# What crop production responses can we expect from surface applied liming?

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## KEY MESSAGES

- Soil acidity cost $170/ha to $228/ha alone in yield penalties in 2015
- Keeping pH at good levels by liming prevents yield penalties
- Increasing soil aluminium levels caused by pH falling below 4.8, provides a good guide to the likely yield penalties incurred

## BACKGROUND

Most soil acidity research in Victoria has been done in pastures and in North East Victoria, with very little in the cropping zone of South West Victoria. Lime response trials for preventing and ameliorating soil acidity have been set up on grower's paddocks across South West Victoria by SFS to help determine the productions responses from different rates of lime in a range of crop species. This work will help us understand the yield penalties we can expect if good pH levels are not maintained and how frequently lime needs to be applied.

## METHOD

Eight lime response trials using six different rates of surface applied lime (0, 500, 1250, 1750, 2500, 3750 kg/ha) were established across South West Victoria in 2014 and are now in their second year of monitoring. A fertility treatment was also included and in 2015 this treatment was either urea or a superphosphate molybdenum mix, both applied at 100 kg/ha. Also established was a trial on the Bellarine Peninsula, where only two rates of lime have been surface applied 0 and 3 t/ha with a stubble burn and lime plus stubble burn treatment in 2014. In 2015 these treatments were replaced with poultry litter at 2 t/ha.

The Woady Yaloak Catchment Group set up three lime trials at Rokewood North, Werneth and Rokewood West cropping sites in 2012. All trials are a randomised block design with 4 replicates with plot sizes approximately 4 m by 14 m. An additional alterative fertiliser trial at Cape Clear which contained lime applied at low rates (250 kg/ha) over 5 years which commenced in 2009 was also monitored for crop yield responses.

The results given are for production responses in the second year. For more detailed methodology and responses in 2014 refer to SFS trial results booklet 2014. Soil pH results are presented are using the $CaCl^2$ method which tests 0.7 pH unit less than the pH method in water.

## RESPONSES

There are many negative effects on plant growth and soil biology, fertility and structure when soils become too acidic. One major effect is when pH falls to 4.8. At this point aluminium starts to become more soluble where it is toxic to plants and restricts their root growth and function. As pH falls below 4.5, the amount of aluminium increases markedly and even plants tolerant of aluminium will suffer yield reductions or fail to persist. Aluminium provides a good predictor of the likely yield response.

The aluminium test used in this program reflects the amount of aluminium within the soil solution which roots are exposed to and is expressed as a percentage of cations. When interpreting the results, the electrical conductivity (EC) which is a measure of salts within the soil of the soil is needed to accurately predict the effect of aluminium on plant growth. A table with critical concentrations of aluminium for different aluminium tests can be found at the SFS website.

Table 1. The exchangeable aluminium levels where yield penalties are likely to be incurred in crops with different sensitivities to aluminium.

| Sensitivity to Aluminium | Exchangeable Al% where yield is reduced in medium EC soils (0.07 to 0.23 dS/m) | Crop and Pasture Species |
|---|---|---|
| Highly Sensitive | 2 to 8 | Barley, Faba bean, Lucerne, Balansa clover, Strawberry clover, Berseem and Persian clovers. |
| Sensitive | 9 to 12 | Canola, Phalaris, Red clover, Caucasian clover |
| Tolerant | 13 to 21 | Wheat varieties, Annual and Perennial ryegrass, Tall fescue, Chicory, Fodder rape, White clovers and Subclover |
| Highly Tolerant | 22 to 30 | Oats, Triticale, Cereal rye, Cocksfoot, Serradellas |

*Source: Table adapted from Soil Acidity monitoring tools (Department of Environment and Primary Industries 2005)*

**Canola production results**

The use of lime at the Bellarine trial site produced significant yield responses of 0.43 t/ha and 0.34 t/ha (figure 1). There was no significant treatment response to the poultry litter treatment (0.1 t/ha). This response was anticipated as canola is sensitive to aluminium and exchangeable levels of aluminium of 17% occurred at the 0-10 cm depth caused by a very acidic pH level of 4.2. Approximately 11% of aluminium is also located in the 10 to 20 cm depth but soil testing has shown that lime is yet to reach this layer and so further responses would be expected if it does.

With canola prices (non GM) at approximately $531/t, the lime potentially earned an extra $228/ha. The upfront cost of lime 3 t/ha spread in 2014 was estimated to be approximately $135/ha which probably should be reapplied in 5 years due to its low pH and so is costed at $27/ha/year.

