Coomandook Ag Bureau

Spader, Mouldboard and Organic Matter

3 Year Report 2013-2015

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Australian Government | National Landcare Programme

Government of South Australia
South Australian Murray-Darling Basin
Natural Resources Management Board

Natural Resources
SA Murray-Darling Basin

Summary

A trial to improve the productivity of deep sandy water repellent soil in the Coomandook are was set up in May 2013. Treatments included mouldboard ploughing, spading, controls, and various organic matter and fertiliser treatments. Yield was measured, and profit/loss calculated.

Results showed that the spader had the best effect of the soil modification treatments. Mouldboard ploughing reduced water repellence in the soil, but did not improve productivity as much as spading. TPR grape marc and Composted Pig Manure had the highest yield benefits, but the costs of transport and the product meant that the most profitable treatment at this site was not the most productive treatment.

Each enterprise will have its own costs and budgeting methods, and this report is intended only as a starting point in calculating which treatments may be best in your situation.

Acknowledgements

Thanks to Paul Simmons for hosting the trial on his property and to the members of the Coomandook Ag Bureau, and to the funders of this project from 2013 - 2015.

List of Abbreviations

Abbreviation	Meaning
Al	aluminium
APM	aged pig manure (left in a heap)
C:N ratio	Carbon to Nitrogen Ratio
Ca	calcium
CPM	composted pig manure (has been through the composting process)
DAP	di-ammonium phosphate
DM	dry matter
K	potassium
MB	mouldboard plough treatment
MED	molarity of ethanol droplet, a measure of water repellence
Mg	magnesium
N	nitrogen
Na	sodium
OM	organic matter
P	phosphorus
TPR	composted grape marc from Tarac Technologies
WR	water repellent

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1. Introduction & Background

The soil in the Coomandook area of South Australia is mostly light grey and brown sands and sandy loams overlying various layers of deep sand, clay, calcareous rubble or rock. There are also areas of grey, black and red clay soils.

The sandy topsoils often have problems with water repellence, a condition where waxes and oils from partially decomposed organic matter have coated the sand grains so that they repel water. These water repellent (WR) sands do not wet up easily, making it difficult to establish a crop. This creates problems with crop growth, weed control and maintaining protective cover on the soil surface. In addition, the sands are often deep with very low nutrient holding capacity. Root growth is shallow and the crops have difficulty coping with hot and dry conditions.

As clay suitable for spreading or delving is difficult or expensive to find and use, clay spreading or delving have limited use in the area. On the deep sands, the use of spading or mouldboard ploughing has been looked at as a possible method to bury water repellent sand and improve root growth deeper into the soil profile. In previous trials elsewhere in SA and WA, it has been seen that these methods have successfully treated WR sand in some situations.

Adding an organically based form of nutrition to the soil in order to improve the nutrient levels has also been seen to improve crops on sandy soils. The slower release of the nutrients from manures, composts or other waste material means that the crop is able to use the nutrition throughout the growing season. Organic matter also improves the nutrient holding capacity of the soil. Mixing in of organic matter to depth encourages root growth deeper in the profile, which allows the crop to use deeper stored water.

As the Coomandook area has large amounts of deep infertile sandy soils, a project was set up to examine ways in which soil modification and/or organic matter could be used to improve crop productivity and profitability on these deep sands where clay application is not an option.

2. Aims

The Coomandook Ag Bureau project aimed to:

1. Investigate treating water repellence on the deep sands without using clay, using a mouldboard plough, spader and control.
2. Improve soil nutrition using a variety of organic matter inputs compared with chemical fertiliser inputs and a control.

3. Methods

The trial was located on Paul Simmons farm, in a paddock next to the Old Dukes Highway (Figure 1) north of Coomandook. The satellite photo from Google Maps shows the site in October 2013 when the surrounding area had been cut for hay.

Figure 1: Location map of trial site.

The layout of the trial is shown in Figure 2 and Table 5.

GPS coordinates were recorded for the corners of the site.

PLOT	Block A	Block B	Block C	Block D	Width	Total
1	Spader + Vetch	MB + CPM	MB + Fert 1	Spader + CPM	10	10
2	MB + Cereal	Spader + CPM	Spader + Fert 2	Control + Fert 3	10	20
3	Spader + Control	MB + Fert 3	MB + APM	MB + Control	10	30
4	Spader + Cereal	MB + Vetch	MB + Cereal	Control + Control	10	40
5	Spader + TPR	Control + Fert 3	MB + Vetch	MB + APM	10	50
6	MB + Fert 2	MB + Fert 2	Spader + APM	MB + Vetch	10	60
7	Spader + Silage	Spader + Vetch	Spader + Fert 1	Spader + Cereal	10	70
8	MB + Silage	Control + APM	MB + Fert 3	MB + CPM	10	80
9	Spader + Fert 1	Spader + Fert 1	MB + Control	Spader + Silage	10	90
10	Control + CPM	MB + Silage	Spader + Cereal	Spader + Fert 2	10	100
11	Spader + Fert 2	Spader + Cereal	Control + Control	MB + Cereal	10	110
12	Spader + Fert 3	Spader + Fert 2	Control + Cereal	MB + Fert 3	10	120
13	Control + Cereal	Spader + Silage	MB + Silage	Spader + APM	10	130
14	MB + APM	MB + TPR	Spader + CPM	MB + Silage	10	140
15	Spader + CPM	Control + CPM	MB + CPM	MB + Fert 2	10	150
16	Control + Silage	Spader + TPR	Control + Fert 3	Control + APM	10	160
17	Control + APM	Spader + APM	Control + APM	MB + TPR	10	170
18	Control + Control	MB + Fert 1	MB + TPR	Control + Fert 2	10	180
19	Spader + CPM *(2nd)	Control + CPM	Control + CPM	Control + CPM	10	190
20	MB + TPR	Control + TPR	Control + TPR	Control + Cereal	10	200
21	MB + CPM	Control + Silage ⟷	Control + Cereal	Control + CPM	10	210
22	Control + Fert 2	Control + Silage	Control + Fert 1	Control + TPR	10	220
23	Control + TPR	MB + APM	Spader + TPR	Spader + Fert 1	10	230
24	MB + Fert 3	MB + Cereal	Spader + Silage	Spader + TPR	10	240
25	Control + Fert 1	Control + Fert 2	Spader + Vetch	Spader + Control	10	250
26	MB + Control	Control + Control	MB + Fert 2	MB + Fert 1	10	260
27	Control + Vetch	Control + Vetch	Spader + Fert 3	Spader + Vetch	10	270
28	Control + Fert 3	Control + Fert 1	Control + Vetch	Spader + Fert 3	10	280
29	MB + Vetch	MB + Control	Spader + Control	Control + Fert 1	10	290
30	MB + Fert 1	Spader + Fert 3	Control + Fert 2	Control + Vetch	10	300
31	Spader + APM	Spader + Control	Spare	Control + Silage	10	310
32	Spare	Spare	Spare	Spare	10	320
	60 (50+10)	60 (50+10)	60 (50+10)	60 (50+10)	240	

Figure 2: Layout of trial site

Soil treatments were Control (nil), Mouldboard ploughing (MB) and Spading. The mouldboard plough used belonged to Roy Hincks and had a 6” working depth. The spader used belonged to Tim Dunstan (DunstanAG) and had a 4 m width and working depth 40 cm max.

	
Mouldboard plough working	Spader

Nutrition treatments were Control (nil), Aged Pig Manure (APM) and Composted Pig Manure (CPM) at 10 t/ha, cereal straw, triticale silage and vetch hay at 5 t/ha, composted grape marc (TPR) at 20 t/ha, and DAP fertiliser, applied before sowing and then twice at 3 week intervals afterwards giving a total of ~ 50 units of N and P (Fert 2), 25 units (Fert 1) and 12.5 units (Fert 3). Applying the fertiliser over time allowed the higher rates to be applied without damaging the crop, and more closely resembled the gradual release of the other organic based treatments. The DAP fertiliser rates were selected to give a range of N and P rates from low to high so that the N and P nutritional effects of the organic matter inputs could be related to those from the fertiliser. These treatments were applied only in year 1.

The soil chemistry analysis is shown in Table 1.

The nutritional analysis of the OM inputs is shown in Table 2, Table 3 and Table 4.

Table 1: Soil Analysis results from Simmons trial site 2013 pre-trial.

ID	Depth	Colour	Gravel %	Texture	pH Level (CaCl2) pH	pH Level (H2O) pH	Conductivity dS/m	Ammonium Nitrogen mg/Kg	Nitrate Nitrogen mg/Kg	Phosphorus Colwell mg/Kg	Potassium Colwell mg/Kg
Simmons Soil Pit Trial Site	0-10	GR	0	Sand	7.3	8.1	0.052	7	11	22	105
	10-30	WH	0	Sand	6.4	6.8	0.023	< 1	6	11	62
	30-60	WH	0	Sand	6.9	7.8	0.027	< 1	5	6	46
	60-65	OR	5	Sandy Clay	8.3	9.2	0.129	< 1	5	4	212
	65-80	OR	5	Clayey Sand	8.2	9	0.157	< 1	5	< 2	217

ID	Depth	Exc. Al meq/100g	Exc. Ca meq/100g	Exc. Mg meq/100g	Exc. K meq/100g	Exc. Na meq/100g	CEC meq/100g	Ca %	Mg %	K %	Na %	Ca mg/kg	Mg mg/kg	K mg/kg	Na mg/kg
Simmons Soil Pit Trial Site	0-10	0.028	2.59	0.53	0.21	0.04	3.40	76.2	15.6	6.2	1.2	518	63.6	81.9	9.2
	10-30	0.027	1.11	0.19	0.14	0.02	1.49	74.6	12.8	9.4	1.3	222	22.8	54.6	4.6
	30-60	0.033	0.84	0.16	0.12	0.01	1.16	72.2	13.8	10.3	0.9	168	19.2	46.8	2.3
	60-65	0.078	5.52	2.13	0.54	0.59	8.86	62.3	24.0	6.1	6.7	1104	255.6	210.6	135.7
	65-80	0.124	5.7	2.36	0.56	0.58	9.32	61.1	25.3	6.0	6.2	1140	283.2	218.4	133.4

ID	Depth	Sulphur mg/Kg	Organic Carbon %	Boron Hot CaCl2 mg/Kg	Chloride mg/Kg	Calcium Carbonate %	DTPA Copper mg/Kg	DTPA Iron mg/Kg	DTPA Manganese mg/Kg	DTPA Zinc mg/Kg
Simmons Soil Pit Trial Site	0-10	4.4	0.79	0.29	8.3	0.2	0.2	22.19	5.45	1.39
	10-30	1.6	0.11		2.9	0.18				
	30-60	1.3	1.08		2.3	0.38				
	60-65	3.6	0.06	1.28	19.8	1.28	0.13	6.36	0.39	0.17
	65-80	5.6	0.05		24.1	0.56				

Table 2: Nutrient analysis of the organic matter

		APM	Cereal	CPM	Silage	TPR	Vetch
Boron	**mg/Kg**	27.9	10.0	36.5	14.2	50.7	30.2
Calcium	**%**	2.75	0.24	2.7	0.5	1.4	1.11
Carbon	**%**	28.1	43.6	19.2	42	41.4	42.7
Chloride	**%**	0.24	0.44	0.86	1.1	0.31	1.07
Copper	**mg/Kg**	96.9	2.38	67.7	7.76	108	2.72
Iron	**mg/Kg**	2872	188	4238	231	1829	172
Magnesium	**%**	0.7	0.14	0.53	0.25	0.15	0.21
Manganese	**mg/Kg**	412	94.4	237	44.6	37.8	22.7
Molybdenum	**µg/Kg**	2400	480	2104	2920	696	744
Nitrate	**mg/Kg**	1608	< 40.00	1060	2571	81.1	< 40.00
Phosphorus	**%**	1.07	0.06	0.85	0.46	0.39	0.19
Potassium	**%**	1.28	1.03	1.23	3.98	3.02	2.09
Sodium	**%**	0.11	0.06	0.41	0.14	0.08	0.26
Sulfur	**%**	0.46	0.11	0.36	0.37	0.21	0.16
Total Nitrogen	**%**	2.14	0.66	1.82	3.4	2.72	1.62
Zinc	**mg/Kg**	525	4.68	1425	38.0	27.0	16.6

