Effect of lime incorporation on soil nutrient availability

Craig Scanlan, Gavin Sarre and Ross Brennan, DAFWA

Purpose: To determine whether a profit can be achieved from incorporating lime in the year it is applied.

Location: 2013 West Midlands Group spring field day site.

Soil Type: Deep yellow sand.

Rotation: Pasture 2012

Growing Season Rainfall (April- October 2013): ~440 mm

Soil Test Results

Table 1: Soil chemical analysis for samples taken April 2013. Data shown are the mean of 9 samples.

Soil depth (cm)	Organic Carbon (%)	Ammonium Nitrogen (mg/kg)	Nitrate Nitrogen (mg/kg)	Phosphorus Colwell (mg/kg)	PBI	Potassium Colwell (mg/kg)	Sulphur (mg/kg)	pH (CaCl$_2$)	Aluminium (CaCl$_2$)
0-10	1.49	5	18	28	17	56	6	6.1	0.4
10-20	0.44	3	6	18	14	40	4	4.9	1.6
20-30	0.18	2	3	10	13	41	3	4.7	2.3
30-40	0.17	2	3	5	17	52	4	4.9	1.2
40-60	0.13	2	3	2	23	60	4	5.4	-
60-80	0.11	2	2	2	26	50	6	5.9	-
80-100	0.09	2	1	<2	32	53	7	6.0	-

The soil type was a deep yellow sand with moderate soil fertility (Table 1). Soil pH_{Ca} was slightly above recommended levels, Colwell phosphorus was above the level required for 95% of maximum production, Colwell potassium was at the level required for 90% of maximum production for > 3 t/ha wheat and sulphur in the 0 to 30 cm exceeded the level required for 90% of maximum production on these soils.

BACKGROUND SUMMARY

Recent work has shown that i) the majority of soils in the WA agricultural zone are below critical levels for soil pH, ii) soil pH below 5.5 has a negative effect on soil phosphorus availability and iii) spading can increase the availability of soil nutrients. Incorporation of lime with rotary spading provides an option for rapid soil amelioration, although cost is a barrier to adoption. If the availability of soil nutrients is improved with rotary spading, it is feasible that growers could shift investment from fertilisers to lime and incorporation. Evidence is required on the effect of rotary spading, and the incorporation of lime with rotary spading on the grain yield response to N, P, K and S fertiliser to identify which nutrients can be left out when investing in soil amelioration

TRIAL DESIGN

Plot size: 20 x 1.54 m.

Machinery use: DAFWA plot seeder and harvester. Imants rotary spader.

Repetitions: 3

Crop type and varieties used: Mace wheat.

Seeding rates and dates: 80 kg/ha on 13th June
Fertilizer rates and dates: See treatments below.
Herbicide rates and dates:
28th May: Trial sown, Talstar @ 2 L/ha, Dominex @ 100 mL/ha, Sprayseed @ 2 L/ha, Treflan @ 1.5 L/ha
13th June: Trial resown, Treflan @ 1.5 L/ha, Sprayseed @ 4 L/ha.

Other applications/ treatment rates and dates: The trial is a split plot design: the layout is divided into main treatments and sub treatments are then applied to each main treatment.

Main treatments:
1. No-till control
2. Cultivation (Rotary spader)
3. Lime sand @ 3t/ha + cultivation

Sub treatments:
1. All nutrients
2. All minus N fertiliser
3. All minus P fertiliser
4. All minus K fertiliser
5. All minus S fertiliser
6. Nil fertilizer

Nutrient treatments
Phosphorus: 20 kg P/ha drilled as Double Phos
Nitrogen: 10 kg N/ha drilled + 10 kg N/ha topdressed at sowing, + 20 kg N/ha topdressed 4 WAS
Potassium: 100 kg K/ha topdressed at sowing as Muriate of Potash
Sulphur: 20 kg S/ha topdressed at sowing as Gypsum (includes fertilizer and chemical treatments)

