Applying high rates of lime lifts sub-soil pH on Morawa loams

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Key messages

- Subsoil acidity is a serious threat to crop production in WA, this is not widely enough appreciated – do a test!
- While tillage will speed amelioration of sub-soils, it may not be essential if high rates of lime are used over time
- Lifting the surface pH above 5.7 ($CaCl_2$) enables dissolved lime or bicarbonate anions to move to depth over time
- Applying 5-8 tonnes over 6 years has increased subsoil pH by 1.2 units at 10-20 cm and 0.6 units at 20-30 cm

Aims

Share the experience of applying large rates of lime without using tillage and retaining stubble to determine the rate of lime movement through time in red and yellow loamy soils of NE Morawa in a low rainfall zone.

Background

The Crabtree Morawa farm, of 2,800 arable hectares, was purchased in October 2007. It is located on the eastern fringe of the agricultural zone in 305 mm annual average rainfall (100 years) 190 km ESE of Geraldton (see map). The farm was cleared from 1922-1960 of predominantly York Gum eucalyptus trees with a naturally slightly acidic soil pH.

Surface pH ($CaCl_2$) soil test results that were taken in March 2008 showed an average pH of 5.3 from 12 sites, with only 3 sites having a low pH of 4.6, 4.8 and 4.9. At this time sub soil acidity was not thought of as limiting farm productivity. The farm experienced annual rainfall deciles from 2008-10 of 5, 4 and 1 and then in 2011 a wet decile 9 year occurred. However, some areas were performing very poorly, especially on the lighter soils. Hence, some targeted topsoil sampling was done and identified these areas had low pH. Two applications of lime, from Aglime Dongara, were applied to the acid areas in 2009 and 2010, totalling 3t/ha.

During the wet 2011 year, some 470 mm was recorded, there were poor yellow patches of the crop observed in most paddocks in June. These anaemic patches had 100 kg/ha of ammonium sulphate topdressed in July in an attempt to mitigate crop yellowing. Despite good rains falling after this fertiliser application these areas remained yellow until crop maturity. This fact suggested that subsoil acidity and aluminium toxicity was most likely the reason for the severely reduced root growth in these areas. Giving the usual rainfall pattern of a dry August and September in the region, exploiting water and nutrients in the sub soil is very important for grain filling and optimising crop yield potential.

Subsequent discussions with Chris Gazey suggested deep sub soil pH tests could be done with some financial assistance from the Australian Government's Caring for our Country project working with SoilTech. Some 34 GPS marked samples were taken from 3 depths being 0-10, 10-20 and 20-30 cm depth in February 2012. The sub soil tests were replicated 3 times from each site and bulked and sub-sampled for pH.

These pH soil results revealed widespread subsoil acidity, 83% of sites had soil pH in the 20-30 cm soil layer being less than 4.8. Many of these sites were from the areas where the crop did not yield in the wet year of 2011. Chris Gazey et al. (2014) has used these farmer surveys to illustrate the widespread occurrence of sub soil acidity in WA. This result prompted the application of 2 t/ha of lime on half of the farm, with a total of 2,650 tonnes applied immediately from March until May 2012. Further lime applications of 2 t/ha were applied on the most acidic soils at the end of harvest in 2012, 2013 and 2014. The intention was to apply high rates of lime to increase the surface pH to above 5.7 to maximise movement into the sub soils being 10-30 cm deep.

The years from 2012-14 were rainfall deciles 1-3 (dry to very dry) and then at the start of 2015 three intense 60 mm rainfall events fell 3 weeks apart starting 31 January. Most of these intense daily rainfall events penetrated the soil due to 8 years of continuous no-till with 100% residue retention. Some of the heaviest soils had low residue levels which allowed some water from the third event to run-off. We speculate that these rains helped the lime the move to depth.

Methods and Results:

Given that up to 8 t/ha of lime had been applied to some areas of the farm from 2012-2014 it was dissapointing that crop yields were still relatively poor in these areas. Hence, it was concluded that much of this applied lime probably remained undissolved in the surface soil. Cultivation does increase the ability of the soil to react with the lime making more dissolved lime, bicarbonate anions, available to be leached into the sub soil. So in April 2015 single disc ploughs were purchased and every second disc removed to ensure deep mixing of the limed topsoil. However, after a week of frustration with back-packer labour ploughing the paddock and as a result it became very rough, the ploughing was abandoned for the year. It was then decided that repeat soil tests should be done before more tillage was done.

