Sodic soil amelioration using lime and Gypsum - Five years of results at Gunning Gap

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Key Messages

- The application of lime and gypsum to a sodic soil has improved soil structure (observations) and fertility (soil test results) in the top soil (0-10cm). However, despite the lime and gypsum being applied 5 years ago, soil tests indicate there has been no change in the sub soil (10-30cm).
  - Improvements in the topsoil have produced variable grain yield and quality responses across years, apparently due to varying available soil moisture over the last 5 crop years.
  - Yield increases with soil amelioration are associated with years where growing conditions were conducive to high yield and/or reasonable levels of sub soil moisture were available (years 2001, 2002 and 2005).
  - In contrast, barley yield declines of 40%-80% and quality down grades due to small grain have occurred with soil amelioration in the years with very dry springs (2003 and 2004). This is thought to be due to the ameliorated top soil promoting additional early season vegetative growth, but the non-ameliorated sub soil being incapable of supporting this additional growth in severe spring conditions leading to the crop "haying off.
- Gypsum produced a greater soil ameliorant effect in the early years, but after 5 years appears to have largely 'run out of puff. In contrast, lime produced smaller benefits in the early years, but it's effects have lasted longer and are still clearly visible after 6 years.

Background

Soil sodicity has been seen as a production constraint on some of the heavy clay soils of the Gunning Gap district. Managing soil sodicity with ameliorants (lime and gypsum) is expensive so the benefits need to be well understood to justify the significant 'capital' investment in soils. This trial was established in 2000 so as to demonstrate the production and associated economic benefits from ameliorating soil sodicity over the long term.

Methods

Location:	Gunning Gap, 35km north west of Forbes, NSW.
Co-operator.	Mark Judson, "Beremana"
Trial History:	Lime and Gypsum
Date spread:	16 May 2000 (initial treatments applied: commencement of trial) 20 March 2002 ($3^1/_2$ t/ha lime on the 'Albretch' treatement plots)
Source:	Bagged agricultural lime and gypsum

Sowing:	2000	2nd June, 45 kg/ha Janz, 85 kg/ha DAP
	2001	17th May, 25 kg/ha Tilga, 85 kg/ha DAP
	2002	29th June, 50 kg/ha Tiiga, 85 kg/ha DAP
	2003	19th July, 50 kg/ha Tilga, 75 kg/ha DAP
	2004	25th June, 50 kg/ha Tiiga, 70 kg/ha DAP
	2005	25th July, 25 kg/ha Tilga, 70 kg/ha DAP +undersown lucerne

Trial Design and analysis:

This trial is based on a randomised block design with six treatments consisting of one nil treatment, four lime rates ('Albrecht' treatment, 2, 6 & 8 t/ha) and one gypsum treatment. The 'Albrecht' treatments had 4t/ha of lime applied in May 2000 and then a further 3.5t/ha of lime applied in March 2002 (as per the recommendations of an 'Albrecht' soil laboratory). All treatments are replicated twice. In each year of the trial the co-operating farmer direct drilled crop across the plots with a combine. The plots were harvested with a plot header. The data has been statistically analysed using AOV or spatial analysis where applicable.

Results

Table 1: Rainfall at "Beremana" sodic soil amelioration trial site (2000 to 2005)

Year	Rainfall (mm) Month Jan	Fe	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	Fallow (Jan -Apr)	Growing season (May to Oct)	Water limited yield potential[A] t/ha
2000	0	22	60	43	62	21	20	70	16	87	70	3	471	124	275	3.0
2001	0	41	24	54	14	53	55	19	34	47	35	1	376	118	222	2.2
2002	0	112	11	12	38	4	8	0	45	0	0	23	253	135	95	0.4
2003	0	29	18	8	2.2	21.7	47	60	7	27	24	11	254	54	165	1.1
2004	6	30	19	2	31	46	16	30	31	4	22	90	326	57	157	1.0
2005	41	34	17	2	0	72	46	39	124	51	83	73	580	94	331	3.7

water limited yield potential (t/ha) = ((Fallow rainfall * X 30% efficiency)mm+(Growing season rainfall -110)mm) X 15(kg grain/mm) /1000

Table 2: Perry laboratory[d] soil test summary of 'Albrecht treatment plots

Date / timing	Depth cm	OC %	pH water	P (Colwell) ppm	S[a] ppm	Zn[a] ppm	CEC meq/l00g	Ca:Mg ralio	Na % of cations
May 2000 before lime	0-10	1.7	6.1	44	28	2.1	26.0	0.87	10.5
May 2001 after 4t/ha lime	0-10	1.5	7.3	26	12	1.3	18.1	1.87	15.8
[c]Suggest optimal level		4-6	6.2	50	15-20	>8	10-20	5.7	0.5-3

