Interaction between soil water repellence and soil nutrient availability

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Purpose: To determine how soil inversion and banded surfactants change the availability of soil nutrients

Location: Jeff Fordhams

Soil Type: Deep yellow sand

Soil Test Results: Samples taken prior to seeding 2012

Organic carbon (%) in 0-10 cm for water repellence treatment applied 2011.

Treatment	OC
Banded wetter	1.06
Mouldboard	0.48
Nil	1.04
Spading	0.59

Colwell P (mg/kg) in 0-10 cm for water repellence treatment and P (kg/ha) applied 2011.

Treatment	0P	20P
Banded wetter	27	29
Mouldboard	18	20
Nil	24	26
Spading	20	22

Colwell K (mg/kg) in 0-10 cm for water repellence treatment and K (kg/ha) applied 2011.

Treatment	0K	60K
Banded wetter	38	43
Mouldboard	33	39
Nil	49	52
Spading	41	49

Rotation: 2011: wheat, 2010: pasture, 2009: wheat

BACKGROUND SUMMARY

Methods for managing non-wetting soils can change the distribution of soil nutrients which may require a change in fertilizer management. In most soils, the nutrient reserves are greatest in the surface layer and this provides the majority of the nutrients required to crops. Soil inversion by mouldboard ploughing or spading changes the distribution of these soil nutrients within the soil profile, which is likely to change the timing of when crops have access to the soil nutrient supply. Banded surfactants may also change the timing of the availability of soil nutrients near the row by allowing this area to wet up more evenly following seeding. This trial has been designed to quantify how much the different methods for managing non-wetting soils change the availability of soil nutrient reserves. 2012 is the second year of this trial.

TRIAL DESIGN

Split-plot design – complete factorial.

Soil management treatments: nil, banded surfactant (Irrigator at 2L/ha with 60L water/ha), mouldboard ploughing, rotary spading

2011

Nitrogen: low [0], high [20 kg N /ha drilled 40 kg N/ha 8 WAS]

Phosphorus: low [0], high [20 kg P/ha drilled]

Potassium: nil, low [0], high [60 kg K/ha topdressed at seeding]

2012

Nitrogen: low [10 kg N /ha drilled], high [10 kg N /ha drilled + 20 kg N/ha 3 WAS + 20 kg N/ha 6 WAS]

Phosphorus: low [0], high [20 kg P/ha drilled]

Potassium: low [0], high[10 kg K/ha drilled]

** low and high rates are repeated on the same plots each year

Plot size: 30 x 1.5m

Machinery use: : DAFWA 3 furrow mouldboard plough, ProFarmer 5000 rotary spader, DAFWA plot seeder

Repetitions: 3

Crop type and varieties used: Hindmarsh Barley

Seeding rates and dates: Sown 15th June @ 80 kg/ha

TRIAL LAYOUT

Replicate	Plot	N	P	K	Treatment
Rep 1	1	10	20	10	Mouldboard
	2	50	20	0	Mouldboard
	3	10	0	10	Mouldboard
	4	10	20	0	Mouldboard
	5	50	0	0	Mouldboard
	6	50	0	10	Mouldboard
	7	50	20	10	Mouldboard
	8	10	0	0	Mouldboard
	9	50	0	0	Banded wetter
	10	10	0	0	Banded wetter
	11	50	0	10	Banded wetter
	12	10	20	0	Banded wetter
	13	50	20	0	Banded wetter
	14	50	20	10	Banded wetter
	15	10	0	10	Banded wetter
	16	10	20	10	Banded wetter
	17	10	20	10	Nil
	18	10	20	0	Nil
	19	50	20	0	Nil
	20	50	0	10	Nil
	21	50	20	10	Nil
	22	10	0	10	Nil
	23	10	0	0	Nil
	24	50	0	0	Nil
	25	10	0	10	Spading
	26	10	20	10	Spading
	27	50	20	10	Spading
	28	50	0	0	Spading
	29	10	20	0	Spading
	30	50	0	10	Spading
	31	50	20	0	Spading
	32	10	0	0	Spading
Rep 2	33	50	0	10	Spading
	34	10	0	10	Spading
	35	50	20	0	Spading
	36	10	20	0	Spading
	37	50	20	10	Spading
	38	10	0	0	Spading
	39	10	20	10	Spading
	40	50	0	0	Spading
	41	50	20	10	Mouldboard
	42	10	0	10	Mouldboard
	43	10	20	10	Mouldboard
	44	10	20	0	Mouldboard
	45	10	0	0	Mouldboard
	46	50	0	10	Mouldboard
	47	50	20	0	Mouldboard
	48	50	0	0	Mouldboard
	49	10	0	10	Banded wetter

