NEW

4.1 HOW EFFECTIVE IS PRILLED LIME IN ADDRESSING ACIDITY?

Lisa Miller[1], Tahlia Ferguson[1], Natalie Jenkins[1], Brett Davey[1], Jillian Lyall[1], Meg Bell[2] & Amanda Pearce[3]

[1]*Southern Farming Systems*
[2]*MacKillop Farm Management Group*
[3]*South Australian Research and Development Institute*

KEY MESSAGES

- Prilled lime was effective at removing soil acidity constraints when used at high rates but not at low rates.
- Direct drilled prilled lime showed some evidence that it could be useful in increasing yields when placed directly into acidic areas within the drill row.
- Incorporation of lime showed increased pH change below 5 cm compared to standard treatments of broadcast lime after three years.

Keywords: soil acidity, soil pH, lime, prilled lime, incorporation

BACKGROUND

Through the National Landcare Program (NLP) project (Building the resilience and profitability of cropping and grazing farmers in the high rainfall zone of Southern Australia) SFS and partners explored several treatments to ameliorate subsurface and subsoil acidity. One of these was prilled lime, superfine pellets of lime which is less than 70 micron in size. Due to its fineness, it is expected to work rapidly to address soil acidity issues. However, because of its high cost ($300 to $700/t depending on the manufacturer), it is used at low rates, commonly one third of standard lime rates. Trial sites were established at Bairnsdale and Rosedale in Gippsland, Avoca in Tasmania, Sherwood and Kybolite, south-eastern South Australia and within paddock strips at Rokewood in southwest Victoria. The results of these trials in relation to prilled lime are discussed.

METHOD

Trial set up varied with each trial operator and occurred in 2019. Randomised block designs with four replicates with plot sizes varying in area, of about 4m by 10m, were used across all trial sites.

Gippsland and Tasmania sites were located within grower's paddocks and agronomy provided by the grower. The South Australian sites were sown and managed by SARDI with a plot harvester used to measure grain yields.

Soil cores were sampled in 3 or 4 locations within each plot and bulked together in 0-5, 5-10 and 10-15 cm depths. Analysis of variance was used to interpret results.

The Rokewood site was a strip trial established by the grain producer, direct drilling prilled lime at 50 kg/ha and 100 kg/ha into the seed row through an air seeder in April 2019. The strips were approximately 24 m by 400m. All trials compared to a control (no application of soil amelioration products). The prilled product was either sourced from Omya (Calciprill®) or Advantage Agriculture (OzCal™).

Table 1 details the location, lime product and starting soil pH($CaCl_2$) at three different depths.

Table 1. *Soil acidity measured by pH($CaCl_2$) at three depths at different trial locations.*

Location	Prilled Product	Lime Product	Starting Soil pH ($CaCl_2$)		
			0-10 cm	10-20 cm	20-30 cm
Bairnsdale, Vic.	Calciprill®	Graymont – Buchan	4.3	4.4	4.5
Rosedale, Vic.	Calciprill®	Graymont – Buchan	4.5	5.0	5.7
Sherwood, SA	Calciprill®	Henschke Industries, Naracoorte SA	4.9	5.0	
Kybybolite, SA	Calciprill®	Henschke Industries, Naracoorte SA	4.8	4.4	
Avoca, Tas.	OzCal™	Graymont – Mole Creek	4.5	4.3	4.5
Rokewood, SW Vic.	OzCal™	None used	4.9	4.2	4.8

Rosedale and Bairnsdale treatments included:

- Nil
- Standard farmer application 2.5 t/ha
- Prilled lime broadcast at 800 kg/ha
- Lime broadcast targeting pH 5.8 at 0-10 cm applied at 4.4 t/ha Bairnsdale and 3.9 t/ha Rosedale
- Lime incorporated to 10 cm targeting pH 5.8 at 0-10 and 5.2 at 10-20 cm, applied at 5.5 t/ha Bairnsdale and 4.6t/ha Rosedale
- Lime broadcast at 5.5 t/ha Bairnsdale and 4.6t/ha Rosedale.