[a]method not described on soil test report [c]suggested optimal levels from Perry soil test report

Table 3: Incitec laboratory[d] soil test summary of 'Albrecht' treatement plots

Date / timing	Depth cm	OC %	**pH** CaCl2	P (Colwell) ppm	S (MCP) ppm	Zn (DTPA) ppm	CEC meq/100g	Ca:Mg ratio	Na % of cations
May 2000 before lime	0-10	0.9	5.7	14	11	0.3 No	18.3	0.83	12.8
after 4t/ha + May 2003 3.5t/ha lime	0-10	No test	7.6	30	13	test No	19.7	1.76	7.9
	10-20	No test	7.8	15	9.7	test	30.9	1.05	13.9
[b]Suggested optimal level		>2	6-7	>45	>20	>1.2	–	>2	<2

[b]suggested optimal levels from Incitec soil interpretation manual

[d]the Perry and Incitec laboratories use different methods for soil analysis of some nutrients.
Therefore it is not possible to directly compare results between the two different labs for all nutrients.

Table 4: Sodic soil amelioration trial results 2000 to 2004

Product & **Rate**	*Yield data*									
Applied	**2000-**	**Wheat**	**2001**	**- Barley**	**2002** - **Barley**		**2003**	**- Barley**	**2004**	- Barley
(t/ha)	Yield (t/ha)	% Nil	Yield (t/ha)	% Nil	Yield (t/ha)	% Nil	Yield (t/ha)	% Nil	Yield (t/ha)	% Nil
Nil	**1.28**	100%	2.58	100% c	0.20	100% e	0.33	100% **a**	0.68	100% a
2.0-Lime	1.22	**95%**	**3.17**	123% ab	0.38	186% b	0.14	41% **c**	0.46	67% b
Albrecht plot[1]	1.34	105%	3.22	125% ab	0.33	162% d	0.08	23% **d**	0.42	62% b
6.0-Lime	1.20	**94%**	3.20	124% ab	0.36	179% bc	0.07	20% **d**	0.39	57% b
8.0-Lime	1.28	100%	3.03	117% b	0.35	170% cd	0.08	23% **d**	0.40	59% b
4.0 - Gypsum	1.40	**109%**	3.34	129% a	0.45	220% a	0.21	**62% b**	0.61	90% a
LSD (5%)	0.45	35%	**0.29**	11%	0.03	13%	0.05	**15%**	0.11	16%
Significance[2]		**No**		Yes		Yes		Yes		*Yes*

[1] - 4t/ha of Lime applied 16th May 2000.
additional 3.5 t/ha Lime applied 20th March 2002 (as per Albrecht recommendation).
[2] - results with differing letters beside them are significantly different ($p<0.05$)

Table 5: Sodic soil amelioration trial results 2005

Product & **Rate**	*Analysis of Trial Results*				
Applied	: **2005 - Barley**				
(t/ha)	Yield (t/ha)	% Nil	Retention **(%)**	Protein (%)	Screenings **(%)**
Nil	2.51	100% c	77.6 a	**10.3** cd	**3.0 b**
2.0-Lime	3.16	126% ab	77.9 a	10.9 bc	**3.1 b**
Albrecht plot[1]	3.52	140% a	76.1 a	11.2 b	**3.6 b**
6.0-Lime	3.26	130% ab	71.9 **b**	11.8 a	**4.5** a
8.0-Lime	3.27	130% ab	73.1 **b**	11.8 a	**4.5** a
4.0 - Gypsum	2.88	115% bc	77.3 a	10.5 c	**3.3**
LSD (5%)	0.51	20%	2.3	0.5	0.6 **b**
Significance[2]		Yes	Yes	Yes	

[1] - 4t/ha of Lime applied 16th May 2000.
3.5 t/ha Lime applied 20th March 2002 (as per Albrecht recommendation).
[2] - results with differing letters beside them are significantly different ($p<0.05$)

Table 6: Economic analysis of sodic soil amelioration trial results 2000 to 2005

Product & Rate Applied (t/ha)	*Economic Analysis* Totals - 2000 to 2005 Extra Income ($/ha)	Lime/Gyp Costs ($/ha)	Net Benefit ($/ha)
Nil			
2.0 - Lime	**$185**	**$100**	**$85**
Albrecht plot[1]	**$238**	**$375**	-$137
6.0 - Lime	**$177**	**$300**	-$123
8.0-Lime	**$159**	**$400**	**-$241**
4.0 - Gypsum	**$264**	**$240**	**$24**

Net benefit = $/ha benefit above Nil treatment after taking into account extra income and costs. [1] - 4t/ha of Lime applied 16th May 2000.

