Understanding the impact of strategic tillage practices on crop performance and soil properties for a deep yellow sand at Goomalling.

Tim Boyes, AgVivo; **Stephen Davies,** DPIRD; **Rob and Daniel Dempster,** 'Adair' Goomalling; **Joel Andrew,** MapIQ.

Key messages

1. Removing subsoil compaction is critical and for some soil types can dramatically improve access to deep soil moisture.
2. Correctly ground-truthing the depth of the compaction layer can drive the success or failure of ripping outcomes.
3. Yield increases at the Goomalling site were largely driven by very deep ripping, with either the very deep ripper or delver, with yield increases of 0.55-0.74 t/ha, an increase of 74-93%. The only other treatment to increase yield was mouldboard ploughing on its own with a 0.44 t/ha, 55% yield increase.

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 Non-wetting soil surface, Compaction and Subsoil acidity and increasing crop productivity.

Method

The Goomalling experiment is a randomised complete block design with 4 replications and has been established on a deep yellow sand (Peartree sand) at Goomalling. The plots were established using the growers existing 12m seeding system. Plots are 4mwide 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. Experimental site location, soil type, annual and growing season rainfall and soil properties.

Site	Rainfall (mm)		Repellence rating	Soil pH ($CaCl_2$)				Severe compaction depth (cm)	Soil fertility (0-10cm)			
	Average annual	Growing season		0-10	Oct-20	20-30	30-40		OC	P	K	S
Goomalling (Deep yellow sand)	365	181 (2017)	Moderate	5.4	4.8	4.5	4.4	20-50+	1	16	67	4

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.

The Goomalling site was sown to Calingiri Wheat at 70kgs/ha on the 12th June 2017 using an Ausplow DBS with splitter boots with 60kgs MAP and 30kgs Muriate of Potash banded under the seed and 70L Maxam Flo banded to deliver total 25.4N, 13P, 6.46S, 15K.

1L Trifluralin 480 was applied as pre-emergent ryegrass control with a knockdown of 1.5L/Ha of Glyphosate 450gai.

Post emergent weed control was achieved with 1L Tigrex plus 250mls LVE MCPA 570.

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 included:

- preliminary soil profile sampling and analysis prior to treatment application
- in-season soil penetration resistance using digital cone recording penetrometer
- topsoil water repellence using the molarity of ethanol droplet (MED) test
- leaf analysis (whole plant) for tissue nutrient concentrations
- Tiller counts
- grain yield and quality

Results and Discussion

Rainfall

The Goomalling site for 2017 season was very challenging because despite good summer rain (160mm Jan-Mar) there was only 33mm rainfall over April-June (data not shown) and a total of 170mm for the growing season to October. Significant periods of Autumn and Spring moisture stress occurred during the critical periods of crop establishment, tiller initiation and grain fill contributing to the lower yields of this site.

Soil Constraints

The effective working depth of the soil 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 2.0MPa (Figure 1). All of the very deep ripping (including Ripping via Delver) treatments removed severe compaction to their working depth of below 60cm with soil penetration resistance of less than 2.5 MPa .

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 (Table 1). The spading, one-way plough and mouldboard plough treatments can mix and bury the lime and less acid topsoil to the working depth however follow up soil testing is yet to be completed at this site to ascertain depth and pH change attributed to lime and soil inversion.

Water repellence in the control plots was moderate based on the laboratory MED test result. Deep ripping exacerbated the expression of water repellence in the test results whereas spading, one way ploughing and mouldboard ploughing decreased the repellence of the topsoils (Figure 2).

Observations were that the non-wetting, whilst moderate in the MED test result, was very expressive at the site. The incomplete inversion of topsoil from ploughing the soil dry left seams of more repellent topsoil and organic matter at the soil surface and the removal of wetting in the observed field result did not appear to be as complete as the lab test outcome (Figure 3). The ploughing outcomes would be improved if ploughing wet soils.