Sherwood and Kybybolite treatments included:

- Nil
- Cultivation only (to 15 cm)
- Standard farmer application broadcast lime 2.7t/ha at Kybybolite and 1.6 t/ha Sherwood
- Surface prilled lime broadcast 2.25t/ha Kybybolite and 1.4t/ha Sherwood
- Lime + incorporation 2.7 t/ha Kybybolite and 1.6t/ha Sherwood
- Prilled lime + incorporation at 2.25 t/ha Kybybolite and 1.4 t/ha Sherwood
- Drilled prilled lime 0.075 t/ha at both sites into drill row*

**This treatment was applied at sowing, to the central buffer plot in each rep. It was added in as an afterthought to see how it performs to address acidity in the sowing row.*

Avoca treatments were applied to cultivated soil and included:

- Nil
- Lime broadcast 3t/ha
- Lime broadcast 6t/ha
- Lime broadcast 9t/ha
- Prilled lime broadcast 300kg/ha
- Prilled lime broadcast 600kg/ha
- Prilled lime broadcast 200kg/ha applied 2019 and 2021.

Rokewood treatments included:

- Nil
- Prilled lime broadcast 250kg/ha (used only in the deep sand)(Figure 1)
- Drilled prilled lime 50kg/ha into seed row
- Drilled prilled lime 100kg/ha into seed row.

Yield monitor data was collected in 24m cells in 2019 and 2020, and paired t analysis completed on extracted data (Figure 2). Soil sampling of the drill row occurred to measure change in soil pH in 2020.

Figure 1. *Prilled lime 250kg/ha broadcast onto the sand soil type at Rokewood.*

Figure 2. *Map of Rokewood strip treatments (red – nil treatment), yellow - drilled prilled lime 50 kg/ha green – drilled prilled lime 100kg/ha, blue - surface spread prilled lime 250kg/ha. Sandy loam textured soil to left and sand on right.*

RESULTS

Bairnsdale and Rosedale

The Bairnsdale site had annual ryegrass issues and below average rainfall in 2019 and flooding damage in 2020 which caused high yield variability amongst treatments. This resulted in poor results, with the high rate trial Coefficient of Variation (CV) in 2019 of 37% and 22% in 2020 with no significant treatment differences. Variation was high amongst individual treatments in 2021 (CV 17%). The barley yield results showed yield significantly increased from all lime applications in comparison to nil, except the broadcast lime which was applied at 4.4 t/ha (Figure 3). The prilled lime treatment showed a positive yield increase compared to the nil treatment but was lower than the treatments with higher rates of lime applied. The soil test results (Table 2), showed only pH improvement at 5-10 cm from the lime incorporated treatment. For the prilled lime, because 100% coverage was not achieved, soil samples have probably not included areas containing prilled lime.

Weather conditions also affected results at Rosedale providing disappointing results in 2019 (CV 12%) and 2021 (CV 30%). No treatments were significantly different over the three years (Figure 4). Canola plots were hand harvested in approximately three randomly placed square metres in 2020 with CV of 12%. The prilled lime had the lowest canola yield in 2020 (2.5 t/ha) and the incorporated lime the highest yield (3.3 t/ha). Unfortunately, efforts to sample soil at the Rosedale site in March 2022 were unsuccessful due to flooding and then subsequent liming of the paddock.

Table 2. *Bairnsdale pH($CaCl_2$) results at different soil depths in April 2022*

Treatment	Soil pH 0-5 cm	Soil pH 5-10 cm	Soil pH 10-15 cm
Nil	4.15 b	4.17 b	4.34 b
Std broadcast 2.5t/ha	4.82 b	4.16 b	4.21 b
Prilled lime broadcast	4.56 b	4.18 b	4.30 b
Lime broadcast	5.78 a	4.40 b	4.27 b
Lime Inc. high rate	5.80 a	5.39 a	4.75 a
Lime broadcast high rate	5.93 a	4.17 b	4.36 b
p-value	0.0001	0.0001	0.0003
LSD (p=0.05)	0.61	Transformed 0.34 - 0.39	Transformed 0.18 - 0.19
CV%	7.89	2.49 t	1.34t

