Assessing rotary spading, mouldboard ploughing and claying for amelioration of pale deep sand

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Purpose:	To assess the impact of various levels of soil disturbance (cultivation methods) on water repellence and productivity and the interaction of these cultivation methods with soil amendments, lime and clay.
Location:	Badgingarra Research Station
Soil Type:	Pale deep sand exhibiting strong topsoil water repellence
Rotation:	Lupins 2006; Oats 2007; Lupins 2008
GSR:	447 mm (DAFWA BRS weather station)

BACKGROUND SUMMARY

One-off soil inversion using mouldboard ploughs and soil dilution (mixing) using rotary spaders have emerged as possible new tools to ameliorate non-wetting soils and increase crop productivity. Additional benefits include improved weed control, soil loosening and an opportunity to incorporate lime to treat subsoil acidity.

TRIAL DESIGN

Soil amendments were applied on the 8 April, which included a nil amendment (control), surface application of 3t/ha limesand, and application of clay-rich subsoil at rate of 150 t/ha which was only lightly incorporated with one pass of offset discs. Clay rich-subsoil was spread using a multi-spreader which provided a relatively even spread of the clay compared to carry graders. Cultivation treatments were applied across the soil amendment strips in a criss-cross design on 21 April and included an untreated (control); offset discs; rotary hoe; deep ripper; rotary spader; and mouldboard plough. The rotary hoe and offset discs worked to depth of about 15 cm and the deep ripper to a depth of 30 cm. A three-furrow Kvernerland mouldboard plough and an Imants 37 series rotary spader were used with both machines having a working depth of 25-30cm. Because the soil was dry on the 21 April the sandy soil had insufficient cohesion between the sand particles to achieve complete soil inversion so an additional mouldboard plough treatment was applied when the soil was wet, just prior to seeding on 28 May and due to the moist conditions was able to work at a depth of 30 cm. Mouldboard plough and deep ripped plots were rolled with a light roller prior to seeding in an attempt to firm the seedbed for sowing. Each plot was sown to Calingiri wheat with a combine on 28 May 2009 at 90 kg/ha with Agstar Extra at 80 kg/ha. Soil penetration resistance was measured with a Rimik CP40 cone penetrometer when the soil was moist (at field capacity). Soils were sampled during the growing season to depths of 40cm and subject to detailed chemical analyses. Additional soil measurements made during the season included bulk density and topsoil (0-5cm) sampling for assessment of water repellence using the water droplet penetration time (WDPT) and molarity of ethanol droplet (MED) tests in the laboratory.

RESULTS AND DISCUSSION

The subsoil used for claying the trial was a sandy clay loam with a clay content of 31% (Table 1). Ideally both the untreated topsoil and the subsoil should be analysed for clay % (particle size analysis), pH and nutrient content prior to claying so that the rate of clay required to overcome water repellence is applied.

Table 1. *Analyses of clay rich subsoil spread at Badgingarra Research Station*

pH_{Ca}	pH_w	mg/kg				EC	Particle size %		
		K	S	P	B	mS/m	Sand	Silt	Clay
5.8	6.4	54	20	2	1	20	64	5	31

The soil at the Badgingarra site was highly water repellent. Water droplet penetration times (WDPT) for untreated soil collected during winter averaged 320 seconds (5½ mins; Table 2). For the treatments we applied, WDPT decreased as the amount of soil disturbance increased. Soil inversion is the highest level of 'disturbance' where the topsoil is essentially turned upside-down, burying the organic matter that has accumulated at the soil surface, whereas the other treatments involve varying degrees of mixing (dilution) of the topsoil. This was reflected in changes to WDPT: the mouldboard plough effectively removed water repellence, and was greatly reduced by rotary spading because this provided a thorough mixing (dilution) of the topsoil and subsoil. (Table 2).

Addition of clay also effectively removed water repellence regardless of the level of cultivation (Table 2). It should be noted that the procedure for collecting the samples, drying them, sieving them to remove stubble and gravel then conducting the WDPT test under standard laboratory conditions does thoroughly mix the clay through the sample. This may not accurately reflect the situation in the field where the mixing of clay through the topsoil can be less thorough and more variable which can mean that the impact of the clay in ameliorating water repellence may be less effective under field conditions than what is apparent from laboratory measurements. Similar issues affect the measurement of the clay % in the top 10 cm, with applied subsoils in the control, deep ripped and offset disc treatments being concentrated near the soil surface and not mixed through the top 15 cm as occurs with the rotary hoe or through the top 25-30 cm with the spader. Claying did increase the clay content of the top 10 cm by 0.5% or more for most of the treatments (Table 2). Clearly inverting the clayed topsoil with a mouldboard plough is not a sensible approach with the benefit of the clay for ameliorating water repellence being completely lost!