	50	50	0	0	Banded wetter
	51	50	0	10	Banded wetter
	52	50	20	0	Banded wetter
	53	10	20	10	Banded wetter
	54	50	20	10	Banded wetter
	55	10	0	0	Banded wetter
	56	10	20	0	Banded wetter
	57	50	20	10	Nil
	58	50	0	10	Nil
	59	10	20	0	Nil
	60	10	0	0	Nil
	61	50	0	0	Nil
	62	10	20	10	Nil
	63	10	0	10	Nil
	64	50	20	0	Nil
Rep 3	65	50	20	0	Mouldboard
	66	10	0	10	Mouldboard
	67	10	20	0	Mouldboard
	68	50	0	0	Mouldboard
	69	50	0	10	Mouldboard
	70	50	20	10	Mouldboard
	71	10	0	0	Mouldboard
	72	10	20	10	Mouldboard
	73	10	0	0	Nil
	74	50	20	0	Nil
	75	50	20	10	Nil
	76	10	20	0	Nil
	77	50	0	0	Nil
	78	50	0	10	Nil
	79	10	0	10	Nil
	80	10	20	10	Nil
	81	50	20	10	Spading
	82	50	20	0	Spading
	83	10	20	10	Spading
	84	50	0	10	Spading
	85	10	0	0	Spading
	86	50	0	0	Spading
	87	10	20	0	Spading
	88	10	0	10	Spading
	89	10	0	0	Banded wetter
	90	10	0	10	Banded wetter
	91	50	0	10	Banded wetter
	92	10	20	0	Banded wetter
	93	50	20	10	Banded wetter
	94	50	0	0	Banded wetter
	95	10	20	10	Banded wetter
	96	50	20	0	Banded wetter

RESULTS/STATISTICS

Crop Establishment

A similar trend in crop establishment occurred in 2011 and 2012: establishment was poorer where tillage had been used. We attribute the decrease in crop establishment in the spading and mouldboard plots to poorer seed soil contact and lower soil moisture. Soil moisture measurements in 2011 showed that the surface of mouldboard and spading treatments dried more rapidly than the control.

Table 1. Effect of water repellence management method on barley seedling density 2012. Different letters show a significant difference ($p < 0.05$).

Main treatment	Average seedling density (plants m^{-2})
1. Nil	132[a]
2. Banded wetter	124[a]
3. Mouldboard	94[b]
4. Spading	108[b]

Tillering biomass and nutrient uptake

Water repellence management method had a significant effect on early nitrogen uptake (Table 2). Where 10N was applied, N uptake was significantly higher (5%) in mouldboard treatments than in the control and banded wetter. Where 10 N was applied, N uptake in spading was significantly higher than the control and banded wetter only at 10% probability. These differences were due to significantly higher shoot N concentration in the mouldboard and spading treatments; there were no significant differences in shoot biomass. A comparison of N uptake at 10 N and 50 N showed significant increases in N uptake in the nil and banded wetter though not in mouldboard and spading. These results suggest that soil nitrogen is more available in the mouldboard and spading treatments than in the nil and banded wetter.

Table 2. Effect of main treatment and N rate on N uptake, shoot biomass N concentration 8 weeks after seeding.

	N uptake (kg ha^{-1})		Shoot biomass (kg ha^{-1})		Shoot N concentration (%)	
Main treatment	10 N	50 N	10 N	50 N	10 N	50 N
1. Nil	18.46	24.63	546	655	3.42	3.81
2. Banded wetter	17.97	24.41	513	624	3.50	3.92
3. Mouldboard	23.86	27.04	542	581	4.47	4.72
4. Spading	22.83	26.04	567	593	3.94	4.45
LSD (5%) all treatments	4.91		136		0.42	

Table 3. Effect of main treatment and N rate on N uptake, shoot biomass N concentration at anthesis. Data shown is mean of P and K treatments.