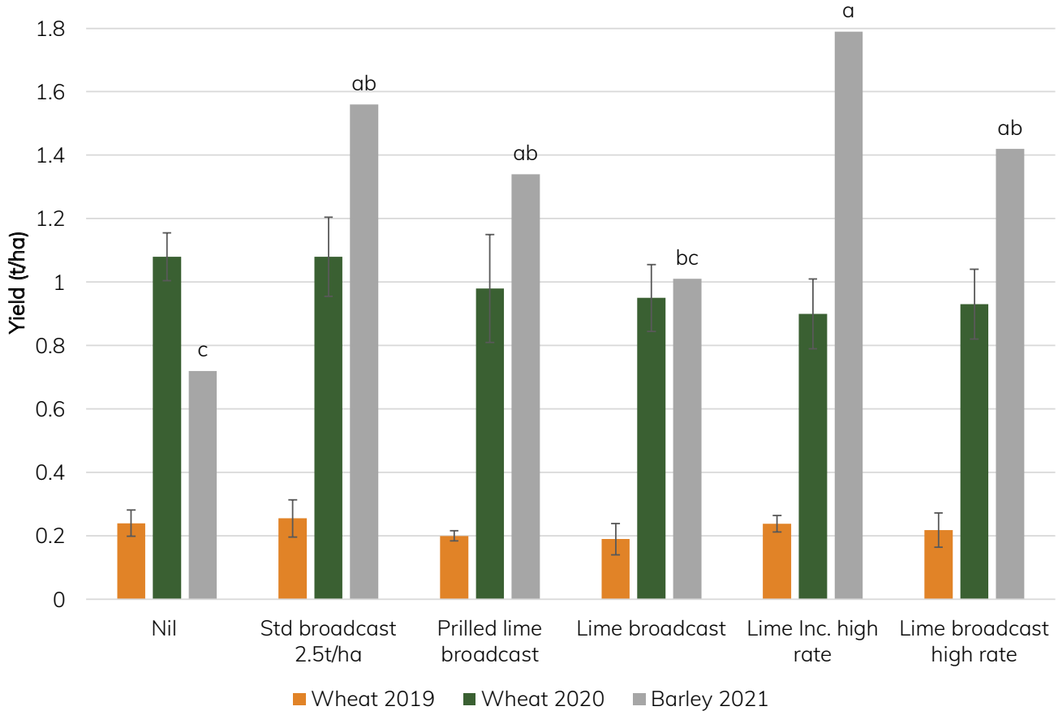

Figure 3. *Bairnsdale mean grain yield (t/ha) of different lime treatments in 2019, 2020 and 2021. Treatment means which are significantly different (P<0.05) are depicted by different letters above yield bars. Standard error bars are shown on not significant treatments.*

