# Getting the soil pH profile right helps with weed control and sustainability

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**Abstract**
Surface application of agricultural lime to treat acidity in the soil profile delivers multiple benefits to the broadacre dryland farming systems in Western Australia. Soil pH measured in 2009 to a depth of 40–50 cm was increased by applications of lime applied in 1991 and 2000. The ameliorated soil pH profile, which meets the Wheatbelt Natural Resource Management 2025 resource targets (Avon Catchment Council 2005) (designed to remove acidity as a constraint to productive agriculture), has provided multiple benefits in terms of increased productivity, increased crop competitiveness, reduced weed burden, reduced risk of soil erosion by wind due to increased biomass cover and potentially reduced off-site effects which result from decreased water use efficiency on profiles with low pH. Current annual losses due to soil acidity for the WA wheatbelt are estimated at between $300–400 million or around 9% of the total crop. The treated soil profile in this trial returned $175/ha benefit from increased wheat yield in 2008 and $225/ha benefit from increased barley grain yield in 2009.

**Key Words**
Soil Acidity, pH, lime, wind-erosion, weeds, wheat.

**Introduction**
Low soil pH is a significant and widespread constraint to dryland agriculture in Australia (Dolling 2001) and world wide (Sumner and Noble 2003). In the Western Australian wheatbelt it has been exacerbated by dryland agricultural practices, especially because the use of lime has not been common-place. Current estimates indicate that; 78 per cent of topsoil (0–10 cm) is below the soil $pH_{Ca}$ targets of 5.5, 25 per cent of the 10–20 cm and 18 per cent of the 20–30 cm layer is below the soil $pH_{Ca}$ targets of 4.8 in the agricultural area of the Avon River Basin which covers 8.3 million hectares or about 45 per cent of the WA wheatbelt (see paper by Andrew and Gazey these proceedings). Western Australian farmers consistently highlight the upfront cost of applying agricultural lime as a significant barrier to treating soil acidity (Fisher 2009). A short-term view of returns on investment dominates decision making and this approach is unable to adequately account for either, the long-term losses which accrue from allowing the profile to continue to acidify, the increased costs to ameliorate the degraded soil or, the long-term gains in productivity and other benefits which result from eliminating this economically manageable constraint.

Quantification of the impact of soil acidity on agriculture has typically been carried out by applying either high rates of lime, more reactive types of lime or more vigorous incorporation of lime in an attempt to ‘simulate’ the gradual removal of the soil acidity constraint by surface applications and time. Each of these experimental approaches has potential to abruptly change more than just the acidity profile. For example, high rates of lime and more reactive lime may change the availability of nutrients and/or the level of microbial activity. A better approach to determining the long-term benefits or implications of treating soil acidity is to follow the changes in long-term trials that span one or more decades. Conducting and managing such long-term trials is both expensive and resource intensive when carried out by department’s of agriculture and reduced investment in these areas has made such work rare. This paper reports the results from 2008 and 2009 gathered from a large-scale long-term trial initiated and managed by growers David and Alex Leake on their property located 17 km north of the WA wheatbelt town of Kellerberrin.

**Methods**
*Establishment and management*
Limesand, neutralising value of 90 per cent (Table 1) sourced from mobile dunes near the coastal town of Lancelin in WA (340 km away from the farm) was surface applied in 1991 at rates of 1, 2.5 or 5 t/ha to plots 15 m wide and 100 m long using a multi-spreader, a nil lime treatment (control) plot was left untreated in each of three replicates. The soil type is a Tenosol locally know as a yellow sandy earth (Schoknecht 2002).

**Table 1. Lime quality parameters for the same lime source used in the trial (Morris 2009).**

| Sieve Range (mm) | % weight | % Neutralising Value (NV) |
|---|---|---|
| 0.000-0.125 | 4.2 | 89.9 |
| 0.125-0.250 | 42.3 | 89.4 |
| 0.250-0.500 | 40.0 | 94.8 |
| 0.500-1.000 | 13.1 | 75.1 |
| >1.000 | 0.5 | 70.1 |
| Weighted Average NV | | **89.7** |

Lime from the same source was applied to the whole paddock including the trial area at 1 t/ha in 2000. The starting pH of the trial area based on soil test results taken around the same time was 4.8 in the surface and 4.5 in the 10–20 cm layer. The soil pH deeper in the soil profile was not measured at the time but is assumed to increase to around 5 which is typical for the soil type. The long-term rotation in the paddock was 2–3 wheat crops and one lupin crop on 25 cm row spacing.

