The effects of lime, gypsum and lime/gypsum combinations, after 2.5 years, on two sodic soils under dryland cropping conditions in the Macquarie Valley, NSW

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Abstract. While gypsum, and to a lesser extent lime, are reported as ameliorants for soil sodicity, there is relatively little information concerning the use of these ameliorants in combination. This study investigates the use of lime and gypsum combinations on selected soil properties relating to sodicity on two different soils used for dryland cropping in the Macquarie Valley of New South Wales (NSW). Lime and gypsum treatments were applied to two soils (lime [L] and/or gypsum [G], applied at t/ha rates: L0G0 [control], L2.5G0, L0G2.5, L2.5G2.5, L2.5G5, L5G2.5, and L5G5) that were sampled after 2.5 years and analysed for soil pH, EC and aggregate stability. Changes in pH and EC, as well as correlations, suggest that lime has dissolved more readily in the presence of gypsum. While aggregate stability was not significantly enhanced, significant relationships between soil EC and aggregate stability were found.

Introduction

The use of lime and gypsum in the amelioration of sodicity under dryland conditions has been well documented (see Ghafoor *et al.* 2001). Even still, there remains a paucity of information concerning the field-based effects of lime and gypsum combinations on sodic soils, irrigated or otherwise (Bennett 2011). The higher dissolution rate of gypsum causes hydrogen ions (H^+) to become displaced from the negatively charged clay faces during exchange with Ca^{2+}, which slightly lowers the pH and increases the solubility of lime (Valzano *et al.* 2001). In the study of Valzano *et al.* (2001), improved soil stability, due to this effect, was still observed after three years and 650 mm of rainfall. Additionally, a slight, but significant, increase in EC was observed after the same timeframe and rainfall in soils with lime applied at 1 $t.ha^{-1}$ and a lime/gypsum combination applied at 2.5 $t.ha^{-1}$/1 $t.ha^{-1}$, respectively, as compared to the control soil. Because the combination of lime and gypsum has been observed to provide a synergistic ameliorative effect that is apparently soil specific, it is important to present further field-based research on a broader range of soils. This study investigates the use of lime and gypsum combinations on selected soil properties relating to sodicity on two different soils used for dryland cropping in the Macquarie Valley of NSW.

Methods

The experimental sites were situated in NSW near Warren (“Bellevue”; 31°32’00.70”S 147°47’46.13”E) and near Trangie (“Agriland”; GR 31°59’20.27”S 14°807’05.06”E) where full-field replicated experimental treatments of sodic ameliorants were applied. These experimental treatments consisted of lime (L) and/or gypsum (G), applied at t/ha rates: L0G0 (control), L2.5G0, L0G2.5, L2.5G2.5, L2.5G5, L5G2.5, and L5G5. Treatments were applied in August and September of 2007. The soil sampled from Bellevue is from an Episodic-Endocalcareous Brown Vertosol. Clay mineralogy suggests that the soil is illite and kaolinite dominant. While some smectite is present, the majority of this appears to be interstratified with illite. Soil sampled from Agriland is from a Calcic Sodic Brown Dermosol. The mineral suite of the Agriland soil is dominated by illite and kaolinite in the A horizon, while smectite is more prominent at depth.

Soil samples we taken 2.5 years post application of lime and/or gypsum using a single stroke, tractor mounted, hydraulic corer with a 45 mm internal diameter soil core. These were taken at approximately 16 m intervals from the furrow and parallel to the rows at 0–100, 100–200 and 200–400 mm depths. A total of 28 samples were taken per treatment, which equated to 392 samples sites, and 1,176 samples by depth, per property. These were air-dried and crushed to pass a 2 mm sieve, with a proportion of intact soil aggregates from each sample set aside. The analysis of the Agriland and Bellevue soil post-lime and gypsum application, included $pH_{1:5}$, $EC_{1:5}$ soil:water (Rayment and Higginson 1992) and aggregate stability in water (ASWAT, Field *et al.* 1997). These measurements were used as proximal indicators of soil stability and ameliorant dissolution in lieu of exchangeable/soluble cation data, which was beyond the scope of the work. Statistical analysis of these measurements was undertaken using analysis of variance, utilising Tukey’s pairwise comparison and honest significant difference (h.s.d.), and correlation analysis.