Table 3: Total Nutrients from OM/fertiliser applied to each treatment

Applied Treatment		APM	Cereal	CPM	Control	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
	Rate	**10 t/ha**	**5 t/ha**	**10 t/ha**	**nil**	**DAP 135 kg/ha**	**DAP 270 kg/ha**	**DAP 67.5 kg/ha**	**5 t/ha**	**20 t/ha**	**5 t/ha**
Carbon	**t/ha**	2.81	2.18	1.92	0	0	0	0	2.1	8.3	2.1
Nitrate N	**kg/ha**	16.1	low	10.6	0	0	0	0.0	12.9	1.62	low
Total N	**kg/ha**	214	33	182	0	24.3	48.6	12.2	170	544	81
P	**kg/ha**	107	3	85	0	27.3	54.5	13.6	23	78	9.5
K	**kg/ha**	128	51.5	123	0	0	0	0	199	604	104.5
S	**kg/ha**	46	5.5	36	0	2.0	4.1	1.0	18.5	42	8
Ca	**kg/ha**	275	12	270	0	0	0	0	25	280	55.5
Mg	**kg/ha**	70	7	53	0	0	0	0	12.5	30	10.5
Boron	**g/ha**	27.9	5.0	36.5	0	0	0	0	7.1	101.4	15.1
Chloride	**kg/ha**	24	22	86	0	0	0	0	55	62	53.5
Copper	**g/ha**	968.8	11.9	677	0	0	0	0	38.8	2161.2	13.6
Iron	**kg/ha**	28.7	0.94	42.4	0	0	0	0	1.15	36.6	0.86
Manganese	**kg/ha**	4.12	0.47	2.37	0	0	0	0	0.22	0.76	0.11
Molybdenum	**g/ha**	24	2.4	21.0	0	0	0	0	14.6	13.9	3.72
Sodium	**kg/ha**	11	3	41	0	0	0	0	7	16	13
Zinc	**kg/ha**	5.2	0.02	14.3	0	0	0	0	0.19	0.54	0.08

Table 4: Estimated available nutrients from OM and fertiliser in Year 1 of the trial.

Available Yr 1		**APM**	**Cereal**	**CPM**	**Control**	**Fert 1**	**Fert 2**	**Fert 3**	**Silage**	**TPR**	**Vetch**
	Rate	**10 t/ha**	**5 t/ha**	**10 t/ha**	**nil**	**DAP 135 kg/ha**	**DAP 270 kg/ha**	**DAP 67.5 kg/ha**	**5 t/ha**	**20 t/ha**	**5 t/ha**
Carbon	**t/ha**										
Nitrate N	**kg/ha**	8.04	0	5.30	0	0	0	0	6.45	0.81	0
Total N	**kg/ha**	107	16.5	91	0	24.3	48.6	12.2	85	272	40.5
P	**kg/ha**	53.5	1.5	42.5	0	27.3	54.5	13.6	11.5	39	4.8
K	**kg/ha**	64	25.8	61.5	0	0	0	0	99.5	302	52.3
S	**kg/ha**	23	2.8	18	0	2.0	4.1	1.0	9.3	21	4
Ca	**kg/ha**	137.5	6	135	0	0	0	0	12.5	140	27.8
Mg	**kg/ha**	35	3.5	26.5	0	0	0	0	6.3	15	5.3
Boron	**g/ha**	14.0	2.5	18.3	0	0	0	0	3.6	50.7	7.6
Chloride	**kg/ha**	12	11	43	0	0	0	0	27.5	31	26.8
Copper	**g/ha**	484.4	5.95	338.5	0	0	0	0	19.4	1080.6	6.8
Iron	**kg/ha**	14.4	0.5	21.2	0	0	0	0	0.6	18.3	0.4
Manganese	**kg/ha**	2.06	0.24	1.18	0	0	0	0	0.11	0.38	0.06
Molybdenum	**g/ha**	12	1.2	10.5	0	0	0	0	7.3	7.0	1.9
Sodium	**kg/ha**	5.5	1.5	20.5	0	0	0	0	3.5	8	6.5
Zinc	**kg/ha**	2.62	0.01	7.13	0	0	0	0	0.09	0.27	0.04

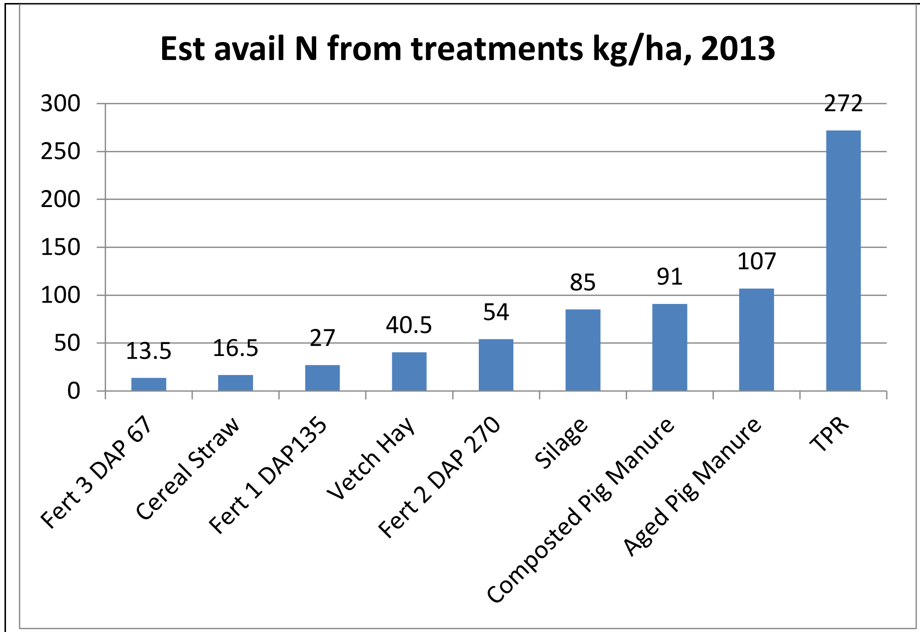

Figure 3: Range of N available from different nutrition treatments

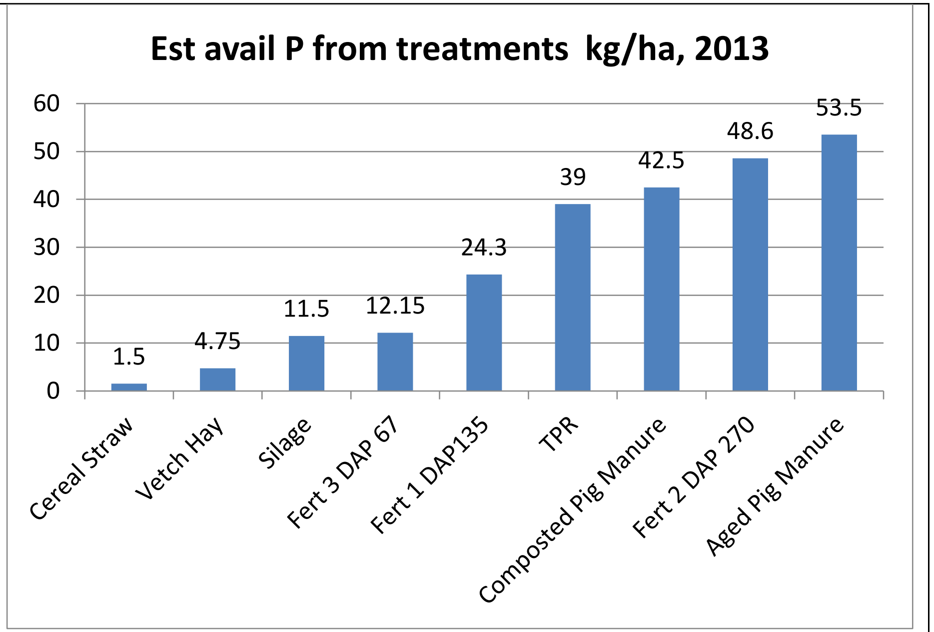

Figure 4: Range of P available from different nutrition treatments

Table 5: Trial layout

	Block					
PLOT	A	B	C	D	Width	Total
1	Spader + Vetch	MB + CPM	MB + Fert 1	Spader + CPM	10	10
2	MB + Cereal	Spader + CPM	Spader + Fert 2	Control + Fert 3	10	20
3	Spader + Control	MB + Fert 3	MB + APM	MB + Control	10	30
4	Spader + Cereal	MB + Vetch	MB + Cereal	Control + Control	10	40
5	Spader + TPR	Control + Fert 3	MB + Vetch	MB + APM	10	50
6	MB + Fert 2	MB + Fert 2	Spader + APM	MB + Vetch	10	60
7	Spader + Silage	Spader + Vetch	Spader + Fert 1	Spader + Cereal	10	70
8	MB + Silage	Control + APM	MB + Fert 3	MB + CPM	10	80
9	Spader + Fert 1	Spader + Fert 1	MB + Control	Spader + Silage	10	90
10	Control + CPM	MB + Silage	Spader + Cereal	Spader + Fert 2	10	100
11	Spader + Fert 2	Spader + Cereal	Control + Control	MB + Cereal	10	110
12	Spader + Fert 3	Spader + Fert 2	Control + Cereal	MB + Fert 3	10	120
13	Control + Cereal	Spader + Silage	MB + Silage	Spader + APM	10	130
14	MB + APM	MB + TPR	Spader + CPM	MB + Silage	10	140
15	Spader + CPM	Control + CPM	MB + CPM	MB + Fert 2	10	150
16	Control + Silage	Spader + TPR	Control + Fert 3	Control + APM	10	160
17	Control + APM	Spader + APM	Control + APM	MB + TPR	10	170
18	Control + Control	MB + Fert 1	MB + TPR	Control + Fert 2	10	180
19	Spader + CPM *(2nd)	Control + CPM	Control + CPM	Control + CPM	10	190
20	MB + TPR	Control + TPR	Control + TPR	Control + Cereal	10	200
21	MB + CPM	Control + Silage ⟷	Control + Cereal	Control + CPM	10	210
22	Control + Fert 2	Control + Silage	Control + Fert 1	Control + TPR	10	220
23	Control + TPR	MB + APM	Spader + TPR	Spader + Fert 1	10	230
24	MB + Fert 3	MB + Cereal	Spader + Silage	Spader + TPR	10	240
25	Control + Fert 1	Control + Fert 2	Spader + Vetch	Spader + Control	10	250
26	MB + Control	Control + Control	MB + Fert 2	MB + Fert 1	10	260
27	Control + Vetch	Control + Vetch	Spader + Fert 3	Spader + Vetch	10	270
28	Control + Fert 3	Control + Fert 1	Control + Vetch	Spader + Fert 3	10	280
29	MB + Vetch	MB + Control	Spader + Control	Control + Fert 1	10	290
30	MB + Fert 1	Spader + Fert 3	Control + Fert 2	Control + Vetch	10	300
31	Spader + APM	Spader + Control	Spare	Control + Silage	10	310
32	Spare	Spare	Spare	Spare	10	320
	60 (50+10)	60 (50+10)	60 (50+10)	60 (50+10)	240	
		Control	Spader	Mould Board Plough		

4. Results and Discussion

4.1 Year 1 (2013)

4.1.1 Dry matter production

Dry matter production in 2013 was improved by the addition of organic matter high in N, but reduced by the cereal straw as the high C:N ratio of the straw tied up N in the soil. Additional DAP also increased DM production when more than 12.5 extra units of N were applied. Spading increased DM production (except with cereal straw), but MB results were variable. The mouldboard plough did not incorporate the straw, hay or silage well and some decreases in production resulted.

