Incorporating lime in order to ameliorate subsoil acidity faster

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Key messages

- Mechanical lime incorporation, using tillage implements suitable for the soil type, enables subsoil acidity to be improved at a faster rate than simply surface application.
- Tillage also addresses other soil constraints and improves crop yield, particularly in the first year on deep sands in medium to high rainfall areas.
- In low rainfall areas on gravel soil and red loam the best return on investment was lime only

Aims

To assess the benefits of lime incorporation on a range of different soil types to improve crop productivity, profitability and soil properties, in particular subsoil acidity.

Introduction

Soil acidity is a significant issue that needs addressing in the wheatbelt with 72% of topsoils and 45% of subsurface soils being below the pH target (Gazey et al, 2014). Lime application is required and, in many areas, the rate that is spread is not high enough and is only applied to the surface. As a result, these areas have acidic subsoils as well as topsoils.

Many growers realise the need for lime to be spread across their properties to address soil acidity issues. Unfortunately the delayed response to surface-spread lime has meant that subsoil acidity remains a large problem even after lime has recently been spread, particularly when lime rates being spread are still below rates required. This project investigated the benefits of incorporating lime sand further down the soil profile to address subsoil acidity at a faster rate.

Method

The effect of lime incorporation on sub soil acidity was investigated across different soil types, using available tillage implements appropriate for the soil type (Table 1). These trials were carried out as large scale farm demonstrations using limesand from Dongara with NV of 94% and two thirds particle size <0.25mm and the other third 0.25-0.5mm. Carnamah involved different lime rates being spread perpendicular to the tillage treatments. Results from the first year are presented. Unfortunately results from subsequent years were unavailable due to changes in paddock management at this site. Tardun involved the different lime rates being applied in the same direction as the tillage treatment as a replicated split plot. At Tardun treatments went the length of the paddock, approximately 900m, and could be segregated into three different soil types.

For each trial the lime/tillage treatments were the width of the harvester and long enough (>100m) to be confident in the yield results gained from the grower's header run at harvest time. Header yields were taken annually for each treatment where possible.

During summer of each season soil sampling was carried out to a depth of 30-40cm and collected in 10cm increments for pH testing. Three or more soil samples were collected annually from the centre points and bulked together for each plot.

Return on investments (ROI) was gained by calculating the difference in the return of each treatment in comparison to the control treatment and divided by the respective costs of each treatment in regards to lime application and tillage method. The ROI was calculated in $/ha, using the average wheat price at harvest time. The ROI for the Tardun site is cumulative as it has been cropped with wheat for 5 years.

Table 1. Lime incorporation farm demonstration sites: Locations, soil types, lime rates applied, year and the tillage implements used to incorporate the lime.

Location	Soil Type	Year & lime rates applied	Tillage Implements and approximate working depth
Tardun *(Average GSR Apr – Sep 189mm)*	Three soil types in the paddock. North - Shallow acid gravel Mid - Loamy sand over gravel South - Red sandy loam with clay content increasing with depth	**2013** 0 t/ha 2 t/ha 4 t/ha	Nil Small Offset discs (10-15cm) TopDown® Plough (20-25cm)
Carnamah *(Average GSR Apr – Sep 295mm)*	Yellow deep sand/Sandy earths	**2014** 0 t/ha 2 t/ha 4 t/ha 6 t/ha	Nil Small Offset discs (10-15cm) Mouldboard Plough (28-35cm) Rotary Spader (28-35cm) TopDown® Plough (20-35cm)

Results

The large scale farm demonstrations, showed the benefit of tillage and lime incorporation on crop yield over a range of soil types. Tillage was the main effect in the first year. In following seasons lime rate had a greater influence as tillage effect decreased.

The effectiveness of the lime incorporation will depend on the degree of mixing achieved by the tillage system and the soil conditions at the time of the tillage operation. The tillage implements used in these farm trials to incorporate the lime vary in both tillage time/area covered in one season and cost. However, successful incorporation of lime using any type of tillage helps increase subsoil pH at a faster rate than surface-spread lime with no incorporation. Lime rates need to be selected in relation to soil pH results from initial soil sampling being carried out.

