Viability of lime and gypsum use in mitigating sodicity in an irrigated Vertosol

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Abstract
The use of gypsum, and to a lesser extent, lime to mitigate sodicity in dryland agriculture has been shown as viable. However, under an increased water application (i.e. irrigation) the dissolution of gypsum could be expected to be more rapid. Lime, due to a lower solubility, could provide a more constant source of calcium to the soil, especially when applied in combination with gypsum. This study investigates the effects of various rates of lime, gypsum and lime/gypsum combinations on an irrigated sodic Brown Vertosol in western NSW. The expected increase in soil EC due to gypsum was not evident after 6 months due to leaching. Additionally, only a high rate lime/gypsum combination was shown to have a positive effect on exchangeable calcium and sodium percentages, as well as aggregate stability. Short-term viability was not assessed efficacious after 6 months for any treatment. Potential for long-term viability was exhibited.

Introduction
Sodicity is inherent to many Australian soils and it is not a man-made problem, but a man-exacerbated one. Within New South Wales 47 % of soil is affected by sodicity (Northcote & Skene 1972) and the resultant clay dispersion. Subsequently, pore blockage, soil compaction and reduced hydraulic conductivity occur, resulting in an adverse soil environment. Gypsum ($CaSO_4.2H_2O$) and, to a lesser extent, lime ($CaCO_3$) have been identified as ameliorants for sodicity that supply sufficient calcium to displace the excess sodium (Greene and Ford 1985; Shepherd 1925; So *et al.* 1978; Valzano *et al.* 2001). However, due to the solubility of gypsum (2410 mg/L), as compared to lime (15 mg/L), it is likely to dissolve and move further into the profile at a faster rate. Additionally, as Greene and Ford (1985) found that 120 to 130 mm of rainfall on a hard setting Red-Brown Earth (Red Sodosol) dissolved 1 $t.ha^{-1}$ of gypsum, it is fair to expect a more rapid movement of gypsum deeper into the profile of a Vertosol when subject to irrigation. Therefore, when considering chemical amelioration as a method to mitigate the effects of sodic topsoils there is a question of viability: should land-managers be trying to eradicate excess sodium, or should they accept the sodicity levels their topsoils contain and simply manage so as to not exacerbate these levels? This study examines the effects of common and exaggerated application rates of gypsum, lime and lime/gypsum combinations for their short-term stability effects on the topsoil, in order to assess the viability of such ameliorant application on an irrigated Vertosol.

Method
The experiment was conducted on an irrigated Brown Vertosol used primarily for cotton production, approximately 40 km north west of Hillston, in western NSW. Treatments ranged from a common application rate of 2.5 $t.ha^{-1}$ of either lime or gypsum to double rates (Table 1). Experimental full field 20 m wide strips (extending from head ditch to tail drain) were applied for each treatment and replicated twice. Sampling of the surface soil, 0 to 100 mm, was conducted in each treatment from the tail drain towards the head ditch after six months. During this six month period 10 $ML.ha^{-1}$ of water was used in 8 irrigation events for a cotton crop. Soil measurements included exchangeable cation analysis using Atomic Absorption Spectrometry consistent with Tucker (1985), Aggregate Stability in WATer (ASWAT; Field *et al* 1997), pH and electrolyte concentration (EC). Further sampling will occur after 2.5 years, in December 2009, to a depth of 800 mm and will additionally incorporate full field hydraulic conductivity measurements using Irrimate™ (Purcell 2008), as well as satelite biomass imagery.

Results and discussion
Exchangeable sodium and calcium percentages
Within six months of treatment application, an expected trend was apparent for both the exchangeable calcium percentage (ECP) and exchangeable sodium percentage (ESP; Figure 1). In treatments where gypsum was applied, ECP generally increased and ESP generally decreased with increasing application rates. Conversely, ESP and ECP levels were maintained where lime was applied alone. In both cases the L5G5 and L2.5G5 treatments caused the greatest changes. However, for both ECP and ESP, only the L5G5 treatment

displayed a significant difference to the control. These results indicate that exchange of sodium with calcium has occurred within six months where gypsum is applied and that the effect is possibly greater when applied in combination with lime.

