Table 3: Average annual acidification rate measured across Corangamite farming systems at different depths based on pH ($CaCl_2$) change over four years (2014–18)

System	Average annual acidification rate of the soil layers (*Application of kg pure lime/ha/year to counteract acidity)		
	0–10 cm	10–20 cm	20–30 cm
Cropping on clay loams	Average pH fall 0.05/year Lime equivalent 180 (Range 85-430)	Average pH fall 0.03/year Lime equivalent 100	Average pH fall 0.03/year Lime equivalent 100
Grazing on clay loams	Average pH fall 0.04/year Lime equivalent 138 (Range 85-345)	Average pH fall 0.01/year Lime equivalent 45	Average pH fall 0.02/year Lime equivalent 50
Hay cutting including lucerne on loams	Average pH fall 0.18/year Lime equivalent 350 (Range 300–400)	Average pH fall 0.09/year Lime equivalent 175	Average pH fall 0.12/year Lime equivalent 230

*Assuming 1 tonne of pure lime/ha lifts pH by 0.29 units in a clay loam and 0.5 in a loam.

soil moisture particularly in a dry finish to the season. But if there is ample soil moisture and the crop's nutritional needs are met, there may not be a significant lime response.

Organic carbon

High soil organic carbon (organic C more than 2%) appears to influence lime response by reducing the impact of aluminium solubility and toxicity.

Other soil constraints

If there are other soil constraints to production present, then a lime response may not be seen. This has been apparent in pasture trials in Southern Victoria where nutrient deficiencies over-rode lime responses.

Lime or fertiliser may not have shown significant differences when applied separately, but together they did. This indicates that lime is not a substitute for fertiliser – both are needed.

Other potential constraints may include compaction, waterlogging or sodicity.

Lime reaction

If you are looking for obvious responses in the first season following lime applications, you may be disappointed. Among this project's trials, there were only two with statistically significant lime responses in grain yield in the first year and that was when pH was low (pH 4.2 and 4.5) and acid sensitive crops were grown.

Lime needs acidity moisture and time to dissolve. Incorporated superfine lime has taken up to 18 months to fully dissolve. Surface applied lime without incorporation is likely to drive up soil pH in the top 1 cm to 6.0 or above where lime stops dissolving. Hence, the benefit of incorporation of some kind.

Acidification rates

If you are farming and removing plant and/or animal products from the paddock, then you are acidifying the soil. Soil acidification is caused by a number of processes, for example, as roots take up cations they release hydrogen ions to maintain charge balance.

Also, the cycling of nitrogen is particularly important, with the addition of urea or ammonium which is converted into nitrate and then leached beyond the rooting zone, leaving behind acidity.

If the agricultural system was closed (that is, products not removed and nitrate not leached), then acidification rates would be zero.

Analysis of trial results and monitoring of 100 un-limed paddocks mainly within the Corangamite catchment, showed that the rate of acidification varies according to the farming system and soil type (Table 3). The measured pH changes varied from 0.05 and 0.18 units per year depending upon the production system.

The decrease in soil pH at 10–20 cm and at 20–30 cm over the four-year period was also found to be highly significant. The equivalent amount of pure lime (100 per cent NV) required to neutralise the annual acidification rate was calculated from the reductions in pH over a four-year period.

Table 4: Acidifying effects of various farm enterprises in the greater than 500 mm per year rainfall zone

System	kg of lime/ha/year to balance acidification
Continuous grain cropping including grain legume	200 to 300
Grazed pastures	100 to 200
Lucerne hay	200 to 700

Adapted from Hollier, 1999.

Lime movement occurs if pH is kept above 5.5

Very few of the recent SFS trials saw lime movement beyond 10 cm because there was not enough time for it to move and because rates were not high enough to saturate the surface with alkalinity to allow it to leach. Any change in pH measured may have been through physical lime falling down cracks.

A lime trial run by NSW DPI from 1992 to 2010 (18 years) is one of a number of trials that only found subsoil amelioration when soil pH in the topsoil was kept above 5.5. Micro-fine lime was incorporated into the top 10 cm and soil pH maintained above 5.5 for the trial duration to counteract acidification and leaching.

After four years, lime had moved to 15 cm, but advanced no further for another four years (2004), but in 2010, lime was detected at 25 and 30 cm. Movement was about 1 cm per year.

