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Can subsoil constraints be combated economically?

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Key Messages

- In 2016, the soil mixing (grizzly or spader) had a greater wheat yield than the control (0.27-0.42 t/ha), regardless of product applied. The incorporation treatments are still being paid off and therefore have not produced the greatest net margin.
- Limesand/No till returned the best net margin for the 2nd consecutive year due to the low yield increases from either application of product or mixing treatment.
- The lime or dolomite treatments had greater yields (0.22-0.5 t/ha) regardless of mixing treatment.
- Care must be taken in interpretation of results due to pH variation across the site.

Aim

To determine which ameliorant practice is the most effective and economic in remediating subsoil acidity at depth.

Background

It is estimated that more than 14.25 million hectares in the Western Australian Wheatbelt is acidic or at risk to become acidic (Gazey et al, 2014) making acidity one of the major limiting production factors to modern day farming systems. In monetary terms this is estimated to cost the agricultural industry $498 million per annum equating to 9% of WA's annual crop (Herbert, 2009).

Soil acidity is a natural process however; modern farming systems accelerate the process through production (Gazey, P, 2015). Two of the main contributing factors to soil acidification in broadacre cropping systems is the use of ammonium based fertilisers and the export of alkaline products in the form of crop (Gazey & Ryan, 2015 a).

Aluminium toxicity is one of the major subsoil constraints that are clearly linked to soil acidity. Elevated levels of aluminium in the soil lead to root pruning resulting in decreased crop growth and yield. Generally, aluminium toxicity will be an issue if your soil pH is ≤ 4.3 (Gazey & Ryan, 2015 b). As a consequence, lime has been one of the major inputs in broadacre farming over the last 20 years, with 100% of Liebe members liming in 2012 (Hollamby, 2012).

This trial was designed by a project committee of Liebe members to determine the most effective liming strategy to maximise the return on investment in the Liebe region. The trial is located west of Wubin on a poor performing paddock that has the potential to improve once subsoil constraints have been addressed.

A target pH of 5.5 to a depth of 300mm was identified and entered into the Liebe Group's Lime Calculator along with the baseline soil pH results. The lime calculator generated a recommendation for lime rates required to achieve the target pH of 5.5. Dolomite has a lower neutralising value than limesand therefore; more product is required to reach the target pH of 5.5, see trial details.

The trial was implemented in 2015 and consists of four replicates of different mixing (untreated, spaded, grizzly) with products applied (untreated, lime, dolomite and lime + dolomite) (Table 1). The trial was top dressed with product and then the different mixing equipment used at right angles to direction of top dressing. In 2015, the pH was measured to 1m in a selection of the plots.

An automated weather station and moisture probes have been installed at the site to monitor the impacts of treatments, giving further insight into cultivation methods and their effect on water use efficiency (WUE). The soil moisture probes were installed in July 2015 in the 3 replicates of the combinations of spaded and untreated mixing with nil product and lime + dolomite (treatment numbers 1, 2, 10 and 11).

Trial Details

Table 1. The mixing treatments and the products applied in the Liebe lime trial at Barnes property (randomised over three replications)

Property	AJ & JA Barnes, west Wubin
Plot size & replication	11.65m x 14m x 4 replications
Soil type	Yellow tammin sand
Soil pH ($CaCl_2$)	Figure 1
EC (dS/m)	Table 2
Sowing date	23/05/2016
Seeding rate	65 kg/ha Mace wheat
Incorporation	23/02/2015: Tiny Grizzly (36 inch discs) 05/03/2015: Spader
Lime History	Pre-trial 2009: 1 t/ha lime Pre-trial 2014: 1.5 t/ha lime 2015: 3.2 t/ha lime only plots, 3.4 t/ha dolomite only plots, 1.65 t/ha each lime & dolomite plots
Paddock rotation	2013 wheat, 2014 fallow, 2015 wheat, 2016 wheat
Fertiliser	07/03/2016: 40 kg/ha MoP 23/05/2016: 55kg/ha DAPSZC 28/06/2016: 75 kg/ha Urea
Herbicides & Fungicides	24/04/2016: 2 L/ha Glyphosate 450, 300 mL/ha LV Ester 680, 5 g/ha Metsulfuron, 0.25% SP 700 Surfactant