3.5 t/ha Lime applied 20th March 2002 (as per Albrecht recommendation).

Results and discussion

Seasonal conditions

The rainfall and water limited yield data presented in Table 1 highlights the tough seasonal conditions experienced in the Gunning Gap district in the years 2002, 2003 and 2004. Crop yields in these years have also been adversely affected by late sowing breaks. Long term rainfall records indicate that these 3 years have been amongst the driest on record (data not shown). The 2005 season was a vast improvement, but the late break meant the crop was sown late. The trial site was hit by hail in 2005, causing a small amount damage (i.e. <10%).

Initial Soil Test Comments

Prior to the commencement of the trial, soil samples from the site were divided and sent to two separate soil laboratories for analysis: Incitec Analysis Systems and Perry laboratories (USA). The Perry laboratory performed soil analyses and provided recommendations based on the 'Albrecht' system. The Incitec laboratory utilised the industry 'standard' analysis procedures and interpretation techniques.

The Perry Lab Albrecht interpretation (Table 2) stated that very low Ca and excess Mg were the major limiting factors, with a total lime deficiency of 10.8 t/ha. It was recommended that lime be applied at a rate of 4 t/ha in the first year and then re-tested to fine tune further lime applications. The lab also recommended 3 kg/ha of Zinc (Zn) sulphate. The Zn Sulphate was not applied and no Zn deficiency symptoms appeared in the crop at any stage. Extensive Zn trials in the Forbes district have never shown a response to Zn fertiliser with wheat (Motley et a/, 2004).

The 'Albrecht' treatments were retested in the second year (i.e. 2001) following the application of lime in 2000, as recommended. Soil samples were again sent to the Perry soil laboratory (USA) for another full Albrecht analysis and interpretation. The second interpretation following the 4t/ha lime application stated excessive Mg and Na, and very low Ca were still the major limiting factors, with a total lime deficiency of 3.5t/ha. In March 2002, 3.5 t/ha of lime was added to the plots previously treated with 4 t/ha lime as recommended. This made for a total lime application rate of 7.5t/ha on the 'Albrecht' treatment plots. A fourth soil test was conducted in May 2003 on the 'Albrecht' plots with top soil and sub soil samples sent to the Incitec Pivot soil laboratory. The results from this test suggested that the lime was having the desired effect of reducing exchangeable Na (i.e. sodicity) and increasing the Ca:Mg ratio (Table 3). However, these test results highlighted that the sub soil was still very sodic (13.9% exch. Na).

2005 Soil test results

All soil amelioration treatments were tested at the beginning of the 2005 season. Soil tests were conducted in the top soil (0-10cm) and sub soil (10-20cm and 20-30cm). The soil test results are presented in table 7.

These results show that the lime and gypsum have both resulted in improvements in the top soil as measured by levels and balance of exchangeable cations. The higher rates of lime appeared to have more affect than either the 2t/ha rate or the gypsum. This beneficial effect can mainly be seen in terms of reduced exchangeable Na and increased Ca. The high rates of lime have reduced the exchangeable Na below 5%, the suggested critical threshold for sodicity (Chan 1995). On the negative side, Zn levels show a clear pattern of being reduced, but not to the point where visual deficiency symptoms were seen.

No changes as a result of lime or gypsum were found in the sub soil depth at either 10-20cm or 20-30cm. Severe drought conditions during 2002, 2003 and 2004 may have been partially responsible for limited movement of ameliorants into the subsoil. However, even in the absence the drought conditions during the trial it is considered that the ameliorant movement into the subsoil of a heavy sodic clay soil such as in the trial will be very slow.

Yield and grain quality response

No significant yield or grain quality effect from soil amelioration treatments were seen in the first year (Table 4). It is thought that the late application of lime and gypsum in May 2000 (i.e. only 2 weeks before sowing) was responsible for the lack of response in that year, with treatments needing more time to react in the soil.

