LIRAC - Long-term changes of a sodic soil 14-years after lime and gypsum application.

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Key Points

- Changes in soil chemistry were found 14 years after application of high rates of lime and gypsum.
- The source of Ca (lime, gypsum or lime + gypsum) had no significant impact on the long term displacement of Na hy Ca.
- The practical message is that any source of Ca, applied at an equivalent Ca rate, gives equal long term benefits in Na displacement.
- Soil chemistry did not change below 30 cm depth.
- Plant yields have been low due to drought. In 2002 there was no significant difference in plant growth after different ameliorants. This result may not be true and may have occurred because of the low yields.

Background Information

The LIRAC soil amelioration trial was set up in 1988 in conjunction with NSW Agriculture staff at Condobolin. The trial was designed to investigate the effects of different soil ameliorants at different rates on sodic soils. There were 5 treatments;

i) nil;
ii) 2.5 t/ha gypsum applied annually;
iii) 10 t/ha gypsum;
iv) 4.8 t/ha lime and
v) 5 t/ha gypsum combined with 2.4 t/ha lime.

The rates were calculated so as to give an equivalent input of calcium (Ca) on each ameliorant treatment. In the early years there were also two irrigation treatments - raised beds and border check - to investigate if irrigation method affected ameliorant effectiveness (these results are not presented here). The trial was run until 1992, when soil samples were collected but never analysed and the staff on the project all left the district.

In 1999 a new soils project was funded by GRDC at Condobolin and the local fanners began asking questions about the old LIRAC trial. It appeared that the data was still available, previous staff seemed keen to assist and so a 1 year project was proposed to gather the old data, collect some new data and to determine the long-term effects of the soil ameliorants. This project was funded in mid-2001.

Methods

When we began to investigate the old data we found that some of the data had been lost due to a computer malfunction and poor storage. Some of the data was available, just not as much as we had hoped.

In the LIRAC paddock there was an exchangeable sodium percentage (ESP; a measure of sodicity) and electrical conductivity (EC; a measure of salinity) gradient running across the trial from east to west, so that all plots in replicate 3 were higher than those in replicate 1. This was not discovered until after the trial was set up. We have overcome this problem by comparing changes over time, rather than changes between replicates. In some cases, changes between replicates have been compared and found to be significant, meaning that the difference between treatments is far greater than any differences across the site.

The treatment with 2.5 t/ha gypsum applied annually was only applied for 2 years, when the original plan had been for 4 annual applications. So instead of all Ca rates being equivalent, the Ca of this treatment is half that of the others.

Many people involved in the trial expressed concern as to the application method of lime and gypsum, saying that the middle of each plot was spread heavily and the edges quite thinly. To overcome this problem we soil sampled towards the centre of each plot but straddling the mid-line.

Soil sampling occurred in March 2002 and 5 cores were taken from each plot to a depth of 90 cm. Each core was sectioned into 10 cm depths to 30 cm and then 20 cm depths until 90 cm, giving 6 sections per core, and these sections were bulked for each plot. Soil was dried at 40°C and sent to the Victorian State Chemistry Laboratory for analysis, following the methods used in 1988-1990. Soils were analysed for pH (both water and $CaCl_2$), electrical conductivity (EC), exchangeable cations using the Tucker method and Walkely-Black organic carbon.

At the end of the 2002 season, plants were cut for a dry matter analysis so that we could have some biological data to see if the changes in soil chemistry were reflected in differences in plant growth.

Results

The objective in applying limestone (L) and/or gypsum (G) is to improve soil structure by displacing sodium (Na) from, and adding Ca to, exchange sites in the soil. This replacement is measured in two ways: the absolute change in exchangeable Ca (Ca_{ex}) and Na (Na_{ex}), and the change in percentage terms (Na% and Ca%) as a proportion of the effective cation exchange capacity (eCEC). Limestone has the additional benefit of lifting soil pH and increasing eCEC, and therefore increasing the soil's capacity to retain Ca.

For the benefit of easy comparison, we will ignore the annually applied gypsum treatment for now, as it has less Ca than the other treatments and makes for a more confused explanation of results.