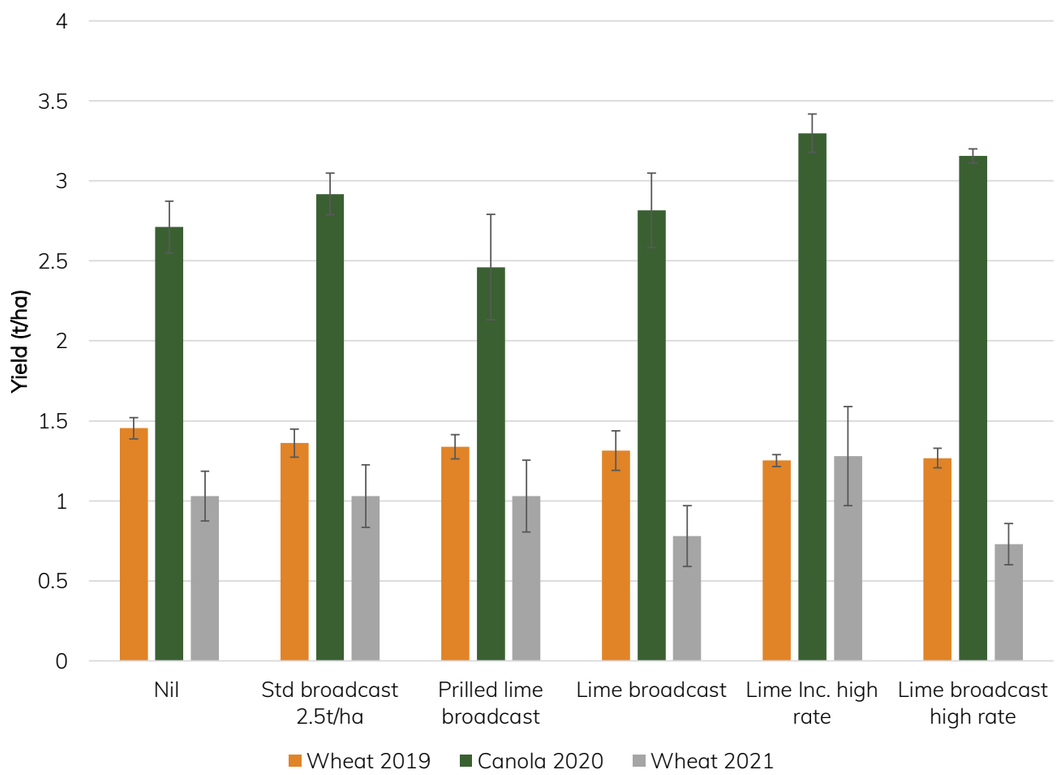

Figure 4. *Rosedale mean grain yield (t/ha) of different lime treatments in 2019, 2020 and 2021 with standard error bars.*

Avoca

The Avoca site in Tasmania was sown to poppies in 2019 and data was collected by the poppy company. Only the alkaloid concentration is shown as it is the main driver of poppy profitability with results nearly being statistically significant (P value 0.06, CV% 7.7). Both the nil and lime broadcast had the highest concentrations of alkaloid at 3.1%. Wheat sown in 2020 had high variation across a couple of treatments due to deer damage (CV 15.6%) and treatments were not significantly different (Figure 5). The soil type was a light textured loamy sand at 0-10 cm and sandy loam at 10-30 cm. The cation exchange capacity (CEC) was very low at 4.1 cmol/kg in the surface soil and the high rates of broadcast lime (6 t/ha and 9 t/ha) were suspected to have suppressed yields due to inducing a micronutrient deficiency, possibly copper. The prilled lime results were same as the control, indicating that the low rate of lime was not enough to remove acidity constraints.

Soil test data taken in 2022 was not available at publishing, however 2020 soil data shows that pH change at 0-10 and 10-20 cm was significantly different between the Lime 9 t/ha and the prilled lime treatments. 2019 soil data taken before treatment applications showed pH treatments were uniform across the site and not significantly different.

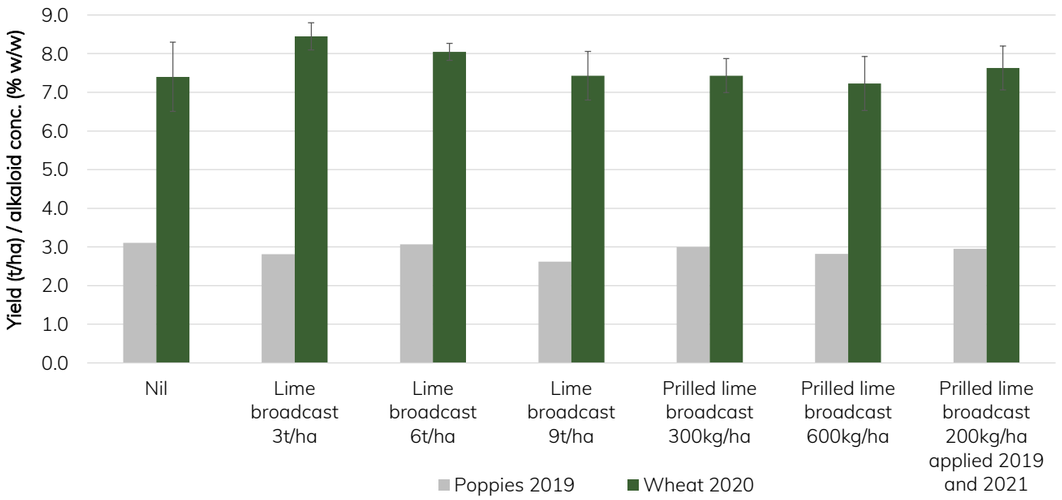

Figure 5. *Avoca poppy alkaloid weight concentration (% w/w) and wheat harvest yield (t/ha) means in 2019 and 2020 with standard error bars shown on wheat. Standard errors of poppy treatment means were not provided.*