The lime and gypsum treatments provided significant yield increases in both 2001 and 2002 (Table 4). The gypsum treatment appeared to be the best treatment in these early years of the trial. The gypsum treatment was the highest yielding in 2001 and 2002. The effects of the lime and gypsum on the soil have been readily observed by visitors to the trial site.

In 2003 and 2004 the lime treatments resulted in severe yield declines (Table 4 and 5), very high grain protein, high screenings and low retention in barley (data not shown). High grain protein levels in excess of 19% in 2003 and 18% in 2004 in the lime treated plots suggested that moisture stress was severe during the grain fill period. This effect was more pronounce with high rates of lime.

Visual observations of the plots suggest that the lime and gypsum treatments encouraged better plant root and foliage growth during the winter and early spring. Severe conditions in early spring appeared to make the crop in these plots more susceptible to moisture stress and "haying off". There has been no visual evidence of increased disease or induced nutritional problems in any of the lime or gypsum treatments.

In 2005 large grain yield responses of up to 40% resulted from soil amelioration. Interestingly these yield increases were also accompanied by grain protein increases rather than protein decreases. A simple calculation of grain nitrogen (N) content indicates that the three high rates of lime (i.e. Albrecht plot, 6t/ha and 8t/ha lime) all removed a similar quantity of N per ha in the grain harvested, being approximately 20 kg N/ha more than the Nil plot. It is not know where this additional N came from, as the N fertiliser rates were the same on all treatments. The low yields compared with the nil treatment in the previous 2 years may partially account for the extra N recovered in the high rates of lime in 2005. However, this is not supported by the soil test data at the beginning of the 2005 season (Table 7) which shows no significant differences in soil N levels between amelioration treatments. It is suggested that soil amelioration encouraged better root growth which not only allowed additional water extraction from the soil (as seen by the large biomass and grain yield increase), but also additional N uptake.

After 6 years the soil amelioration effect of gypsum appears to have gradually declined, becoming more like the Nil treatment, both in terms of visual crop growth and grain yield and quality.

This trial site has been sown to lucerne pasture. Initial visual observations indicate better lucerne establishment and growth on the lime ameliorated plots. The persistence of the lucerne will be monitored over the coming years.

Analysis of Income & **Ameliorant Costs**

A simple economic analysis has been prepared looking at the total grain income and ameliorant costs. No allowance has been included for the 'capital' nature of ameliorant costs, i.e. expenditure on lime/gypsum is 'up front' and the yield increases (benefits) are spread across a number of years. To fully account for this, a analysis that 'discounting' of returns from ameliorant application needs to be prepared.

Using a simple economic analysis of the yield responses associated with soil amelioration treatments over the last 6 years indicates that the 2t/ha lime and 4t/ha gypsum treatments have been profitable before an allowance for discounting of returns (Table 6). The results of the economic analysis have been greatly influenced by the low yields achieved in drought years of 2002, 2003 and 2004. Low rainfall and water limited yield potentials have generally resulted in poor profitability from crop production in the Gunning Gap area during this time, let alone systems that have high soil ameliorant costs.

Based on the trends seen in this trial to date, the economic benefits of ameliorating the soil with lime are expected to continue into the future. However, the gypsum appears to have 'run out'.

One effect not accounted for in this economic analysis is possible cost savings with machinery operations on ameliorated soils. The better soil structure makes it much easier to work with in terms of cultivation and crop emergence, a factor that is well acknowledged but difficult to put a dollar figure on.

The lack of ameliorant effect in the sub soil is likely to affect the profitability of all amelioration program on sodic soils such as this, and needs to be taken into account when considering such an investment. This trial site will be monitored into the future to see how well the lucerne persists and if any of the top soil amelioration extends into the sub soil over time.

References

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Table 7. Autumn 2005 soil test results in the top sol (0-10cm) and sub soil (10-20cm and 20-30cm