	N uptake (kg ha^{-1})		Shoot biomass (kg ha^{-1})		Shoot N concentration (%)	
Main treatment	10 N	50 N	10 N	50 N	10 N	50 N
1. Nil	45.1	61.9	4476	5473	1.00	1.13
2. Banded wetter	41.3	59.0	4062	5113	1.01	1.15
3. Mouldboard	64.1	77.2	5232	5577	1.19	1.39
4. Spading	41.0	57.5	4111	4584	0.99	1.25
LSD (5%) all treatments	17.7		1124		0.10	

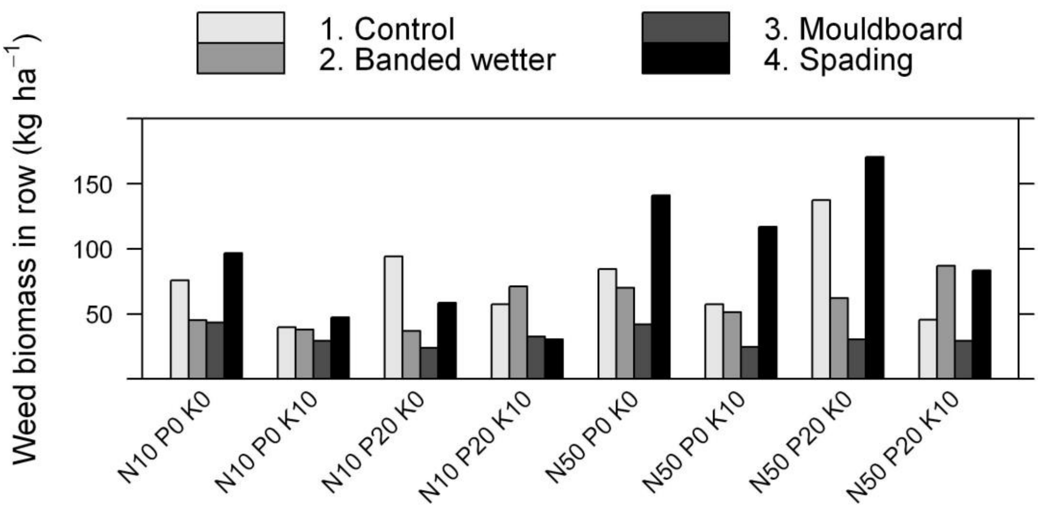

Figure 1. Weed biomass in row at anthesis. L.S.D. (5%) for all treatments is 75 kg ha^{1}.

Phosphorus and potassium uptake at 8 weeks after seeding showed a different pattern to N uptake (data not shown). For phosphorus, there were no significant differences between P uptake at 0 P for the main treatments; they we all approximately 2 kg P ha^{-1}. However, there were significant responses in uptake to applying P (uptake at 20 P – uptake at 0 P) which in decreasing order were; control (1.09), spading (0.99), banded wetter (0.98) and mouldboard (0.52). For potassium, there were no significant differences in K uptake between the main treatments where 0 or 10 kg K ha^{-1} was applied. There were large though not significant responses of K uptake to the addition of K (K uptake at 10K – K uptake at 0K) which in decreasing order were spading (6.99), mouldboard (6.48), banded wetter (5.36) and control (5.16).

Pit-face sampling

Pit face root measurements revealed some major differences in spatial root distribution in the main treatments. Acrylic screens were placed against pit faces at the end of plots and a dot was marked where each root intersected the pit face. The number of root intersections observed for the different main treatments varied markedly; 4380 in the control, 2745 in the banded wetter, 4617 in the mouldboard and 2931 in the spading. These differences may reflect spatial variation. There were similar patterns observed for the % of roots in surface 10 cm as in 2011: 70% in the control, 69% in spading, 66% in banded wetter and 26% in mouldboard plough. There were also some major differences between main treatments in the number of roots observed between 40 and 70 cm depth; 5.6% in mouldboard, 4.5% in control, 0.9% in spading and 0.5% in banded wetter 0.5%.

Visual analysis of the pit faces showed some clear differences in spatial root distribution (Figure 1). The control pit face had the most roots following macropores (old root channels), followed by mouldboard, with very few observed in spading and banded wetter. Root proliferation around buried organic material was evident in the mouldboard pit face.