	23/05/2016: 2.2 L/ha Glyphosate 450, 300 mL/ha LV Ester 680, 20 mL/ha Hammer, 2 L/ha Trifluralin 480, 2 L/ha Boxer Gold, 200 mL/ha Chlorpyrifos 500EC, 1% Ammonium Sulphate 06/07/2016: 1 L/ha Velocity, 0.5% MOS
Growing season rainfall	90mm (Jan-April), 179mm GSR (April – Oct)

Treatment Number	Lime Treatment	Tillage Type
1	Control	No Till
2	Control	Spader
3	Control	Grizzly
4	Limesand	No Till
5	Limesand	Spader
6	Limesand	Grizzly
7	Dolomite	No Till
8	Dolomite	Spader
9	Dolomite	Grizzly
10	Lime & Dolomite	No Till
11	Lime & Dolomite	Spader
12	Lime & Dolomite	Grizzly

Results

Now in its second year, crop establishment was far better with an established seed bed. Frost was not an issue on the site in 2016. The trial has a number of factors influencing the results with inconsistent soil acidity profiles and a large weed burden. Both factors are believed to have had an impact on yield and quality. As a result, care must be taken when interpreting data.

Limesand was applied to the paddock on two occasions prior to the trial being implemented in 2009 (1 t/ha) and 2014 (1.5 t/ha). From the baseline soil results in Figure 1a it can be observed that this lime has not moved through the profile and is still sitting in the 0-5cm layer of topsoil.

Table 2: Baseline soil properties (0-40cm) collected prior to treatments being imposed, February 2015 by Liebe Group

Depth (cm)	EC (dS/m)	Organic Carbon (%)	NH_4 (mg/kg)	$N0_3$ (mg/kg)	Phosphorus Cowell (mg/kg)	Potassium Cowell (mg/kg)	Sulphur (mg/kg)	Aluminium (meq/100 g)
0-5	0.104	0.79	3	23	38	42	15.4	0.12
5-10	0.048	0.71	1	13	36	24	9.7	0.24
10-20	0.029	0.36	1	7	16	22	11.6	0.42

20-30	0.025	0.28	1	5	6	17	19.4	0.34
30-40	0.025	0.16	2	4	3	18	24.7	0.24

Variability of pH across the trial

The pH was measured in 10 plots across the trial in 2015 (after 1.5 t/ha lime applied in 2014) but prior to the mixing and lime treatments being applied. Soils are classed as acidic when the pH is less than 5.5 in topsoil and less than 4.8 at depth (Gazey et al. 2014). There were two types of pH profiles which related to difference in the soil type (as classed by CSBP) (Figure 1a).

1) Acid band - Soils which are acidic in 10-30 or 10-40cm layers and not acidic below these depths. These were more commonly the sandy earth (more clay soils).
2) Acid to depth – Soil which were acidic from 5cm to 60cm or deeper (these were the sandy soils).

After the soil restructuring was applied and settled over 2015, the soil was resampled in every plot in May 2016. The soils were then separated into 5 classes using as acidic (Fig 1b).

1) Acid to depth
2) Acid from 10-20cm layer to depth
3) Acid band 10-20cm layer and non-acid at depth
4) Acid band 10-30cm layers and non-acid at depth
5) Non-acid

There were moderate aluminium levels (2-4ppm) in the acid 0+ and acid 10/20+ profiles. However, these pH profiles belonged to a range of management options (treatment by product).