Carnamah

The effect of tillage on yield in the first year is shown at Carnamah on deep yellow loamy sand (Figure 1). As the implement mixes the soil it loosens the soil to various depths, depending on method being used that enables an increase in the root growth of the plants to explore less compact soil. This increases the crop's water and nutrient uptake, therefore leading to higher yields. Lime effects on wheat yield in the following years were unable to be measured at Carnamah as the whole paddock, including the trial site, was mouldboard ploughed.

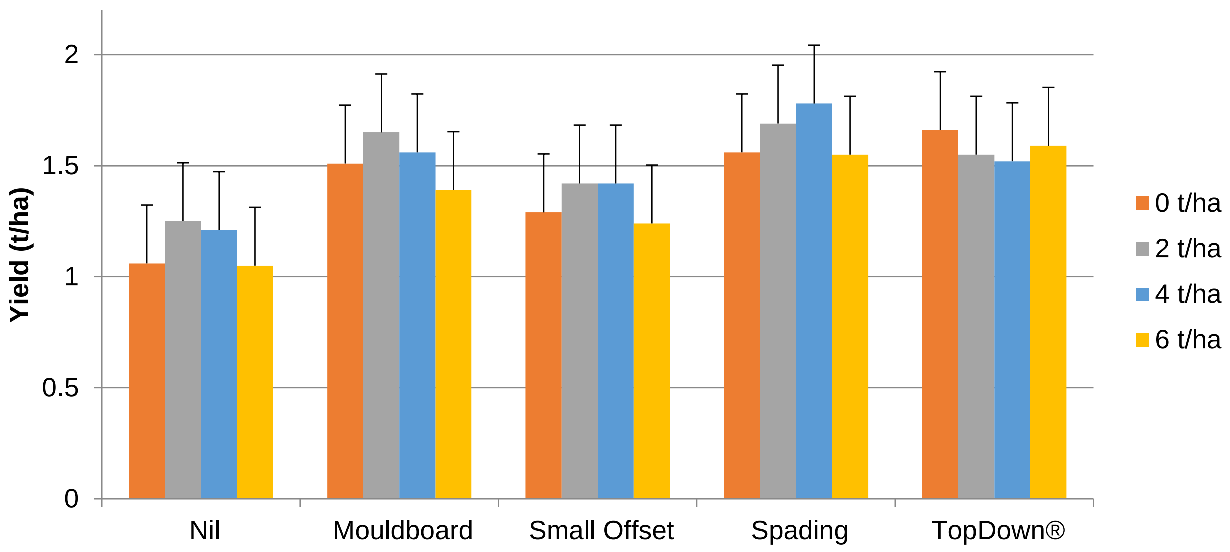

Figure 1. 2014 wheat yield response to lime incorporation method applied prior to sowing in 2014, Carnamah deep loamy yellow sand (p = 0.05, Lsd = 0.15).

Figure 2 shows that spading and mouldboard tillage methods significantly increased the midsoil pH (10-20cm) through the incorporation of 2 t/ha lime. Successful mouldboard tillage completely inverts 28-35cm of soil therefore increasing subsoil pH after lime incorporation but brings the inverted acidic subsoil to the surface and significantly reduces the topsoil pH (Figure 2). Therefore lime application should be carried out after this tillage method as well.