Table 3. *Avoca pH($CaCl_2$) results at different soil depths in 2020.*

Treatment	Soil pH 0-10 cm	Soil pH 10-20 cm	Soil pH 20-30 cm
Nil	4.79 ab	4.46 ab	4.83 a
Lime broadcast 3t/ha	4.53 b	4.55 ab	5.02 a
Lime broadcast 6t/ha	4.96 ab	4.37 ab	4.34 a
Lime broadcast 9t/ha	5.55 a	4.79 a	4.59 a
Prilled lime broadcast 300kg/ha	4.58 b	4.16 b	4.37 a
Prilled lime broadcast 600kg/ha	4.63 b	4.39 ab	4.78 a
Prilled lime broadcast 200kg/ha applied 2019 and 2021	4.46 b	4.15 b	4.43 a
p-value	0.041	0.039	0.54
LSD (p=0.05)	0.67	0.39	0.85
CV%	9.37	5.98	10.38

Sherwood and Kybybolite

At the MacKillop Farm Management Group sites, the prilled lime treatments were broadcast at rates equivalent to lime. At the Sherwood site with starting pH($CaCl_2$) of 4.9, no treatments were significantly different from each other in any of the three years (CV 13.8% in 2019, 6.7% in 2020 and 10.9% in 2021). The drilled prilled product resulted in the lowest yield in each year (Figure 6) despite showing reasonable pH change. In contrast the prilled lime incorporated treatment had the highest yield increases over the three years including 0.6 t/ha of barley in 2020 and 0.4 t/ha of faba bean in 2021. It also had significantly higher soil pH change at 0-5 and 5-10 cm compared to the nil treatment (Table 4).

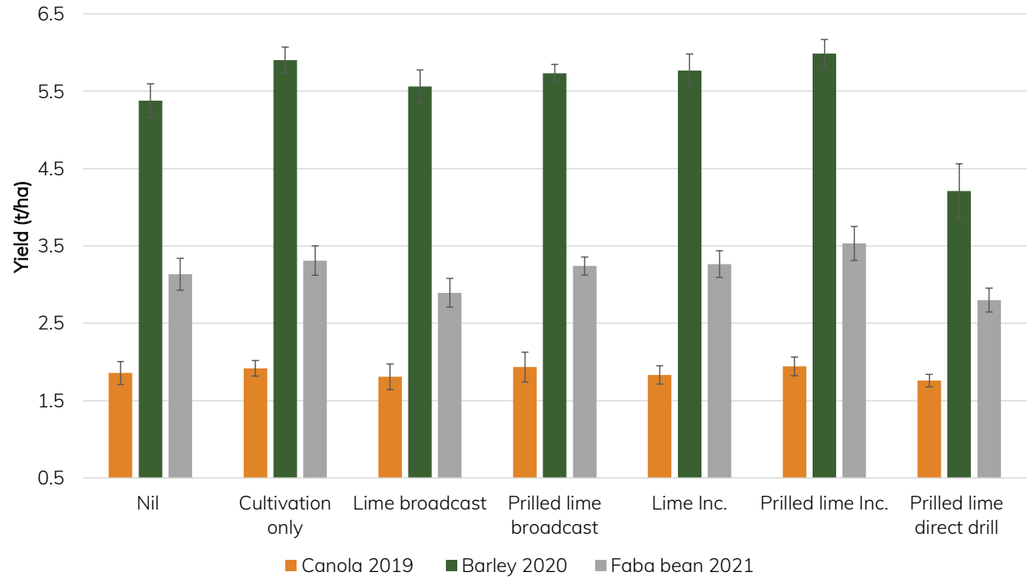

Figure 6. *Sherwood grain yield (t/ha) means of different lime treatments in 2019, 2020 and 2021 with standard error bars.*