Table 6: Dry Matter production (t/ha) of barley in 2013.

	APM	Cereal	Control	CPM	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
Control	6.17	6.02	5.5	7.74	6.37	7.44	5.27	6.03	7.59	7.12
MB	5.79	3.93	5.27	6.77	6.05	6.84	4.59	6.02	7.09	4.78
Spader	6.76	3.37	6.44	6.51	7.1	6.83	6.84	7.48	8.51	7.07

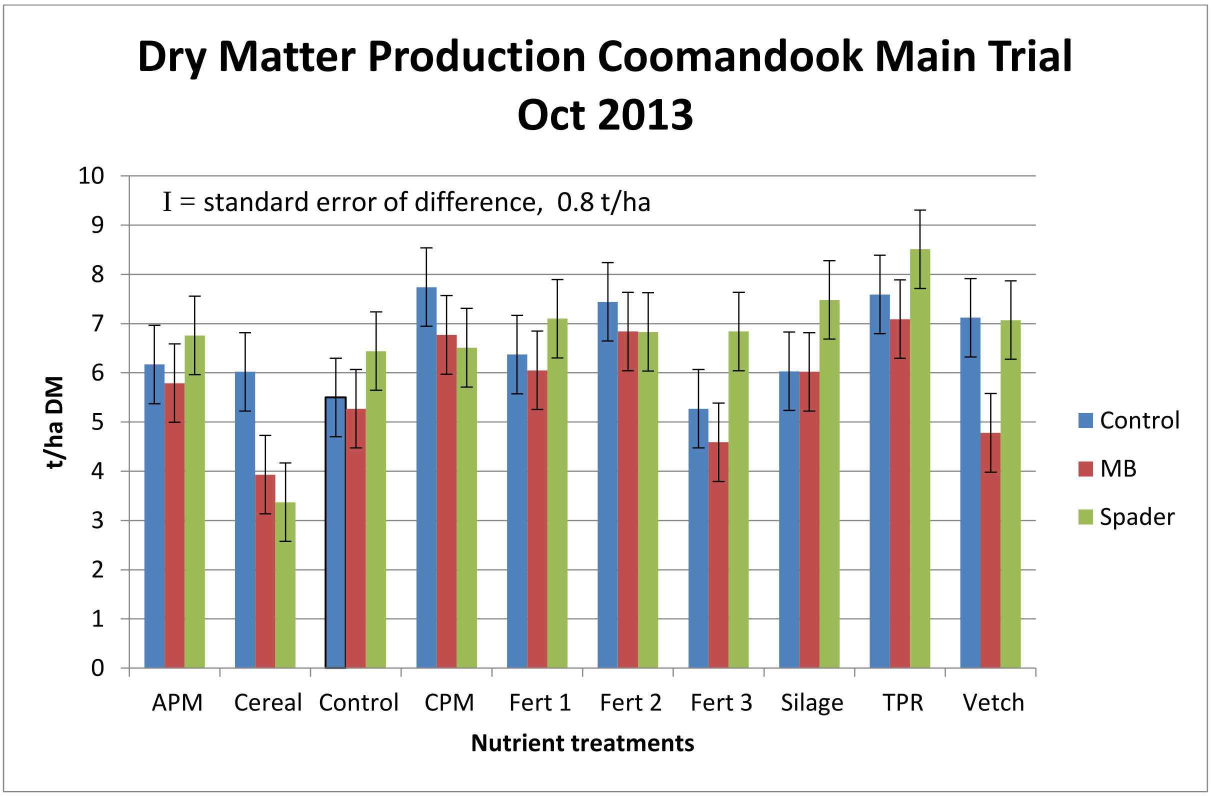

Figure 5: Dry Matter production (t/ha) at crop flowering, Oct 2013.

4.1.2 Yield

The harvest results are shown in the table and graph below, firstly as the actual amounts, then as a % of the control (no soil treatment, no extra nutrition, only the usual farmer care). Statistical analysis showed that there was a significant interaction of the soil modification and nutrient type ($p = 0.042$, lsd = 0.54).

Table 7: Yield (t/ha) Commander Barley 2013

	APM	Cereal	Control	CPM	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
Control	1.77	1.22	1.31	1.75	1.93	1.93	1.05	1.91	1.93	1.71
MB	1.68	1.13	1.35	1.83	1.72	1.65	1.21	1.37	1.91	1.12
Spader	1.71	1.35	2.05	1.84	1.74	1.68	2.22	1.62	2.06	1.73

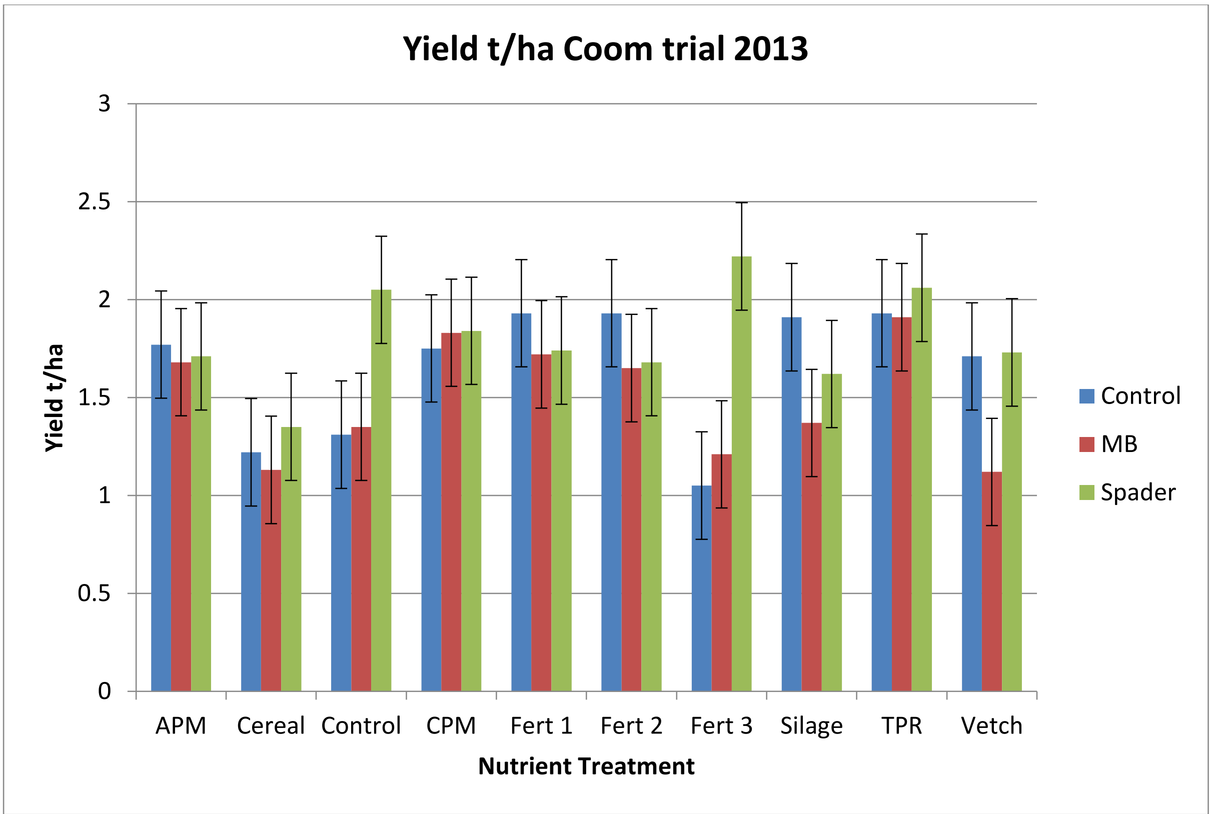

Figure 6: Yield (t/ha) Commander Barley 2013

Table 8: Yield as % of control – Commander Barley 2013

	APM	Cereal	Control	CPM	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
Control	135%	93%	100%	134%	147%	147%	80%	146%	147%	131%
MB	128%	86%	103%	140%	131%	126%	92%	105%	146%	85%
Spader	131%	103%	156%	140%	133%	128%	169%	124%	157%	132%

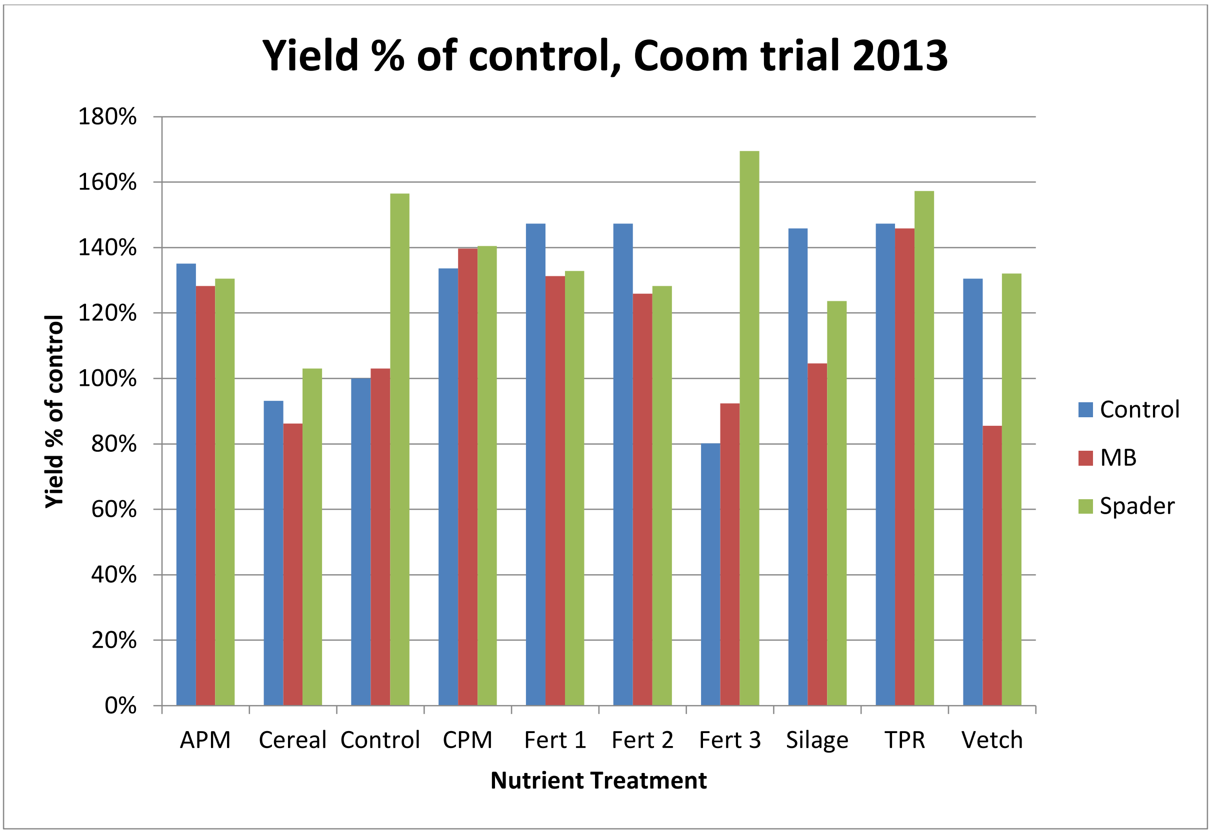

Figure 7: Yield as % of control – Commander Barley 2013

The spader had a strong effect on improving yield over the control when no extra nutrition was applied. Where extra nutrition was applied, the spader did not have an additional effect in this year, probably due to the late sowing and good rains allowing the soil to wet up.
Mouldboard ploughing had no or very little effect on the yields compared to the control.

