Lime incorporation into acidic subsoils – assessing cost, efficacy, value and novel approaches

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Key messages

1. Several options exist to ameliorate subsoil acidity with incorporated lime. The method chosen will depend on pH profile, yield potential, budget, area affected, soil type and occurrence of other constraints that may be impacted.
2. Modified deep ripping techniques can incorporate more topsoil and surface applied lime while at the same time effectively removing subsoil compaction.
3. Applying adequate lime to ameliorate the soil pH profile to depth is of utmost importance and the rate of lime applied should not be compromised to pay for incorporation, although lime applications can be split with some applied before and some a year or two after incorporation.

Aims

To provide an overview and improve understanding of the range of tillage implements available to growers to incorporate lime, their respective costs and benefits and to assess novel options.

Method

Surface applied lime can take many years to ameliorate subsoil acidity. Ongoing acidification has resulted in lower subsoil pH's and the depth of the acidic layer is increasing. This has generated renewed interest in one-off lime incorporation using strategic tillage to reduce the time required to ameliorate the subsoil acidity and to get a more rapid return on investment from applying lime. Effective amelioration of subsoil acidity requires the creation of continuous pathways of pH corrected soil from the soil surface through the acidic subsoil layer.

This paper examines the work of a number of research and demonstration sites that have been implemented in the last few years (Table 1) to look at lime incorporation methods using various implements and the efficacy with which the lime has been mixed through the soil profile.

Table 1. Trial Details

Lime incorporation trials established in 2013-14 and tillage implements used for the purpose of this overview.

Site No.	Location	Soil type	Trial type	Incorporation implements tested	Funder
1	Dandaragan	Deep yellow sand	Replicated	Shallow leading tine ripper, Modified ripping (3 methods), Grizzly deep digger	COGGO
2	Dandaragan	Deep yellow sand	Demo	Deep ripper, Grizzly deep digger, Grizzly offsets, Spader, Modified blade plough	COGGO
3	Dandaragan	Deep yellow sand	Replicated	Mouldboard, Spader, Deep Ripping, Scarifier, Offsets, One-way Plough, Deep rip + Spader	GRDC
4	Badgingarra	Pale sandy gravel	Demo	Offsets, Offsets + Deep Ripping	GRDC
5	Nungarin	Deep yellow 'Wodjil' sand	Demo	Offsets, Deep Ripping, One-way Plough, Spader	GRDC
6	Carnamah	Deep yellow sand	Replicated	Offsets, Spading, Mouldboard, Top Down,	NACC

Efficacy of lime incorporation has been visually assessed using universal pH indicator on soil pit faces or in some cases by soil sampling to measure the soil pH. In this paper grain and pasture productivity will not be reported as an indicator of successful lime incorporation as the responses are confounded by cultivation effects and responses can take some years to develop depending on the starting pH and soil variation. The more acidic the pH and the higher the soil aluminium levels the more likely there will be large crop growth and yield responses from overcoming the acidity constraint with incorporated lime.

Results

The efficacy with which various implements can incorporate surface applied lime depends on numerous factors including:

- Soil type, in particular clay content, which can affect the cohesion, fracturing and flow of the soil.
- Soil moisture conditions – in sandplain soils moisture can help the sand maintain its form (greater cohesion) allowing slots to remain open for longer but may reduce fracturing and soil flow. Wetter soils are softer so this can improve the penetration of soil by implements and reduce the draft. Dry surface sand flows easier when worked (less cohesion) which can be an advantage for moving limed topsoil behind soil openers. Optimal movement probably occurs when there is some subsoil moisture but the limed topsoil is dry and can readily flow into the fractured subsoil.
- Implement type – variations between machinery brands such as width of tines, curved or laid-back tines which may promote a lifting (delving) action; curvature (dish depth) of discs are just some examples.
- Implement setup and use – for disc ploughs and mouldboard ploughs setup greatly influences the incorporation result. Having ploughs more open will increase the work rate and the space between ploughshares available for soil to move but may limit the working depth.
- Speed of operation – higher speeds can result in more soil throw and mixing but may require a shallower working depth.

Table 2. Efficacy Summary

Details of tillage implements and a summary of their efficacy when assessed for lime incorporation.