Table 4. *Sherwood pH($CaCl_2$) results at different soil depths in 2022*

Treatment	Soil pH 0-5 cm	Soil pH 5-10 cm	Soil pH 10-15 cm
Nil	4.74 b	4.48 b	4.77 a
Cultivation only	5.02 b	4.64 ab	5.12 a
Lime broadcast	5.22 b	4.68 ab	5.09 a
Prilled lime broadcast	5.69 ab	5.08 ab	5.28 a
Lime Inc.	5.65 ab	5.06 ab	5.16 a
Prilled lime Inc.	6.40 a	5.29 a	5.37 a
Prilled lime direct drill	5.26 b	4.81 ab	5.33 a
p-value	0.006	0.023	0.593
LSD (p<0.05)	0.77	0.47	0.69
CV%	9.55	6.57	8.98

Kybybolite has higher annual rainfall (long term average 481mm) than Sherwood (459mm) and lower starting soil pH. Statistical treatment differences were detected in 2020 and 2021 with acid sensitive crops of barley and faba bean. The incorporated lime produced an extra 1.6 t/ha of barley compared the control and 0.7 t/ha more faba bean (Figure 7). Prilled incorporated lime also produced good results although similar to broadcast lime. Drilled prilled lime was similar in results to the nil treatment although produced nearly 0.4 t/ha more faba bean than the control, however this effect was not significantly different.

The highest pH changes came from most lime applications in the 0-5 cm depth except for drilled prilled lime and where lime and prilled lime were incorporated at 5 to 10 cm. No significant pH change was detected at 10 to 15 cm, although both incorporated treatments recorded the highest pH change. Soil sampling may not have occurred within the drill row and therefore areas which received drilled prilled lime may have been missed in sampling.

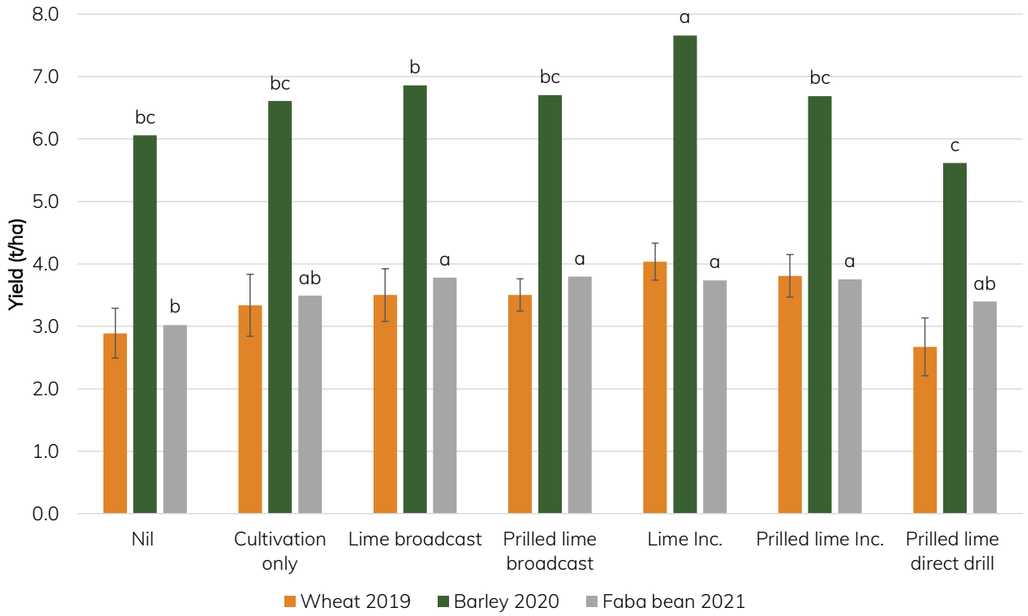

Figure 7. Kybybolite mean grain yield (t/ha) of different lime treatments in 2019, 2020 and 2021.
Treatment means followed by the same letter do not significantly differ (p=<0.05). Standard error bars shown on wheat where treatment differences where ns.