Adding pig manure improved yields by ~ 30-40% with all soil treatments. Composted PM had a slight increase over aged, but not very much. TPR (grape marc) showed very good results, but the high cost of this would require it to have a very long residual effect for it to be worthwhile. The straw and hay had some problems with incorporation, particularly with the mouldboard plough. However the vetch hay showed good improvements either with the control or the spader. Cereal straw locked up N in the soil and showed poor results. Silage was intermediate.
The DAP treatments showed that improvements in yield could also be produced with extra fertiliser put out in smaller applications over time. Fert 3 was the lowest rate, Fert 1 intermediate and Fert 2 the highest. There was not a significant difference between Fert 1 and Fert 2, so an intermediate rate would probably be sufficient to increase yields by about 30%, but would have to be put out over time. The same fertiliser applied up front would probably cause problems with burning young plants and then not be available at the end of the season.

Adding organic matter that contained significant amounts of nutrients improved the yield of the crop strongly, regardless of whether it was spaded or mould boarded. When the soil was mould boarded without extra nutrition, there was no improvement in yield. Spading without extra nutrition did show a yield increase.

4.2 Year 2 (2014)

No new nutrition treatments or soil treatments were applied in 2014. The monitoring was to look at the ongoing effects of the 2013 treatments.

The site was sown to lupins on the 24/5 May 2014, and treated as per district practice.

No dry matter cuts were taken in 2014.

4.2.1 Yield

The harvest results are shown in the tables and graphs below, firstly as the actual amounts, then as a % of the control (no soil treatment, no extra nutrition, only the usual farmer care).

Note that the statistical analysis showed that only soil modification significantly affected the lupin yield – OM/fertiliser had no effect in 2014.

Table 9: Lupin yield (t/ha) 2014

	APM	Cereal	Control	CPM	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
Control	1.34	1.35	1.41	1.38	1.17	1.28	1.25	1.05	1.22	0.83
MB	1.84	1.84	1.65	1.83	1.67	1.66	1.85	1.75	1.56	1.67
Spader	1.91	2.04	1.57	2.26	1.86	2.14	1.34	1.67	1.73	1.42

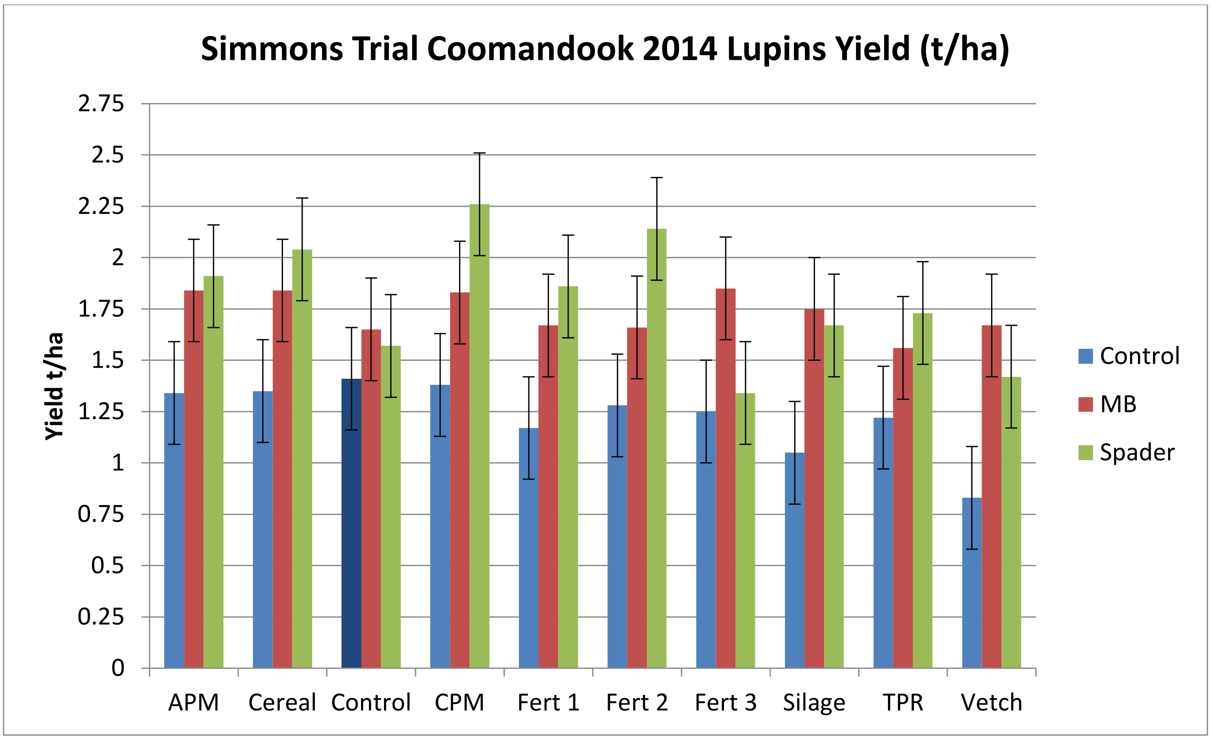

Figure 8: Lupin yield (t/ha) 2014

Table 10: Lupin yield (% of control) 2014

	APM	Cereal	Control	CPM	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
Control	95%	96%	100%	98%	83%	91%	89%	74%	87%	59%
MB	130%	130%	117%	130%	118%	118%	131%	124%	111%	118%
Spader	135%	145%	111%	160%	132%	152%	95%	118%	123%	101%

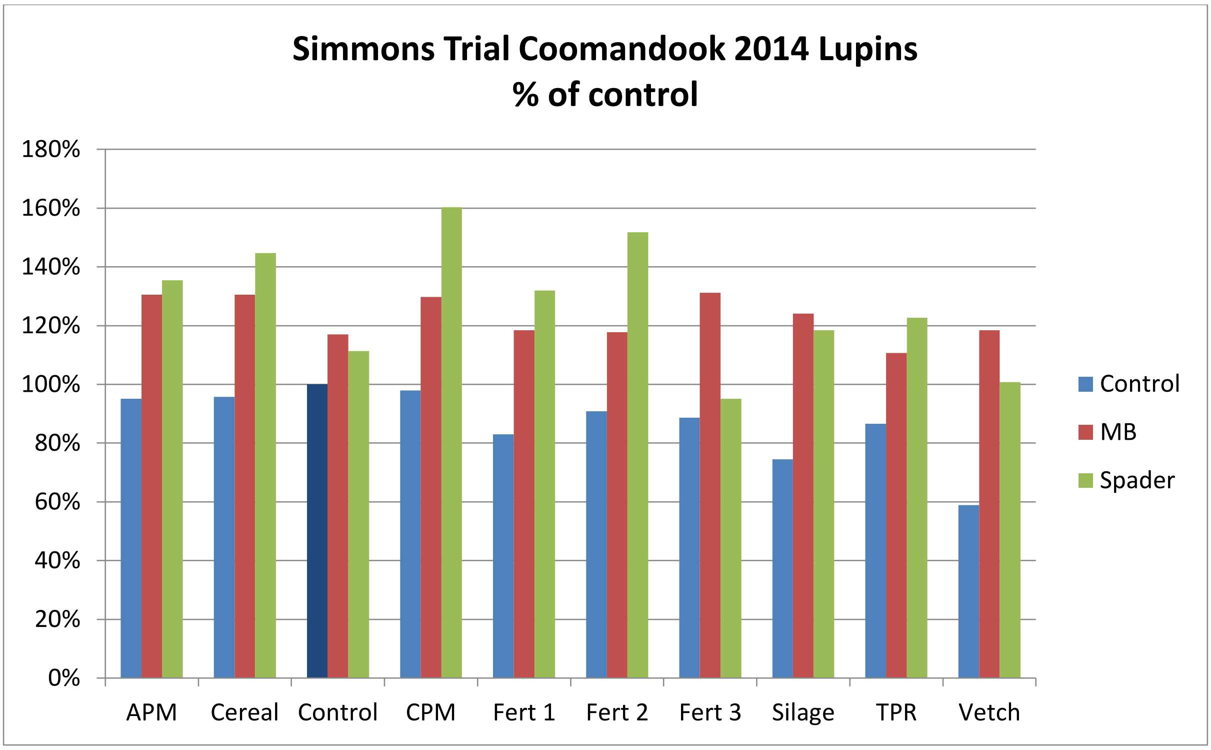

Figure 9: Lupin yield (% of control) 2014

The control–unmodified soil had a yield of 1.41 t/ha, and the nutrition treatments on the unmodified soil were similar or lower yielding. Vetch and silage were particularly low – it may be that the remaining organic matter affected the lupins in a negative way. There could have been higher root disease, or the concentration of nutrition in the topsoil may have reduced root growth into the subsoil, leading to haying off in the dry spring. The high variation in the trial meant that nutrition was not significant.

Soil modification did show a significant effect on yield. Mouldboard ploughing on average increased the lupin yield. Note that the cereal straw treatments on both the MB plough and the spader showed yield improvements in 2014, as opposed to yield penalty in 2013. Nutrition that was tied up in 2013 may have become available to the lupins in 2014. Also, as lupins are a legume and have N-fixing bacteria, the tie-up of soil N by carbon may have had less effect.

Spading increased yield again over the MB plough results. When the nutrition treatments are averaged out, it can clearly be seen that both MB plough and spader have improved yields over the control. This is due to the reduction in water repellence caused by the soil modification (see section 4.5).

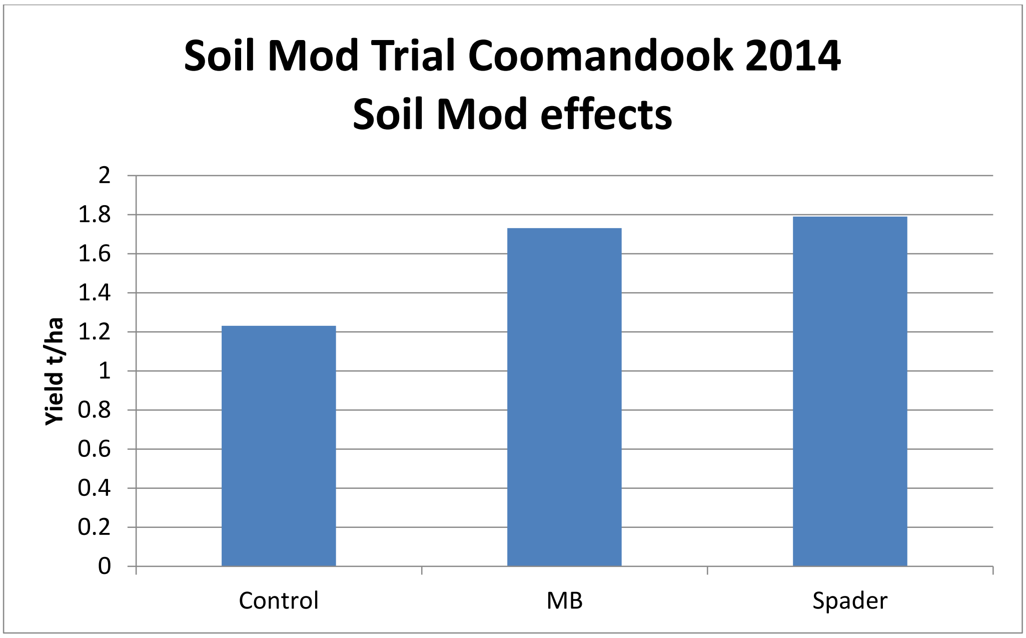

Figure 10: Effect of soil modification on Lupin yield 2014.

A reduction in yield is seen in most of the nutrition treatments on the control plots. This may be due to the early dry spring, as plants with high early vigour but with shallow root depth would have suffered more moisture stress than those with deeper root systems in the modified soils.