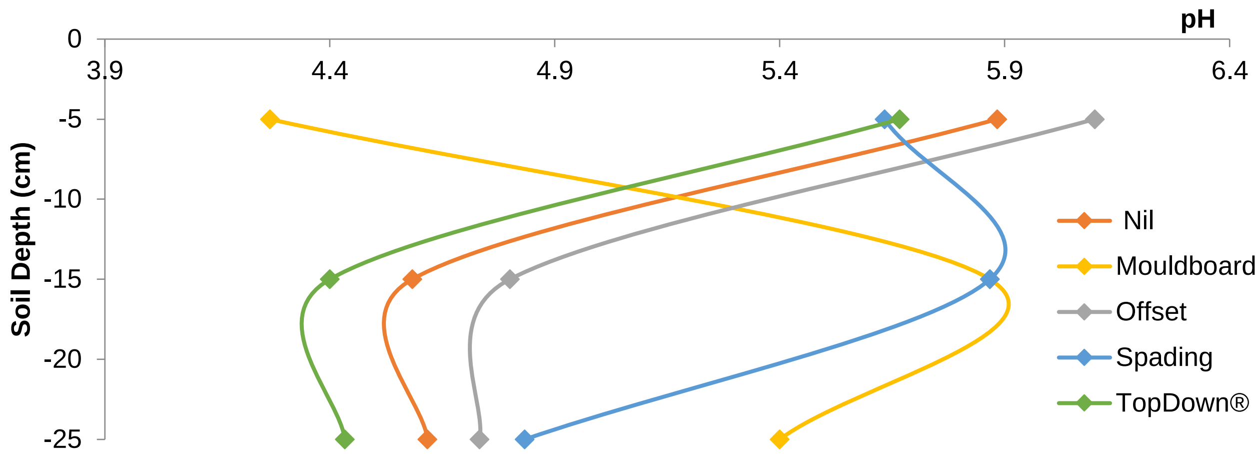

Figure 2. Soil pH after 1 year in relation to 2 t/ha lime being incorporated into deep loamy yellow sand with different tillage implements. Lsd (0.05) 0-10cm = 0.61, 10-20cm = 0.65, 20-30cm = 0.80.

Positive return on investments (ROI), when only looking at costs associated with lime and tillage, was achieved through tillage alone in the first year at Carnamah with the yield benefits gained (Figure 1). Table 2 shows the ROI of the tillage treatment alone. It also shows positive ROI for 2 t/ha lime being incorporated with an offset, simply due to this tillage method being cheaper than the other treatments.

Table 2. Return on Investments (ROI) achieved through tillage methods in the first year (2014) at Carnamah. The lime rate at bottom of table in italics shows cost of lime being transported, spread and incorporated using offset.

Machine	Treatment Cost ($/ha)	Yield (t/ha)	ROI ($/ha)
Nil	0	1.06	**0**
Mouldboard	125	1.51	**1.08**
Spading	135	1.56	**1.11**
TopDown®	125	1.66	**1.44**
Offset	40	1.29	**1.72**
2 t/ha Lime	*100*	*1.42*	***1.08***

Costs include: Lime at $10/t, transport fees at 10c/t/km and spreading at $8/t, along with the incorporation cost in the table. Grain price was taken as the average wheat price at harvest time in 2014 ($300/t).

Tardun

Lime application, on its own, significantly improved wheat yield for the Tardun trial by the third season (Figure 3) and this yield improvement through lime application was seen in the following years (Table 3).