Variation across the paddock and down the profile

The average paddock pH can be misleading when trying to make decisions about liming. To make informed decisions about liming, it is good to know what you are dealing with. The use of pH mapping or using yield maps to identify low production zones and then taking exploratory cores within them both have merit.

The Rokewood subsoil acidity site provides a good example of how soil acidity changes spatially and vertically down the soil profile. The Rokewood trial is 100 by 140 metres and the variation in soil pH is 2 units in the top 10 cm (Table 5).

Table 5: Average pH ($CaCl_2$) and Exchangeable Al results for the Rokewood trial site, 2017

Depth	Average soil pH	Range of soil pH	Average Al % of exchangeable cations
0–10 cm	5.11	4.1–6.1	2.75%
10–20 cm	4.10	3.8–4.4	19.33%
20–30 cm	4.71	4.1–5.5	3.41%
30–40 cm	5.76	4.8–7.1	0.09%

NSW Agriculture broadcasting lime onto the soil surface at the Rokewood trial site.

Jeremy Jones, Precision Ag specialist with Dalby Rural Supplies says the real savings that growers are seeing through the use of optical sprayers are in resistance management through the use of more modes of action and maintaining a low seed bank. (PHOTO: N Lyon)

fallow, enabling the operator to apply residuals to known weedy patches while also applying a knock-down to kill existing plants prior to planting. This capability already exists with SwarmFarm's robotic platforms that currently carry the WEEDit sensors.

Can optical sprayers be used to apply all herbicides?

Short answer: Many products now carry registrations for optical sprayer application.

Longer answer: When the rates used in the optical sprayer are within the application rate range on the label, there is no problem using an optical sprayer or any other. Some labels have an application range specified for optical sprayers.

Some minor use permits are available for use patterns that lie outside the conditions on the product label. For example, APVMA permit number 85049 provides for the control of volunteer and ratoon cotton in fallow using optical spot spray technology using specified tank mixes and application rates. Always read the label to check that the use pattern you plan to follow is legal.

Can optical sprayers help reduce spray drift?

Short answer: Yes, less product is applied to begin with, putting less particles into the air. The new nozzles increase the proportion of coarse droplets, in line with the new 2,4-D guidelines.

Longer answer: Optical sprayers are acknowledged as a useful tool to reduce spray drift. When the optical sprayer is engaged and the coverage area is below the threshold, the required buffer zone is reduced. ■

HOW TO ASK A WEEDSMART QUESTION

Ask your questions about the advances in spray technologies on the WeedSmart Innovations Facebook page WeedSmartAU, Twitter @WeedSmartAU or the WeedSmart website *https://weedsmart.org.au/category/ask-an-expert/*

'WeedSmart' is an industry-led initiative that aims to enhance on-farm practices and promote the long term, sustainable use of herbicides in Australian agriculture.

Thermal weed control – just hot air, or site-specific reality?

DID you know that rotary hoeing requires less energy than steaming? Or offset discing requires less energy than microwaving?

Well that's the case when it comes to controlling weeds.

An epic effort to review 170 papers by a team from the University of Sydney (Guy Coleman *et al*) has shown that mechanical weed control options (eg. tillage) can use significantly less energy than thermal options (eg. heat) to kill weeds. Herbicide energy use sits somewhere in the middle.

But what are thermal weed control options?

Basically, they're tools that use heating or freezing to rupture plant cells, which can result in plant death. Lasers, flaming, steam and microwaves are a few examples of thermal weed control, and they've been creating a bit of a stir amongst the ag community lately. Not only do they offer an alternative to herbicides, but just as importantly they offer an alternative to tillage – a word that can send shivers up the spine of many a committed no-till farmer!

There is one slight hurdle for thermal weed control though, in that it has significantly higher energy requirements. Microwave technology to control weeds uses an average 23500 MJ per hectare compared with 192 MJ for herbicides and just 15 MJ for a set of sweeps!

Before we all throw our hands up in the air, the review also found that when thermal weed control options are applied using site-specific technology, eg. similar to that used for 'green on brown' weed control in fallows, energy requirements are reduced by 99 per cent. Thermal options suddenly look much more feasible for broadacre cropping!

Incidentally, site-specific weed control using herbicide and mechanical options also reduces energy requirements by 97 per cent.

Lasered weed. (PHOTO: Guy Coleman)