Soil Depth	Ammelioration	Organic C	NH	NO]'	P Colwell	K Colwell	S KCL40	FeDTPA	Mn DTPA	Cu DTPA	Zn DTPA	pH	pH	Conductivity	CEC	Ca	K	Mg	Na	Exchangeable cations				Ca:Mg
		%	mglkg	mglkg	mglkg	mglkg	mglkg	mglkg	mglkg	mglkg	mglkg	$CaCl_2$	Water	dS/m	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	Ca	K	Mg	Na	ratio
0-10cm	Nil	1.0	1.7	23	34	288	5.6	42	40	2.1	0.51	5.9	6.9	0.13	16.2	6,0	0.69	8.0	1.6	36,8%	4.3%	49.4%	9.6%	0.7
	2.0-Lime	1.0	1.5	30	30	272	5.9	19	16	1.6	0.42	6,9	7.9	0.16	18.3	9,1	0.67	7.2	1.4	49,6%	3.6%	39.2%	7.6%	1.3
	Albrechiplot[1]	0.9	1.0	25	36	270	5.4	17	12	1.5	0.39	7,5	8,5	0.17	20.5	11.3	0.68	7.1	1.4	55.3%	3,3%	34.7%	6.7%	1.6
	6.0-Lime	0.9	1.0	30	31	288	5.8	18	11	1.5	0,46	7.7	8,5	0.17	20.4	11.8	0.71	6.9	1.1	57.7%	3.5%	33.6%	5.3%	1.7
	8.0-Lime	0.9	1.5	30	26	272	6.1	18	11	1.4	0.37	7.7	8.7	0.15	20.5	12.0	0.66	6.7	1.2	58.5%	3.2%	32.6%	5.7%	1.8
	4.0 - Gypsum	1.1	2.0	29	21	286	9.8	34	32	1.9	0.43	6.0	6.9	0.14	16.6	7.5	0.71	7.2	1.2	45.3%	4.3%	43.2%	7.3%	1.0
	LDS	0.1	0.9	8	18	20	1.4	8	7	0.3	0.08	0.3	0.3	0.02	1.4	0.8	0.04	0.9	0.2	3.0%	0,4%	2.6%	1.0%	0.2
	CV	5.4	33.4	15.4	30.6	3.6	11.1	15.8	16.3	8.2	10.0	2.5	2.3	7.8	4.0	4.5	3.30	6.6	8.3	3.1	6.1	3.4	6.9	6.8
10-20cm	Nil											7.6	8.9	0.26	29.1	11.2	0.47	12.0	5.4	38.7%	1.6%	41.2%	18.5%	0.9
	2.0-Lime	-	-						-	-		7.7	8.7	0.33	29.5	11.2	0.49	12.1	5.7	37.9%	1.6%	41.1%	19.4%	0.9
	Albrechiplot[1]		-				-		-	-		7.5	8.6	0.29	28.9	11.5	0.45	11.6	5.3	40.1%	1.6%	40.2%	18.1%	1.0
	6.0-Lime		-				-		-	-		7.5	8.7	0.24	27,5	10.9	0.44	11,3	4,8	39.7%	1,6%	41,2%	17,6%	1,0
	8.0-Lime	-	-				-		-	-		7.6	8.9	0.21	29.3	12.1	0.44	12,1	4.7	41.2%	1.5%	41.2%	16.1%	1.0
	4.0-Gypsum	-	-				-		-	-		7.6	8.6	0.40	28.9	10.6	0.45	11,8	6.1	36.6%	1.5%	40.8%	21.1%	0.9
	LDS											0.6	0.5	0.11	3.1	1.2	0.04	1.3	1.4	3.5%	0.2%	3.2%	3.2%	0.1
	CV											4,1	3.0	20,7	5,6	5.6	4.00	5.9	13.7	4.7	5.3	4.0	8.9	7.6
20-30cm	Nil											7.7	8.6	0.44	28.9	11.1	0.45	11.7	5.6	38.3%	1.6%	40.8%	19.4%	0.9
	2.0-Lime											7.9	8.8	0.43	30.1	11.9	0.48	12.3	5.4	39.7%	1.6%	40.9%	17.8%	1.0
	Albrechiplot[1]		-									8.2	9.0	0.56	31.5	11.4	0.51	12.8	6.7	36.3%	1.6%	40.8%	21.3%	0.9
	6.0-Lime		-									7.9	8.9	0,37	29.7	11.5	0.49	12.2	5.6	38.6%	1.6%	41.1%	18.7%	0.9
	8.0-Lime		-									7.7	8.7	0.33	29.0	11.5	0.46	12.0	5.2	39.5%	1.6%	41.2%	17,7%	1.0
	4.0-Gypsum		-									7.9	8.8	0.41	30.1	12.3	0.50	12.3	5.0	41.2%	1.7%	40.7%	16,5%	1.0
	LDS											0.9	0.5	0.37	4.4	1.4	0.02	1.8	2.2	4.0%	0.2%	4.3%	5.3%	0.2
	CV											6.0	3,0	44.6	7,7	6.4	2.20	7.5	20,5	5.4	6,5	5,4	14.7	8.6