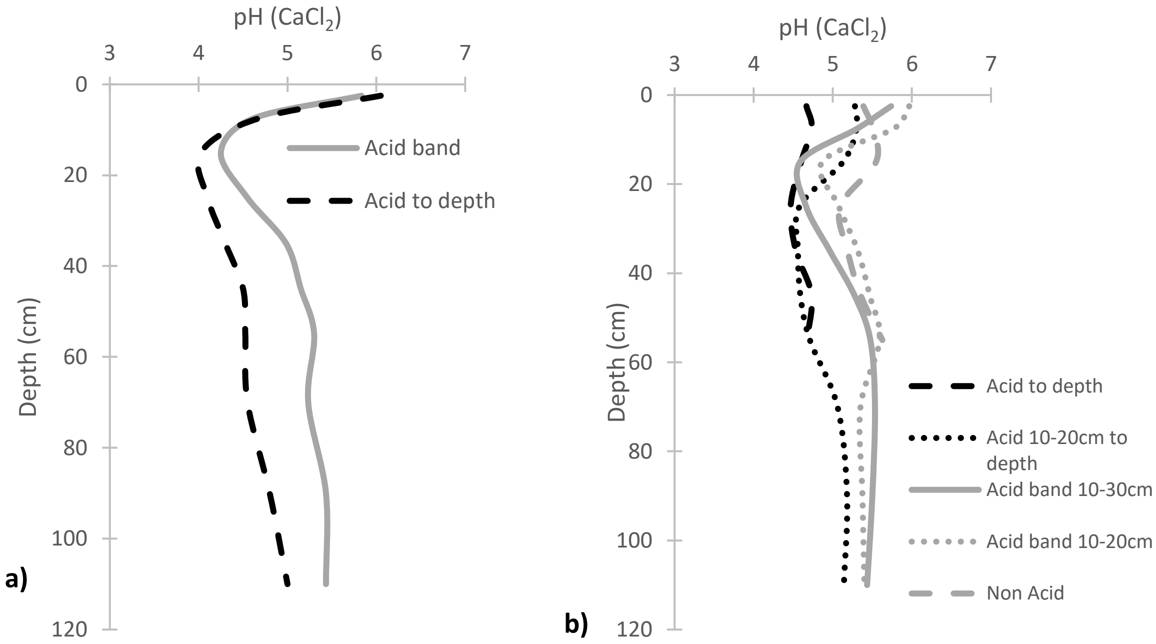
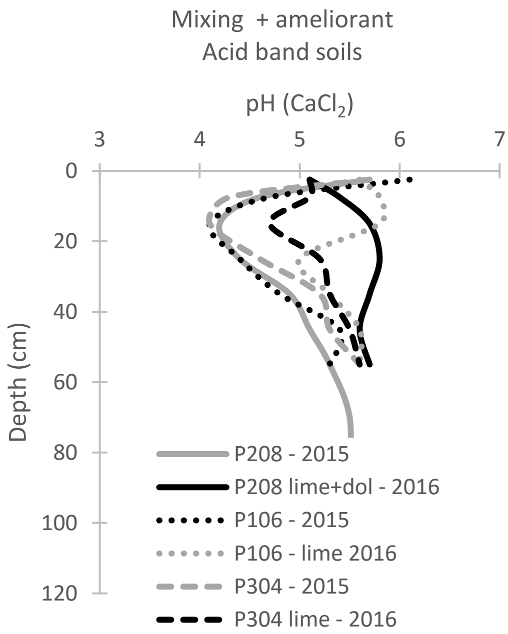
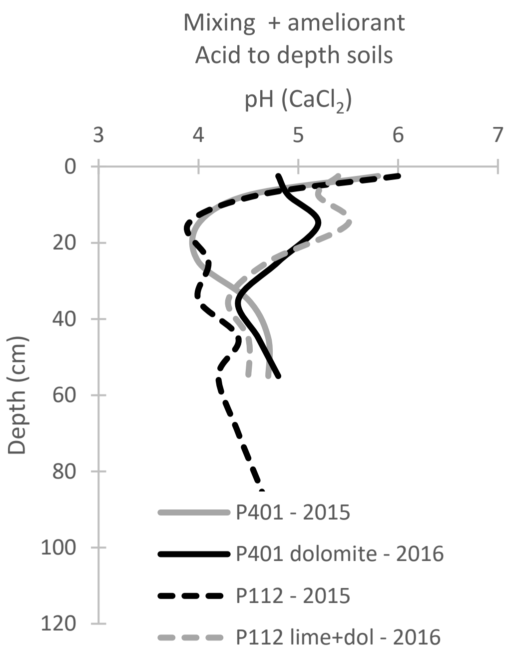


Figure 1: The pH profile for the 10 plots measured in 2015 grouped by their profile type as Acid to depth (--) and Acid band soils (--) (a) and the five different pH profile types of all plots (48) after soil mixing treatments and different products have been imposed measured in 2016 (b).