*Soil pH measurement*

The soil profile to 50 cm in 10 cm increments was sampled in October 2009 using a 5 cm diameter steel tube. A sample was taken from each of 4 locations in each plot and corresponds with 2009 crop biomass assessment. Soil pH was measured in one part soil to five parts 0.01 M $CaCl_2$ which is the standard for WA.

*Crop assessment: 2008 grain yield and 2009 barley and weed biomass and grain yield*

Strips of crop were cut from within the large plots using a small plot harvester in 2008 and 2009, wheat and barley grain was weighed in the field and yield calculated. One half-meter squared quadrat consisting of two 1 m rows and inter-rows from each of four locations in each plot was cut at ground level and collected in October 2009, corresponding to maximum biomass for the barley. Each sample was sorted into barley and weeds. Dry biomass was weighed after oven drying the samples at 60 °C for 72 hours.

## Results and discussion

*Soil pH changes*

Lime applied in 1991 (with an additional 1 t/ha across all treatments in 2000) increased the soil pH to a depth of 30–40 cm when applied at the highest rate of 5 t/ha. This soil pH profile meets the recommended targets and productivity will not be constrained by the effects of low pH soil. The 2.5 t/ha lime treatment has a soil pH profile that is intermediate between the unlimed and the highest lime treatment and subsurface acidity is at a level where it is expected to affect productivity. The soil pH profile for the unlimed treatment and the treatment that received the least amount of lime 18 years previously were not different from each other (Figure 1). In previous years the soil pH profile in the 1 t/ha treatment would have been better than that for the unlimed treatment (but has now reacidified).

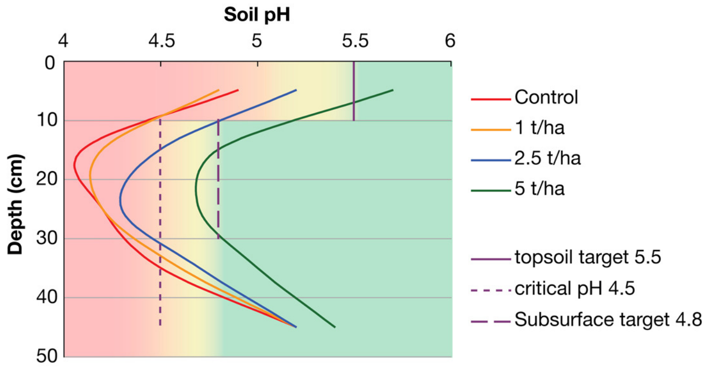


**Figure 1. Soil pH measured in 2009, 18 years after initial lime application.**

*2008 grain yield and 2009 plant biomass and grain yield*

Wheat grain yield in treatments receiving either 1 or 2.5 t/ha lime were not significantly different ($p < 0.05$) and produced about $100 per hectare more grain than the unlimed control. The treatment receiving 5 t/ha of lime was higher yielding again and produced about $175 per hectare more grain (Table 2). Treatment differences of at least this magnitude have been common during the life of the trial (D. Leake pers. comm.).

**Table 2. Wheat grain yield for lime treatments at Kellerberrin in 2008. Grain yields followed by the same letter are not significantly different ($p < 0.05$).**

| 1991 Lime treatment (t/ha) | Wheat grain (t/ha) | Relative to maximum (%) | Yield increase (kg grain/ha) | $ value of extra grain @ $300/t in 2008 |
|---|---|---|---|---|
| 0 | 2.92 a | 83 | | |
| 1.0 | 3.30 b | 93 | 330 | $99 |
| 2.5 | 3.20 b | | | |
| 5.0 | 3.50 c | 100 | 580 | $175 |
| LSD (P=0.05) | 0.19 | | | |

A significant wheat grain increase was recorded in the 1 t/ha lime treatment in 2008 despite the soil pH profile being similar to the unlimed control. Although weed numbers were not assessed in 2008 it was observed that the unlimed treatment had the most weeds. It is likely that the wheat did better in the 1 t/ha treatment because there was less competition for water and nutrients from the weeds. In previous years when the soil pH profile was less acidic, the crops would have grown better, more effectively competing with the weeds compared to the unlimed treatment and there would have been less build-up of a weed seed bank. The barley and weed biomass measured in 2009 (Figure 2) support the weed competition theory. Weed biomass decreased and barley biomass increased as the lime rate increased. Where soil acidity had been removed as a constraint to production (5 t/ha lime treatment) the total biomass increased by 1.6 times compared the unlimed acidic profile and the weed biomass was reduced to only three per cent of the total biomass.