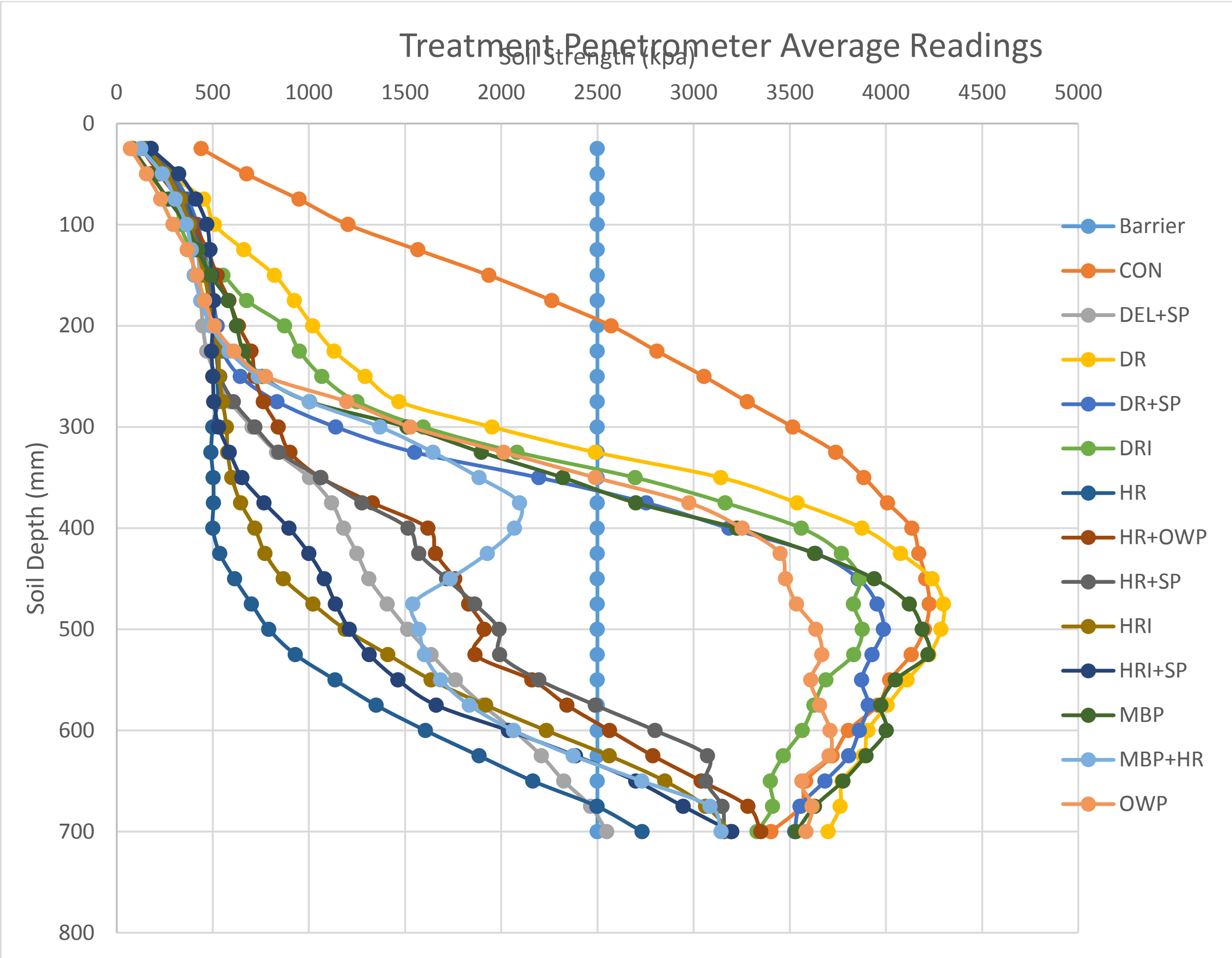

Figure 1. Soil strength measured in kpa comparing tillage treatments as measured by a RIMIK data logging Penetrometer in August of 2017 when soils reached moisture field capacity.

