Farming systems and soil acidity

Soil acidity is a natural process but is greatly accelerated by more intensive and productive farming systems. More than two million hectares of agricultural land in SA are susceptible to soil acidification.

It is caused by an accumulation of acid hydrogen ions in the soil through the accumulation of organic matter; addition and leaching of nitrogen from fertilisers and legumes; nitrate leaching; and the removal of alkaline nutrients in plant and animal products. These processes also result in the losses of nutrients such as calcium, potassium and magnesium.

Soil pH is a measure of the acidity (amount of hydrogen ions present in the soil). As the amount of hydrogen ions increase the soil acidity increases. Soil pH is measured on a logarithmic scale so that a pH of 6 is 10 times more acidic than a pH of 7 and a pH of 5 is 100 times more acidic than a pH of 7.

Soil acidity affects productivity

When the soil pH falls below 5.5 ($CaCl_2$) for crops and 5.0 ($CaCl_2$) for pastures, then productivity starts to decline.

When pH falls below 5.0 ($CaCl_2$), toxic amounts of aluminium and manganese can be released into the soil solution. Aluminium solubility increases markedly as the soil pH ($CaCl_2$) drops below 5.0 and aluminium goes from having a negligible effect on plants to having a large effect. Soluble aluminium is toxic to roots of many plants and therefore limits their access to soil, water and nutrients.

At a low soil pH microbial activity declines and nutrients such as phosphorus, magnesium, calcium and molybdenum become less available. Agricultural production can significantly decline and fertilisers become less effective.

As the soil becomes more acidic fewer agricultural plants grow. Canola, lucerne, annual medics and faba beans are very sensitive to soil acidity.

Acidification in the sub-surface soil (10-20 cm), the layer below the normal depth of cultivation is becoming an increasing problem.

Soil acidity can be prevented or counteracted by applying lime or other alkaline material.

Factors affecting soil acidification rates

There are a number of factors that affect the rate of soil acidification.

Soil type: pH drops faster in sandy soils. These soils have a lower cation exchange capacity and so are less able to retain nutrients against leaching. They also have a lower water holding capacity, resulting in greater drainage and leaching down the profile.

CARING FOR OUR COUNTRY

Government of South Australia
Department of Environment and Natural Resources

Agricultural Bureau of South Australia Inc.
PATHWAY TO IMPROVEMENT

RURAL SOLUTIONS SA

Clay soils have a greater cation exchange capacity and a greater water holding capacity and therefore can buffer against acidification.

Soils with a higher organic matter can also buffer against pH change. However, once the pH falls in clay soils and/or soils with high organic matter then greater amounts of lime are required to raise the pH to a target level compared to sandy soils and or soils with a low organic matter.

Rainfall: Higher rainfall increases the rate and intensity of leaching alkaline nutrients down the soil profile.

Land use: Higher production systems that use more nitrogen fertilisers and removal of more farm produce (grain and hay). All farm inputs such as fertilisers and chemicals indirectly accelerate acidity when they lead to increased yields and therefore greater rates of product removal.

Effects of fertilisers on acidity

Higher rates of nitrogen fertilisers are now being used in farming systems. Fertilises such as ammonium sulphate, urea and ammonium nitrate are converted in the soil to nitrate in a chemical reaction that releases some acid hydrogen ions and increases soil acidification. Deep placement of nitrogen is likely to increase acidification in the sub-surface over time.

Similarly, elemental sulphur in some products is converted to sulphate in soil by bacteria, also releasing some hydrogen ions.

Sound nutrition programs must be maintained to support productive and profitable farming systems. Lime should be applied to compensate for fertiliser-induced acidification effects.

Implications of productive farming

Increasing farm productivity through the use of high nitrogen fertilisers, incorporation of grain and pasture legumes within the rotations, higher crop yields and removal of other produce (hay and wool) are all important to maximise financial returns. However, all of these practices can accelerate the rate of soil acidification (Table 1).

The removal of farm produce (grain, hay and wool) take alkaline nutrients off the paddock causing an acidifying effect in the soil. Lucerne hay has a particular high acidifying effect because of the high amounts of alkaline elements it contains.

Table 1: Productive farming practices and effect on soil acidification

Farming practices	Rate of acidification
Use of nitrogen fertilisers	Increase
Deep placement of nitrogen fertiliser	Increase
In horticultural crops – change from urea and ammonium nitrate to calcium nitrate	Decrease
More crop legumes in the rotation	Increase
Improved pasture legumes	Increase
No-till	No direct effect
Hay cuts (especially lucerne)	Increase
High crop yields – removal of grain	Increase
Removal of wool, milk and meat	Slight increase
Retaining stubbles	Slight increase
Perennial pastures	Slight decrease
More efficient use of nitrogen i.e. less leaching	Decrease

Table 2 shows the amount of lime required to balance the acidity from various farming practices. The use of continuous cropping with high nitrogen inputs will require 2.5 tonnes/hectare of lime after 10 years to maintain the current soil pH compared to the traditional cropping pasture rotation that will only require 1 tonne/hectare of lime after 10 years.

Monitoring of soil pH and strategic applications of lime should be part of routine farm management to ensure that soil pH is maintained above the critical levels.