4.3 Year 3 (2015)

4.3.1 Dry matter production

The analysis of the dry matter production in 2015 showed that nutrition treatment affected DM production, but soil treatments did not. DM production overall was high. There was variation through the trial, and the season had problems with establishment on the water repellent sands early on, good rains in June but a very early finish with a hot dry spring.

Table 11: DM production (t/ha)

	APM	**Cereal**	**Control**	**CPM**	**Fert 1**	**Fert 2**	**Fert 3**	**Silage**	**TPR**	**Vetch**
Control	17.3	12.9	12.52	16.43	15.11	17.23	14.94	15.85	18.07	16.18
MB	15.47	14.42	16.03	14.11	16.88	16.89	14.98	12.96	17.81	12.93
Spader	17.49	14.61	15.34	13.57	15.02	13.17	18	14.63	17.35	16.49

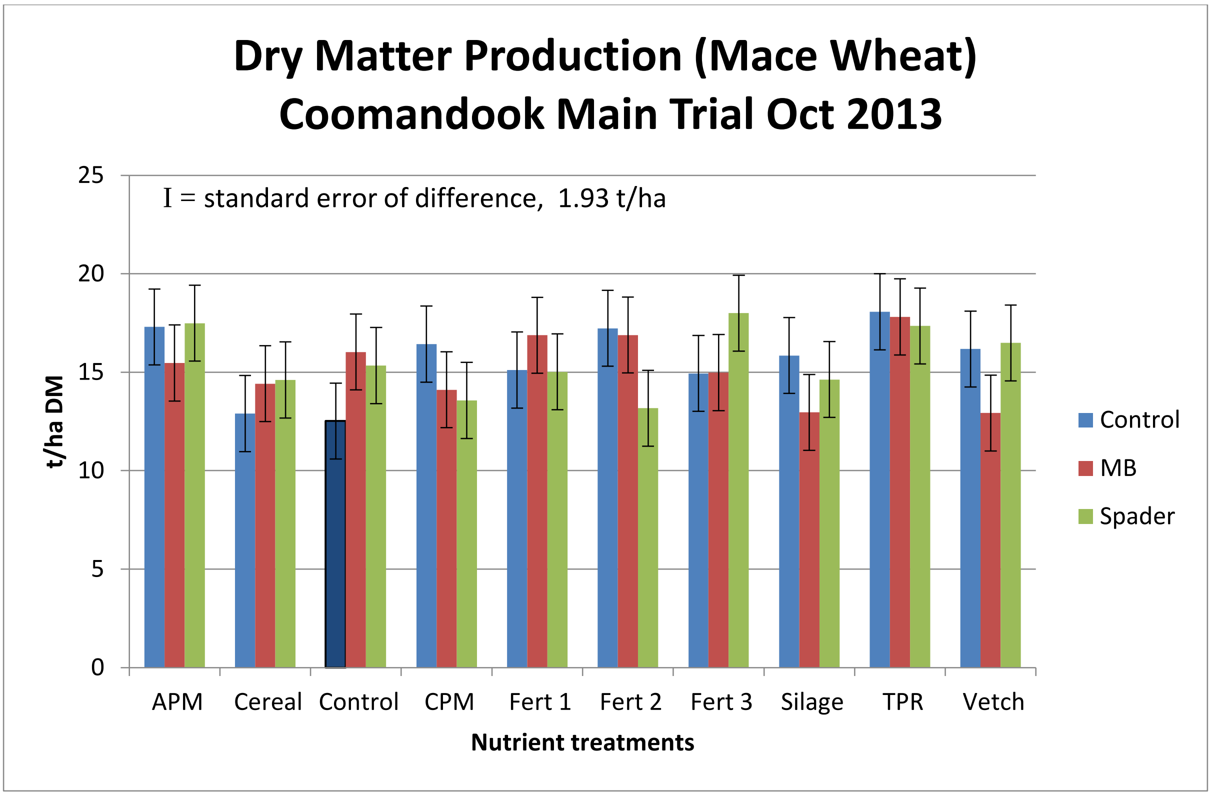

Figure 11: DM production (t/ha) 2015

4.3.2 Yield

Analysis of yield data showed that there was a significant interaction of the soil modification and the nutrients applied.

Table 12: Yield (t/ha) Mace wheat 2015

	APM	Cereal	Control	CPM	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
Control	2.99	1.92	1.86	2.94	3.02	3.13	1.15	3.01	3.22	2.81
MB	1.9	2.14	1.79	3	2.44	2.89	1.77	1.67	3.39	1.57
Spader	2.56	2.24	2.8	2.72	2.79	2.61	3.29	2.19	3.42	2.78

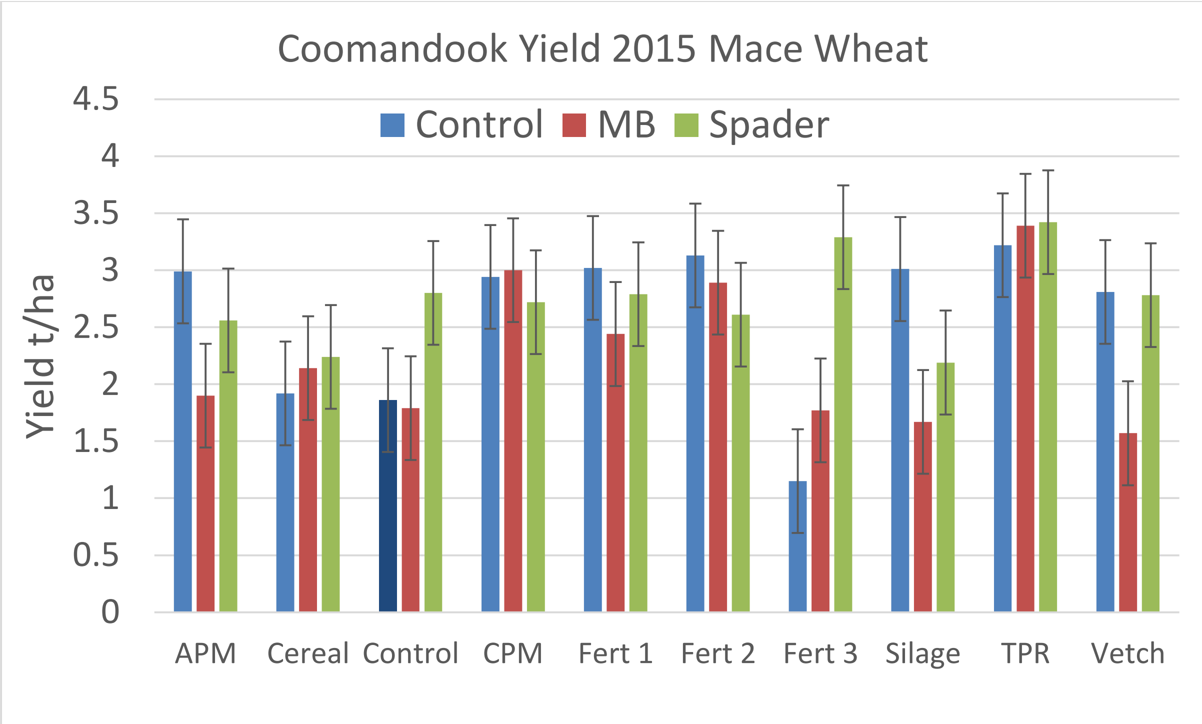

Figure 12: Yield (t/ha) Mace wheat 2015

When no OM or fertiliser was applied, the spaded plots had higher yields than the control or mouldboard plough. The addition of OM still had effects in the 3rd crop after application for TPR, CPM and APM, Silage, Vetch and the higher fertiliser rates (Fert 1 and Fert 2). This is surprising for the DAP fertilisers.

4.3.3 Quality Data

Wheat quality measurements were also taken to check if treatments made any difference to the grade and hence price received.

Due to the dry spring conditions, all treatments were graded AH1, and had high protein.

Screenings were affected by the soil modification treatments, with the modified soils having higher screenings than the control. This may be due to more vigorous early growth and larger numbers of heads set, which with the dry finish did not fill as well.

Table 13: Screenings % of Mace wheat 2015

	Control	MB	Spader
Screenings (%)	1.54	1.96	2.13

Protein levels were affected by both soil modification and nutrients, however, protein levels were high in all treatments and this did not affect the wheat grade.

Table 14: Protein levels for all treatments, 2015

	APM	Cereal	Control	CPM	Fert 1	Fert 2	Fert 3	Silage	TPR	Vetch
Control	13.7	14.8	14.9	14	14	13.9	15.3	14.3	14.3	13.7
MB	14.8	15.2	15.6	14	14.8	14.1	15.3	16	14	15.2
Spader	15.5	14.7	14.9	15	14.2	14.8	14.2	15.2	14.2	14.6

Hectolitre weight was affected by the soil treatments and the nutrients, but all measurements were well above the minimum level.

4.4 Profit/Loss Analysis - All Years

The data from all years of the trial was combined to give a cumulative profit/loss statement.

Prices for (Feed) barley were from the Stock Journal Grains section Feb 2014, Lupin price was from Paul Simmons, and Wheat price was the best price available for H1 at Tailem Bend from the ezi-grain website 7/3/16.

Table 15: Setup Costs for each treatment

Soil Mod	Nutrient	Product rate (t/ha)	Cost of product per ton	Cost of product on paddock, per ha	Trans	App	Soil Mod Cost (per ha)	Cost/ha no transport	Total Cost/ha
Control	APM	10	10	100	10	10	0	110	120
	Cereal	5	0	0	10	10	0	10	20
	Control	0	0	0	0	0	0	0	0
	CPM	10	20	200	10	10	0	210	220
	Fert 1	0.135	675	91.1	10	10	0	101.13	111.13
	Fert 2	0.27	675	182.3	10	10	0	192.25	202.25
	Fert 3	0.0675	675	45.6	10	10	0	55.56	65.56
	Silage	5	50	250	10	10	0	260	270
	TPR	20	0	0	960	10	0	10	970
	Vetch	5	260	1300	10	10	0	1310	1320
MB	APM	10	10	100	10	10	170	280	290
	Cereal	5	0	0	10	10	170	180	190
	Control	0	0	0	0	0	170	170	170
	CPM	10	20	200	10	10	170	380	390
	Fert 1	0.135	675	91.1	10	10	170	271.13	281.13
	Fert 2	0.27	675	182.3	10	10	170	362.25	372.25
	Fert 3	0.0675	675	45.6	10	10	170	225.56	235.56
	Silage	5	50	250	10	10	170	430	440
	TPR	20	0	0	960	10	170	180	1140
	Vetch	5	260	1300	10	10	170	1480	1490
Spader	APM	10	10	100	10	10	230	340	350
	Cereal	5	0	0	10	10	230	240	250
	Control	0	0	0	0	0	230	230	230
	CPM	10	20	200	10	10	230	440	450
	Fert 1	0.135	675	91.1	10	10	230	331.13	341.13
	Fert 2	0.27	675	182.3	10	10	230	422.25	432.25
	Fert 3	0.0675	675	45.6	10	10	230	285.56	295.56
	Silage	5	50	250	10	10	230	490	500
	TPR	20	0	0	960	10	230	240	1200
	Vetch	5	260	1300	10	10	230	1540	1550

Table 16: P/L Year 1 (2013)