Warncoort also used canola in its rotations in 2015 but due to the dry spring the results were variable across the site (-0.1 t/ha to 0.33 t/ha) and the CV was too high (28.33) for results to be trustworthy (see table 2). The pH at this site was 4.5 but with only 2.4% aluminium in the 0-10 cm depth. In 2012 the Rokewood North trial recorded production responses of 0.53 t/ha with a 90% confidence at the 2.5 t/ha ($p$= 0.013, CV 9.58) with levels of 3% exchangeable aluminium. Canola is thought to suffer yield declines at levels of 9% aluminium at medium EC (see table 1).

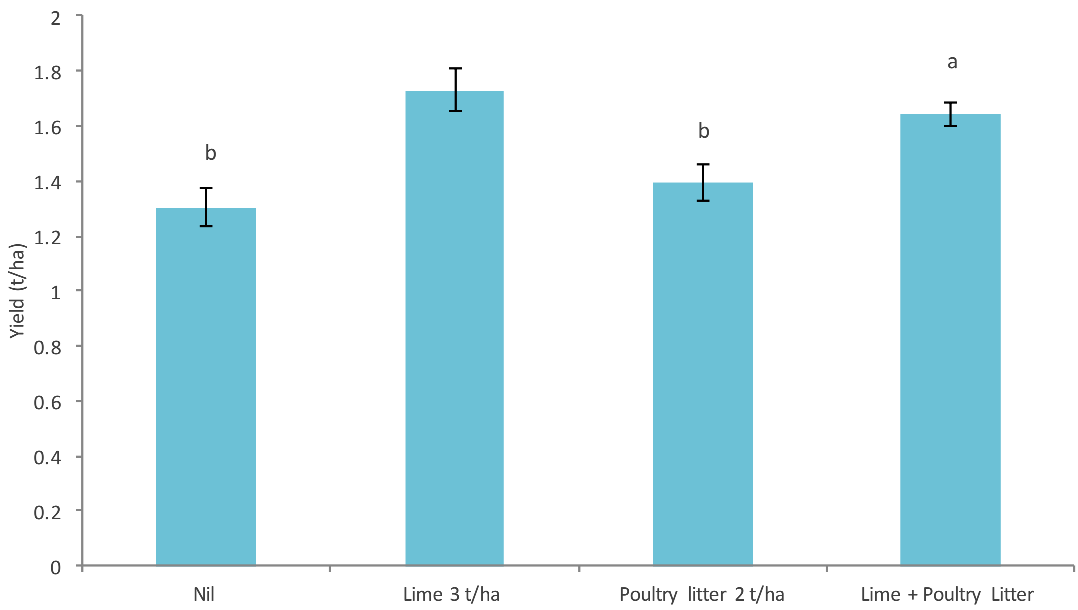


Figure 1. Mean canola yields (t/ha) at the Bellarine trial site with and without Lime or poultry litter in 2015. Means followed by the same letter do not significantly differ, $p$=0.001, LSD (p=0.05) = 0.169 t/ha. Error bars indicate the standard error of the mean.

**Faba bean production results**

The Rokewood North used faba beans in 2015 and had a 0.34 t/ha to 0.39 t/ha increase over the nil lime treatments (farm fert and farm fert + TM) is shown in figure 2. TM is a biological stimulant. The Rokewood North site in 2015 had a pH of 4.5 with 5.5% exchangeable aluminium at 0-10 cm. Soil pH for rhizobia function is reported to decline at pH levels of 5.0 or less and yields are expected to decline at aluminium levels of 2% to 8% at medium EC. At prices of $485/t we earn an extra $170/ha, not counting the extra nitrogen this has likely fixed which is estimated to be about 20 kg N/ha. Lime spread at 2.5 t/ha costs about $115/ha. Hopefully the extra nitrogen fixed will benefit the following crop.

The Shelford site also had faba beans in its rotation. It has a pH of 4.9 and 0.4% aluminium at the 0-10 cm and showed no significant production response to lime. The Werneth site grew faba beans in 2014 and had no significant treatment responses with 4.7% aluminium with a pH of 4.5 recorded at the 0-10 cm depth but yield was thought to have been affected by Chocolate Spot Disease. Its following white wheat crop had showed no yield response but a small but significant increase in protein content at Lime 2.5 t/ha of 0.72% lifting protein levels to 12.1% ($p$=0.02), CV 2.35 above a Farm Fert + Lime 250 kg/ha + TM.

