# Changes in soil pH as a result of lime addition as affected by rates, time and incorporation method

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**Abstract**
Sandplain soils on the south coast of Western Australia are naturally acidic. Cropping systems can further reduce soil pH by as much as 0.3 pH units in seven years. A series of experiments were established to determine the effects of lime addition on soil pH within the root zone. Lime applied at rates ranging from 0.5 to 8.6 t/ha resulted in significant increases in topsoil pH. Only the highest rates of lime (> 1.5 t/ha) resulted in pH increases beyond 15 cm depth seven years after application. Only systems that incorporated lime at depth and or mixed soils to depth through slotting/trenching resulted in significant crop yields and soil pH increases within the root zone (0 - 60 cm) immediately after being applied. The resultant crop yields where subsoils pH was modified were as much as 80% higher than the control.

**Key Words**
Acidification, limesand, application methods, amelioration.

**Introduction**
The sandplain soils on the south coast of Western Australia cover some 2 M ha and are widely used for agricultural production. The soils are naturally acidic. This combined with grain removal, acidic fertilizers and nitrate leaching has resulted in a reduction in soil pH within the root zone in farmed soils when compared to native soils. The rate of acidification is exacerbated by poor chemical buffering associated with low organic carbon (<1.5%) and clay (<3 %) contents. Consequently soil pH is declining from relatively low base with most cropped sandplain soils having a pH <5 within the root zone. Limesand (crushed native limestone) is almost solely used to ameliorate acidity on the south coast of WA. However limesand, being comparatively insoluble, takes time to increase soil pH at depth within the soil profile. In order to understand how to manage soil acidification a series of experiments were conducted on the Esperance sandplain between 1999 and 2009. The aim of this research was to measure soil pH changes over time in soils treated with limesand applied at different rates and application methods.

**Methods**
Three experiments were established between 1999 and 2006 (Table 1). Each of the experiments was statistically designed as a randomised block with three replicates. The three experimental sites were located within 50 km of Esperance, WA on grey deep sandy duplex soils which are classified under the Australian system as hypocalcic mesonatric Sodosols (Isbell 1996). These soils form part of the Esperance sandplain and consist of a fine sand A horizon overlying a sodic B horizon light to medium clay. The sands are often > 60 deep, have low organic carbon (<1.5 %) and cation exchange (<4 me/100g) within the Ap horizon with values decreasing with depth. Soil $pH_{Ca}$ commonly ranges from 4.3 to 5.5 with exchangeable aluminium less than 10 ppm. Two sources of liming material were used in the experiments, limesand and G Lime. The limesand was quarried at Dalyup (40 km to the west of Esperance) and had a neutralising value of 69% with 97% of particles less than 0.5 mm. The G lime, a by-product of cement manufacture, has a neutralising value of >85 % and 90% of particles less than 1 mm. For sites 1 and 2 the limesand and G lime were applied using commercial spreaders.

For site 3, limesand was either top dressed at rates of 1.6, 4.3 and 8.7 t/ha or incorporated to 60 cm depth within a slot. The slots were dug with a trenching machine with each slot 0.15 m wide and 0.6 m deep. Three slots per plot were dug along the length of the plot spaced at 0.5 m intervals. Limesand was added manually to the trenched spoil, mixed and manually incorporated back into each slot. Soil pH was measured in 0.1M $CaCl_2$ solution using the method of Rayment and Higginson (1992). Crop yields were measured at sites 1 and 2 using commercial harvesters and at site 3 using a ‘Kingaroy’ plot header with a 1.65 m wide front.

**Table 1. Site location, year established, treatments, plot sizes and sampling dates.**

| Site | Lat | Long | Established | Treatments | Plot size | Date Sampled |
|---|---|---|---|---|---|---|
| 1 | -33.6907 | 122.0977 | 1998 | Control<br>0.5 t/ha GL^<br>1.5 t/ha GL<br>1.5 t/ha LS*<br>3 t/ha LS | 20 m wide by 100m long | 11/2005 |
| 2 | -33.6910 | 121.9143 | 2001 | Control<br>1 t/ha LS<br>2 t/ha LS | 20 m wide by 100m long | 2007 |
| 3 | -33.6738 | 121.9676 | 2006 | Control<br>1.6 t/ha LS<br>4.3 t/ha LS<br>8.7 t/ha LS<br>Slots to 60 cm<br>Slots to 60 cm + 4.3 t/ha LS | 2 m wide by 20 m long | 6/2007<br>6/2009 |

* LS=Limesand ^GL = G Lime

## Results

Site 1 soil pH decreased by as much as 0.3 units to a depth of 25 cm when compared to the control after 7 years (Figure 1a). pH responses to G Lime and Limesand were evident at all rates applied with significant increases in soil pH recorded for the lowest application rate (0.5 t/ha) to the highest rate (3 t/ha) within the 0-10 cm layer at Site 1 (Figure 1a). Only the 3 t/ha treatment resulted in significant increase in pH below 15 cm, however, there was no significant lime effect on soil pH below 25 cm. At site 2 significant increases in soil pH were recorded for both treatments (1 and 2t limesand/ha) when compared to the control six years after the initial applications (Figure 1b). The rates required to change soil pH at a given depth were similar to Site1 in that the 1 t/ha treatment only increased soil pH to a depth of 10 cm where as the 2 t/ha significantly increased soil pH to a depth of 20 cm.

