Soil Acidity – Can Gypsum Increase Wheat Yields on Aluminium Toxic Soils?

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Key messages

Surface applied gypsum can improve wheat yields on soils with sub soil aluminium toxicity.

Gypsum offers a rapid return on investment that can help fund increased lime and/or dolomite applications.

Check the salt content of gypsum sources – quality sources have less than 1% salt.

Aims

A survey of south western agricultural soils of Western Australia from 2005 - 2012 showed that 72% of topsoils and 45% of sub surface soils were below the targets pH_{CaCl2} of 5.5 and 4.8, respectively (Gazey *et al*., 2013).

Lime sand is applied to improve the pH but crop responses are rare in the first few years following application. Lime use is also limited by high freight costs of transporting quality sources (generally coastal and north of Perth) to far away farms.

Aluminium (Al) toxicity is often a major constraint of acid sub soils.

Field trials in the eastern wheatbelt have previously indicated that gypsum could be used to increase wheat growth in Al toxic subsoils in sandy soils of low rainfall (McLay *et al*. 1994 I).

Gypsum is used to reduce Al toxicity in countries such as Brazil and South Africa, but is still not generally recommended in Western Australia.

There are several inland gypsum reserves in Western Australia close to cropping land affected by aluminium toxicity.

The aim of this research is to investigate further whether gypsum can be used as an ameliorant of Al toxicity to improve the profitability of crops grown on acid soils in Western Australia.

Method

In 2008 a replicated small plot experiment was established near Bonnie Rock (370 km north east of Perth) on a 'wodgil' pale yellow loamy sand over sandy loam gravel at 30-60cm. The average soil pH ($CaCl_2$) of untreated soil at the site in 2008 was 4.4 at 0-10cm, 4.2 at 10-20cm and 4.2 at 20-30cm. Average extractable Al (in 0.01 M $CaCl_2$) was 4, 10 and 12mg/kg respectively. Lime sand sourced from Lancelin (80% effective neutralising value - ENV), gypsum from an industrial source in Canning Vale and dolomite from Watheroo (90% ENV) were applied to the surface according to the following trial design:

1. Untreated control
2. 1 t/ha lime
3. 2 t/ha lime
4. 4 t/ha lime
5. 1 t/ha gypsum
6. 2 t/ha lime + 1 t/ha gypsum
7. 2 t/ha dolomite
8. 2 t/ha dolomite + 1 t/ha gypsum

There were 3 replicates of each treatment in a randomised block design. All treatments were reapplied in March 2013 with dolomite sourced from Beaufort River (60% ENV).

The site was sown to wheat in 2008, narrow leafed lupins in 2009, wheat in 2010, wheat in 2011, and wheat in 2013, 2014 and 2015. The site had a chemical fallow in 2012. Each wheat crop was sown with 50kg/ha Agflow (6N, 9P, 3S). Additional N (50L/ha Flexi-N = 21N) was only applied in 2015. The lupins were fertilised with 50kg/ha Double Phos (9P, 2S). Plots in each year were sown with an experimental plot cone seeder with knife points on 22cm spacings.

Plant tissue samples were collected from each wheat crop between mid-tillering and stem elongation to assess nutrient status and treatment effects.

Each crop was harvested with a small plot header and sampled for grain quality.

All plots were soil sampled to 30cm in December 2015 to measure effects on soil pH, exchangeable cations, extractable aluminium, electrical conductivity and sulphur (one soil sample per plot). Effects on hydraulic conductivity were also analysed by measuring infiltration rates on selected plots with a Mini Disk Infiltrometer.

Annual rainfall from 2008 to 2015 ranged from 129 to 409mm (average 282mm) with growing season rainfall (April – October) varying from 102 to 238mm.

Results

Harvest results 2008 - 2015

Since 2008, total wheat yields have been significantly improved by lime, dolomite and gypsum (Table 1).

In 2008, there was a surprising first year response of 0.3t/ha to 2t/ha lime, but gypsum increased yield by 0.4t/ha (with or without lime or dolomite)

2009 lupins were not harvested due to crop failure in all treatments.

In 2010, there was an additional 0.3t/ha response to gypsum applied two years earlier but in 2011 it was only significant where lime was also applied ($P \leq 0.05$).

In 2013, there was a 0.2t/ha response to reapplication of gypsum in that year.

In 2014, grain yields were less than 1t/ha and treatment differences were not significantly different ($P \leq 0.05$).

There was a further response to gypsum in 2015 but it was only significant where lime was also applied ($P \leq 0.05$).

Wheat grain yields have not been significantly different between lime and dolomite treatments.

Hectolitre weights and screenings have not been affected by any of the ameliorants in any of the six years.

Table 1. Wheat grain yields from 2008 to 2015.