TRIAL LAYOUT

	Buffer	Buffer	Buffer	
Rep 1	Plot 101: All-N nil	Plot 201: All-K nil	Plot 301: All-S nil	
Rep 1	Plot 102: All nil	Plot 202: Nil nil	Plot 302: All-P nil	
Rep 1	Buffer	Buffer	Buffer	
Rep 1	Plot 103: All-S Spading	Plot 203: All Spading	Plot 303: All-P Spading	
Rep 1	Plot 104: Nil Spading	Plot 204: All-K Spading	Plot 304: All-N Spading	
Rep 1	Buffer	Buffer	Buffer	
Rep 1	Plot 105: All-P Spading + lime	Plot 205: All Spading + lime	Plot 305: All-K Spading + lime	
Rep 1	Plot 106: All-N Spading + lime	Plot 206: All-S Spading + lime	Plot 306: Nil Spading + lime	
	Buffer	Buffer	Buffer	
Rep 2	Plot 107: All-K Spading	Plot 207: Nil Spading	Plot 307: All-S Spading	
Rep 2	Plot 108: All-P Spading	Plot 208: All-N Spading	Plot 308: All Spading	
Rep 2	Buffer	Buffer	Buffer	
Rep 2	Plot 109: All-K Spading + lime	Plot 209: All-P Spading + lime	Plot 309: All-N Spading + lime	50.4 m
Rep 2	Plot 110: All Spading + lime	Plot 210: Nil Spading + lime	Plot 310: All-S Spading + lime	
Rep 2	Buffer	Buffer	Buffer	
Rep 2	Plot 111: All-S nil	Plot 211: All-P nil	Plot 311: All-K nil	
Rep 2	Plot 112: Nil nil	Plot 212: All-N nil	Plot 312: All nil	
	Buffer	Buffer	Buffer	
Rep 3	Plot 113: Nil Spading + lime	Plot 213: All-N Spading + lime	Plot 313: All Spading + lime	
Rep 3	Plot 114: All-S Spading + lime	Plot 214: All-K Spading + lime	Plot 314: All-P Spading + lime	
Rep 3	Buffer	Buffer	Buffer	
Rep 3	Plot 115: All-K nil	Plot 215: All nil	Plot 315: All-N nil	
Rep 3	Plot 116: All-P nil	Plot 216: All-S nil	Plot 316: Nil nil	
Rep 3	Buffer	Buffer	Buffer	
Rep 3	Plot 117: All Spading	Plot 217: All-P Spading	Plot 317: Nil Spading	
Rep 3	Plot 118: All-N Spading	Plot 218: All-S Spading	Plot 318: All-K Spading	
	Buffer	Buffer	Buffer	
	20 m	20 m	20 m	

RESULTS/STATISTICS

Cultivation with or without lime led to significant changes in soil pH in the surface 30 cm (Figure 1). The cultivation treatment led to a significant decrease in soil pH 0-10 cm and a significant increase in soil pH 10-20 cm. In the lime + cultivation treatment, no statistically-significant change in soil pH 0-10 cm was observed though a significant increase was observed in soil pH 10-20 cm and 20-30 cm.

Soil nitrate increased depending upon the cultivation treatment, and the increase was significant in respect to total N supply (data not shown). The total soil nitrate in 0-40 cm was 48, 53 and 80 kg/ha for the control, cultivation and lime + cultivation treatments respectively. The difference in total soil nitrate between the control and lime + cultivation treatments was 32 kg/ha which is enough soil nitrogen to produce approximately 0.7 t/ha wheat grain.

There was a yield response to cultivation, though the addition of lime did not result in additional grain yield. The mean yield for the cultivation and lime + cultivation treatments were 3142 and 3169 kg/ha respectively, significantly higher than control at 2543 kg/ha.

The yield for the Nil nutrient treatments was only significantly lower than the All nutrient treatments for the control main treatment. It appears as though cultivation has increased the availability of soil nutrients which has decreased the need from nutrients as fertilizer. Of the 4 macro-nutrients used as treatments (N, P, K, S), grain yield was most sensitive to omitting N fertilizer although the grain yield loss was not statistically significant.