Table 1 Applied experimental treatments of lime, gypsum and lime/gypsum combinations with regard to calcium equivalent and cost.

Treatment	*Abbreviation*	*Lime (t/ha)*	*Gypsum (t/ha)*	*Calcium* Equivalent (t/ha)*	*Cost** (AUD$/ha)*
Control	L0G0	0	0	0	0
1	L2.5G0	2.5	0	1	275
2	L0G2.5	0	2.5	0.5	187.5
3	L2.5G2.5	2.5	2.5	1.5	462.5
4	L5G2.5	5	2.5	2.5	737.5
5	L2.5G5	2.5	5	2	650
6	L5G5	5	5	3	925

* Based on 200 kg.t^{-1} of calcium in gypsum and 400 kg.t^{-1} of calcium in lime (Abbott and McKenzie 1986).
** Based on actual expenditure including freight: lime AUD$110 per ton; and, gypsum AUD$75 per ton.

It is also recommended from this data that six months is not long enough to dissolve lime under irrigation at an initial pH of 8.2, irrespective of plant growth inputs. Furthermore, the rapid leaching of gypsum may not allow sufficient time for the calcium from gypsum to enhance lime dissolution through hydrogen displacement.

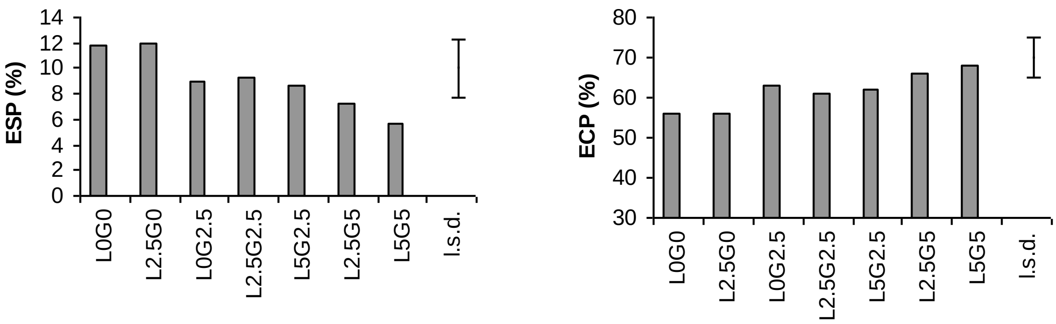


Figure 1 Exchangeable calcium percentage and exchangeable sodium percentage to 100 mm depth for the Mount View soil. Bars represent least significant differences (l.s.d.)

Electrical conductivity

From Table 2 it can be seen that the soil EC was not significantly different between any of the treatments and the control, which is not consistent with findings of previous studies. Gypsum (Davidson and Quirk 1961; McKenzie *et al.* 1993) and lime (Naidu and Rengasamy 1993; Shainberg and Gal 1982) have both been shown to cause an initial increase in electrical conductivity (EC).Valzano *et al.* (2001) observed significant differences in EC due to gypsum application after one year in a dryland system. Subsequently, the observed soil EC effect declined after three years; the decline attributed to leaching via rainfall. For the irrigated Mount View soil, the total water applied, including rainfall, was 1209 mm.ha^{-1} for the six month period. Considering the solubility rates for gypsum, 120-130 mm.ha^{-1} dissolving 1 t.ha^{-1}, observed by Greene *et al.* (1985), it is suggested that most of the gypsum has dissolved and been leached from the 0 to 100 mm layer. It is not suggested that an initial raise in EC has not occurred, rather that the magnitude of wetting has caused it to have occurred and subsided within six months. Depending on the magnitude of the period in which this EC flux has occurred, important implications for mitigating dispersive properties for seedling emergence are apparent.