One concern often raised when cultivation is used is that organic carbon will be lost as a result of the soil disturbance. Certainly cultivation can encourage microbial breakdown of soil organic matter however, the extent of this can be overemphasised when only the top 10 cm of soil is considered. In this trial cultivation did not significantly effect the total organic carbon content in the top 30cm of soil which ranged from 19-25 tonnes organic carbon/ha but the more extreme levels of cultivation did drastically change the distribution of the organic carbon in the soil (Table 2). The impact of this change on nutrient availability, microbial activity, water holding capacity and soil carbon sequestration is not yet clear. As these soils will now revert to minimum tillage systems for at least 10 years it is possible that the overall amount of carbon stored in the top 30 cm of the soil will be increased through cultivation. This will be the subject of future measurement.

Table 2. *Mass of organic carbon, clay per cent, water droplet penetration time (WDPT) and penetration resistance for various soil amendment treatments applied to a pale deep sand at Badgingarra in 2009.*

Cultivation	Amendment	Mass Organic Carbon (t/ha)				Clay % 0-10*	WDPT seconds	Resistance (MPa)	
		0-10	10-20	20-30	Total 0-30			At 20cm	At 30cm
Nil	Nil	12.8	5.6	3.1	21.5	3.7	320	2.8	4.0
	Clay	11.1	5.5	2.4	19.0	4.2	1	-	-
Offset Discs	Nil	11.5	5.8	3.6	20.9	3.4	190	2.3	3.7
	Clay	13.3	5.5	3.3	22.1	4.2	1	-	-
Rotary Hoe	Nil	13.5	5.0	1.9	20.4	3.9	75	2.3	3.7
	Clay	13.1	4.7	2.4	20.2	3.9	4	-	-
Deep Ripped	Nil	-	-	-	-	3.4	155	0.5	1.4
	Clay	-	-	-	-	4.9	1	-	-
Rotary Spader	Nil	7.3	8.6	3.7	19.6	2.9	11	1.3	3.1
	Clay	10.2	8.6	3.7	22.5	3.4	4	-	-
Mouldboard (wet)	Nil	5.1	10.8	9.7	25.6	2.7	1	0.6	0.9
	Clay	4.0	8.5	8.4	20.9	2.4	1	-	-

** The measured clay % of the soil in the absence of applied clay is higher than expected. In general sands with clay contents in excess of 3% are not repellent. It is suspected that this is a measurement error however this is still being investigated. The increases in clay % as a result of clay spreading and the relative differences between treatments appear to be correct.*

While the soil pH profile at this site was good (Figure 1) as a result of a good liming history, lime was included as a soil amendment in the trial to look at both its impact on soil water repellence and also to assess the effectiveness of a range of cultivation tools at incorporating lime into subsoils. All cultivation methods improved lime incorporation resulting in higher pHs in the 10-20 and 20-30cm layers (Figure 1). The deeper cultivation of the rotary spader resulted in increased subsoil pH in the 30-40 cm layer also (Figure 1). The biggest increase in subsoil pH was achieved using the mouldboard plough (Figure 1) although this was driven through the inversion of pH 6.0 topsoil into the subsoil as well as the burying of surface applied lime.

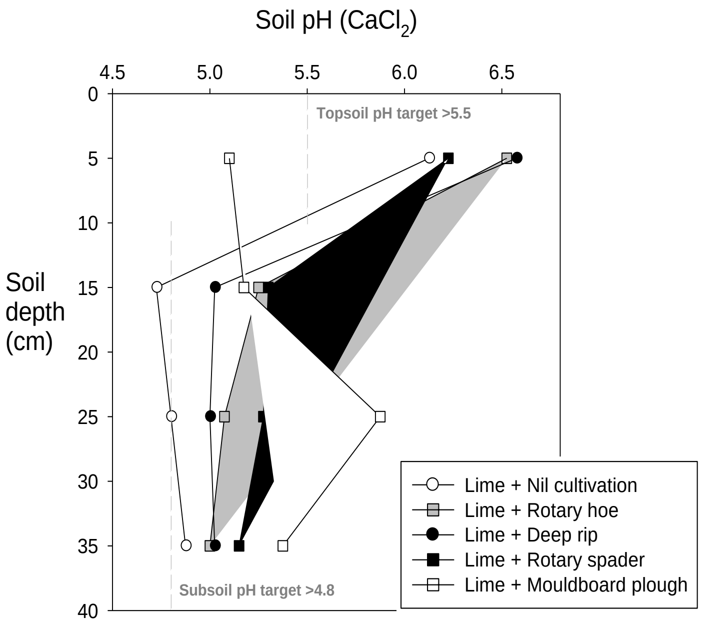

Figure 1. *Change in soil pH as a result of incorporation of lime using various cultivation techniques on a pale deep sand at Badgingarra, 2009.*