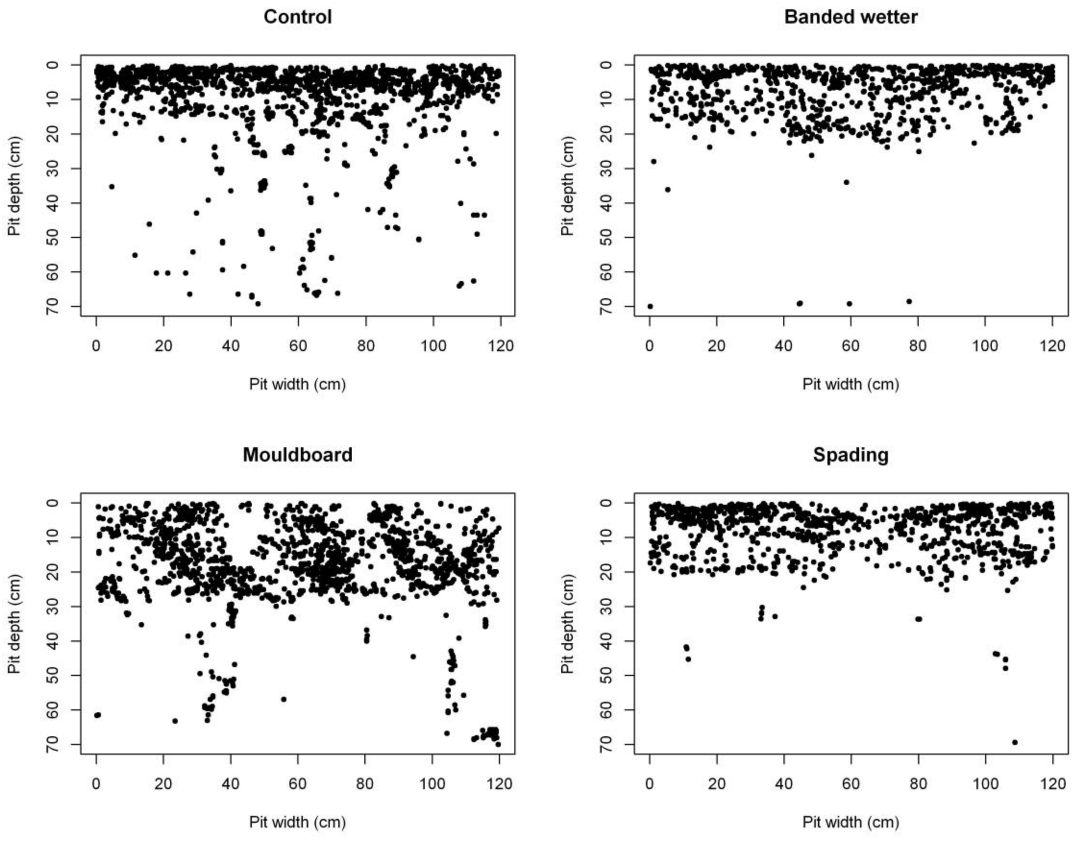

Figure 2: Root intersection maps for barley (Z 71: Kernal watery ripe) measured 11th October 2012. Each map is a cross-section of a plot, viewed in the same direction as the plot.

Weed biomass at flowering

The water repellence management method and nutrient treatment both had significant effects of weed biomass in the crop row, although the interaction was not statistically significant. Overall, average weed biomass was greatest in spading, followed by control, banded wetter and mouldboard, which were 93, 74, 58 and 32 kg ha^{-1} respectively. Only the mouldboard and spading were significantly different. The three nutrients had different effects on weed biomass; adding K always decreased weed biomass in the control and spading, with mixed results in the banded wetter and mouldboard.

Flowering biomass and nutrient uptake

Nitrogen uptake at anthesis showed a similar pattern to that at tillering (Table 3). Where 10 N was applied N uptake was significantly higher in mouldboard than the other treatments, which resulted in higher shoot N concentration and biomass. The shoot biomass response to adding nitrogen (mean for each main treatment at 50N - mean for each main treatment at 50N) differed between management treatments. The biomass response in the control and banded wetter were 997 and 1051 kg ha^{-1} respectively, whereas the mouldboard and spading were 345 and 473 kg ha^{-1} respectively. It seems that the response to N was less in the mouldboard because the crop had accessed more soil N, and was lower in the spading treatment because the yield potential was low. These results suggest that soil N is more available over the course of the season in the mouldboard treatment.

Grain yield

Analysis of variance showed that both the main treatment (water repellence management) and sub treatment (nutrition treatments) had a significant ($p < 0.05$) effect on grain yield. Using the average for all nutrition treatments, average grain yield (kg ha^{-1}) was highest in the control (2494), followed by mouldboard (2400), banded wetter (2199) and spading (1890). Using the average for all main treatments, grain yield was lowest for N0 P0 K0 (1838) and highest for N50 P20 K10 (2792). The interaction between main treatment and nutrition treatment was significant at 10%.