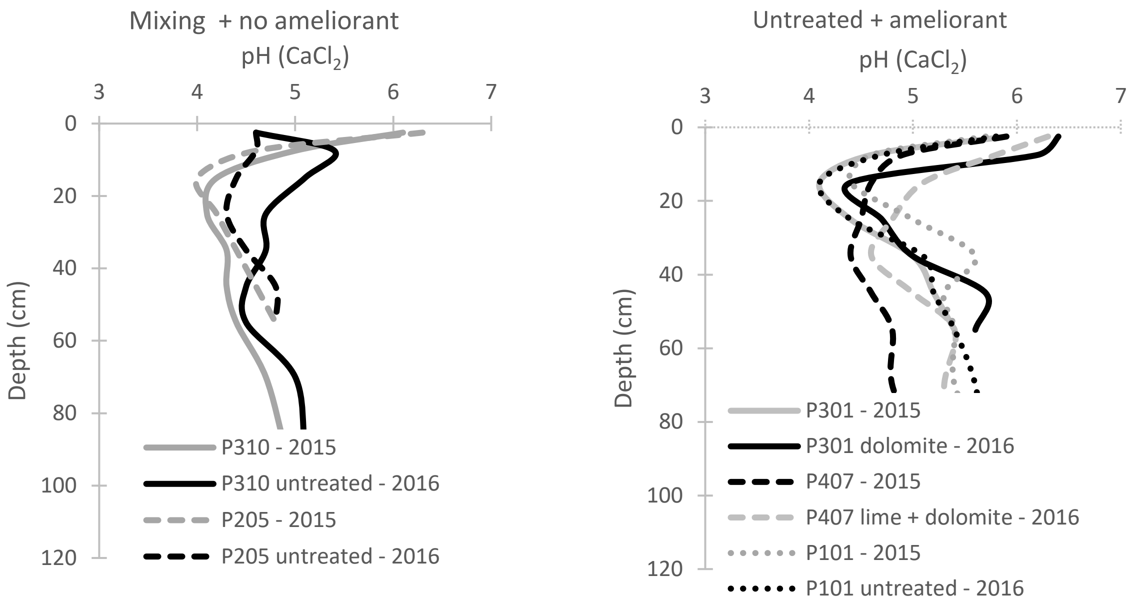
The changes in the pH profiles from lime and mixing can be seen with the 10 pH profiles which were measured before and one year after treatments had been applied (Fig 2). Mixing with product reduced the high pH in the 0-10cm layer, and increased the pH in the 10-30cm layers

(Fig 2a,b). Without mixing, the products did not greatly change the pH of the soil (Fig 2d).





a) **b)**



c) d)

Figure 2: The pH profiles of the 10 plots which were measured in 2015 and 2016, grouped by mixing (grizzly/spading or none) and addition of lime (or lime + dolomite or none) separated into acid to depth or acid band pH profile type

Weed burden and crop establishment

The site had a significant weed burden, particularly brome grass and radish, which had a significant impact on grade and is expected to have had a detrimental effect on yield. Tillage treatments didn't have a significant effect on weed burden in the final grain sample.

Crop establishment was much more even in the second year following the grizzly and spading. All plots averaged 19-22 plants/m^2 in comparison to last year's poorer establishment of approximately 8 plants/m^2 on the grizzly and spaded treatments.

Harvest results

The 2016 growing season received 179mm rainfall with only 10 rainfall events over 10mm. Soil moisture probes showed the small events only filled the top 20cm of the soil profile. This is believed to have limited treatment response as the increased soil profile available was not capitalised. In a lower rainfall year or when rainfall is more sporadic the benefit of ameliorated subsoils is expected to be more evident.

All lime + dolomite treatments have performed unusually poorly (Table 3) in comparison to the products individually. This is not due to the products but instead reflective of the original soil profile which is more acid. Five of the nine lime + dolomite treatments were acid 10-20cm to depth with only one treatment classified as non-acid.