		Year 1 (2013) 25 June Barley					
Soil Mod	**Nutrient**	**Yield Y1 (t/ha)**	**Extra yield over control (t/ha)**	**Extra $ (F1 barley at $225/t)**	**Est Profit/Loss Y1 (per ha) no OM costs**	**Est. Profit/Loss Y1 (per ha) no trans cost**	**Est. Profit/Loss Y1 (per ha)**
Control	APM	1.77	0.46	$103.50	$103.50	-$6.50	-$16.50
	Cereal	1.22	-0.09	-$20.25	-$20.25	-$30.25	-$40.25
	Control	1.31	0	$0.00	$0.00	$0.00	$0.00
	CPM	1.75	0.44	$99.00	$99.00	-$111.00	-$121.00
	Fert 1	1.93	0.62	$139.50	$48.38	$38.38	$28.38
	Fert 2	1.93	0.62	$139.50	-$42.75	-$52.75	-$62.75
	Fert 3	1.05	-0.26	-$58.50	-$104.06	-$114.06	-$124.06
	Silage	1.91	0.6	$135.00	$135.00	-$125.00	-$135.00
	TPR	1.93	0.62	$139.50	$139.50	$129.50	-$830.50
	Vetch	1.71	0.4	$90.00	$90.00	-$1,220.00	-$1,230.00
MB	APM	1.68	0.37	$83.25	-$86.75	-$196.75	-$206.75
	Cereal	1.13	-0.18	-$40.50	-$210.50	-$220.50	-$230.50
	Control	1.35	0.04	$9.00	-$161.00	-$161.00	-$161.00
	CPM	1.83	0.52	$117.00	-$53.00	-$263.00	-$273.00
	Fert 1	1.72	0.41	$92.25	-$168.88	-$178.88	-$188.88
	Fert 2	1.65	0.34	$76.50	-$275.75	-$285.75	-$295.75
	Fert 3	1.21	-0.1	-$22.50	-$238.06	-$248.06	-$258.06
	Silage	1.37	0.06	$13.50	-$156.50	-$416.50	-$426.50
	TPR	1.91	0.6	$135.00	-$35.00	-$45.00	-$1,005.00
	Vetch	1.12	-0.19	-$42.75	-$212.75	-$1,522.75	-$1,532.75
Spader	APM	1.71	0.4	$90.00	-$140.00	-$250.00	-$260.00
	Cereal	1.35	0.04	$9.00	-$221.00	-$231.00	-$241.00
	Control	2.05	0.74	$166.50	-$63.50	-$63.50	-$63.50
	CPM	1.84	0.53	$119.25	-$110.75	-$320.75	-$330.75
	Fert 1	1.74	0.43	$96.75	-$224.38	-$234.38	-$244.38
	Fert 2	1.68	0.37	$83.25	-$329.00	-$339.00	-$349.00
	Fert 3	2.22	0.91	$204.75	-$70.81	-$80.81	-$90.81
	Silage	1.62	0.31	$69.75	-$160.25	-$420.25	-$430.25
	TPR	2.06	0.75	$168.75	-$61.25	-$71.25	-$1,031.25
	Vetch	1.73	0.42	$94.50	-$135.50	-$1,445.50	-$1,455.50

Table 17: P/L Year 2 (2014)

		Year 2 (2014) 24th May Lupins			
Soil Mod	**Nutrient**	**Yield Y2 (t/ha)**	**Extra yield over control (t/ha)**	**Extra $ (Lupins @ $400/t)**	**Est. Profit/Loss Y2 (per ha)**
Control	APM	1.34	-0.07	-$28.00	-$28.00
	Cereal	1.35	-0.06	-$24.00	-$24.00
	Control	1.41	0	$0.00	$0.00
	CPM	1.38	-0.03	-$12.00	-$12.00
	Fert 1	1.17	-0.24	-$96.00	-$96.00
	Fert 2	1.28	-0.13	-$52.00	-$52.00
	Fert 3	1.25	-0.16	-$64.00	-$64.00
	Silage	1.05	-0.36	-$144.00	-$144.00
	TPR	1.22	-0.19	-$76.00	-$76.00
	Vetch	0.83	-0.58	-$232.00	-$232.00
MB	APM	1.84	0.43	$172.00	$172.00
	Cereal	1.84	0.43	$172.00	$172.00
	Control	1.65	0.24	$96.00	$96.00
	CPM	1.83	0.42	$168.00	$168.00
	Fert 1	1.67	0.26	$104.00	$104.00
	Fert 2	1.66	0.25	$100.00	$100.00
	Fert 3	1.85	0.44	$176.00	$176.00
	Silage	1.75	0.34	$136.00	$136.00
	TPR	1.56	0.15	$60.00	$60.00
	Vetch	1.67	0.26	$104.00	$104.00
Spader	APM	1.91	0.5	$200.00	$200.00
	Cereal	2.04	0.63	$252.00	$252.00
	Control	1.57	0.16	$64.00	$64.00
	CPM	2.26	0.85	$340.00	$340.00
	Fert 1	1.86	0.45	$180.00	$180.00
	Fert 2	2.14	0.73	$292.00	$292.00
	Fert 3	1.34	-0.07	-$28.00	-$28.00
	Silage	1.67	0.26	$104.00	$104.00
	TPR	1.73	0.32	$128.00	$128.00
	Vetch	1.42	0.01	$4.00	$4.00

Note that there are no costs for OM and Soil modification in year 2 as they only occur in year 1.

Table 18: P/L Year 3 (2015)

		Year 3 (2015) Mace Wheat			
Soil Mod	**Nutrient**	**Yield Y3 (t/ha)**	**Extra yield over control (t/ha)**	**Extra $ (Mace Wheat H1@$279.61/t)**	**Est. Profit/Loss Y3 (per ha)**
Control	APM	2.99	1.13	$315.96	$315.96
	Cereal	1.92	0.06	$16.78	$16.78
	Control	1.86	0	$0.00	$0.00
	CPM	2.94	1.08	$301.98	$301.98
	Fert 1	3.02	1.16	$324.35	$324.35
	Fert 2	3.13	1.27	$355.10	$355.10
	Fert 3	1.15	-0.71	-$198.52	-$198.52
	Silage	3.01	1.15	$321.55	$321.55
	TPR	3.22	1.36	$380.27	$380.27
	Vetch	2.81	0.95	$265.63	$265.63
MB	APM	1.9	0.04	$11.18	$11.18
	Cereal	2.14	0.28	$78.29	$78.29
	Control	1.79	-0.07	-$19.57	-$19.57
	CPM	3	1.14	$318.76	$318.76
	Fert 1	2.44	0.58	$162.17	$162.17
	Fert 2	2.89	1.03	$288.00	$288.00
	Fert 3	1.77	-0.09	-$25.16	-$25.16
	Silage	1.67	-0.19	-$53.13	-$53.13
	TPR	3.39	1.53	$427.80	$427.80
	Vetch	1.57	-0.29	-$81.09	-$81.09
Spader	APM	2.56	0.7	$195.73	$195.73
	Cereal	2.24	0.38	$106.25	$106.25
	Control	2.8	0.94	$262.83	$262.83
	CPM	2.72	0.86	$240.46	$240.46
	Fert 1	2.79	0.93	$260.04	$260.04
	Fert 2	2.61	0.75	$209.71	$209.71
	Fert 3	3.29	1.43	$399.84	$399.84
	Silage	2.19	0.33	$92.27	$92.27
	TPR	3.42	1.56	$436.19	$436.19
	Vetch	2.78	0.92	$257.24	$257.24

In years 2 and 3, there are no costs of treatments, so in those years, the increase or decrease in the crop yield is what determines whether there was additional profit or loss.

When all costs are taken into account (cost of nutrition, transport, and spreading), the cheaper OM options of APM and CPM show a profit when used either alone or in combination with spading. Composted pig manure appears to have a more consistent effect, but costs slightly more. The high cost of buying or transporting amendments such as silage, vetch or TPR (grape marc) means that they are not cost-effective in this situation.

The extra DAP fertiliser at the medium and high rates applied through the first season has had an ongoing effect over the 3 years of the trial. The reason for this is unknown.

Looking at the soil modification alone, spading is profitable after 3 years, but mouldboard ploughing is not.

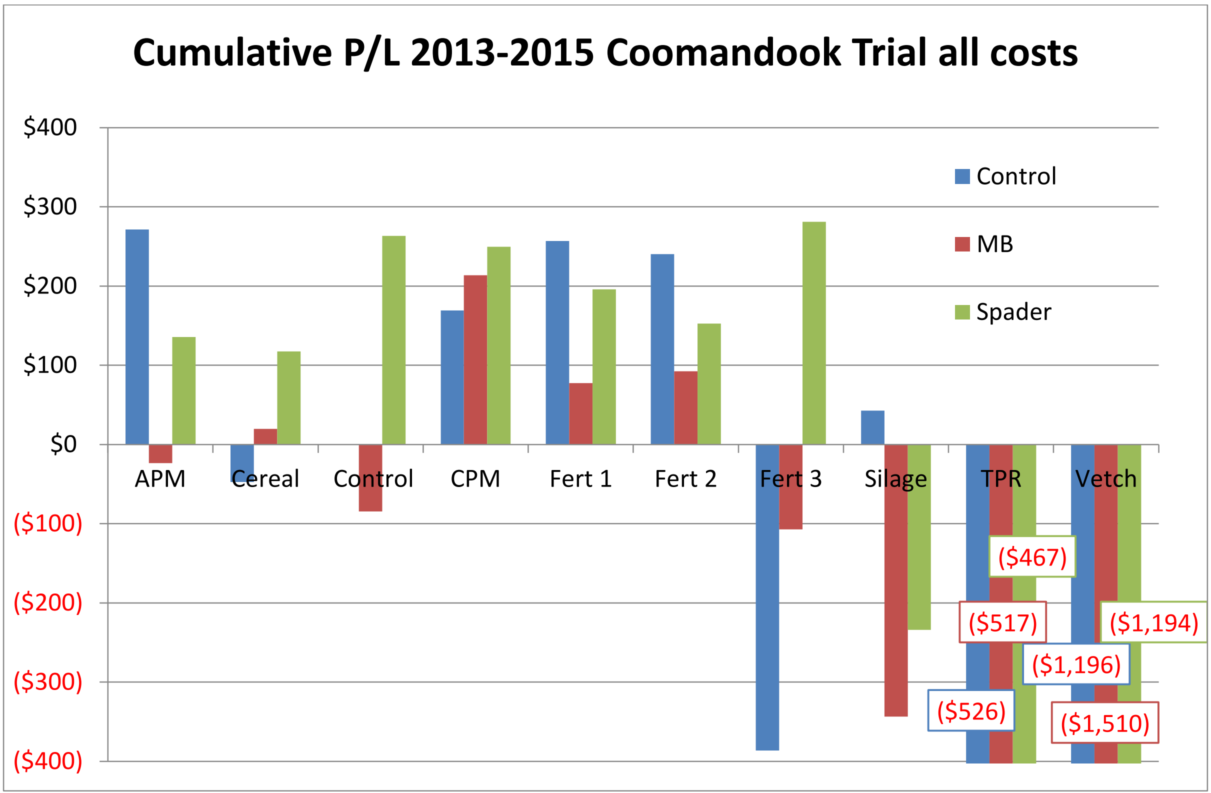

Figure 13: Overall P/L when all costs are included.

If transport costs are removed from the equation, then TPR shows a large profit over the 3 years, with more profit with spading. The high cost of Vetch hay means that it is not profitable to use this as a source of OM if it needs to be bought in. CPM maintains profit.