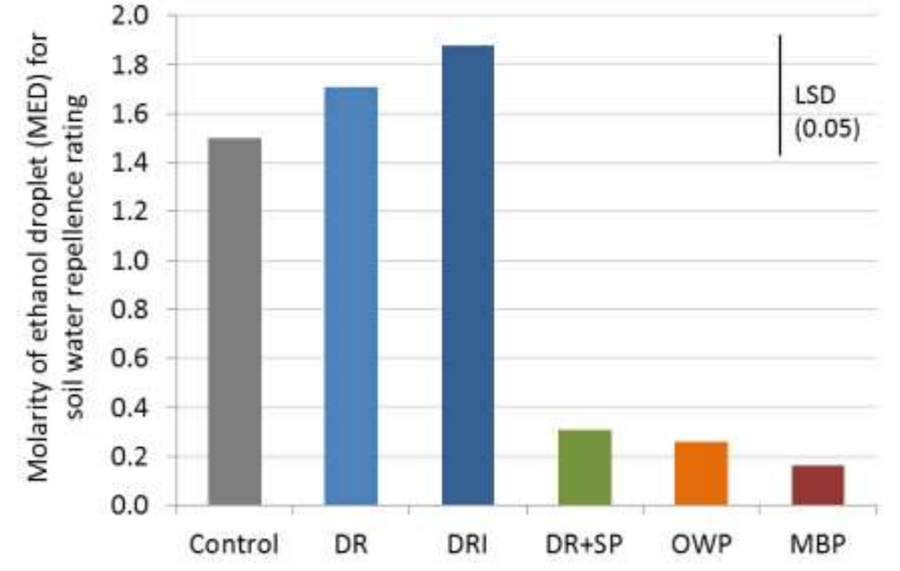

Figure 2. Molarity of ethanol droplet (MED) for soil water repellence rating.

Goomalling - Crop Growth and Grain Yield

Due to the moderate water repellence at the Goomalling site, exacerbated by the dry Autumn conditions (33mm rainfall April to June), crop establishment in the untreated control plots and wider trial area was very poor in 2017.

At Goomalling plant counts were not undertaken and instead tiller counts were completed in late August. On average there were 49 tillers/m^2 for the control treatment. There were higher tiller numbers for treatments with mouldboard ploughing, delving and very deep ripping with one-way ploughing, and spading on top of very deep ripping either with or without topsoil inclusion (Table 3). As a consequence of low tiller numbers grain yields were low, 0.8 t/ha for the untreated control (Table 3).

Yield increases were largely driven by the deeper ripping, with either the very deep ripper or delver (also ripping to 700mm plus), with yield increases of 0.55-0.74 t/ha, an increase of 74-93%. The only other treatment to increase yield was mouldboard ploughing on its own with a 0.44 t/ha, 55% yield increase (Table 3).

Statistically significant treatment effects were Heli-ripping (Very deep ripping to 700mm) (93% change), Very deep ripping with inclusion plates(63%), Very deep ripping plus spading(74%), One Way Ploughing plus very deep ripping(84%), Very deep ripping with inclusion plates plus spading(84%), Mouldboard ploughing plus Very deep ripping(76%) and Mouldboard Ploughing(55%)\ (Figure 4)

Liming appeared to have no impact on grain yield responses in 2017 (Data not presented).

Figure 3. Comparison of rainfall infiltration at the Goomalling site on the 7th July 2017 during a 5mm rainfall event. Treatments clockwise from top left are Mouldboard Plough; One Way Plozza Plough; Delving and Spading and Heli-ripper and Spading.