Table 3: Main effect of lime treatments on yield and quality at west Wubin, 2016

Treatment Number	Lime Treatment	Yield (t/ha)	Protein (%)	Hectolitre (kg/hL)	Screenings (%)

1,2,3	Control	2.22	b	9.35	b	80.78	3.14
4,5,6	Limesand	2.72	a	9.56	a	79.97	2.84
7,8,9	Dolomite	2.40	ab	9.33	b	80.53	2.78
10,11,12	Lime & Dolomite	2.18	b	9.50	ab	74.00	2.67
P value		*0.016*		*0.033*		*0.351*	*0.608*
LSD		*0.358*		*0.108*		*NS*	*NS*
CV (%)		*18.1*		*2.3*		*13.4*	*30.9*

Results followed by the same letter do not significantly differ from each other (P=0.05).
NS=Not significant.

Table 4: Main effect of tillage treatments on yield and quality at west Wubin, 2016.

Treatment Number	Tillage Type	Yield (t/ha)	Protein (%)	Hectolitre (kg/hL)	Screenings (%)
1,4,7,10	No Till	2.15 b	9.32 b	75.39	2.97
2,5,8,11	Spader	2.57 a	9.54 a	81.38	2.95
3,6,9,12	Grizzly	2.42 ab	9.44 ab	79.70	2.65
P value		*0.028*	*0.022*	*0.267*	*0.516*
LSD		*0.310*	*0.156*	*NS*	*NS*
CV (%)			*18.1*	*2.3*	*13.4*

Results followed by the same letter do not significantly differ from each other (P=0.05).
NS=Not significant.

Table 5: Interaction of cultivation and lime on yield and quality results for Mace wheat at west Wubin, 2016

Treatment Number	Lime Treatment	Tillage Type	Yield (t/ha)	Protein (%)	Hectolitre (kg/hL)	Screenings (%)
1	Control	No Till	1.90 cd	9.33 bc	80.51	3.28
2	Control	Spader	2.34 abcd	9.48 b	81.90	3.72
3	Control	Grizzly	2.41 abcd	9.25 bc	79.94	2.41
4	Limesand	No Till	2.52 abc	9.08 c	80.54	2.78
5	Limesand	Spader	2.78 ab	9.43 b	81.14	3.12
6	Limesand	Grizzly	2.86 a	9.48 b	79.92	2.44
7	Dolomite	No Till	2.29 abcd	9.35 bc	80.03	2.76
8	Dolomite	Spader	2.74 ab	9.83 a	80.94	2.51
9	Dolomite	Grizzly	2.17 bcd	9.50 b	78.94	3.24
10	Lime & Dolomite	No Till	1.88 d	9.53 ab	60.49	3.05
11	Lime & Dolomite	Spader	2.43 abcd	9.45 b	81.53	2.46
12	Lime & Dolomite	Grizzly	2.23 bcd	9.53 ab	80.00	2.49
P value			*0.042*	*0.011*	*0.309*	*0.534*
LSD			*0.619*	*0.312*	*NS*	*NS*
CV (%)			*18.1*	*2.3*	*13.4*	*30.9*

NS=Not significant.

Economic Analysis

For the second year the lime sand/no till treatment has given the greatest gross return at 225% Return on Investment (ROI) in 2015 and 190% in 2016, returning a net benefit of $334.95/ha. While still producing return on investment, the lime/dolomite/spader (11) treatment has yet to produce a net benefit, Table 6. This is reflecting the -11% ROI from 2015 and only 59% ROI in 2016 which means the payback period is more than two years. In 2016 the poorest performing treatment was the lime/dolomite/no till (10), Table 6.

