plots (no tillage) plus lime was measured at an increase of 0.3 at 0-10cm with no improvement in pH below 10cm (Figure 2.). Deep ripping plus spading plus lime measured no change in pH at 0-10cm, an increase of 0.7 units at 10-20cm and increase of 0.2 units at 20-30cm. No improvement was measure below 30cm.

Very deep ripping with inclusion plates plus spading plus lime measured a reduction in pH of 0.4 units at 0-10cm, an increase of 0.4 units at 10-20cm, an increase of 0.3 units at 20-30cm and an increase of 0.2 units at 30-40cm.

One way ploughing plus lime measured a reduction of pH of 0.9 units at 0-10cm, an increase of 0.9 units at 10-20cm, and an increase of 0.4 units at 20-30cm.

Mouldboard ploughing plus lime measured a reduction of pH of 1.4 units at 0-10cm, an increase of 0.9 units at 10-20cm, and an increase of 0.6 units at 20-30cm and an increase of 0.3 units at 30-40cm.

The reduction of pH at the soil surface and its general improvement at depth in both the spading and inversion tillage techniques is consistent with our understanding of the physical burial and inversion of topsoil under these tillage interventions.

Water repellence in the control plots was moderate based on the laboratory MED test result. Deep ripping exacerbated the expression of water repellence whereas spading, one way ploughing and mouldboard ploughing decreased the repellence of the topsoils (Figure 3).

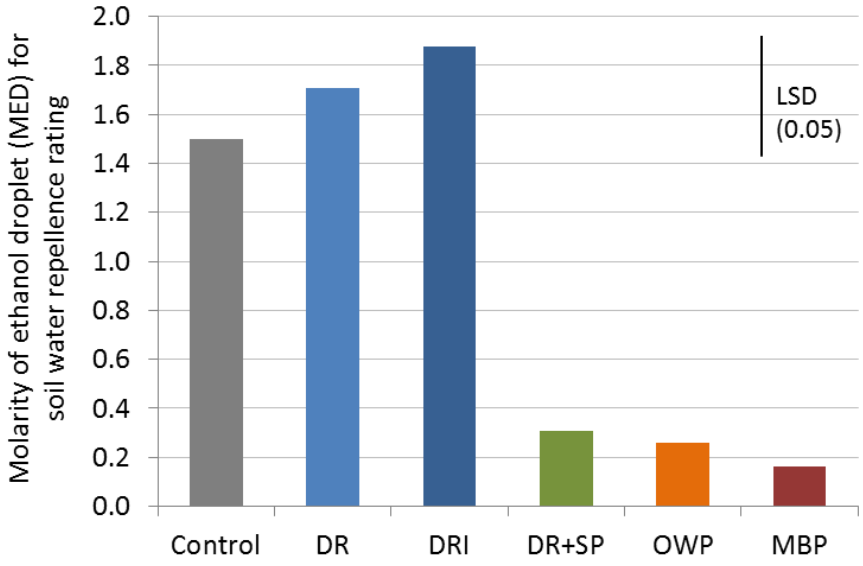

Figure 3. Molarity of ethanol droplet (MED) for soil water repellence rating. (Measured 2017)

Goomalling - Crop Growth and Grain Yield

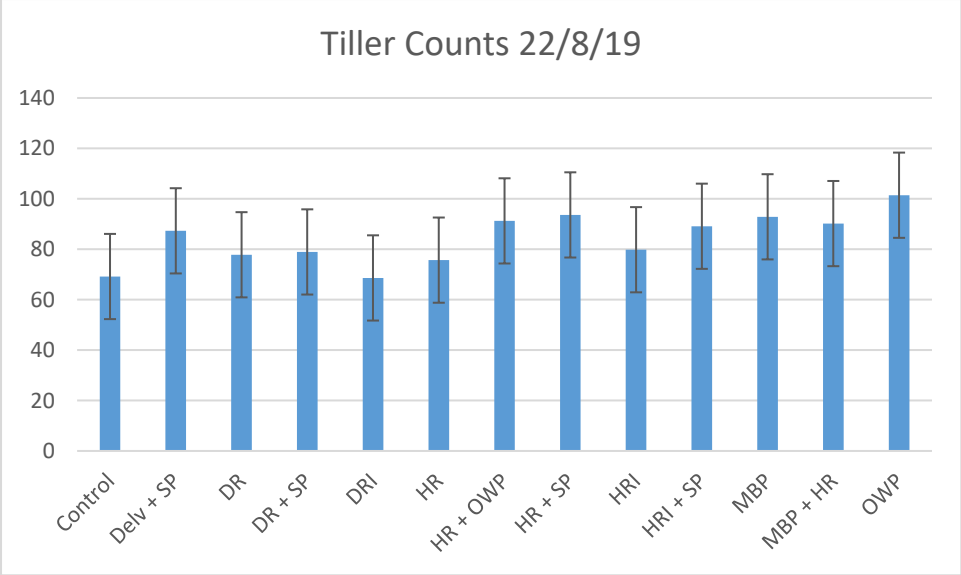

Figure 4. Wheat plant tiller counts in 2019 from selected treatments.

Tiller Counts

Crop establishment outcomes in 2019 were poor. Another year of dry sowing (25/5/19) in a sandy surfaced soil, and the subsequent significant wind events in the days leading up to the June 7th break, compromised furrow integrity, seeding depth, pre-emergent chemical separation and ultimately successful establishment.

Opening and crop establishing rain (11.9mm, 16.2mm and 21mm) was received within a week of dry sowing the crop however wheat crop establishment numbers were well below the optimum agronomic target of 150 plants/m^2 in all treatments (Data not shown).