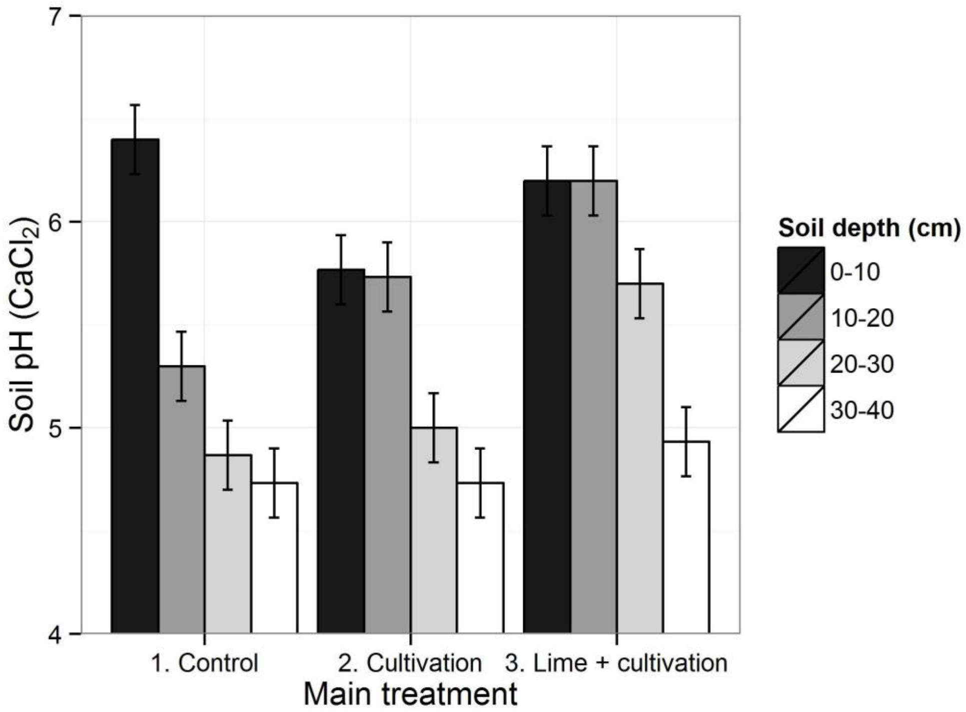

Figure 1: Soil pH measured 8th August (17 weeks after application). Where error bars do not overlap a statistically significant difference was observed. Soil samples were taken from the nil nutrient treatment only.

Table 2: Grain yield (kg/ha) for the main and nutrient treatments. Data are from machine harvest of 3 replicates for each treatment. Treatments are statistically significantly different where the difference in grain yield is greater than the LSD.

Main treatment	Nutrient treatment					
	All	All-K	All-N	All-P	All-S	Nil
Dandaragan						
1. Control	2886	2772	2285	2585	2796	1936
2. Cultivation	3289	3373	2688	3236	3662	2603
3. Lime + cultivation	3301	3127	2964	3493	3217	2910
LSD (5%)	862					

FINANCIAL ANALYSIS OF RESULTS

The economic analysis of this trial is compromised because fertiliser rates were higher than used in practice (e.g. we used 100 kg K/ha). The fertiliser rates used in this trial were designed to examine the effect of the main treatments on soil nutrient supply, and consequently high fertiliser rates were required to meet the trial aims. However, we can use the nil nutrient treatments to examine the effect of the lime and cultivation expenditure on the net margin.

The lime + cultivation treatment had a slightly lower net margin than the control and cultivation treatment. The net margin for the nil nutrient treatments in the control, cultivation and lime + cultivation treatments were 426, 407, 400 $/ha respectively. From a statistical point of view, the grain yield and net margin of the cultivation and lime + cultivation treatments are the same. From an applied point of view, a mean yield benefit from incorporating lime of ~ 300 kg/ha (compared to cultivation only) is nearly enough to cover the costs of 3t/ha limesand in the first year alone (wheat @ $240/t and limesand @ $25/t). Similary, the yield benefit from cultivation (~600 kg/ha) compared to the control was enough to pay for 87% of the cost of the cultivation (cultivation at $165/ha).

DISCUSSION

Our results suggest shifting investment from nutrients to lime and cultivation and maintaining profit in the first year for the 2 sites we ran is a feasible proposition. However, this is dependent on the soil constraints and existing soil fertility. In this trial, it appears that the cultivation response was driven by an increase in the mineralisation rate of organic matter. The incorporation of lime did not provide any yield benefit; while the rotary spader provided adequate mixing of the lime this had no impact on growth because soil pH was already above target levels. The yield benefit from cultivation was enough to offset the cost of the cultivation and most of the lime application, and the net margin in the year of application could be improved by reducing fertiliser rates.

Based upon work to date, we propose the following checklist to assess whether cultivating to incorporate lime will bring significant economic benefit over topdressing lime only.

1) Soil pH_{Ca} in the 0-10 and 10-20 cm soil layer need to be well below the recommended levels of 5.5 and 4.8 respectively. While we don't have sufficient data to provide an estimate of yield response from lime application as a function of soil pH_{Ca}, our knowledge of the relationship between exchangeable Al and soil pH for WA soils suggests an immediate response to lime incorporation is almost certain where soil pH_{Ca} falls below 4.5.

2) Soil fertility needs to be adequate. For example, a boost in mineralisation rate did not occur at Dalwallinu in a similar trial where organic carbon 0-10 cm was 0.6% but it did occur in this trial where organic carbon was 1.5%. Colwell P needs to be above 20 mg/kg in these soils where expenditure on P fertiliser is being reduced.

3) The implement used to achieve the incorporation is an important factor, if the implement can mix to the depth where the soil pH constraint occurs then an immediate payback on lime and cultivation is possible. If the implement cannot mix to the depth where the soil constraint occurs the benefits from incorporating lime need to be balanced against the cost of the cultivation and the risks to crop emergence and soil erosion posed by cultivation. Alternatively if the soil pH constraint is not too deep in the profile it may be possible to use a less costly implement to incorporate the lime.

PEER REVIEW
Steve Davies

ACKNOWLEDGEMENTS
Thanks to Dave Gartner and Anne Wilkins (WMG), Trevor Bell, Steve Cosh, Larry Prosser and Damien Priest (DAFWA) and to the Negus family.