Aggregate stability

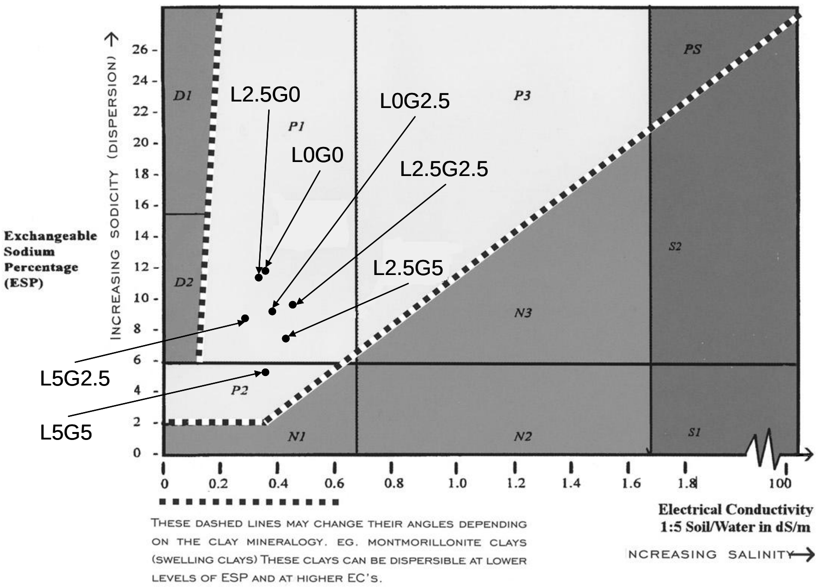
Aggregates from all treatments and the control were potentially dispersive according to ASWAT, which is supported by the soil chemical data. However, the proportion of aggregates to undergo spontaneous dispersion in the L5G5 treatment differed significantly to the control, and the L5G5 treatment was observed to have a significantly lower dispersion index than the control soil. However, the majority of aggregates in the L5G5 treatment did disperse to some degree after reworking, which could be expected given the ESP is proximal to the sodicity defining threshold of 6 % (Sumner 1993). These results suggest that irrespective of lime and gypsum application, the soil under all treatments remain potentially dispersive to some degree.

Table 2 Mount View 0 – 100 mm soil chemical attributes after 6 months from ameliorant application (Cations are exchangeable; α = 0.05)

Treatment	*Ca*	*Mg*	*K*	*Na*	*CEC*	*EC*	*pH*
			cmol(+)/kg			*dS/m*	
L0G0	3.50	2.02	0.03	0.73	6.29	0.35	8.2
L2.5G0	3.59	2.02	0.02	0.76	6.39	0.37	8.7
L0G2.5	4.45	1.99	0.02	0.63	7.09	0.39	8.4
L2.5G2.5	4.15	2.02	0.03	0.63	6.83	0.43	8.5
L5G2.5	4.37	2.05	0.20	0.59	7.04	0.32	8.7
L2.5G5	4.90	1.95	0.01	0.54	7.40	0.40	8.5
L5G5	4.99	1.89	0.02	0.41*	7.32	0.38	8.5
p value	0.06	0.10	0.51	0.01	0.17	0.62	0.4

** treatments with significant difference to L0G0 at respective p-value*

The ESP/EC matrix (Figure 2) shows the dispersive potential of the Brown Vertosol decreasing with application of gypsum, which may suggest that lime has had no influence on cation exchange. However, a meaningful difference is observed between the L5G5 and L2.5G5 treatments where only the former has fallen in the P2 zone. The importance of this result is that if EC declines at this same ESP then the L5G5 treated soil will not revert to be spontaneously dispersive, which all other treatments have the potential to do. Furthermore, both the L2.5G5 and L5G5 treatments have received 5 t.ha^{-1}of gypsum. However, only the L5G5 treatment falls in the P3 zone as well as showing significant difference in ESP, which suggests the difference may be due to a possible synergistic effect of gypsum and lime at high rates.



Zone	*Sodicity*	*Salinity*
D1 & D2	Severe dispersion	No limitations
P1, P2, & P3	Potential dispersion	No limitations (P3 slight to moderate)
N1, N2 & N3	Nil dispersion (N1 low dispersion)	Slight to moderate limitation (N1 none)
S1 & S2	Nil dispersion	Severe limitations
PS	Dispersion with working	Severe limitations

Figure 2 Mount View ESP/EC matrix for depth 0 to 100 mm (after McKenzie and Murphy 2005)

Extension

Gypsum has previously been shown to provide a heightened EC in the short term, leading to many landholders using lower applications of gypsum to flocculate the soil in the germination and establishment phase of their crops and pastures. However, this study suggests that irrigation speeds up the EC flux.