Pleasingly, improved crop yield in 2015 was observed where they previously grew poor yielding wheat crops. This was despite a dry spring (17 mm of rain falling in August and 1.5 mm of rain falling in September) which followed 72 mm in July. With a 1.3 t/ha final average wheat crop in 2015, funds were available to invest in worth of soil tests by repeating the 34 soil tests undertaken in 2012 and adding another 20 sample sites. This time all the sites were sampled to 50 cm in 10 cm increments. In November 2015, after harvest, SoilTech returned to the same GPS co-ordinates and repeated the soil tests, but to 50 cm.

Applied lime; amount, quality and cost: The amount of lime-sand applied to these 34 sites varies from 5-8 t/ha over a 5 year period. The quality of the lime is excellent, coming from the Aglime pit in Dongara. A typical neutralising value of this lime is 94 to 95%.

The purchase cost of the lime is about $7/t and $17/t cartage to the farm. Application cost is perhaps $6/t, with farm labour (often myself) using a Scania truck with a 9 tonne Bredal spreader, usually covering 10 m width. The spread cost of applied lime therefore totals about $30/t.

Soil pH in the 20-30 cm soil test results revealed a large increase with 67% of sites having soil pH greater than 4.5 (Figure 2). Although 10 sites still have soil pH < 4.2. The average increase in soil pH for the depths 0-10 cm, 10-20 cm and 20-30 cm is; 0.9, 1.2 and 0.6 (Figure 3). This is a very pleasing result. The low critical pH level of 4.8 has been achieved at all depths, on average over the farm.

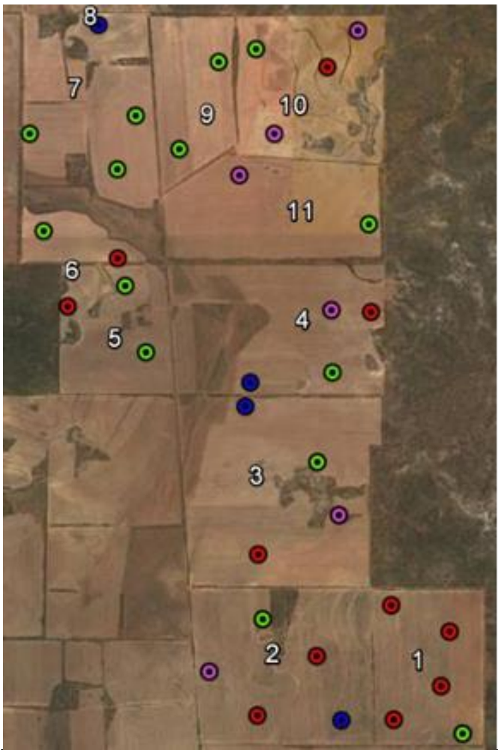


Figure 1: Soil pH ranges for the 20-30 cm soil layer 3.8-4.0 ●, 4.0-4.2 ●, 4.2-4.5 ●, >4.8 ● in January 2012,

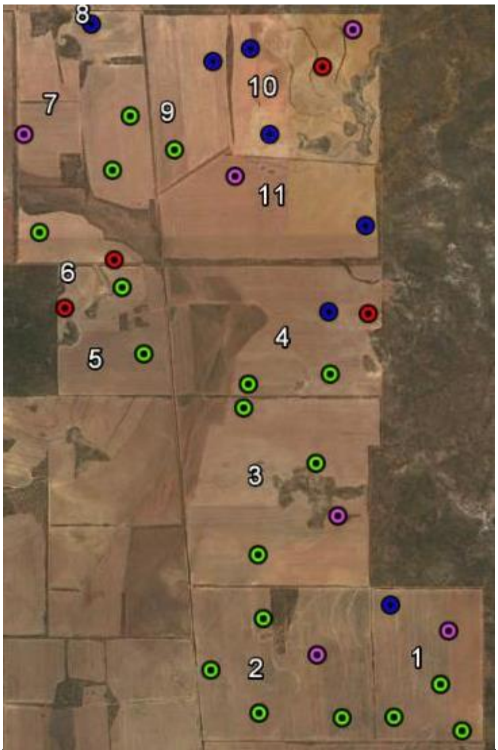
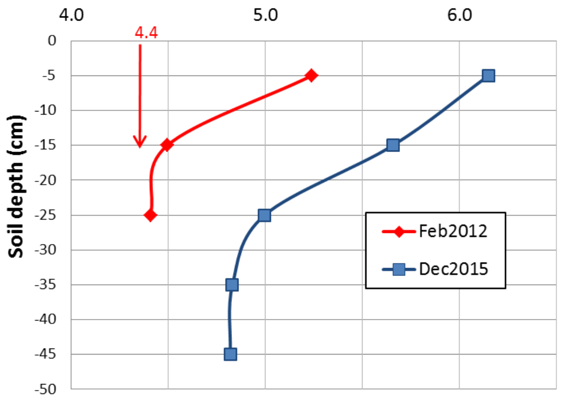