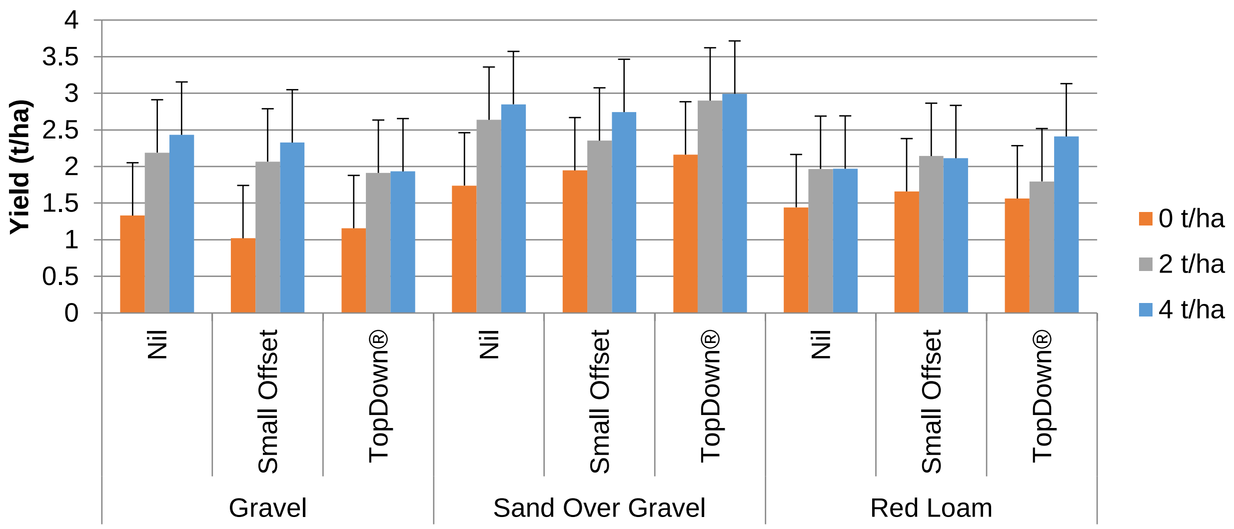

Figure 3. Wheat yield harvested at Tardun 2015, three seasons after lime incorporation was carried out when lime accounts for the major effect, method of incorporation insignificant (p = 0.05, Lsd = 0.72).

Incorporation of lime through tillage resulted in a more rapid increase in subsoil pH than liming alone. The sand over gravel site at Tardun shows this increase (Figure 4). Lime application significantly increasing the topsoil pH (0-10cm) and the incorporation of this lime, using a TopDown®, significantly increased the midsoil pH (10-20cm).

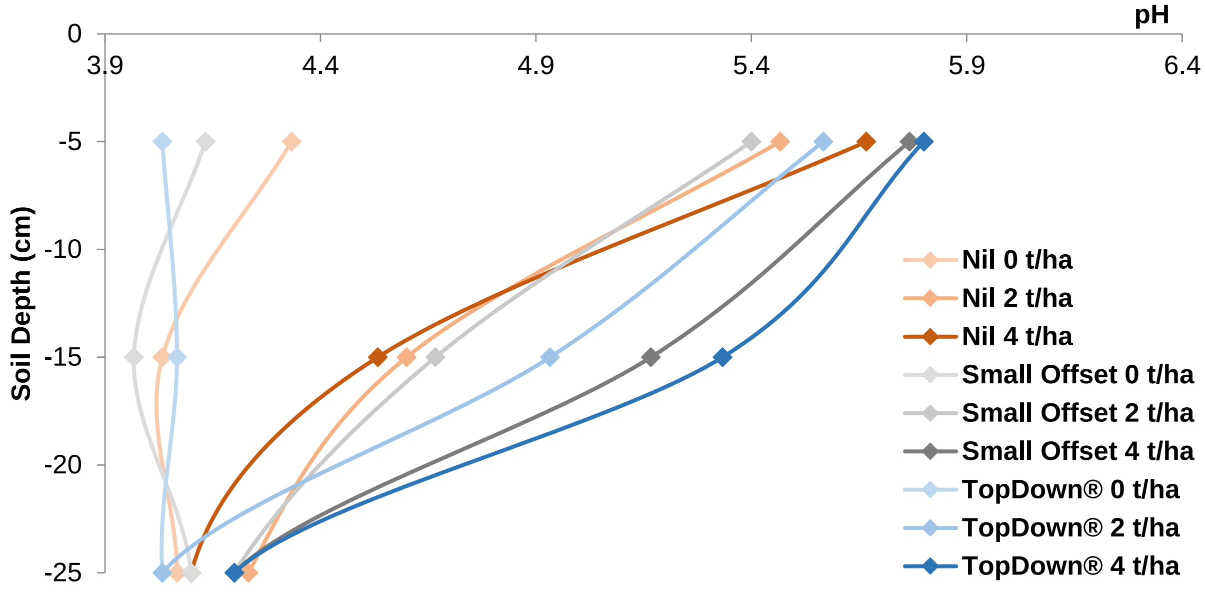

Figure 4. Soil pH in relation to lime incorporation treatments on sand over gravel soil after two years, Tardun (April 2015). Lsd (0.05) 0-10cm = 0.38, 10-20cm = 0.40, 20-30cm = 0.43.