Trt	Treatment 2008 and 2013 (t/ha)	Wheat Yield (t/ha) 2008	2010	2011	2013	2014	2015	Total
1	Untreated control	1.87	1.04	2.15	1.48	0.67	1.66	8.8
2	1 lime	2.06	1.25	2.32	1.59	0.77	1.84	9.8
3	2 lime	2.18	1.26	2.39	1.57	0.79	1.91	10.1
4	4 lime	2.20	1.32	2.60	1.74	0.89	2.04	11.0
5	1 gypsum	2.30	1.37	2.24	1.71	0.87	1.92	10.5
6	2 lime + 1 gypsum	2.30	1.54	2.59	1.84	0.88	2.19	11.3
7	2 dolomite	2.01	1.28	2.25	1.70	0.84	2.10	10.2
8	2 dolomite + 1 gypsum	2.31	1.33	2.46	1.76	0.94	2.12	11.0
	Prob	0.007	0.03	0.004	0.03	0.18	0.01	<0.001
	Lsd (0.05)	0.21	0.22	0.22	0.20	ns	0.27	0.78

Economics

After eight years the most profitable treatment has been two applications of 1t/ha gypsum (Table 2). Even though lime and dolomite were profitable without gypsum, profitability was much higher when applied with gypsum.

Table 2. Cost of ameliorants, average wheat yields after six years and net present value (NPV) in response to combinations of lime, gypsum and dolomite applied in 2008 and 2013.

Trt	Treatment 2008 and 2013 (t/ha)	Cost/application ($/ha)	Average yield (t/ha)	NPV ($/ha)
1	Untreated control	0	1.48	-
2	1 lime	59	1.64	90
3	2 lime	118	1.68	47
4	4 lime	236	1.80	-21
5	1 gypsum	44	1.74	231
6	2 lime + 1 gypsum	162	1.89	208
7	2 dolomite	124	1.70	35
8	2 dolomite + 1 gypsum	168	1.82	116

Assumptions: wheat $250/t, lime $59/t (ex Lancelin), gypsum $43/t (ex Kalannie) and dolomite $62/t (ex Watheroo). Costs include freight + spreading. Benefits after the first year are discounted by an assumed interest rate of 6%, to generate its value in year one (NPV).

Plant analysis – All wheat years

Sulphur was not limiting without gypsum (data not shown).

Soil analysis - December 2015

Soil pH and extractable Al

Two applications of 4t/ha lime have increased the topsoil pH from 4.6 to 6.3, and the 10-20cm layer from 4.2 to 4.5 (Table 3). Although not statistically significant, there was a trend indicating that dolomite was more effective than lime at increasing pH at the surface and 10-20cm layer. Gypsum had no effect on soil pH.

Sub soil extractable Al was decreased by lime and dolomite, but less so by gypsum (Table 3).

Table 3. Soil pH ($CaCl_2$) and extractable Al (0.01 M $CaCl_2$) measured in December 2015 in response to combinations of lime, gypsum and dolomite applied in 2008 and 2013.

Trt	Treatment 2008 and 2013 (t/ha)	pH ($CaCl_2$) Soil depth (cm)			Extractable Al ($CaCl_2$) Soil depth (cm)		
		0-10	10-20	20-30	0-10	10-20	20-30
1	Untreated control	4.6	4.2	4.2	1	13	17
2	1 lime	5.5	4.5	4.4	<0.2	5	8
3	2 lime	5.9	4.5	4.4	<0.2	3	7
4	4 lime	6.3	4.5	4.4	<0.2	3	6
5	1 gypsum	4.4	4.2	4.4	1	9	13
6	2 lime + 1 gypsum	5.8	4.5	4.3	<0.2	2	8
7	2 dolomite	6.2	4.7	4.3	<0.2	2	15
8	2 dolomite + 1 gypsum	6.1	4.7	4.4	<0.2	1	6
	Prob	<0.001	0.035	0.42	na	<0.001	0.06
	Lsd (0.05)	0.38	0.29	ns	na	3.8	8.1

Electrical conductivity

Electrical conductivity was doubled by gypsum from 0.05dS/m in the top soil and from 0.036dS/m (data not shown).

In the sub soil (10-20cm), there was some correlation between the ratio of extractable aluminium and electrical conductivity (EC) and wheat yields (data not shown).

Previous studies have shown that on similar WA problem soils wheat yields were best related to the ratio of the soil acidity index Al_T/EC (where Al_T is total Al) (McLay *et al*. 1994 II).

Sulphur and hydraulic conductivity

Without gypsum, S levels averaged 11 (0-20cm) and 18mg/kg (20-30cm). With gypsum applied, S levels averaged 47 (0-10cm) and 38mg/kg (10-30cm) (data not shown)

Infilltrometer measurements showed gypsum had no effect on hydraulic conductivity (data not shown).

Conclusions

The results of this experiment indicate the potential for gypsum to be used to improve the productivity and profitability of acid soils which have sub soil aluminium toxicity as a major constraint.

The use of gypsum as an ameliorant for Al toxicity should be attractive to farmers where high freight costs limit the affordability of quality lime.

The quicker response to gypsum compared to lime and/or dolomite offers more immediate returns. These can then be reinvested in increased quantities of quality lime and/or dolomite. Gypsum had no effect on pH.

Soil and plant sulphur concentrations were adequate for crop nutrition without gypsum, and gypsum had no effect on hydraulic conductivity.

The response to gypsum is most likely due to reduced sub soil Al toxicity.

References:

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Key words

Soil acidity, aluminium toxicity, gypsum, lime, dolomite, wheat

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