How fast is lime moving and is it treating acidity at depth?

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KEY MESSAGES

- Surface applied liming will only move to address subsurface acidity if pH(Ca) in the topsoil is kept greater than 5.5
- Surface applied lime movement is very slow and may take many years to treat subsurface acidity
- Check the plant back period for legumes if using sulphonyl urea herbicides as surface applied liming makes the pH level in the top 2.5 cm high and will affect its break down

BACKGROUND

With concerns of acidity occurring at the 10-20 cm depth and the lack of production responses in trials using surface applied lime, SFS investigated how far and fast surface applied liming was moving at a Bellarine trial site and Woady Yaloak Catchment Group sites.

METHOD

Lime movement at the Bellarine lime trial was studied with regular soil sampling. Four 10 cm cores were taken periodically from each plot in the Nil treatment and the Lime 3t/ha treatment and divided into 2.5 cm increments. Treatments across the four replicates were bulked together and their pH tested using the $CaCl^2$ method. The soil was also tested in 10 cm increments.

Soil testing was done on six Woady Yaloak Catchment group lime trials where lime was surface applied in 2012. Four 30 cm cores were taken from each plot in the Nil treatment and the Lime 2.5 t/ha treatment and divided into three 10 cm increments. Treatments across the four replicates were bulked together and their pH and exchangeable cations tested. Soil pH results reported in this paper use the calcium chloride test which is approximately 0.7 units lower than the water method due to its consistency across seasons.

Lime movement in the first year

The soil test results across the site at the Bellarine site at the start of the trial showed the site was highly acidic in the topsoil and that pH increased with depth (see table 1). The soil pH in the 0-10 cm was 4.2 and is an average of pH values occurring throughout the 10 cm depth. Increment testing showed that the range within the 10 cm depth was from 4.3 in the top inch down to 4.1. Soil pH is generally always highest in the top 2.5 cm where most of the organic matter is found. Most lime responses occur when exchangeable aluminium exceeds 5% which becomes increasingly available as pH decreases.

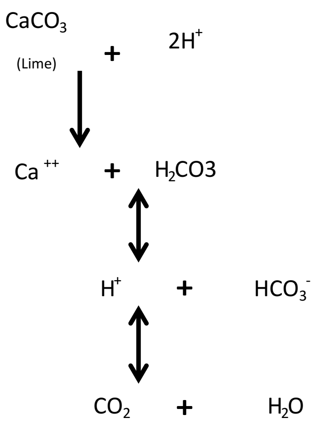
Table 1. Soil test results at the Bellarine trial site in 2014

Depth (cm)	Soil texture	pH ($CaCl^2$)	Exchangeable Aluminium%
0-10	Loam	4.2	17%
10-20	Clay Loam	4.4	10%
20-30	Clay	4.9	2.5%

Lime moved to about 5 cm after one year, which partly explains why lime responses are rarely seen in the year of application (see table 2). However yield responses were seen at this site due to its high acidity and acidity sensitivity of barley and canola grown in 2014 and 2015. This lime movement is similar to South West Sustainable Grazing System trials in the nineties (Nicholson, 1999) and reported in other trials, although in an un-seasonally high rainfall year, lime moved to 10 cm after one year in Department of Agriculture trials near Hamilton (Quigley et al, 1998). This last response was likely observed because of the high rainfall, with faster movement occurring from large leaching rainfall events which can wash particulate fine lime down soil macro-pores (Scott et al, 2000). The rate of lime movement at the Bellarine site is expected to slow in the second year possibly to about 1 cm per year.

The pH in the top 2.5 cm of soil increased to high levels (pH 6.2). This could have implications for growing pulses as there are extended plant back periods for legumes (22 months) with some sulphonyl urea herbicides as without acid conditions they are slow to breakdown eg. Logran (Hawthorne W, 2007).

Not all the lime dissolved in the first year and some was evident on the surface. The reason for this is that lime dissolves when there is moisture and acid soils. Most of the alkalinity is moved through the leaching of bicarbonate ions which is also governed by pH levels. How lime chemically breaks up in the soil and forms bicarbonate ions is complex and a description is given below courtesy of Brendan Scott, Research scientist from Charles Sturt University, NSW.



Reaction 1. In wet and acid soil, calcium carbonate in lime (CaCO3) breaks up into calcium and carbonic acid (H2CO3). This reaction can be rapid under acid conditions or extremely slow if pH(Ca) is greater than 5.8 (Whitten, 2000).

Reaction 2. Carbonic acid (H2CO3) can convert into bicarbonate ions (HCO3-). This is a two way reaction. Carbonic acid only converts into bicarbonate ions when the pH is greater than 5.5. When it's less than this the carbonate stays in the form of carbonic acid and you can get downwards movement of acidity.

Reaction 3. Bicarbonate ions react with excess hydrogen ions (H+) that were causing acidity to become chemically bound in water and form gaseous carbon dioxide. Any excess bicarbonate ions (alkalinity) are leached downwards in the soil solution to the next soil layer and the reactions are repeated.

The implications of lime movement is that in surface applied lime, the soil pH in the top 5 cm may be quite high but the pH in the next 5 to 10 cm may be much lower as the bicarbonate ions become all used up. It's expected at this site that because of the high acidity in the topsoil that the 3 t/ha of lime will be all used up before it even reaches 10 cm depth.