Depending on this, the use of such a management strategy may not be efficacious. Therefore, an in depth investigation into the longevity of the EC effect under irrigated soils in the first six months would be of benefit.

Conclusions

The initial rise in soil EC had subsided within 6 months due to leaching, where in dryland agriculture the same EC raise has been recorded as lasting upwards of one year. This may hold important ramifications for seedling emergence and establishment.

Rapid gypsum dissolution was caused by the increased magnitude of water passing into the soil from irrigation and rainfall. However, under the same circumstances, lime applied alone did not display any increase in dissolution. Therefore, it was concluded that six months is too short a time period for lime dissolution to have a significant ameliorative effect on an alkaline, irrigated sodic soil. However, when applied as 5 $t.ha^{-1}$ in conjunction with gypsum at 5 $t.ha^{-1}$ there is evidence of a greater effect than when the same amount of gypsum is applied with 2.5 $t.ha^{-1}$ of lime. This suggests there is potential for a synergistic effect in the long-term. This is an important result as this synergy caused by the combination of lime and gypsum could provide a more constant source of calcium to the topsoil.

Furthermore, the use of the common application rate of 2.5 $t.ha^{-1}$ for these ameliorants was shown to cause little improvement in soil surface sodicity on the irrigated Vertosol. This leads to the preliminary conclusion that the use of lime or gypsum alone at the conventional rate is not a viable means of mitigating sodicity in the short-term. Conversely, even though the high rate application of lime and gypsum in combination showed significant improvement in soil structure it is not possible to draw the conclusion that such a treatment is viable. The cost of lime and gypsum in combination at the highest rate is substantial and outweighs the improvement in structure in the short-term. Hence, the longevity of this effect needs to be assessed over time to determine the overall viability of treatments, although the high rate treatments do show potential.

References

Abbott, TS & McKenzie, BM (1986) *Improving soil structure with gypsum*. Agfact AC 10, NSW Agriculture,

Davidson, LJ & Quirk, JP (1961) The influence of dissolved gypsum on pasture establishment of irrigated clays. *Australian Journal of Agricultural Research* **12,** 100-10.

Field, DJ, McKenzie, DC & Koppi, AJ (1997) Development of an improved vertisol stability test for SOILpak. *Australian Journal of Soil Research* **35,** 843-52.

Greene, RSB & Ford, GW (1985) The effect of gypsum on cation exchange in two red duplex soils. *Australian Journal of Soil Research* **23,** 61-74.

McKenzie, DC, Abbott, TS, Chan, KY, Slavich, PG & Hall, DJM (1993) The nature, distribution and management of sodic soils in New South Wales. *Australian Journal of Soil Research* **31,** 839-68.

McKenzie, DC & Murphy, BW (2005) *Use this graph to interpret your soil tests and predict the dispersion and/or salinity characteristics of your soils*, Don Stanger Public Relations

Naidu, R & Rengasamy, P (1993) Ion interactions and constraints to plant nutrients in Australian sodic soils. *Australian Journal of Soil Research* **31,** 801-19.

Purcell, J (2008) *Whole farm water management*. Aquatech Consulting Pty Ltd, Narribri & Warren.

Shainberg, I & Gal, M (1982) The effect of lime on the response of soils to sodic conditions. *Journal of Soil Science* **33,** 489-98.

Shepherd, AN (1925) Experience on Yanco irrigation area. *Agricultural Gazette New South Wales* **36,** 261-3.

So, HB, Taylor, DW, Yates, WJ & McGarity, JW (1978) In *Modifications of soil structure.* (Eds. Emerson, WW, Bond, RD & Dexter, AR) John wiley & sons, Chichester, pp. 363-70.

Sumner, ME (1993) Sodic soils: a new perspective. *Australian Journal of Soil Research* **31,** 683-750.

Tucker, BM (1985) A proposed new reagent for the measurment of cation exchange properties of carbonate soils. *Australian Journal of Soil Research* **23,** 633-42.

Valzano, FP, Murphy, BW & Greene, RSB (2001) The long term effects of lime ($CaCO_3$), Gypsum ($CaSO_4.2H_2O$), and tillage on the physical and chemical properties of a sodic red-brown earth. *Australian Journal of Soil Research* **39,** 1307-31.