There was no significant interaction between clay addition and cultivation on crop harvest data so data presented (Table 3) shows the impact of the cultivation treatments only. Mouldboard ploughing increased shoot dry weight at maturity by 30% (1.8 t/ha; Table 3). The increases in shoot dry weight as result of deep ripping (17%, 1.1 t/ha), offset discs (13%, 0.8 t/ha) and the rotary spader (8%, 0.5 t/ha) were not statistically significant (Table 3). Similar effects were seen for head dry weight. There was no significant increase in head number with cultivation although the trends were similar to those seen for head dry weight with the mouldboard plough treatment having the highest number of heads, being 11% greater than the control. Similarly there was no statistically significant grain yield response to cultivation in 2009. Grain yield for the offset discs, rotary hoe and spader treatments were similar to the control with more substantial trends toward higher yield for the deep ripping and the mouldboard plough treatments which had average yields of 2.4 t/ha compared with 2 t/ha for the control (Table 3). Gross soil disturbance treatments such as these can induce increased variability in the early years of research trials but hopefully this variability may decline as disturbed soils settle in future seasons.

Table 3. *Plant density, shoot dry weight, head number and machine harvest grain yield for Calingiri wheat grown at Badgingarra, 2009.*

Cultivation	No. Plants/m^2		Hand harvest cuts			Machine harvest Grain Yield (t/ha)
	Nil	Clay	Shoot DW (t/ha)	Head DW (t/ha)	Head No./m^2	
Nil	127	116	6.2	3.6	301	2.0
Offset Discs	68	94	7.0	4.0	309	2.1
Rotary Hoe	77	126	6.2	3.5	294	2.1
Deep Ripping	101	84	7.3	4.3	320	2.4
Rotary Spader	140	141	6.7	4.0	302	2.2
Mouldboard (dry)	100	96	8.1	4.8	334	2.4
Mouldboard (wet)*	66	42	8.0	4.9	330	-
l.s.d. (P<0.10)	*33*		*1.2*	*0.8*	*28*	*0.4*

** Machine harvest grain yields for mouldboard plough (wet) not available due to poor establishment. Yields are likely to have been similar to mouldboard plough (dry) treatment given similar shoot and head DW and head numbers measured using plant cuts taken from parts of the plots where establishment was OK.*

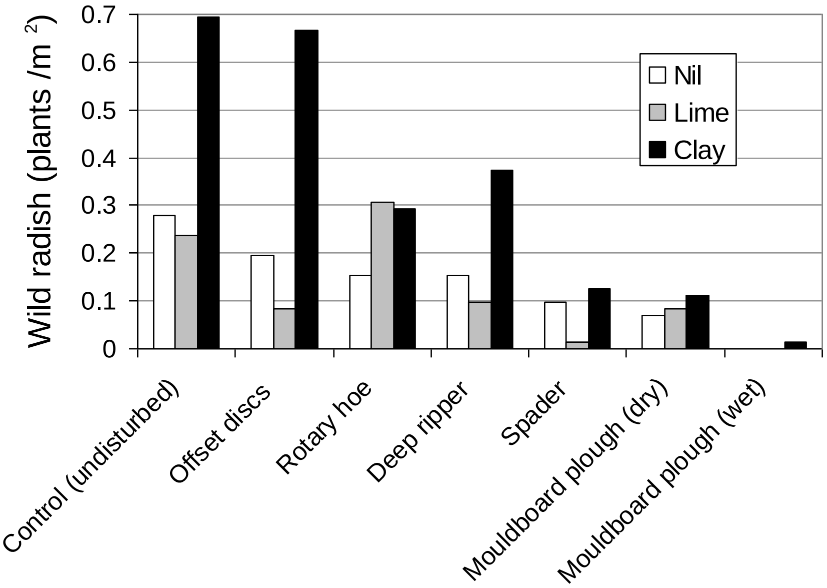

Figure 2. *Impact of cultivation technique, lime and clay additions on the populations (plants/m^2) of wild radish weeds at Badgingarra, 2009.*

Wild radish control at the site ranged from 30% for the offset discs, 45% for the deep ripper and rotary hoe, 65% for the spader and 100% for the mouldboard plough (wet) without the addition of clay (Fig 2).

CONCLUSION

One of the fundamental problems of pale deep sands is their poor water and nutrient holding capacity. While cultivation techniques can overcome water repellence they do not necessarily greatly alter the lack of water holding capacity. Similarly addition of clay at rates of 100-150 t/ha can be used to overcome water repellence but will not greatly increase water holding capacity. Deep ripping or the soil loosening caused by rotary spading or mouldboard ploughing allows faster root growth and improved nutrient and water uptake and this appears to be one of the primary reasons for the improved yields. The advantage of the rotary spader and mouldboard plough over deep ripping alone is improved weed control and reduced water repellence although the longevity of this is unknown. Reduced water repellence may prove to be more significant in certain seasons and more sensitive crops. Sustained productivity benefits are likely to be required for these approaches to be economically viable.

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