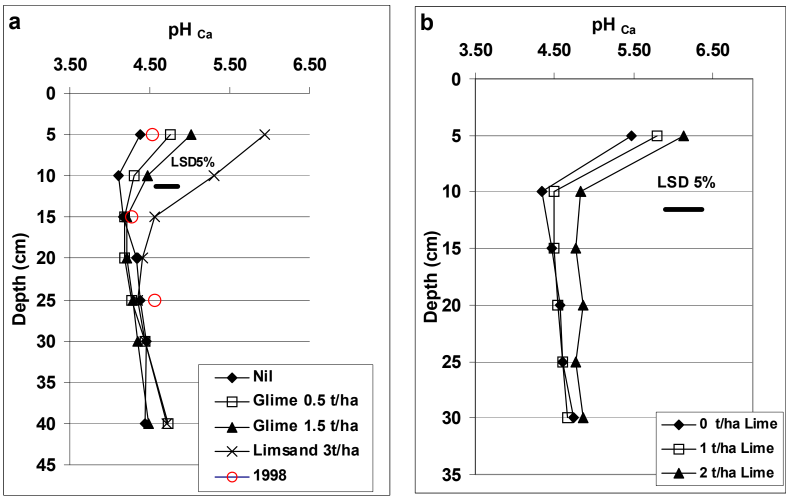


**Figure 1. Effect of lime application on soil pH with depth a) Site 1 - seven years after lime application b) Site 2 - six years after lime application.**

Crop yields were not affected by lime addition at either site in any of the years measured despite the changes in soil pH. Exchangeable aluminium levels were less than 8 ppm at all depth measured. The results also show that the higher the surface soil's pH the greater the depth soil pH was modified through lime addition. This data is consistent with current recommendations that maintaining soils at a pH 5.5 or more will markedly increase the depth to which the soil pH is increased with lime (Gazey pers. com). However, the results from both these sites highlight the problem of achieving significant increase in soil pH at depths greater than 25 cm in sandplain soils.

At Site 3 no differences in soil pH were found between the surface applied lime treatments in 2007. Slots with applied lime significantly increased soil pH to a depth of 60 cm (Figure 2a). In 2009, significant increases in pH were found due to surface applied lime only at a depth of 10 cm and where limes rates were greater than 1.6 t/ha (Figure 2b).

 
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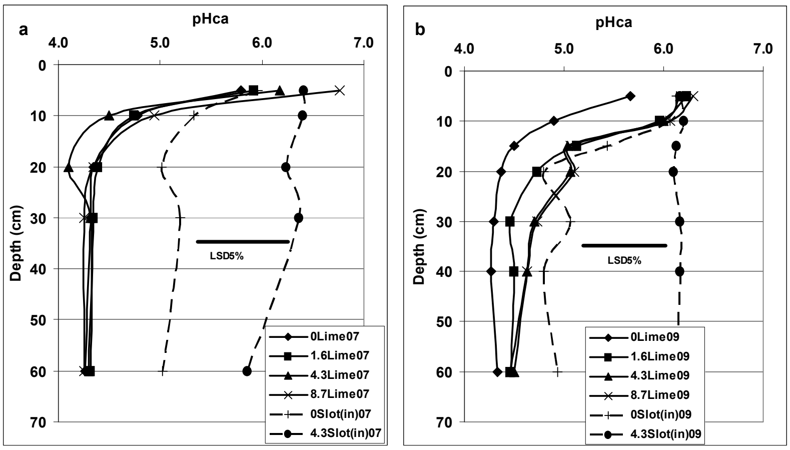


**Figure 2. Changes in soil pH with depth at site 3 measured in (a) 2007 one year after application and (b) 2009 three years after the application of differing lime rates and incorporation methods. Note that changes in pH were measured within the slots.**

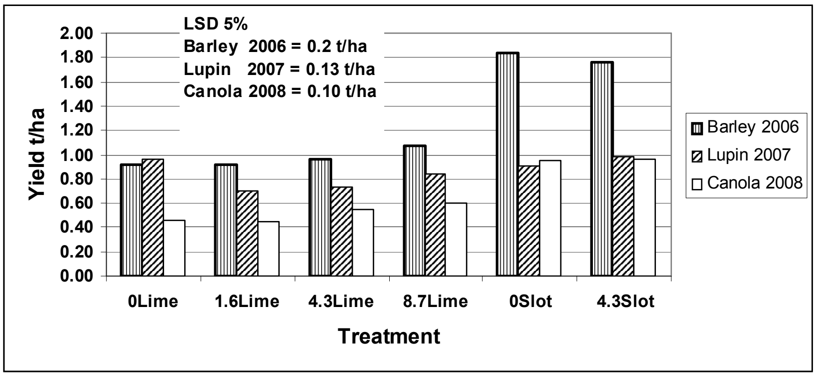


**Figure 3. Effects of surface applied lime and slotting treatments on barley (2006), lupin (2007)and canola (2008) grain yields.**

The slotted treatments increased soil pH to 60 cm depth both where lime had and had not been applied. Only the slotted treatments with lime resulted in significantly higher pH than the control deeper in the soil profile. Where lime had been applied in the slots then soil pH was increased by approximately 2 pH units. Significant increases in barley and canola crop yields were measured where the soil had been slotted to 60cm depth, regardless of whether lime was added or not. Canola yields were also increased ($P<0.05$) where lime was broadcast at rates greater than 1.6 t/ha. Lupins were the least responsive to the lime and slotting treatments.

## Conclusions

- South coast WA sandplain soils are inherently prone to acidification due to their parent material and low chemical buffering capacity.
- Soil pH declined by up to 0.3 units over 7 years within a standard cropping system..
- Surface applied lime increased soil pH to 25 cm depth when applied at rates exceeding 1.6 t/ha.
- The depth to which soil pH changes occur is related to amount of lime applied, initial soil pH and time since application.
- Both surface and deep incorporated lime increased barley and canola yields as a result of increased soil pH and reduced soil strength.
- Techniques for rapidly increasing the subsoil pH using deep tillage with lime applications can resolve subsoil acidity issues. However separating the chemical from the physical effects was not possible in this study.

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