Incorporation implement (approx. cost range $/ha)	Overview of tillage by implement	Typical working depth (cm)	Depth of lime incorporation achieved (cm)	Lateral spread of lime and incorporation efficacy
Deep ripping ($45-55/ha)	Narrow strong deep working tines used to break out subsoil compaction	30-40	10-15, variable	Limed topsoil tends to be mixed in the surface layer where the tine passes through but generally the slot behind the tine closes rapidly so there is little opportunity for limed topsoil to fall deeper into the subsoil
Shallow-leading tine ripping ($40-50/ha)	Ripping with shallow leading tines allowing deeper break out by deeper working, trailing tines	40-50	10-15	Limed topsoil can be incorporated better due to multiple tines disturbing the soil in the one pass, although incorporation is still limited as tines are narrow and slots close rapidly behind the tines
Ripper with wings ($45-55/ha)	Wings mounted on ripper tines that operate below the soil surface when ripping which creates greater soil disturbance as they tend to lift subsurface soil	30-40	20-25	Limed topsoil can flow into the space opened up via the lifting (delving) action of the wings. Lateral incorporation is improved with ‘tongues’ of topsoil up to 8 cm wide on either side of the ripping tine where the wings had passed.
Ripper with ‘Horwood’ opener ($45-55/ha)	Plates extend behind the ripping tine to hold open the soil slot longer operating just below the topsoil	30-40	20-26	Holding the slot open for longer below the soil surface allows limed topsoil to drop into the subsoil. A continuous seam of limed topsoil was achieved but the slot narrowed with depth being only 1-2 cm wide at depth.
Ripper with ‘Railway Fishplate’ opener ($50-60/ha)	Plates bolted onto the side of the ripper tines effectively increased the tine width and the degree of soil disturbance	30-40	19-23	More disturbance resulted in more mixing. Width of mixing was increased up to 14 cm in some instances but this was variable.
‘Deep digger’ ($60-70/ha?)	Large wide curved tines in a V-shaped arrangement capable of ripping deeper than standard deep rippers	40-60	23-25	Wider tines and some delving action allows some topsoil flow around and behind the tines but overall incorporation is fairly minimal for cost. Tines would need to be modified to achieve better incorporation.
Offsets ($40/ha)	Standard offset (two-way) discs that cultivate the topsoil	10-15	10-15	Very little limed topsoil is incorporated into the subsoil layers due to inadequate working depth. Mixing will still improve the reaction of the lime in the topsoil that may then allow for faster lime movement into the subsoil.
Large offsets ($50-60/ha)	Large offset (two-way) discs, typically greater than 70cm in diameter, that can cultivate deeper than standard offsets	24-25	24-25	Limed topsoil is effectively incorporated to the working depth. Some layering occurs on an angle from the surface but generally the mixing is good. Visually it appears about two-thirds to three-quarters of the profile is treated to the working depth. The incorporation depth can be less if hardpans or gravel layers prevent disc penetration.
One-way plough	Discs throw the soil one-way, can achieve partial turning of	15-25	15-25	Limed topsoil is partially mixed and layered on an angle from the surface because of the

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($30-40/ha)	the soil but mixing occurs as soil tumbles off the disc.			cultivation process. Despite partial inversion and layering continuous pathways of limed topsoil are still available for root growth. About half to two-thirds of the topsoil is buried. Can bring acidic subsoil to the surface so more surface lime may be required post-ploughing.
Modified blade plough ($40-50/ha)	Lifting plates attached to back of the blades lifts soil up to then roll off the back and sides of the plates	21-23	20-23	Effective in mixing limed topsoil to the working depth in reasonably wide seams, 10-15 cm wide, spaced about 15 cm apart.
Rotary spader ($120-150/ha)	Rotating spades bury some topsoil while lifting up some subsoil. About two-thirds of the topsoil is buried below 10 cm. Soil tends to take on marbled appearance.	28-35	28-35	Very effective at mixing limed topsoil into the subsoil. Does lift some acidic subsoil to the surface so additional lime may be required in subsequent years. Because spades are offset and overlapping lime is incorporated through the entire profile to the working depth, although pockets of acidic subsoil may remain.
Mouldboard plough ($100-150/ha)	Curved mouldboard shares lift, roll and invert the soil aided by skimmers that scalp the topsoil into the base of the furrow. Square ploughs achieve a similar result.	28-35	28-35	Inversion buries limed topsoil in a layer and can bring a thick layer of acidic subsoil to the surface that needs treating with more surface-applied lime. Continuous ameliorated pathways are not always present if inversion has been effective.
‘TopDown’ plough (>$100/ha?)	A combination of leading offset discs then curved ripping tines, levelling discs and packers.	20-35	20-25	Off set mixes well through to their working depth. Curved ripping tines then open a slot allowing surface soil to fall in to 20-25 cm. This incorporation is a broad ‘V’ shape beginning at the width of the tine at the surface and finishing to a point at 20-25 cm. The curved tines also lift acidic sub surface soils to the surface in seams. Not as effective in gravelly soils or soils with hard pans or layers that are difficult to penetrate.

The more expensive implements, such as rotary spaders, mouldboard and ‘TopDown’ ploughs and large offsets are more effective at getting large amounts of limed topsoil to depth but with a higher capital and operating cost (Table 2). Modified deep rippers and one-way ploughs (Table 2) tend to be cheaper and can provide seams of limed topsoil to depth for much lower cost. Productivity responses may not be as large when only part of the acidic soil profile has been fixed, though this depends on spacing of the ameliorated seams.