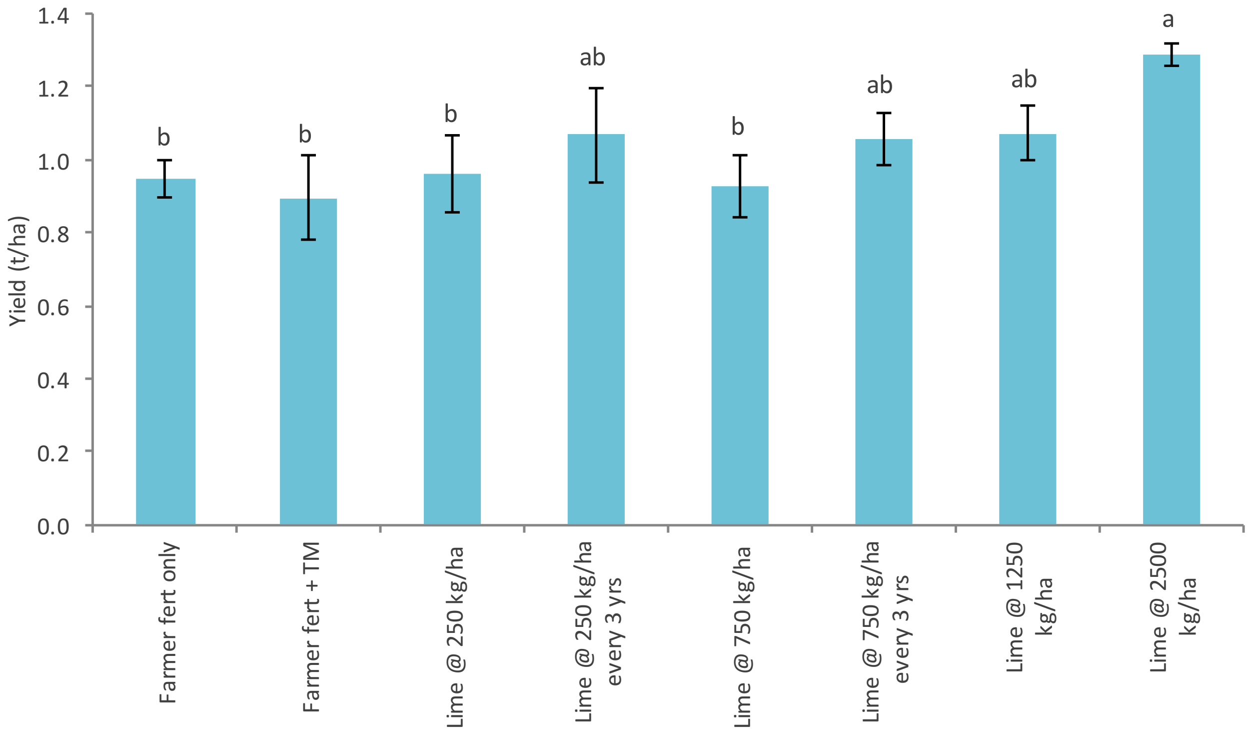


Figure 2. Mean yield results (t/ha) at the Rokewood North site for different treatments.
*Means followed by the same letter do not significantly differ, LSD ($p$<0.05) = 0.23 t/ha.*

**Barley**

Four trials had barley in their rotation in 2015 and no significant results were obtained. Barley is similar to faba beans in that it is extremely sensitive to aluminium. At the Mingay and Modewarre site aluminium levels were just below 2% and there were no obvious treatment results.

At the Yulecart and Westmere sites aluminium levels were at 9% and 4% and within the range which was expected to impact on production. The Westmere site showed a significant reduction in yield where Lime 2.5 t/ha plus urea 100 kg/ha was applied at GS 31. The nitrogen from the urea applications and the removal of acidity has most likely grown additional tillers which were not supported with the very dry spring, resulting in empty heads and they have probably taken moisture away from the main tillers causing a yield penalty.

**Wheat**

There were no significant treatment responses at any of the wheat sites (Werneth, Rokewood West, Gatum or Cape Clear). Wheat is tolerant of aluminium, which need to be above 13% at medium EC to suffer yield penalties. Gatum had the highest aluminium content of 12.8% measured in 2014 in the 0-10 cm and although Lime 2.5 t/ha produced an extra 0.38 t/ha it was not significant due to the variation amongst yields collected from each of the four treatment plots. So we cannot be confident that we had a lime response. Some of this variation was due to emu damage. All the other sites had aluminium levels of 5% or less.