Table 6. Economic analysis of different soil ameliorant treatments at west Wubin, 2015, 2016 and combined

Treatment #	Invest. - Cultivation	Investment - Product	Total Investment	Yield	Av Profit 2015	Return on Investment 2015	Yield	Av Profit 2016	Return on Investment 2016	Combined Profit	Extra Profit/year from Investment	Average Return on Investment	Net Benefit (Combined Profit - Investment)
11	$120.00	$84.15	$204.15	2.1	66	-11%	2.43	132	59%	199	49	24%	-$5.22
10	$0.00	$84.15	$84.15	1.8	94	8%	1.88	7	-7%	101	0	0%	$17.24
2	$120.00	$0.00	$120.00	1.8	104	13%	2.34	112	83%	216	57	48%	$95.84
12	$85.00	$84.15	$169.15	2.1	179	54%	2.23	87	44%	266	83	49%	$96.86
9	$85.00	$60.00	$145.00	1.9	169	56%	2.17	75	43%	244	71	49%	$98.67
1	$0.00	$0.00	$0.00	1.8	88		1.90	13		101			$100.95
8	$120.00	$60.00	$180.00	1.9	125	20%	2.74	205	107%	330	114	64%	$149.66
5	$120.00	$74.20	$194.20	2.2	207	61%	2.78	213	103%	419	159	82%	$225.18
7	$0.00	$60.00	$60.00	2.3	219	218%	2.29	102	149%	321	110	183%	$260.77
6	$85.00	$74.20	$159.20	2.2	209	76%	2.86	232	138%	441	170	107%	$281.51
3	$85.00	$0.00	$85.00	2.4	245	184%	2.41	129	137%	374	136	160%	$288.63
4	$0.00	$74.20	$74.20	2.2	255	225%	2.52	154	190%	409	154	208%	$334.95

Note: Grain prices based on farm gate price, standard across all treatments.
Total Cropping Costs based on the actual Fertilisers and Chemicals applied plus the Farmanco Benchmarking 2015 low and medium rainfall average crop costs including fixed costs of $125/ha and excluding Fertiliser and Chemical have been utilised.
Cultivation cost based on an average contractor rate of $85/ha (Grizzly) $120/ha (Spader). Cartage cost based on contractor rate of $10/t dolomite (Watheroo) and $21/t limesand (Greenhead). Spreading of lime treatments based on contractor rate of $8/ha. Cost of lime applied prior to trial being implemented not taken into account.

Table 7. Economic analysis of different lime treatments at west Wubin, 2015, 2016 and combined

Product	Investment - Cultivation	Investment - Product	Total Investment	Yield 2015	Average Profit 2015	Return on Investment 2015	Yield 2016	Average Profit 2016	Return on Investment 2016	Combined Profit	Extra Profit/year from Investment	Average Return on Investment	Net Benefit (Combined Profit - Investment)
Control	$68.33	$0.00	$68.33	2.0	$104.48	-	2.22	$43.66	-	$148.14	$64.60	-	$79.81
Lime Sand	$68.33	$74.20	$142.53	2.2	$182.52	55%	2.40	$158.56	81%	$341.08	$161.07	61%	$198.55
Dolomite	$68.33	$60.00	$128.33	2.0	$129.85	20%	2.72	$86.18	33%	$216.03	$98.54	39%	$87.70
Lime/ Dolomite	$68.33	$84.15	$152.48	2.0	$72.24	-21%	2.18	$34.54	-6%	$106.78	$43.92	-60%	-$45.71

Table 8. Economic analysis of different cultivation treatments at west Wubin, 2015, 2016 and combined

Tillage	Investment - Cultivation	Investment - Product	Total Investment	Yield 2015	Average Profit 2015	Return on Investment 2015	Yield 2016	Average Profit 2016	Return on Investment 2016	Combined Profit	Extra Profit/year from Investment	Average Return on Investment	Net Benefit (Combined Profit - Investment)
No Till	$0.00	$54.59	$54.59	2.0	$123.16	-	2.15	$27.90	-	151	66	-	$96.48
Spader	$120.00	$54.59	$174.59	2.0	$84.41	-22%	2.57	$124.54	55%	209	95	54%	$34.37
Grizzly	$85.00	$54.59	$139.59	2.2	$159.24	26%	2.42	$89.76	44%	249	115	82%	$109.42

The lime sand treatments appear to be retaining the benefits (or increasing in the second year) while the Grizzly only treatment is dropping rapidly as the initial response was likely to be due to the large release of nitrogen through increased mineralisation (Davies, 2011).

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http://www.liebegroup.org.au/working-together-to-deliever-multiple-benefit-messages-to-growers-through-a-whole-systems-approach-to-soil-management/

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