Conclusion

Deep ripping is still a common practice for many growers with deep sandplain soils in order to remove subsoil compaction and increase productivity. Deep ripping is typically done before seeding wheat and the frequency of ripping can range from every 2 years out to 5 or more. In these studies the possibility of incorporating more limed topsoil when deep ripping was investigated in order to increase the benefits associated with an existing tillage practice. So far the findings indicate that an opener behind the ripping tine that holds open the slot allowing more limed topsoil to fall into the subsoil can successfully create continuous, but relatively narrow pathways for root growth. Increasing the width of the slot and holding it open for a greater distance behind the tine using a larger opener may improve this amount of limed topsoil incorporated into the subsoil. Addition of wings to the ripping tine and increasing the width of the tine also helped but the limed topsoil did not get as deep although the seams were often wider. Deliberate dragging or pushing of limed topsoil into the slot using harrows, wings or smaller tines is yet to be investigated. Deep ripping approaches typically leave some soil cover so the wind erosion risk is reduced compared to the spader, mouldboard and other ploughs, which completely remove the soil cover and expose the soil to wind erosion.

Large deep working offsets and the modified blade plough also proved quite effective in incorporating significant amount of limed topsoil. Smaller lighter offsets and deep ripping approaches without the deliberate use of openers, wings or other additions were not very effective.

Other approaches not assessed here are also being considered or actively developed. Where cost of ripping is prohibitive, deep working points at narrow row spacing (< 20 cm) and working at reasonable speeds does provide soil mixing and lime incorporation to 12-15cm. Growers are modifying one-way ploughing techniques using fewer and larger discs to provide greater working depth with greater soil inversion that has advantages for weed control and reducing water repellence.

Combining tools or tillage approaches may also offer additional advantages. For example, an initial pass with offset discs to mix the surface-applied lime more evenly through the topsoil followed by deep working tines with openers that allow deeper movement of the now loosened topsoil deeper into the subsoil is likely to be more effective. This is the principle behind some one-pass tillage systems, such as the Vaderstad 'TopDown' plough, which combines offset discs, deep working tines, levelling discs and packers on the one tillage implement.

The cost of one-off tillage to incorporate lime can vary significantly ranging from about $30/ha if using a second-hand one way disc plough through to >$150/ha if using a rotary spader, excluding the cost of lime. For growers already deep ripping to remove subsoil compaction trying to create seams of limed topsoil through the addition of simple openers may be a cost-effective way of starting to address the problem although several years of deep ripping may be needed to create sufficient pathways to benefit the entire crop. Seams of limed soils also means there are still large curtains of unlimed soil that limit root exploration for nutrient and water uptake that may still limit grain production. Large offset discs or one-way ploughs are also likely to be cheaper and yet quite effective provided they can achieve good soil penetration and working depth. Rotary spaders are the most effective at incorporating lime throughout the whole profile to the working depth but the slow work rate, high cost and applicability due to soil type (e.g. rocks and roots) limits their use.

It is critically important to sample soil pH to depth prior to investing large sums in lime application and incorporation. Typically it has been found that on sandplain soils the yield benefit of one-off deep cultivation or deep ripping is large enough to cover the cost of the tillage in the first year so the subsequent productivity benefits associated with more rapidly fixing the soil pH by incorporating lime can be realised sooner. Other factors such as water repellence, herbicide resistant weeds, subsoil compaction, wind erosion risk and soil type will impact on the choice of incorporation implement used.

Key words

Subsoil acidity; Lime; Lime incorporation; Plough; Deep ripping; pH

Acknowledgments

Thanks to West Midlands Group, Peter and Daisy Negus, Scott and Ian Bowman and Neil and Jason Davis for hosting and managing trials. Thanks to David Paish helping make the ripper openers and Peter Horwood for the design. The support of McIntosh and Son machinery in Moora, Cunninghams Ag Services machinery in Three Springs, Rohan Broun, Shane and Greg Jolly, Glen and Todd Quartermaine, Hutton and Northey machinery in Mukinbudin, Aim Machinery in Merredin, AgLime of Australia is greatly appreciated.

COGGO Project: Developing and testing innovative, practical and reliable methods for incorporating lime into acidic sandplain subsoils – West Midlands Group

NACC Project: Demonstrating innovative practices for the amelioration of sub surface Acidity to improve soil health; 1412-05-01

GRDC Project Numbers: LIE0008 Working together to deliver multiple benefit messages to growers through a whole systems approach to soil management; DAW00204 Developing agronomic strategies for water repellent soils in WA; Kwinana-East RCSN Project - Developing and testing innovative, practical and reliable methods for incorporating lime into acidic sandplain top and subsoils in the eastern wheatbelt, Synergy Consulting; DAW00236 Soil acidity is limiting grain yield.

Paper reviewed by: Wayne Parker (DAFWA) and Ross Brennan (DAFWA)