Results and discussion

Treatment effects on, and relationship between, pH and electrolyte concentration

Lime is known to increase the pH of soils through Ca^{2+} exchange and the formation of bicarbonate (HCO_3^-), the rate of which depends on the rate of lime dissolution (Cregan *et al.* 1989), viz. the lime must dissolve in order for a change in pH to occur. The increases observed in pH for the Bellevue topsoil indicate that lime has dissolved throughout the 2.5 yr period since application and subsequently raised the pH (Fig.1). While the pH results for Agriland are not statistically significant, the slight rise in pH where lime has been applied could be attributed to lime dissolution (Fig.1). The general effect of gypsum on soil pH is a slight acidifying effect, due to displacement of H^+ (Valzano *et al.* 2001). While not a significant result in this study, the consistently lower mean pH value where gypsum alone was applied is most likely due to this process. This was more pronounced in the Bellvue soil than the Agriland soil, therefore it is likely that gypsum has had a longer lasting pH effect in the Bellevue soil (control initial pH of 7.1) as compared to the Agriland soil (control initial pH of 6.4). The presence of lime where gypsum is applied has also been shown to decrease the dissolution of gypsum (Naidu *et al.* 1993). Combining the effects of pH and the presence of lime with gypsum on dissolution longevity, this would explain the propensity of the L2.5G5 treated soil to have a significantly higher pH than the soil treated with L0G2.5 at Bellevue.

As lime dissolves it can also augment the EC of the soil (Naidu *et al.* 1993). Valzano *et al.* (2001) observed the application of lime (1 $t.ha^{-1}$) to have increased topsoil EC after three years and 650 mm of rain in a Brown Sodosol (pH approximately 6.0–6.3 in the topsoil). Similarly, increases in soil EC for the current study were observed where lime had been applied for both Agriland and Bellevue (Fig.2). For the Bellevue soil, the L2.5G2.5 and L2.5G5 treatments caused a significant increase in EC as compared to the L0G2.5 treatment ($0.15>p>0.05$). Whilst gypsum is more commonly known to increase EC than lime, it is likely that the EC effect due to gypsum has subsided due to leaching and the time afforded to dissolution (Sumner 1993). Interestingly, where gypsum was applied alone, the general effect was a slight decrease in EC. This can be attributed to a probable short-term improvement in soil structure, due to gypsum application, that has resulted in enhanced leaching of electrolyte over a longer period of time than lime applied alone could achieve (Valzano *et al.* 2001). This reinforces the short-term nature of the EC effect of gypsum and the need to reapply gypsum to maintain such an effect.

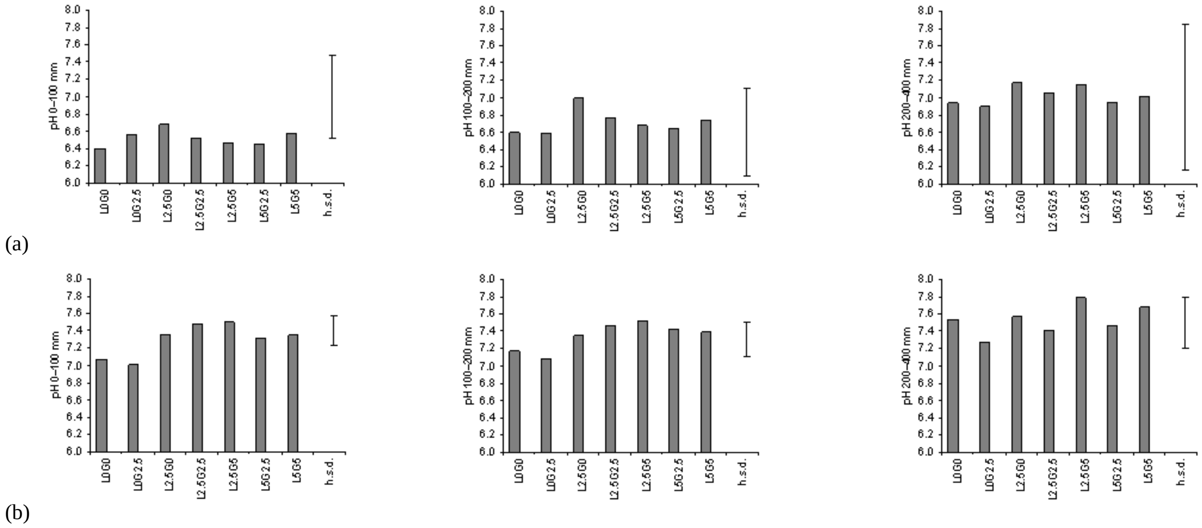


Figure1. Changes in soil pH as a result of treatment effect after 2.5 years. Graphs in row (a) pertain to Agriland, and graphs in column (b) pertain to Bellevue