Table 5. Kybybolite pH($CaCl_2$) results at different soil depths in 2022

Treatment	Soil pH 0-5 cm	Soil pH 5-10 cm	Soil pH 10-15 cm
Nil	4.75 b	4.39 a	4.32 a
Cultivation only	4.80 b	4.33 a	4.23 a
Lime broadcast	5.64 a	4.80 a	4.57 a
Prilled lime broadcast	5.78 a	4.84 a	4.47 a
Lime Inc.	5.76 a	4.97 b	4.63 a
Prilled lime Inc.	6.27 a	4.85 b	4.62 a
Prilled lime direct drill	4.83 b	4.44 a	4.43 a
p-value	0.0004	0.039	0.518
LSD (p<0.05)	0.66	0.46	0.48
CV%	8.17	6.67	7.20

Rokewood

There were two main soil types within the Rokewood paddock that were tested with drilled prilled lime. A sandy loam, with clay at 15-20 cm and a deep sand with an acid throttle around 30-40 cm, clay at 50-60 cm. The prilled lime was drilled into the soil at 25 mm with an airseeder immediately prior to seeding. RTK GPS was used to place seed and fertiliser directly into the same row.

Results in the drilled prilled lime showed statistically significant results p<0.01 in the sandy loam at both prilled lime rates (Figure 8), increasing yields by 0.2 to 0.25 t/ha but no significant increases were recorded in the sand, or the surface spread application for wheat in 2019 (Figure 9). In the second year, canola did not show a response to the prilled lime drilling in the sandy loam at either rate (Figure 10) or in the sand by broadcasting. However, there was a significant response in the sand (0.42 t/ha) to drilled prilled lime at 100 kg/ha (Figure 11).

Soil sampling occurred in the drill row in April 2020 and pH tested in 15 paired samples in the sandy loam soil and this indicated that there was consistent pH increase in the 0-5 cm and 5-10 cm with the prilled lime treatment but only a small increase at 10-15 cm (Table 6).

Table 6. Rokewood pH($CaCl_2$) results at different soil depths in sandy loam soil in 2020.

Depth	Nil	Prilled lime 100 kg/ha
0-5 cm	5.40	6.32
5-10 cm	4.28	4.90
10-15 cm	4.19	4.30

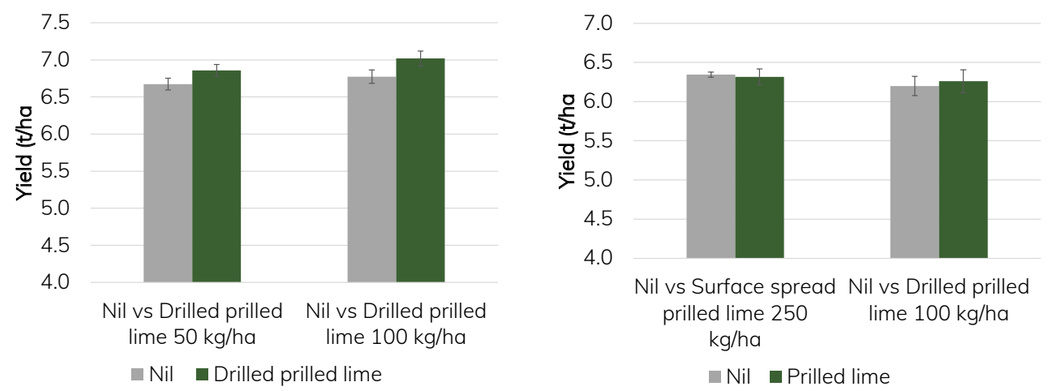

Figure 8 and 9. Rokewood wheat 2019 yield (t/ha) results for paired samples in sandy loam (left) and sand soil (right) with variance bars.