Table 2. Total mean crop yields (t/ha) for 2015 year at different SFS trial sites

| Treatment | Modewarre Barley | Mingay Barley | | Warncoort Canola | Yulecart Barley | Gatum Wheat | Shelford Faba bean | Westmere Barley | |
|---|---|---|---|---|---|---|---|---|---|
| Nil (Farmer Fert) | 4.0 | 4.0 | a | 0.8 | 3.3 | 3.0 | 1.2 | 1.3 | ab |
| Lime 0.5 t/ha | 4.2 | 4.0 | a | 0.8 | 3.5 | 3.1 | 1.3 | 1.5 | ab |
| Lime 1.25 t/ha | 3.9 | 4.0 | a | 0.9 | 3.3 | 3.2 | 1.1 | 1.7 | a |
| Lime 1.75 t/ha | 4.0 | 4.1 | a | 0.8 | 3.6 | 3.1 | 1.3 | 1.5 | ab |
| Lime 2.5 t/ha | 4.2 | 3.9 | a | 0.7 | 3.5 | 3.4 | 1.3 | 1.6 | ab |
| Lime 2.5 t/ha + Fert | 4.2 | 3.9 | a | 1.1 | 3.4 | 3.1 | 1.4 | 0.7 | bc |
| Lime 3.75 t/ha | 4.0 | 3.8 | a | 0.9 | 3.5 | 3.2 | 1.2 | 1.6 | ab |
| Fertiliser only | 4.1 Super Moly | 4.1 Super Moly | | 1.0 Super Moly | 3.3 Super Moly | 3.3 Urea | 1.2 Urea | 1.1 Urea | abc |
| P value | ns | ns | | ns | ns | ns | ns | 0.014 | |
| LSD (*p*=0.05) | | | | | | | | 0.47 | |
| CV | 6.9 | 9.3 | | 28.3 | 9.9 | 12.53 | 13.3 | 23.9 | |

*Means followed by the same letter do not significantly differ.*

Table 3. Total mean crop yields (t/ha) for 2015 year at different Woady Yaloak trial sites

| Treatment | Rokewood West Wheat | Werneth Wheat |
|---|---|---|
| Nil (Farm Fert) | 2.8 | 4.0 |
| Farm fert + TM | 2.7 | 4.0 |
| Farm fert + TM + Lime 0.25 t/ha | 2.8 | 3.8 |
| Farm fert + TM+ Lime 0.75 t/ha | 3.0 | 3.8 |
| Lime 250 kg/ha once | 2.9 | 3.7 |
| Lime 250 kg/ha every 3 years | 2.9 | 3.9 |
| Lime 750 kg/ha once | 2.7 | 3.8 |
| Lime 750 kg/ha every 3 years | 2.9 | 3.8 |
| Lime 1.25 t/ha | 2.8 | 3.8 |
| Lime 2.5 t/ha | 2.9 | 3.8 |
| P value | ns | ns |
| CV | 5.75 | 5.57 |

*Means followed by the same letter do not significantly differ.*

Table 4. Total mean crop yields (t/ha) for 2015 year at Cape Clear alternative fertiliser trial.

| Treatment | Wheat (t/ha) | |
|---|---|---|
| Nil | 1.2 | a |
| DAP @ 75 kg/ha | 1.9 | a |
| Pig manure applied in 2014 | 1.9 | a |
| Seasol & Powerfeed 5L/ha each | 1.4 | a |
| Wormcastings + Lime 250 kg/ha for 5 yrs | 1.6 | a |
| TM + DAP 37.5 kg/ha | 1.5 | a |
| Nutrisol | 1.2 | a |
| Humates | 1.5 | a |
| P value | ns | |
| CV | 32.0 | |

**What rate of lime should I use?**

Is it better to trickle out low rates of lime or apply large quantities? The economics of lime spreading mean that the minimum application rate of lime is thought to be about 1 t/ha, although if done in-conjunction with sowing or fertiliser application lower rates may become economical. Rates of 500 kg/ha are supposedly needed to overcome pH buffering capacity in soils with reasonable organic matter (ie. above 2%) which relates to one off applications but presumably soil buffering capacity will be overcome with consecutive applications. No significant yield results were obtained from using one off low rates of lime (250, 500 or 750 kg/ha) in our current trials.

The lime at the Cape Clear site was applied at 250 kg/ha every year for 5 years equating to 1 t/ha. Whilst this has not provided significant yield responses, it will have increased pH which is due to be measured in 2016. Apparently in continuously cropping systems in South Africa, lime is applied every year (Scott, 2000).

Generally the higher the rate of lime, the larger the pH change and the faster the reaction. However this does not hold true in surface applied liming as once pH levels become too high, the dissolution of lime slows as it requires acidity to break down. The lime rate of 3.75 t/ha has generally not yielded any better than the 2.5 t/ha rate which suggests this may be occurring. It hasn't also yielded significantly worse than other rates indicating it may not be harmful by affecting microbiology or inducing nutrient deficiencies.

The higher rates of lime will likely achieve better coverage and overcome any variability caused by lime spreading. The rate of lime should be governed by pH but generally with surface applied lime, a rate of 2.5 t/ha seems to be about right.

## ACKNOWLEDGEMENTS

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## REFERENCES

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