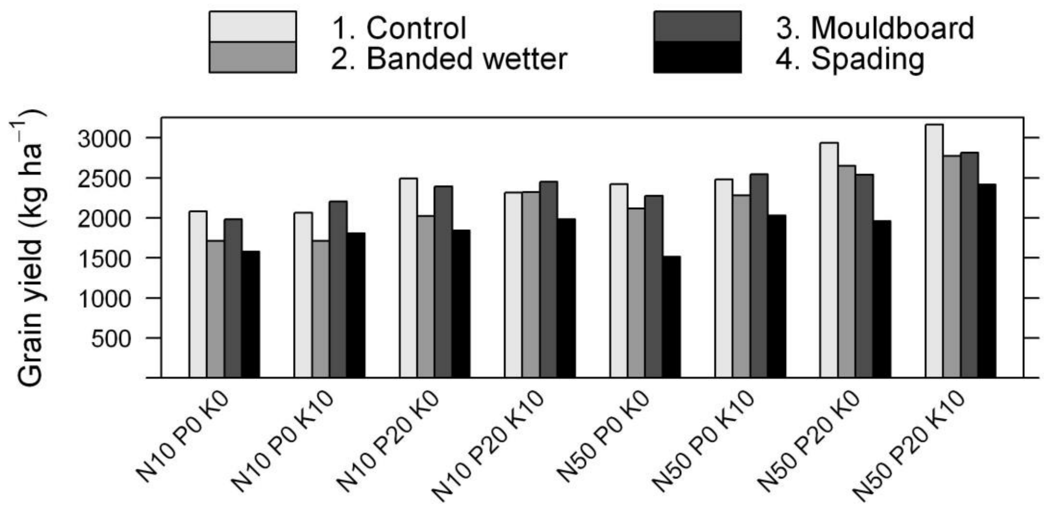

Figure 3. Mean grain yield for each main treatment and nutrition treatment. LSD (5%) for all treatments is 473 kg ha^{-1}.

OBSERVATION/ DISCUSSION/ MEASUREMENTS

The negative effect of water repellence management at this site is at odds with other work in this project. In both years we have observed a lower grain yield in the banded wetter, mouldboard ploughing and spading treatments than in the control at this site. However, the average yield response to mouldboard ploughing and spading was 550 to 600 kg/ha over 28 sites (Davies *et al.* 2012). The most obvious difference between this site and others in our project was crop establishment: plant density was reduced by mouldboard ploughing and spading at this site, whereas it was improved at other sites. It seems that the level of water repellence that occurred at this site (~ 5 minutes water drop penetration time) was not severe enough to impede germination and seedling survival. The difference in yield response to mouldboard ploughing and spading at this site and others suggests that plant density 6 to 8 weeks after sowing could be a useful measure for determining whether a site will respond positively to soil inversion.

While the water repellence at this site was not severe enough to affect crop establishment, it did affect soil nutrient availability. The greater response to fertiliser P in the control compared to the other treatments partly reflected yield potential but also reflected crop access to soil P, i.e. it was less available in the control. It is unlikely that the difference in yield response to fertiliser P was due to spading or mouldboard ploughing changing the vertical distribution of soil P: prior to soil inversion Colwell P was ~ 24 mg kg^{-1} from 0 to 20 cm meaning that the soil P profile post soil inversion was very similar to that of the control (Scanlan *et al.* 2012). Infiltration patterns revealed using Brilliant Blue at this site showed that the control plots did not wet evenly and this had important implications for soil P availability; P in dry soil was not available to the crop.

The differences in N uptake observed in 2012 reflected both a change in the vertical distribution of organic matter and different soil moisture dynamics. Mouldboard ploughing and spading resulted in different organic carbon profiles than the control. In addition higher soil moistures were observed at 10 to 20 cm soil depth in the mouldboard ploughing and spading treatments than in the control and banded wetter (Scanlan *et al.* 2012). The higher N uptake in the soil inversion treatments was a strong indicator that more N mineralisation had occurred, and that for an equivalent yield potential lower fertiliser N rates may be possible. However, we do not have any data on the longevity of this effect. We will continue to observe these nutrient dynamics in this trial for another 2 years. Tissue testing for N on soils that have been treated for water repellence using soil inversion is recommended because a) it provides an indicator of soil N supply and b) fertiliser recommendation models are not calibrated to the organic carbon profiles created by soil inversion.

PEER REVIEW/REVIEW

This paper was reviewed by Paul Blackwell (DAFWA), Margaret Roper (CSIRO) and Bill Bowden for the 2013 Agribusiness Crop Updates.

ACKNOWLEDGEMENTS/ THANKS

Thanks to Jeff Fordham for hosting the trial and to Dave Gartner, Gavin Sarre and Damien Priest for help with trial work. Thanks also to the West Midlands Group for help with extension of this research.