The way lime dissolves and moves has implications for getting fast responses from surface spreading or banding lime rather than mixing it evenly throughout the soil as the pH can become too high for the chemical reactions to occur and a proportion of the lime will sit there undissolved until the soil becomes more acid. Large clumps of lime (approximately 5 mm diameter) have been observed to remain intact for at least 20 years surrounded by high soil pH.

Temporal soil pH variation can occur following unseasonal conditions such as long hot dry periods and this can be up to 0.45 pH unit. This is evident in the site testing in March were the pH is recorded at 4.4 after previously been 4.7 in October. Therefore soil test results taken in unseasonal conditions should be used to guide decisions rather than be relied on to make precise decisions.

Table 2. Soil pH change at different times at the Bellarine lime trial site where lime 3 t/ha was applied April 2014.

Depth	Starting pH April 2014 before lime 2014	June 2014 (2 months after liming)	August 2014 (4 months after liming)	Oct 2014 (6 months after liming)	March 2015 (12 months after liming)	June 2015 (15 months after liming)
0 - 2.5 cm	4.3	4.6	5.0	5.5	5.4	6.2
2.5 - 5cm	4.1	4.4	4.4	4.7	4.4	4.7
5 cm - 7.5 cm	4.1	4.2	4.1	4.5	4.4	4.2
7.5 - 10 cm	4.2	4.3	4.2	4.3	4.3	4.2

Lime movement after three years

Trials established by the Woady Yaloak catchment group in 2012 and now monitored by SFS show that surface applied lime has not moved after three years into the 10-20 cm soil layer (Table 3). This highlights the problem with soil testing only in the 0-10 cm as it creates a false impression that acidity has been successfully treated with liming when often it has not.

This slow lime movement is not unusual, where trials show surface applied lime taking between 2 to 15 years to move beyond 10 cm (Scott 1992). We anticipate that after 4 to 5 years the pH change might only occur at the 10-15 cm depth, involve only minimal pH change and only on those sites with pH greater than 5.5 in there topsoil.

The Pittong site on granite soils is a good example of how the underlying subsurface acidity can constrain production even though the topsoil acidity has been addressed. The exchangeable aluminium increases from 2% at 0-10 cm to 17% at 10-20 cm and 20% at 20-30 cm. To date this site has shown no yield responses to lime and this is because the lime has not yet reached this acidic layer.

Table 3. Soil pH change recorded in autumn 2015 in surface applied lime 2.5 t/ha (autumn 2012) and un-limed plots in Woady Yaloak Catchment Group trials

Site	**Illabarook**		**Pittong**		**Mt Mercer**		**Werneth**		**Rokewood North**		**Rokewood West**	
Type	Pasture		Pasture		Pasture		Crop		Crop		Crop	
Texture & Geology	Sandy loam Sedimentary		Sandy Loam Granite		Clay Basalt		Clay loam Basalt		Loam Alluvial		Clay Loam Basalt	
Starting pH in 2012	4.9		5.2		4.8		4.7		4.8		4.8	
Depth (cm)	**Nil**	**Lime**	**Nil**	**Lime**	**Nil**	**Lime**	**Nil**	**Lime**	**Nil**	**Lime**	**Nil**	**Lime**
0-10	5.3	6.2	5.1	5.5	4.9	5.6	4.5	5.2	4.6	5.6	4.7	5.4
10-20	4.9	4.8	4.6	4.6	4.7	4.8	5.1	5.0	4.8	4.8	5.1	5.1
20-30	5.1	5.1	4.5	4.5	4.9	4.9	5.8	5.7	5.3	5.1	6.4	6.5

Under what conditions do we achieve lime movement?

We have commonly used soil pH(Ca) of 5.0 in the topsoil to trigger liming and although this helps avoid yield losses it does not create enough excess alkalinity to prevent subsurface acidity. It is advised to target a soil pH of 5.5 in the topsoil (0-10cm) to allow lime movement down the profile to ameliorate subsoils (Hollier 1999). This is particularly relevant if surface liming and there is an acidity issue at depth. The pH target for alkalinity movement is based on the formation of bicarbonate ions which is controlled by pH levels. Soil pH in the subsurface and subsoil depths should be kept greater than soil pH 4.8 in to avoid yield losses mainly caused by aluminium toxicity.

There was evidence of lime movement in six Corangamite soil monitoring program paddocks which histories involved having lime applied 3 to 10 years earlier than soil testing and often in multiple applications. These paddocks had subsurface soil pH levels above 4.8 seemingly as a result of having kept topsoil pH above 5.5. This was in contrast to 11 paddocks that had also been limed but their topsoil pH was less than 5.5 and they still had subsurface acidity issues. Evidence of lime movement has been reported in many trials and shown to occur in the long term liming trial at Wagga Wagga which commenced in 1992 and specifically looked at lime movement from the topsoil to the subsurface and under what pH levels this occurred (Li et al, 2010).

The implications are that if producers want to only broadcast lime then they need to apply lime more frequently to keep pH levels above 5.5 within the topsoil. If yield is being limited by subsurface or subsoil acidity then surface applied lime is not going to fix it quickly. To get a fast response then producers will need to place the lime where the acidity is and this will mean some type of incorporation. SFS plan to establish two demonstration sites using different incorporation methods in 2017 with GRDC support.

ACKNOWLEDGEMENTS

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