As lime is required to dissolve in order to provide a potential rise in pH, it stands that if lime is also responsible for increases in EC, pH should strongly and positively correlate with EC. This was the case for both the Agriland and Bellevue soils (Fig.3). Irrespective of statistical significance within each measurement (i.e. within pH or EC), a significant correlation is meaningful in that it shows the effect is a result of treatment application, and not just random 'noise'. Of the two soils, the relationship was most consistent in the Bellevue soil, which is probably because the pH is approximately half a unit higher in this soil, meaning that the rate of dissolution would be slower. During the lifetime of the experiment 1222 and 1322 mm of rain fell on Bellvue and Agriland, respectively, that would have also affected the dissolution rate of gypsum and the subsequent effects on lime. Thus, the longevity of the EC effect is more likely to be greater for Bellevue.

This is not to say that an EC effect due to lime has not occurred at Agriland. Indeed, the 200–400 mm layer shows that a highly significant relationship between pH and EC exists. The fact that the upper layers do not show such a relationship is most likely a result of improved aggregate stability and increased leaching, as well as a higher concentration of electrolyte in the leachate, due to enhanced dissolution from a lower pH than the Bellevue soil.

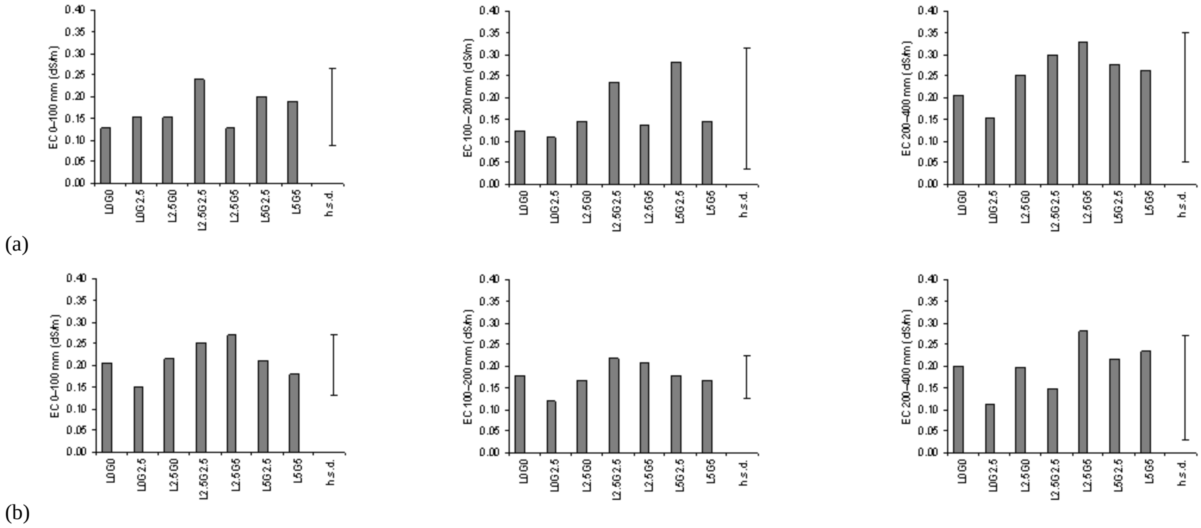


Figure 2. Changes in electrolyte concentration as a result of treatment application after 2.5 years. Graphs in row (a) pertain to Agriland, and graphs in column (b) pertain to Bellevue

Treatment effect on aggregate stability

While there were no significant effects on aggregate stability resulting from treatment application, there was an evident trend for aggregate stability to be enhanced where lime and gypsum combinations had been applied in comparison to the control soil (Fig.4). The variability in ASWAT data was high, which could have occurred as a result of a dilution effect, viz. A difference in ameliorant effect throughout the soil layer, especially as the boundary of the adjacent soil layer is approached (exacerbated by cut-and-fill land-forming techniques). For the Agriland soil, the L2.5G2.5 and L5G2.5 treated soils were observed to persist as the soils with the lowest DI, or equally the lowest DI, throughout the layers investigated. For the Bellevue soil, the treatment providing the most consistent decrease in DI was the L2.5G5 treatment; this is possibly due to a greater amount of gypsum required to augment lime dissolution at higher pH than that of the Agriland soil. For both soils, the treatments having the greatest effect on DI throughout the investigated profile were the higher EC treatments, as compared to the remaining treatments (Fig.4). Hence, aggregate stability is likely augmented by lime dissolution through the addition of greater amounts of electrolyte.