14 years after application, all ameliorants (L, L+G, G) lowered Na_{ex} and Na% in the top 10 cm of soil compared with the control soil (see table at the end of the paper). In order, the effect was G had a greater effect than L+G which had a greater effect than L, as might be expected, but after 14 years the differences among the 3 ameliorants were not statistically significant. Conversely, L had the best residual effect on Ca_{ex} in the top 10 cm of soil, followed by L+G, with G equal to the control. However since limestone raised the pH of the soil significantly compared with the other treatments, the eCEC was also increased by liming and the Ca% was not significantly different among the three ameliorants (at 53-55 Ca%). The 3 ameliorants lowered Mg% relative to the control (41% down to 36 - 38%) and raised the Ca:Mg ratio above that of the control (from 1.23 up to 1.47 - 1.57). However these Mg effects are small and unlikely to be of biological significance let alone of practical value.

In the 10-20 cm soil layer the EC (saltiness of the soil water) was marginally decreased equally by the 3 ameliorants. Na_{ex} and Na% were also lowered relative to the control, but there was no difference among the three ameliorants. Similarly, Ca% was increased by the same amount by the three ameliorants and Mg% was decreased slightly by them.

At 20-30 cm depth the Na% was decreased and the Ca% increased significantly and equally by the 3 ameliorants.

There were no effects below 30 cm depth.

At the end of the 2002 season, plants were cut for a dry matter analysis to determine if these changes in soil chemistry were reflected in differences in plant growth between treatments. The 2002 season was extremely dry and no irrigation water was available, so the wheat was very poor and patchy. No significant differences in yield were found between the treatments due to the low yields and the high variability. It was deemed that these samples were unsatisfactory and plant sampling should occur when the season ensured good plant growth. This has not occurred.

Conclusion

After 14 years the beneficial effects of the 3 ameliorants were still evident in the soil and had penetrated to 30 cm depth. The source of Ca (L, G or L+G) had no significant impact on the long term displacement of Na by Ca. The presence of alkali (lime) in the ameliorant (L and L+G) had a small effect on the retention of Ca in the surface soil due to the increase in ECEC with pH (ECEC = $2.74pH_{ca}$, $r^2=0.70$, $P=0.08$).

The practical message is that any source of Ca, applied at an equivalent Ca rate, gives equal long term benefits in Na displacement. These benefits are measurable 14 years after application. The choice between limestone and gypsum as ameliorant for sodic soils therefore rests on short term results (McKenzie *et al,* 2002) and cost.

Unfortunately the season of 2002 did not allow us to establish the biological significance of these residual effects on soil properties. It is our hope that adequate plant data will be collected soon to give more practical application to these soil results.

The project is effectively incomplete and at this stage we have few conclusions to offer. The only real conclusion we have is that changes in soil chemistry have been brought about by high rates of application of a soil ameliorant, regardless of the choice of ameliorant (lime, gypsum or lime and gypsum). Without the associated plant data, we can reach no other conclusions.

Recommendations

Heavy rates of lime and gypsum application produce equivalent soil chemistry changes in the long-term, on these slightly acidic, sodic and saline clay soils along the Lachlan River at Condobolin.

Further research

We question as to why the soil chemistry changes have only moved to 30 cm depth - similar to the movement of lime reported in long-term soil acidity trials. It has been reported that gypsum is more soluble and moves more readily than lime but these results indicate little difference between the two products. Further work into the nature of the movement of gypsum would be beneficial, particularly some long-term movement studies in other locations.

LIRAC 2002 SOIL DATA SUMMARY - different letters at each depth, for each chemical property, indicate a significant difference between treatments (*P* < 0.05) (NOTE: This table shows the data for the annual gypsum application treatment (gyp2). The text did not refer to this treatment).