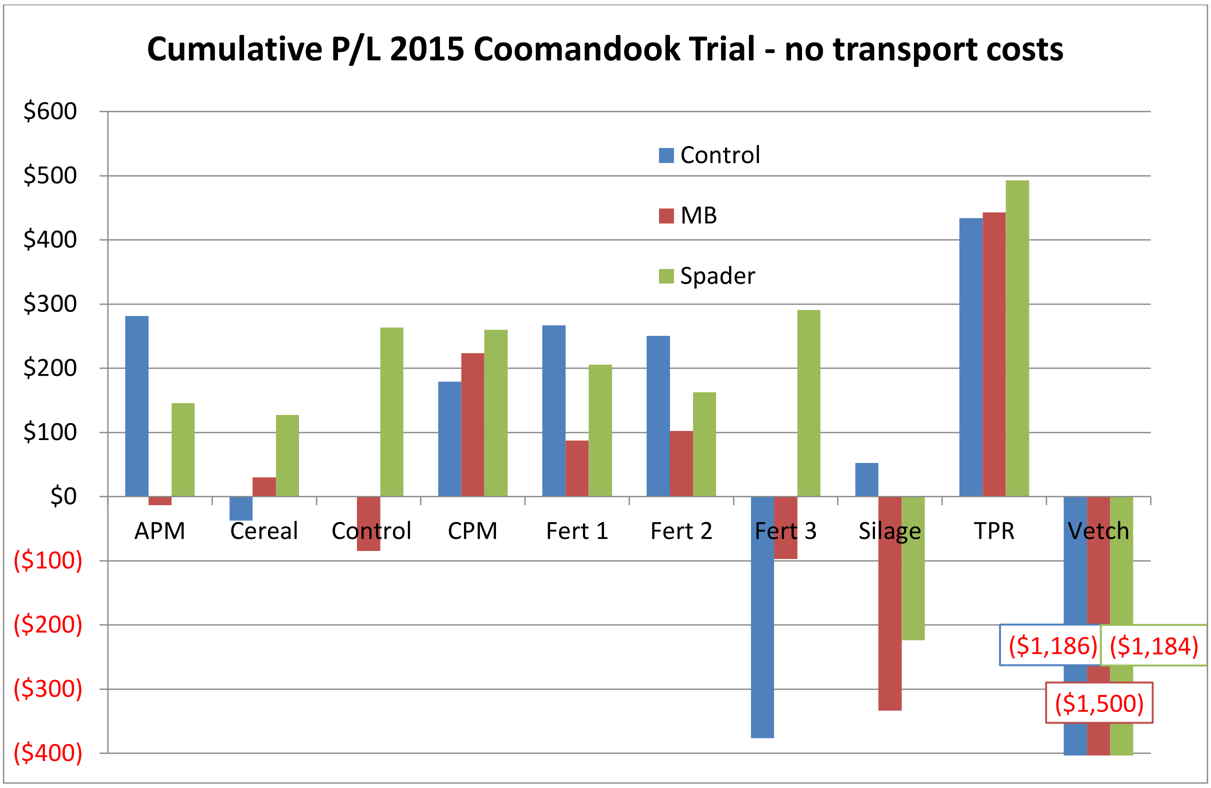

Figure 14: Overall P/L when there are no transport costs for OM.

If the cost of organic matter is removed from the equation (ie free supply of compost, manure or hay/straw/silage), then aged or composted Pig Manure and TPR Grape Marc are all profitable. (Costs for granular fertiliser have been retained.) Vetch hay is less profitable than these inputs, and problems with incorporation of hay, straw or silage using the mouldboard plough mean that the combination is less profitable than either surface application of the nutrients or spading.

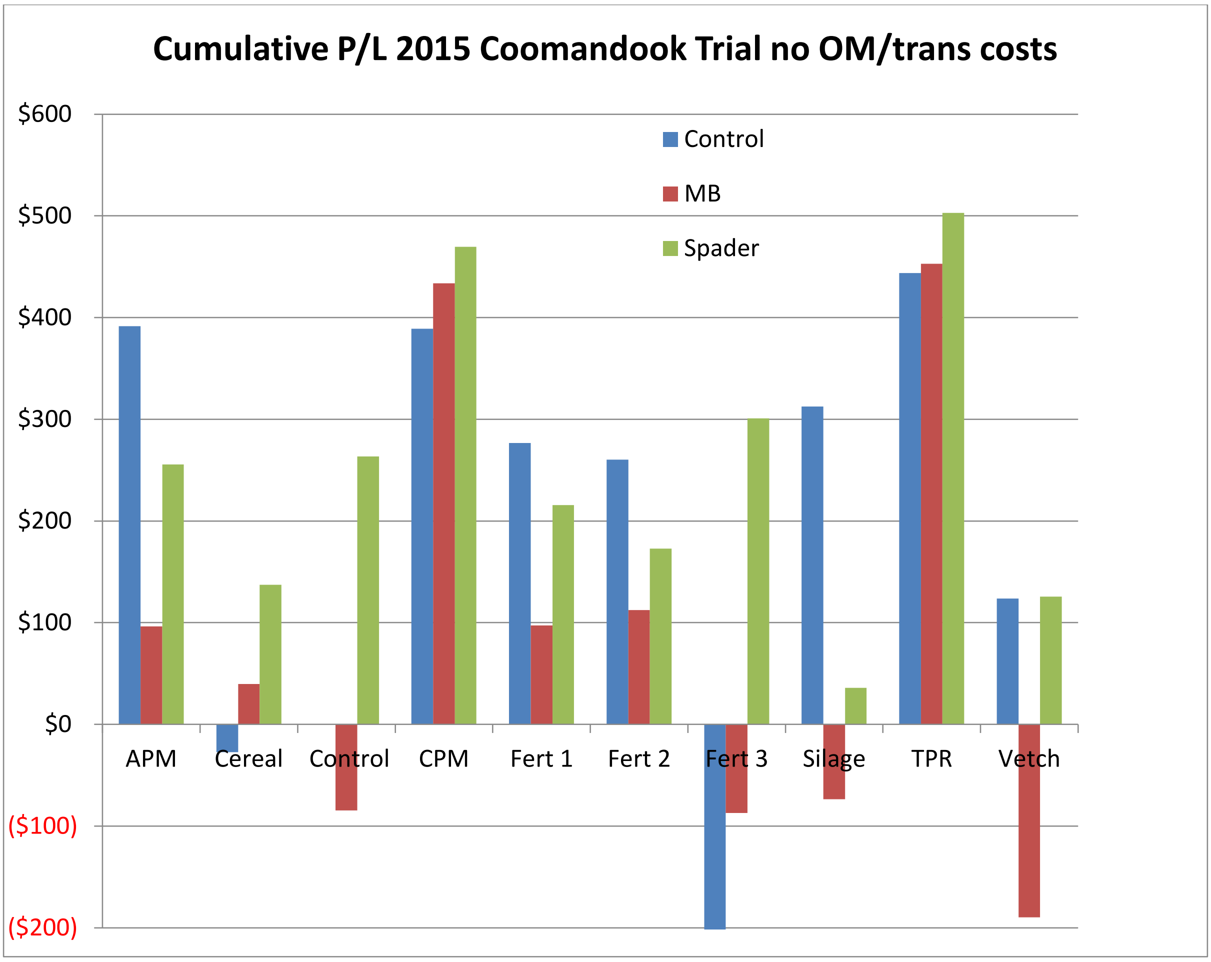

Figure 15: Overall P/L with no costs for OM or transport

Table 19: Year by year profit/loss comparisons.

										All years cumulative		
Soil Mod	Nutrient	Est Profit/Loss Y1 (per ha) no OM costs	Est. Profit/Loss Y1 (per ha) no trans cost	Est. Profit/Loss Y1 (per ha)	Est. Profit/Loss Y2 (per ha)	Cum Profit/Loss Y2 (per ha) no OM costs	Cum Profit/Loss Y2 (per ha) no trans cost	Cum Profit/Loss Y2 (per ha)	Est. Profit/Loss Y3 (per ha)	Cumulative P/L no OM cost	Cumulative P/L (no trans)	Cumulative P/L
Control	APM	$103.50	-$6.50	-$16.50	-$28.00	$75.50	-$34.50	-$44.50	$315.96	$391.46	$281.46	$271.46
	Cereal	-$20.25	-$30.25	-$40.25	-$24.00	-$44.25	-$54.25	-$64.25	$16.78	-$27.47	-$37.47	-$47.47
	Control	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	CPM	$99.00	-$111.00	-$121.00	-$12.00	$87.00	-$123.00	-$133.00	$301.98	$388.98	$178.98	$168.98
	Fert 1	$48.38	$38.38	$28.38	-$96.00	-$47.63	-$57.63	-$67.63	$324.35	$276.72	$266.72	$256.72
	Fert 2	-$42.75	-$52.75	-$62.75	-$52.00	-$94.75	-$104.75	-$114.75	$355.10	$260.35	$250.35	$240.35
	Fert 3	-$104.06	-$114.06	-$124.06	-$64.00	-$168.06	-$178.06	-$188.06	-$198.52	-$366.59	-$376.59	-$386.59
	Silage	$135.00	-$125.00	-$135.00	-$144.00	-$9.00	-$269.00	-$279.00	$321.55	$312.55	$52.55	$42.55
	TPR	$139.50	$129.50	-$830.50	-$76.00	$63.50	$53.50	-$906.50	$380.27	$443.77	$433.77	-$526.23
	Vetch	$90.00	-$1,220.00	-$1,230.00	-$232.00	-$142.00	-$1,452.00	-$1,462.00	$265.63	$123.63	-$1,186.37	-$1,196.37
MB	APM	-$86.75	-$196.75	-$206.75	$172.00	$85.25	-$24.75	-$34.75	$11.18	$96.43	-$13.57	-$23.57
	Cereal	-$210.50	-$220.50	-$230.50	$172.00	-$38.50	-$48.50	-$58.50	$78.29	$39.79	$29.79	$19.79
	Control	-$161.00	-$161.00	-$161.00	$96.00	-$65.00	-$65.00	-$65.00	-$19.57	-$84.57	-$84.57	-$84.57
	CPM	-$53.00	-$263.00	-$273.00	$168.00	$115.00	-$95.00	-$105.00	$318.76	$433.76	$223.76	$213.76
	Fert 1	-$168.88	-$178.88	-$188.88	$104.00	-$64.88	-$74.88	-$84.88	$162.17	$97.30	$87.30	$77.30
	Fert 2	-$275.75	-$285.75	-$295.75	$100.00	-$175.75	-$185.75	-$195.75	$288.00	$112.25	$102.25	$92.25
	Fert 3	-$238.06	-$248.06	-$258.06	$176.00	-$62.06	-$72.06	-$82.06	-$25.16	-$87.23	-$97.23	-$107.23
	Silage	-$156.50	-$416.50	-$426.50	$136.00	-$20.50	-$280.50	-$290.50	-$53.13	-$73.63	-$333.63	-$343.63
	TPR	-$35.00	-$45.00	-$1,005.00	$60.00	$25.00	$15.00	-$945.00	$427.80	$452.80	$442.80	-$517.20
	Vetch	-$212.75	-$1,522.75	-$1,532.75	$104.00	-$108.75	-$1,418.75	-$1,428.75	-$81.09	-$189.84	-$1,499.84	-$1,509.84
Spader	APM	-$140.00	-$250.00	-$260.00	$200.00	$60.00	-$50.00	-$60.00	$195.73	$255.73	$145.73	$135.73
	Cereal	-$221.00	-$231.00	-$241.00	$252.00	$31.00	$21.00	$11.00	$106.25	$137.25	$127.25	$117.25
	Control	-$63.50	-$63.50	-$63.50	$64.00	$0.50	$0.50	$0.50	$262.83	$263.33	$263.33	$263.33
	CPM	-$110.75	-$320.75	-$330.75	$340.00	$229.25	$19.25	$9.25	$240.46	$469.71	$259.71	$249.71
	Fert 1	-$224.38	-$234.38	-$244.38	$180.00	-$44.37	-$54.37	-$64.37	$260.04	$215.66	$205.66	$195.66
	Fert 2	-$329.00	-$339.00	-$349.00	$292.00	-$37.00	-$47.00	-$57.00	$209.71	$172.71	$162.71	$152.71
	Fert 3	-$70.81	-$80.81	-$90.81	-$28.00	-$98.81	-$108.81	-$118.81	$399.84	$301.03	$291.03	$281.03
	Silage	-$160.25	-$420.25	-$430.25	$104.00	-$56.25	-$316.25	-$326.25	$92.27	$36.02	-$223.98	-$233.98
	TPR	-$61.25	-$71.25	-$1,031.25	$128.00	$66.75	$56.75	-$903.25	$436.19	$502.94	$492.94	-$467.06
	Vetch	-$135.50	-$1,445.50	-$1,455.50	$4.00	-$131.50	-$1,441.50	-$1,451.50	$257.24	$125.74	-$1,184.26	-$1,194.26

4.5 Water Repellence Measurements

Water repellence of the topsoil (0-10 cm) was measured after harvest in December 2015 to determine if the treatments were still effective. The method used was the Molarity of Ethanol test (King 1981), where a series of solutions with different concentrations of ethanol (from 0 – 24 % pure ethanol) are dropped on the soil surface and observed for 10 seconds.