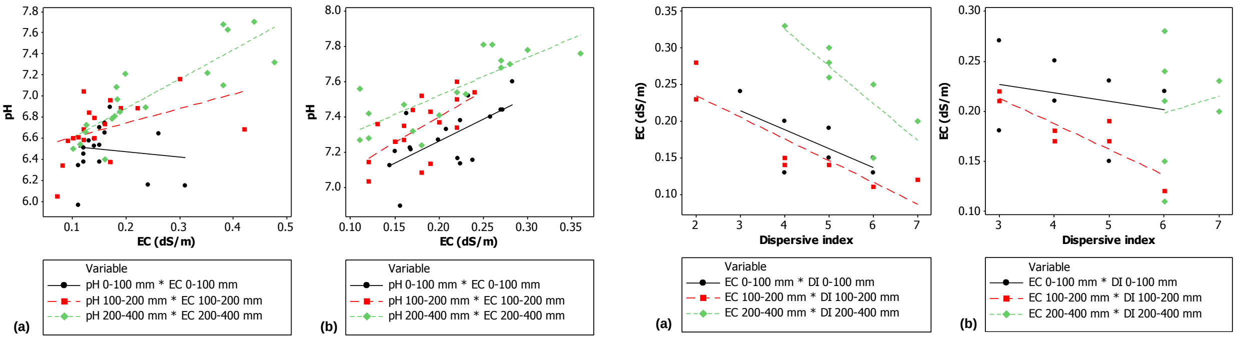
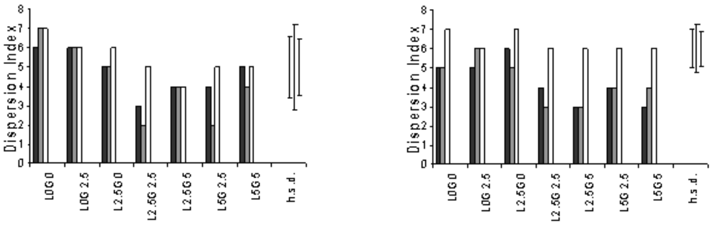


Figure 3. Correlation analysis of pH and EC, as well as EC and DI, by experimental site: (a) Agriland and (b) Bellevue

The work of Quirk and Schofield (1955) shows that the flocculation of clay particles is highly dependent on the electrolyte concentration within a soil. The Agriland soil clearly shows that the EC is significantly and negatively related to the dispersive potential of the soil for all layers, while only the 100–200 mm layer for the Bellevue soil shows a significant relationship (Fig.3). For the Bellevue soil, it is suggested that the recent cut-and-fill land-forming (in the year 2005, as compared to 1992 at Agriland) is responsible for the variation. It is probable that such cut/fill variability would mask the effects of treatment application, unless pronounced. Furthermore, fill areas would be more likely to benefit from a small rise in EC than would the exposed subsoil of cut areas with a higher ESP. This reinforces the fact that sodic soils, and their level of stability, are dependent on more than just ESP (Sumner 1992).



(a) (b)

Figure 4. Changes in aggregate stability in water as a result of treatment application after 2.5 years; (a) represents Agriland data; (b) represents Bellevue data; columns within treatments represent the 0–100 mm (black), 100–200 mm (grey) and 200–400 mm (white) layers; h.s.d. intervals are ordered relative to the layer order.

Possibility of a synergistic effect between lime and gypsum on soil sodicity

As soil exchangeable cations were not determined, it is only possible to speculate on the effects of lime and gypsum combinations on soil sodicity levels. However, it is feasible that synergy between lime and gypsum has occurred. Where EC levels were significantly different, application of lime and gypsum had occurred in combination (Fig.2). Valzano *et al.* (2001) found a similar result for EC after three years on a Brown Sodosol where a L2.5G1 treatment had been applied. Thus, the observed EC levels in the current study may be indicative of a lower ESP. Furthermore, if lime is responsible for the maintenance of EC, and greater EC where applied in conjunction with gypsum, then it is quite probable that the soil solution is Ca^{2+} enhanced where combinations are applied (Valzano *et al.* 2001). The Bellevue soil was the only soil with significant differences in EC after 2.5 years (Fig.2), and of the two soils, is the most likely to have benefitted from a synergistic effect, although this does not preclude the Agriland soil from such an interaction. As previously discussed, the lower pH in the Agriland soil (Fig.1) may have caused the amendments to have completely dissolved in before soil sampling occurred after 2.5 years. The EC/pH relationship in the 200–400 mm layer for this soil suggests that lime has had an effect on soil EC, albeit possibly dwindling (Fig.3). Therefore, the possibility of a lime/gypsum synergy after 2.5 years, while unable to be proven, should not be ruled out. Cation analysis of these soil samples should be undertaken in the future.

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