Similarly poor tiller counts mirrored the early poor plant establishment counts in 2019 with the control plots averaging only 69 tillers/m^2 compared to 2018 tiller counts in the control of 264 tillers/m^2.

The reduction of repellent topsoil through inversion ploughing techniques and spading appeared to have the most significant positive impact on tiller counts and subsequent crop density when measured 22nd August.

One way ploughing increased tiller density 32% to 101 tillers/m^2 on average, Mouldboard ploughing increased tiller density 26% to 93 tillers/m^2 on average and Deep ripping plus spading increased tiller density 22% to 89 tillers/m^2.

Yield

Yields in 2019 were very low due to spring drought conditions.

Yield increases in 2019 were again largely driven by Very deep ripping, stand alone or in conjunction with other tillage techniques with yield increases of 0.15t/ha- 0.28t/ha (lsd 0.083t/ha), an increase of 39-73%. (Figure 5)

Mouldboard ploughing with Very deep ripping (0.56t/ha) and without Very deep ripping(0.54t/ha) provided yield increases of 42%-47% respectively.

Liming had no impact on grain yield responses in 2019 as per 2017 and 2018 (Data not presented).

Wheat yield potential for this site for 2017 and 2018, with a dry finish, was estimated to be 1.93t/ha and 1.8t/ha respectively and in 2019 at 1.07t/ha (see modified French-Schultz calculator at www.soilquality.org.au/calculators/yield_potential). The untreated control only achieved 41%(2017), 49%(2018) and 35%(2019) of yield potential, while very deep ripping achieved 93% (2017),89%(2018) and 54%(2019) and very deep ripping with spading 72%(2017),91%(2018) and 61%(2019) of wheat yield potential.

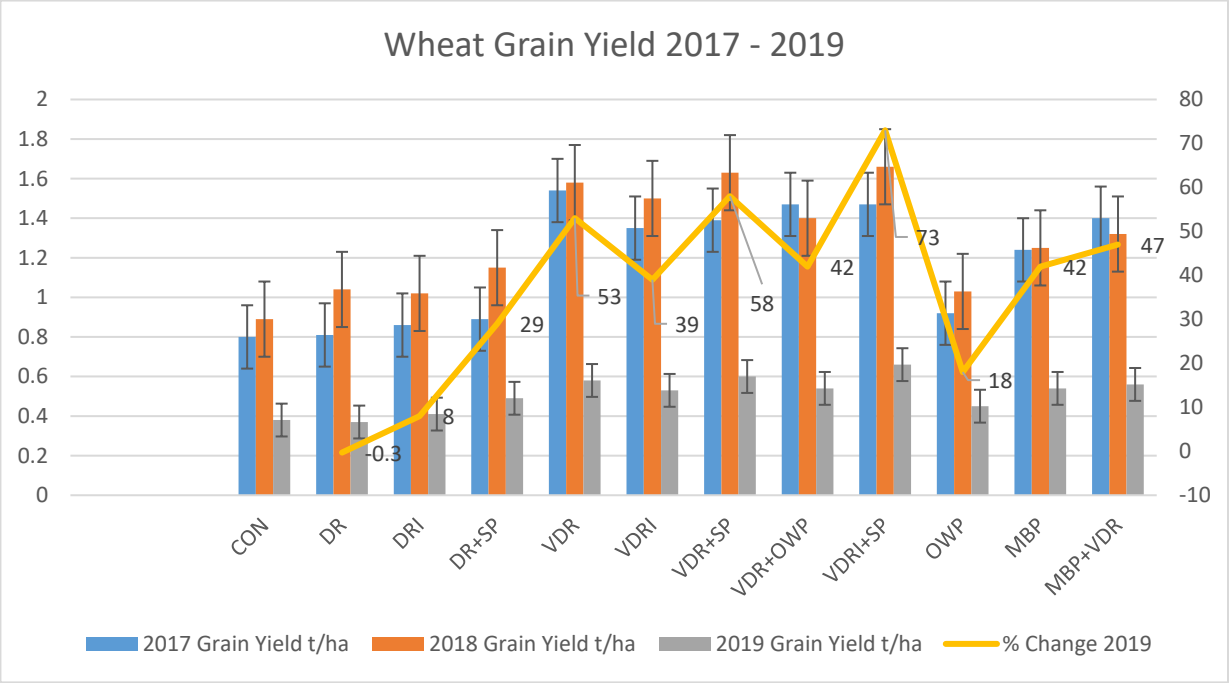

Figure 5. Wheat grain yields in 2017, 2018 and 2019 in response to strategic deep tillage treatments applied in 2017 on deep yellow sand at Goomalling, Western Australia. LSD (0.05) of 0.16t/ha 2017 and 0.19t/ha 2018 and 0.083t/ha 2019

Conclusion

On deep yellow sand at Goomalling repellence removal was important to achieve better crop establishment and subsequent tiller number. Very deep ripping greatly improved tiller survival while ploughing treatments suffered significant tiller loss between August and November resulting in loss of production potential. Deep compaction removal below a working depth of 400mm was important again in 2018, as it was in 2017, to improve root access to more of the moisture deeper in the soil profile and deliver a yield benefit. A lack of subsoil water holding capacity at this site appears to greatly reduce the potential yield that can be achieved at this site. Some amelioration treatments set up yield potentials during the crop development stage that appear too high to be regularly met for this deep sand.

Key words

Soil amelioration; soil water repellence; soil compaction; soil acidity; strategic deep tillage

Acknowledgments

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