A positive ROI was achieved after 3 years at Tardun once the lime and tillage methods were paid off through soil improvement and increased yields (Table 3). Lime application without incorporation proved to be the greatest benefit in this trial.

Table 3. Cumulative Return on Investments (ROI) achieved through lime incorporation over 5 years at Tardun.

Machine	Lime Rate	Treatment Cost ($/ha)	2013 ($285/t)		2014 ($300/t)		2015 ($295/t)		2016 ($240/t)		2017 ($265/t)	
			Yield (t/ha)	ROI ($/ha)	Yield (t/ha)	ROI ($/ha)	Yield (t/ha)	ROI ($/ha)	Yield (t/ha)	ROI ($/ha)	Yield (t/ha)	ROI ($/ha)
Nil	0 t/ha	0	0.43	0	1.53	0	1.50	0	2.19	0	1.14	0
	2 t/ha	64	0.45	0.09	1.63	0.56	2.26	4.06	2.31	4.52	2.16	8.74
	4 t/ha	128	0.44	0.02	1.63	0.26	2.42	2.36	2.37	2.70	2.50	5.50
Offset ($40/ha)	0 t/ha	40	0.52	0.64	1.49	0.34	1.54	0.62	2.25	1.01	1.19	1.28
	2 t/ha	104	0.54	0.30	1.62	0.56	2.19	2.50	2.36	2.90	2.45	6.23
	4 t/ha	168	0.57	0.24	1.62	0.40	2.39	1.96	2.27	2.09	2.35	3.98
TopDown® ($125/ha)	0 t/ha	125	0.44	0.02	1.47	-0.12	1.63	0.17	2.16	0.13	1.28	0.41
	2 t/ha	189	0.48	0.08	1.56	0.12	2.20	1.21	2.26	1.31	2.09	2.63
	4 t/ha	253	0.52	0.10	1.63	0.22	2.45	1.32	2.32	1.45	2.12	2.46
Lsd (p=0.05) for lime only			*ns*		*ns*		*0.24*		*0.09*		*0.22*	

Costs include: Lime at $10/t, transport fees at 10c/t/km and spreading at $8/t, along with the incorporation cost in the table. Grain prices were taken as the average wheat price at harvest time for that year.

Conclusion

These trials have shown increases in subsoil pH when working lime through the profile with tillage. To improve the knowledge on the amount of lime to apply, soil testing needs involve more than just the topsoil. Samples should also be taken further down the soil profile.

Many growers are interested in the benefit of different tillage methods for amelioration of soil compaction, water repellence and weed control. The significant influence on crop yield from the different tillage methods used in the first year at Carnamah is most likely due to the tillage ameliorating other soil constraints. This provides an ideal time to spread a significant amount of lime on the surface prior to tillage to increase subsoil pH at a faster rate than surface applied lime.

Results from 5 years at Tardun have not supported our assumption that incorporating lime with tillage improves profitability with the greatest ROI coming from no incorporation of lime at 2t/ha. This is due to both location and soil type. Low rainfall areas like Tardun typically have lower yield responses (Farre et al, 2008) to tillage as lower rainfall limits yield potential and depth of wetting and crops are dependent on topsoil moisture at critical stages of development. Small amounts of rainfall at the correct time will have great influence on yield. Research has shown that soil type itself also determines whether tillage is beneficial (Farre et al, 2008). Tillage on soils with substantial amounts of gravel or that are shallow, like Tardun, is typically not beneficial, while there can be a large yield response to tillage on deep sand, as seen at Carnamah.

Evidence from other trials has shown that paddock renovation through the incorporation of lime can provide benefit over time (Davies, 2014). If the implement can mix to the depth where the soil pH constraint occurs then an immediate payback on lime and cultivation is possible (Scanlan et al, 2014).

Key words

Subsoil acidity, lime incorporation, yield increase

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