Figure 2: Soil pH ranges for the 20-30 cm soil layer 3.5-4.0 ●, 4.0-4.2 ●, 4.2-4.5 ●, >4.8 ● in December 2015.

The blue line in the graph in figure 3 clearly shows the improved sub soil pH on the limed soils. While the topsoil and subsoil (10-30 cm) has been strongly improved, further deep sub soil tests in December 2015 show that 39% of all the sites (21 of 54) have a soil pH of 3.8-4.2 in the 40-50 cm soil layer. Deeper soil sampling, below 30 cm appears to be important for identifying these areas of deep sub soil acidity.

While lime movement has been successful on most areas, over a 5-6 year period, it has not been successful on paddock 10 (Figure 4) where crop growth has also been limited also by low soil P and organic matter. These areas are likely destined for deep grizzly ploughing in 2016, but certainly at least another 2 t/ha of lime.

Fig 3: Soil pH change with depth & time (4 ys) at the Crabtree Morawa farm (avg 34 sites)



Conclusion

This work gives encouragement for farmers to test for subsoil acidity in loamy soils; it may well be a sleeping giant causing poor crop yields. This data shows that farmers can overcome severely acidic subsoils by applying large amounts of lime and allowing rainfall to move the lime to depth in a no-till and 100% stubble retention system. This data is consistent with that of Flower and Crabtree (2011) who found that on sandier Tammar soils at Meckering that 2-4 t/ha of applied lime was able to significantly lift subsoil pH without the use of tillage.

It is acknowledged that the cost of applied lime is significant and will vary for farmers based on their distance to quality lime. There is also a cost associated with tillage to incorporate lime if that strategy is employed. If more financial strength existed on the Crabtree Morawa farm then perhaps a more aggressive tillage strategy may have been employed several years ago and would likely have returned immediate good lime responses.

Some 45% of the WA wheatbelt soils has subsoil pH (10-30 cm) of less than 4.8 prior to 2012 (Gazey et al; 2013). Despite this result most farmers are not testing their subsoils. Indeed, it is estimated than less than 30% of farmers that conduct soil tests are testing for subsoil pH in WA (Wes Lefroy, pers com). It also shows that severe subsoil acidity can be rectified in loams through time without tillage provided high levels of lime are applied and given several years of even modest rainfall.

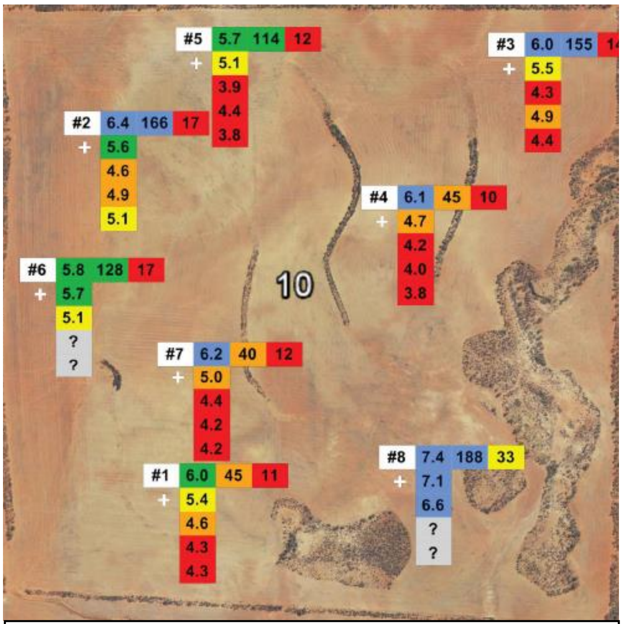


Figure 4. Soil fertility in Dec 2015 in the problem paddock #10 at 8 sites, showing pH values at 10 cm depth increments (vertical numbers) and K and P ppm levels horizontal (CSBP soil test results).

Key words

Lime, acidification, sub-soil, wheat, pH, Western Australia.

Acknowledgments

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