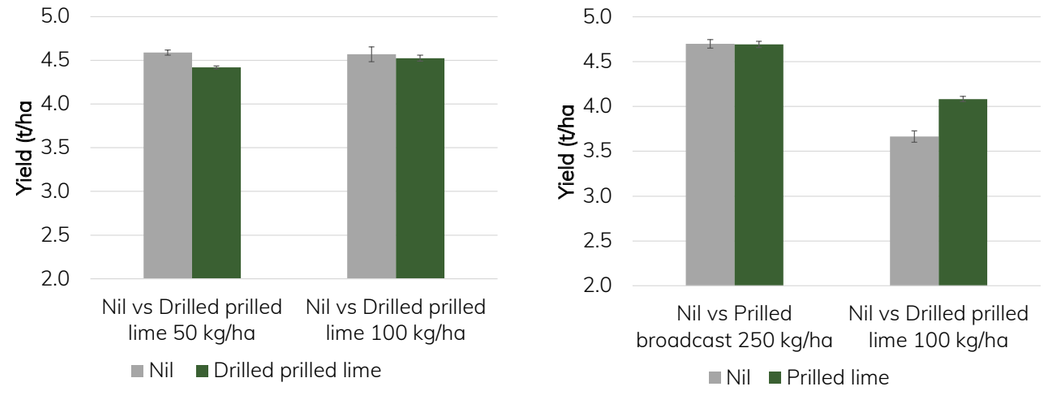

Figure 10 and 11. Rokewood canola 2020 yield (t/ha) results for paired samples in sandy loam (left) and sand soil (right) with variance bars.

DISCUSSION

The results indicated that the responses to lime have been rate related. The higher rates have created more yield response apart from the trial at Avoca. This was possibly due to inducement of micronutrient tie ups resulting in deficiencies where high rates of lime have been applied to the soil which had low cation exchange capacity.

Higher lime rates contain more carbonate which is the acid neutralising component of lime. Where lime and prilled lime were applied at similar rates at Kybybolite, both products have been effective at increasing yields in acid sensitive crops of barley and faba bean and increasing soil pH. Responses were not as clear cut in the Sherwood trial which had less soil acidity, with initial starting pH($CaCl_2$) 4.9 at 0-10 cm.

The lower prilled rates did not show much evidence of increasing pH or consequently increasing yields at Bairnsdale, Rosedale or Avoca. However, there was a barley yield response to prilled lime at Bairnsdale and this was likely caused by the creation of increased soil pH change at 0-5 cm, but not by amelioration of deeper acidity (Figure 2, Table 2). Based on these results, higher rates of lime are desirable, and the cheaper cost of lime (approximately $70/t spread) would be a more economical choice for ameliorating highly acid sites than the use of prilled lime at $300 to $700/t.

The dissolving of lime into calcium and carbonate requires moisture and acidity. With lime concentrated into a pellet, the surrounding soil may increase in pH and slow down the reaction of lime. Lime may only begin to dissolve again when acidity increases. It is speculated that this may counteract the fineness of the prilled lime product and therefore the rate at which hydrogen ions are neutralised. The prilled lime has been described to slump when it starts to react with soil (personal communication Gaus Azam, DPIRD soil scientist, WA).

If nitrogen is deep banded, and if nitrate leaching occurs, then excess hydrogen ions created by conversion of ammonium into nitrate remain in the soil solution. There is spatial separation between where the hydrogen ions occur and where lime is placed on the surface. With the slow movement of lime (approx. 2 cm/year), this can mean deeper acidity could remain untreated for four or five years. Therefore, placement of prilled lime may help offset some of the acidity that might occur within the drill row.

Price *et al* (2020) first reported success of ameliorating subsurface acidity (soil pH(CaCl2) 4.3) within the sowing row through placement at 7.5 to 12 cm by a conventional seeder at a prilled rate of 300 kg/ha at Wagga Wagga. However, uses of higher rates of drilled prilled lime (greater than 100 kg/ha) may be restricted in air seeders as the Rokewood grain producer reported issues with blockages. There was some evidence that the drilled prilled lime resulted in increased wheat yields at Rokewood in the year of application and increased soil pH within the sowing row but there were limited benefits at Sherwood and Kybybolite.

The trials have also shown that mixing the lime through the soil helps achieve faster pH change below 5 cm and has generally increased yields. The testing of soil at 5 cm increments has been useful in detecting acidity and monitoring lime reactions.

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