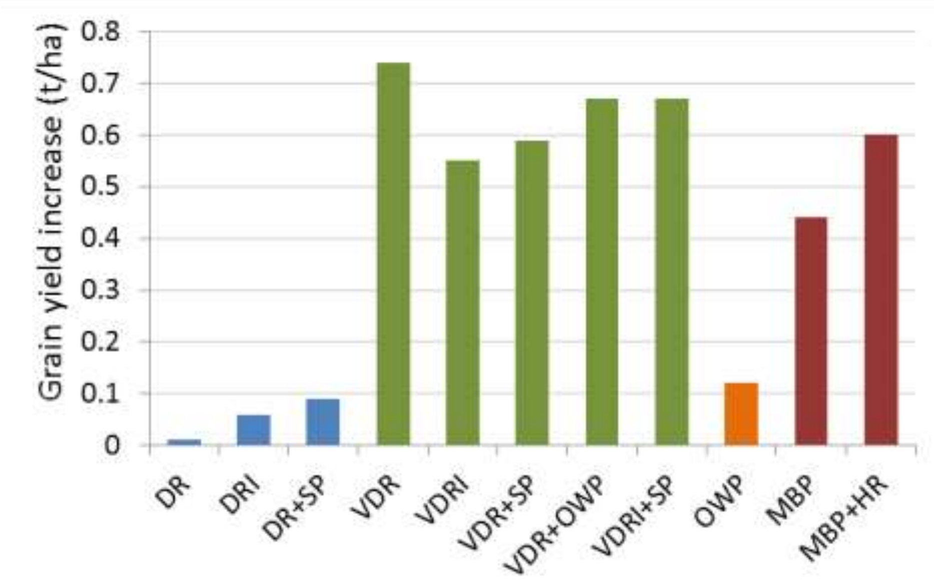

Figure 4. Wheat grain yields in 2017 in response to one-off deep tillage soil amelioration treatments on deep yellow sand at Goomalling, Western Australia. Bars represent LSD (0.05) of 0.16 t/ha 2017.

Treatment	Goomalling 2017			
	Tiller No.	Grain Yield	Yield Change	
	#/m^2	t/ha	t/ha	%
CON	49	0.8	-	-
DR	58	0.81	0.01	2
DRI	39	0.86	0.06	8
DR+SP	50	0.89	0.09	12
HR	59	1.54	0.74	93
HRI	55	1.35	0.55	69
HR+SP	62	1.39	0.59	74
HR+OWP	76	1.47	0.67	84
HRI+SP	80	1.47	0.67	84
OWP	59	0.92	0.12	15
MBP	65	1.24	0.44	55
MBP+HR	69	1.4	0.6	76
DLV+SP	70	1.52	0.72	91
LSD (0.05)	*15*	*0.16*		
LSD (0.10)	*12*	*0.14*		

Table 3. Summary head or tiller density, grain yield and yield change 2017 at Goomalling. Values significantly different from the control are highlighted in green for LSD at 5% level and blue for LSD at 10% level.

Economic Returns

Treatment	Cost ($/ha)	Gross benefit ($/ha)	Net benefit ($/ha)	Years to break-even Sustained	Years to break-even Declining
DR	45	3	-42	>10	>10
DRI	50	14	-36	4	>10
DR+SP	150	21	-129	7	>10
VDR	90	172	82	1	1
VDRI	95	128	33	1	1
VDR+SP	190	137	-53	2	2
VDR+OWP	140	155	15	1	1
VDRI+SP	195	155	-40	2	2
OWP	50	28	-22	2	3
MBP	120	102	-18	2	2
MBP+VDR	200	139	-61	2	2

Table 4. Estimated economic benefits over control for a range of deep tillage treatments

[a] Estimated farm-gate price for wheat grade ASW1 of $231/t
[b] Assuming an ASW1 wheat grade with estimated farm-gate price of $231/t.
[c] Net benefits include gross economic benefit minus treatment cost
[d] Years to break-even with either a sustained 2017 yield response (Sust.) or declining (Decl.) yield response trajectory, where economic returns halve each year. Note treat findings with caution when extrapolating only 1-2 years yield results over 10 years.
n/a = treatment not present in given season or location.

The year to break-even (Table 4) is estimated either assuming a sustained trajectory (economic returns generated in 2017 are sustained through time) or a declining trajectory (assuming economic returns halve each year). Only the Very deep ripping, Very deep ripping with inclusion plates and One Way Plough plus very deep ripping cover their cost in the first season. With a pessimistic declining trajectory of returns all of the treatments cover their cost in the second season except for the One way plough and standard deep ripping treatment plus or minus the inclusion plates and with spading.

Conclusion

On deep yellow sand at Goomalling repellence removal was important to achieve better crop establishment and subsequent tiller number. Deep compaction removal below a working depth of 400mm, particularly in a dry season, was important to improve root access to more of the moisture in the profile and deliver yield benefit.

Key words

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

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