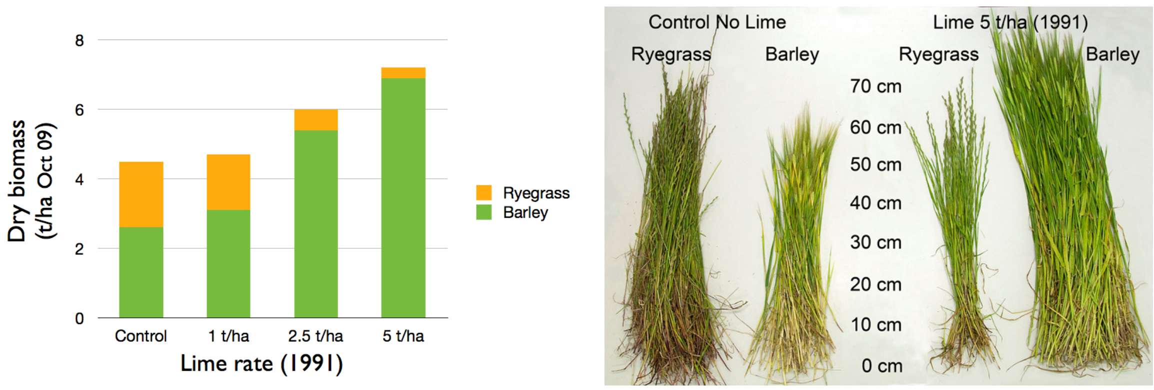


**Figure 2. Barley and ryegrass biomass from the long-term Kellerberrin lime trial in 2009. Note the barley plant size as well as total biomass differences (photo).**

Barley grain yield in 2009 increased almost linearly with the rate of lime application. Over three times the yield was recorded for the 5 t/ha lime treatment (non-limiting soil pH profile) compared to the unlimed acidic soil profile (Table 3)

**Table 3. Barley grain yield (feed quality) for lime treatments at Kellerberrin in 2009. Grain yields followed by the same letter are not significantly different ($p < 0.05$).**

| 1991 Lime treatment (t/ha) | Barley grain (t/ha) | Relative to maximum (%) | Yield increase (t grain/ha) | $ value of extra grain @ $148/t in 2009 |
|---|---|---|---|---|
| 0 | 0.70 a | 32 | | |
| 1.0 | 1.10 b | 49 | 0.40 | $60 |
| 2.5 | 1.76 c | 79 | 1.06 | $157 |
| 5.0 | 2.22 d | 100 | 1.52 | $225 |
| LSD (P=0.05) | 0.37 | | | |

## Conclusion

Managing soil acidity can provide multiple benefits to the farming system and the environment. Soil pH is the keystone to many of the so-called ‘soil health’ issues. A soil free of constraints imposed by low pH can support a wider range of rotation choices, increased productivity–both grain and biomass, better weed control, improved nutrient availability and cycling by microbial activity. Reduced soil degradation resulting from further acidification and potentially decreased soil erosion from wind due to increased biomass cover are also additional benefits.

Unfortunately, all too often, very few of these benefits are considered in an economic analysis of managing soil acidity when too much attention is directed towards ‘what will be the short-term return on investment?’ There is a need to improve the economic analysis to include the value of soil-services to adequately account for i) the cost of degrading the soil resource, ii) the cost of ‘loaning’ alkalinity from the resource (by continuing to farm without applying lime) and iii) the value of a maintained or recovered soil pH profile.
It is possible to purchase, transport (250 km) and spread 1 t/ha of 90 per cent neutralising value fine lime for $40 in the Western Australian wheatbelt.

**References**

Avon Catchment Council (2005). The Avon Natural Resource Management Strategy. The Regional Natural Resource Management Strategy for the Avon River Basin. (Avon Catchment Council). http://www.avonnrm.org.au/regional_strategy/documents/avon_nrm_strategy_2005.pdf

Dolling P (2001) Soil acidification: an insidious soil degradation issue. In: ‘Australian Agriculture Assessment 2001’. (National Land & Water Resources Audit) http://www.anra.gov.au/topics/soils/acidification/index.html

Fisher J (2009) Soil Acidity and liming focus group workshops 3–5 August 2009. (Désirée Futures Report 2009-01) *in press*

Morris C (2009) Code of Practice Product Information Sheet AgLime of Australia Lancelin limesand (Lime WA Inc.) http://www.limewa.com.au/Product%20Information%20Sheets/AglimeLancelin.pdf

Schoknecht 2002 Soil groups of Western Australia – a simple guide to the main soils of Western Australia Technical Report 246 Edition 3 (Department of Agriculture and Food Western Australia) http://www.agric.wa.gov.au/PC_92472.html

Sumner ME, Noble AD (2003) Soil acidification: the world story. In ‘Handbook of Soil Acidity’. (Ed. Z Rengel) pp. 1-28. (Marcel Dekker: New York).