		pHw	pHC	EC	TSS	OM	oc	N	S	Ca	Mg	Na	K	eCEC	Ca:Mg	Ca%	Mg%	Na%	K%
0-10 an																			
	Nil	7.28^{b}	6.23^{b}	0.08^{ns}	0.028 ns	1.72^{ns}	0.89^{ns}	0.09^{ns}	3.33^{ns}	9.9^{a}	8.28^{ns}	1.25^{b}	1.00 ns	20.5^{ns}	1.23^{a}	49^{a}	41.0^{C}	6.5^{b}	5.33"
	Lime	*7.57^{c}*	6.55^{c}	0.07	0.023	1.63	0.83	0.09	3.33	*11.7^{c}*	7.72	0.97^{a}	0.97	21.3	1.57^{c}	55.3^{c}	36.3^{a}	5.17^{a}	5.00^{a}
	Gyp2	6.98^{ab}	5.98^{ab}	0.07	0.023	1.73	0.90	0.10	4.00	10.4^{ab}	8.05	0.95^{a}	1.07	20.5	1.33^{ab}	51.3^{b}	39.5^{bc}	5.17^{a}	5.67"
	Gyp	6.83^{a}	5.88^{a}	0.07	0.025	1.80	0.92	0.10	4.00	9.95^{a}	6.98	0.77^{a}	1.12	19	1.47^{bc}	53.3^{bc}	37.7^{ab}	4.50^{a}	6.50^{b}
	g+lime	7.15^{b}	6.17^{b}	0.08	0.023	1.70	0.89	0.09	4.17	11.2^{bc}	7.65	0.82^{a}	1.03	20.7	1.53^{c}	54.7^{C}	37.3^{ab}	4.33^{a}	5.33^{a}
5%lsd		0.267	0.257	0.012	0.006	0.24	0.12	0.009	0.922	1.04	1.09	0.240	1.69	2.113	0.153	2.291	2.39	0.925	0.993
10-20 cm																			
	Nil	8.30^{ns}	7.18^{ns}	0.14^{b}	0.05 ns	1.13^{ns}	0.58^{ns}	0.06^{ns}	5.83^{ns}	11.3^{ns}	9.93^{ns}	2.57^{b}	0.55 ns	24.5^{ns}	1.17^{a}	46.8^{a}	41.3^{c}	11.0^{b}	2.67^{ns}
	Lime	8.18	7.08	0.11^{a}	0.04	1.12	0.57	0.06	4.83	12.0	9.15	1.93^{a}	0.50	23.7	1.35^{c}	51.2^{b}	39.2^{a}	8.50^{a}	2.67
	Gyp2	7.90	6.87	$0.1 1^{a}$	0.04	1.17	0.60	0.06	6.33	11.4	9.43	1.77^{a}	0.55	23.2	1.25^{ab}	49.5^{b}	41.2^{bc}	8.00^{a}	2.68
	Gyp	7.92	6.82	0.11^{a}	0.04	1.08	0.56	0.06	5.67	11.7	9.07	1.80^{a}	0.48	23.2	1.33^{bc}	51.0^{b}	39.7^{ab}	8.33^{a}	2.50
	g+lime	8.00	6.87	0.09^{a}	0.03	1.10	0.56	0.06	5.00	11.8	9.25	1.55^{a}	0.53	23.0	1.3^{bc}	51.3b	40.5^{ah} c	7.17^{a}	2.83
5%lsd		0.36	0.37	0.032	0.01	0.13	0.07	0.007	1.40	1.65	1.17	0.528	0.07	3.11	0.096	1.947	1.63	1.57	0.30
20-30 cm																			
	nil	8.68^{ns}	7.58^{ns}	0.17^{ns}	0.06 ns	0.95^{ns}	0.50^{ns}	0.052 ns	11.67 ns	11.1^{ns}	9.63^{ni}	3.37^{b}	0.43 ns	24.5^{ns}	1.20^{ns}	45.8^{a}	39.7^{DS}	14.2^{b}	2.0^{ns}
	lime	8.63	7.50	0.14	0.05	0.88	0.45	0.052	10.67	12.0	9.32	2.78^{ah}	0.42	24.5	1.33	49.2^{h}	38.3	11.7^{a}	2.0
	gyp2	8.43	7.37	0.15	0.05	0.98	0.50	0.052	11.67	11.5	9.67	2.57^{a}	0.47	24.3	1.22	47.8^{ab}	40.3	11.2^{a}	2.3
	gyp	8.52	7.48	0.16	0.05	0.92	0.47	0.050	13.17	11.4	9.33	2.72^{a}	0.45	24.0	1.27	48.2^{ab}	39.5	11.7^{a}	2.0
	G+lime	8.47	7.32	0.12	0.04	0.93	0.47	0.052	8.67	11.8	9.57	2.38^{a}	0.43	24.3	1.27	49.3^{b}	40.2	10.2^{a}	2.0
5%lsd		0.24	0.27	0.04	0.013	0.11	0.06	0.004	3.84	1.02	0.90	0.622	0.07	2.19	0.124	2.75	1.93	2.052	0.32