The waxes and oils that coat the sand grains will repel water but are dissolved by ethanol. Soils with low water repellence can take in pure water easily, but soils with high water repellence need to have a higher amount of ethanol added to the water to dissolve the waxes and oils and allow the mixture to soak in under 10 seconds. The concentration of ethanol in the solution (molarity) that soaks into the soil in less than 10 seconds gives a guide to how repellent the soil is.

Table 20: Water repellence ratings, from King, 1981.

Rating	Severity of repellence	Occurrence	MED
1	Not significant	Subsoils, drift sand, beach sand	–
2	Very low	Ploughed virgin land, undisturbed clear areas between native plants	–
			–
			–
3	Low	Under mallee, banksia, newly developed land	0·0
			0·2
4			0·4
			0·6
5			0·8
			1·0
6	Moderate	Under yacca and native pine. Perennial pastures (5–10 years old). Crop–pasture rotations	1·2
			1·4
7			1·6
			1·8
8			2·0
			2·2
9	Severe	Under yacca. Perennial pastures (10–15 years old), old annual pastures with no cropping	2·4
			2·6
10			2·8
			3·0
11	Very severe	Old lucerne, perennial veldt grass and phalaris pastures (>15 years old). Dry bare patches in pastures	3·2
			3·4
12			3·6
			3·8
			>3·8

Statistical analysis showed a strong effect of both spading and ploughing on the severity of the water repellence. Nutrition treatments had no effect on water repellence. The mean water repellence of the control plots was 3.6 MED – classed as very severe. The mean water repellence of the plots with spading or with ploughing was 1.8 MED for each (moderate water repellence).

As some plots had clay brought to the surface by the spader/plough, these plots were re-classified separately and the data re-analysed. This showed that in plots where clay was present, the MED dropped to a mean of 0.06 (not repellent). This data is shown in Figure 16.

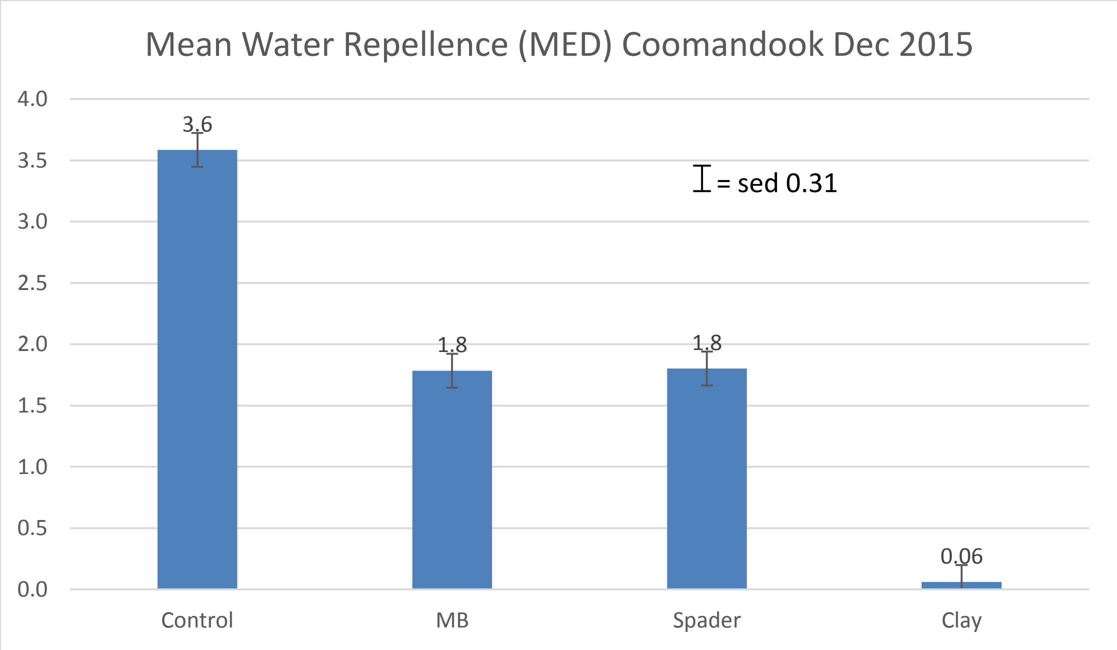

Figure 16: MED of soil modification treatments (Dec 2015) including plots with clay as a separate category.

Observation of the crop in 2015, a year in which water repellence was strongly evident in the district, showed that some control plots had obvious signs of water repellence, with uneven germination, lower plant numbers and lower plant density.

5. Conclusions

Treating water repellent sand using soil modification without clay can be done using either a spader or a mouldboard plough. In this trial, testing the soil 3 years after the initial soil modification treatment showed that treatments with either the plough or the spader had decreased water repellence. When the costs of treatment and improvements in productivity were taken into account, the spader was the most beneficial as crop productivity was improved more than the productivity with the mouldboard plough.

No organic matter amendment or fertiliser rate had any effect on the water repellence of the sand in this trial.

Crop productivity was measured over 3 years from 2013 to 2015 as yield and biomass production. The years 2013 and 2015 showed a statistically significant interaction of soil treatment and nutrition – meaning that the productivity of the crop depended on both the soil treatment and the nutrition applied. In 2014, when lupins were the crop, soil modification was significant but nutrition was not. For lupins, the nutrition is less important and overcoming water repellence for good establishment of the crop is the most important thing.

Generally, spaded plots had higher yields than mouldboard plough plots or the control plots. Plots with extra nutrition high in N and P yielded higher than controls. Cereal straw reduced yield in year 1 as there was a strong drawdown on N. The plots with hay, straw or silage did not perform as well for the mouldboard plough as the machine had difficulty incorporating these amendments.

In terms of yield, the outstanding OM types were TPR (grape marc) and CPM (Composted pig manure). Aged pig manure also performed well, but had more variation in the response. Vetch hay improved yield for the control and spaded plots, but problems with incorporation on the ploughed plots reduced yields.

The profitability of compost, manure or plant matter depends greatly on the cost of the product and the cost of transport. Generally, the cheapest closest source of nutrition with reasonable nutrient content is the most profitable, provided it is able to be handled and used with machines available. Adding OM with no soil modification can increase yield for cereals, but may cause yield loss in dry seasons or with lupins. Increased growth of roots in the topsoil with no root growth deeper can lead to haying off in spring.

6. Key Points

Modifying deep sandy soils where clay is unavailable using mouldboard ploughing or spading can reduce water repellence for at least 3 years – probably longer.

Adding a balanced source of organic matter with some N content can help to improve crop yields, especially for cereal crops.

Proper planning is essential to get a good result. The results are likely to last many years so it is important to get it right the first time. The conditions at the time that the soil is worked are very important to get the best result and to prevent soil erosion.

- Soil should be wet up as much as possible, so do working in late autumn/winter.
- The soil is likely to be soft afterwards, so it may be necessary to roll it to get good depth control for seeding and good seed-soil contact.
- Use OM sources that spread easily and that can be incorporated by the machinery. Hay or straw are not incorporated well by mouldboard ploughs and can cause problems.
- Plant a crop as soon as possible to reduce risk of wind erosion.

In this trial, spading provided the best returns on soil modification. Most spaders available work best between 20-40 cm deep, and are very good at mixing and incorporating high rates of dry matter. It is essential that the spader travels slow enough to mix the soil properly (< 6 km/hr). Spading incorporated organic matter well and modified to soil down to 35-40 cm, allowing better root growth to that depth.

The mouldboard plough work reduced water repellence in the surface soil to the same extent as the spader. However the machine did not work as deep as the spader, so root growth was less at depth. When no OM was added, it left very infertile soil at the surface, which can cause problems with establishment of crops. The plough also did not incorporate straw, hay or silage well. A mouldboard plough would be a second option if a spader were not available and water repellence was the main problem in the field. It may be wise to use extra nutrition at sowing if a mouldboard plough is used, to compensate for low surface soil nutrition.

The types of organic matter trialled showed that OM with higher N, P and K levels performed best at increasing crop yield. Grape marc (TPR), composted pig manure and aged pig manure were in this category. The rates used may be able to be varied depending on the OM available, spreader and the soil and rainfall area. Hay, straw and silage all had problems with incorporation with the MB plough. Vetch hay and silage had sufficient nutrition to improve yields of cereal crops. Cereal straw showed a strong effect of reducing available N in the soil, which reduced crop yields in the first year. DAP fertilizer applied over time did improve crop yields, but would cause extra work and costs of application.

Different crops reacted in different ways to the treatments. This is important when planning the rotation to go onto treated paddocks. The lupin crop in 2014 showed a strong response to the reduced water repellence. Cereals were much more responsive to nutrition than lupins, probably because the lupins provided their own N whereas the cereals relied on soil N. However, lupin yield was decreased by vetch hay – there may be an issue with lupins and vetch residues.

The types of crops grown will also affect how quickly the soil modification cost is paid for. A responsive, high priced crop will pay faster than a low value, less responsive one.

The work on budgeting in the trial showed that the cost-effectiveness of the various treatments depends strongly on the cost of the organic matter.
Spading alone costs more than MB alone, but gave a better yield result, and so was more cost-effective.
The nutrition treatments showed that OM with good levels of N and P would improve yield, so the most cost effective OM was that which had least transport costs and low price. Composted pig manure and TPR grape marc had highest yields, but the high price of transporting grape marc made it less cost-effective.

7. Recommendations

This project has provided excellent scientific data for research to both the local group and to other interested farmers via field days, workshops and fact sheets.

Further work could look at:

- Soil testing the plots to see the residual effects of the nutrition treatments applied.
- Measuring water use efficiency in various treatments
- Continue to measure water repellence and yield at the site to see how long the effects will last.

Related work could include:

- Trialling different rates of compost/OM (eg TPR) to find the most cost-effective rate.
- Trial new sources of OM – green waste, harvest waste?
- Comparing new sources of amendments – eg biochar, low rates of high purity clay (bentonite, zeolite), salt flat clays.
- Examining the possibility of using green manure/brown manure/summer crops as an OM source.

8. Recommendations for Farmers

- When considering modifying your soil, get to know all the problems present. It is water repellence alone? Poor nutrition? Shallow rock underneath? Deep infertile sand? Dig some holes across the area to see if it is all the same. When you know the whole picture, it is easier to put together a plan to deal with all of it, which saves time and money in the long run.
- Look at a number of options and the costs.
- Consider what is practical for you, both short and long term.
- If modifying the soil is the best action, plan it to get the best result. Soil modification lasts a long time whether it is done well or poorly, so you want to do it well.

- In a situation similar to this trial, with water repellent sand over a deep infertile sand, spading with a cost-effective source of high N and P organic matter would be a good option.
- Do the soil modification late in the season to allow time for some water to enter the soil.
- Roll the new surface if necessary to get even sowing depth, and ensure the crop is sowed soon after to minimise erosion risk.
- Monitor for signs of nutrient deficiency – not all organic matter nutrients are available in the first year, and availability will depend on biological factors such as soil temperature, so the crop may still need additional fertiliser.

9. Further Reading

King, P. (1981). "Comparison of methods for measuring severity of water repellence of sandy soils and assessment of some factors that affect its measurement." Soil Research **19**(3): 275-285.