Figure 1: Field testing pH kit

Monitoring of soils

In highly productive farming systems it is essential to monitor soil pH by regular soil testing. This should be done at least every five years. Soil samples should be taken from the same soil type and land use and both the surface and the sub-surface soil layers should be sampled.

When sampling for soil pH it is best to collect 20 to 30 samples from the top-soil and the same amount from the sub-soil. The samples from each layer should be kept separate and thoroughly mixed and a representative sample taken from each layer to be sent to the laboratory.

When sampling for soil pH, use a fixed transect (i.e. put markers on fence lines) as this allows for re-testing and better monitoring of changes of soil pH over time rather than just random sampling.

Table 2: Contributions of farming systems and fertilisers to soil acidification

Soil acidity contributing factor	Typical acidification rate kg lime/ha/ year to balance acidity		
	Acidifying	Neutral	Reducing acidity
Land Use Systems			
Low intensity grazing	50		
Medium intensity grazing – some hay cuts	100		
High intensity grazing – regular hay cuts	150		
Cropping – pasture rotation	100		
Intensive cropping – some pasture, high N inputs	200		
Continuous cropping – high N inputs	250		
Dryland grazed lucerne	80		
Horticulture - high N input (acidifying forms)	Up to 500		
Products removed (per tonne/ha removed)			
Wool[1]	14		
Milk	4		
Meat[1]	17		
Wheat	9		
Lupins	20		
Canola	2		
Lucerne hay	70		
Export oaten hay	25		
Clover hay	40		
Fertilisers (per kg of N or S/ha applied)			
Urea	1.8		
Ammonium nitrate	1.8		
Ammonium sulphate	5.4		
Calcium nitrate[2]			-1.8
Calcium ammonium nitrate[2]*		0	
UAN Solution	1.8		
Di-ammonium phosphate (DAP)	3.6		
Mono-ammonium phosphate (MAP)	5.4		
Superphosphate*		0	
Muriate of potash*		0	

Rate of soil acidification is estimated as the quantity of lime needed each year to neutralise the acidification induced by the farming system, products removed and fertiliser in a medium rainfall area.

Acidification rates indicated for the above farming system are typical of quoted figures for Southern Australia.

Acidification rates caused directly by fertilisers are based on common and normal application rates and assuming 50% of nitrate leached.

UAN– Urea and ammonium nitrate (solution).

Rate of acidification in clay soil is slower than in sands because they can 'buffer' against pH change.

*A slow decline in soil pH is induced by these 'neutral' fertilisers through acidification effects of increased crop and pasture production.

[1]Further acidification occurs with set stocking of sheep due to uneven deposition of animal excreta in stock camps

[2]Generally only used in horticultural systems

pH variability and paddock zoning

Surface soil pH can vary even within the same soil type and land use across the paddock and at depth. The diagram below shows the variation in soil pH that occurs in a paddock with red-brown earth soils in the mid north of SA. Each sample is 100 metres apart.

The more samples taken and tested will provide a better guide to variation of soil pH across the paddock and then the paddock can then be zoned according to similar pH levels. Once the paddock is zoned then various rates of lime can then be applied on the surface in each zone to raise the soil pH with the use of variable rate technology. Varying the rates of lime rather than applying a set amount across the paddock will be more efficient and effective. Applying lime at various rates on the surface will help to achieve the target pH of 5.5 $CaCl_2$ across the whole paddock.

Sandy loam top-soil (0-10 cm)
Amount of lime (t/ha) required to raise the soil pH to 5.5 ($CaCl_2$)

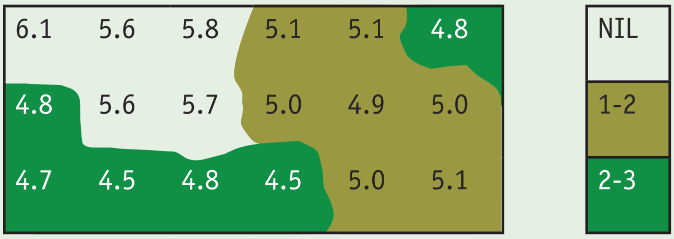

Figure 2: Soil pH ($CaCl_2$) variability over a paddock (one sample point represents one hectare)

Liming

Soils that are acid or becoming acid should be limed to remain productive.

If lime is not regularly applied to acidifying soils, productivity will decline over time resulting in a loss of income.

Liming to raise the pH of surface soils is relatively straight forward but lifting soil pH in the sub-surface layer is much more difficult due to the low solubility and slow movement of lime through the soil For information on correcting sub-surface pH refer to the fact sheet 'Identification and treatment of sub-surface soil acidity'.

Figure 3: Liming in the mid north of SA

Many farmers now practice no-till farming. In a no-till farming system with minimal soil disturbance lime movement is slower compared to a reduced tillage or conventional farming system. It is recommended that in this system, either use slightly higher rates of lime or apply lime earlier than normal. It may even be worth incorporating the lime with a cultivation in the year of application to improve its effectiveness if the soils are significantly acidic.

Lime quality

Lime quality is an important consideration. The most effective liming products are those that have a high neutralising value (i.e. greater than 80%) and a small particle size.

Lime is a good investment to maintain the soil pH as well as soil health and to maintain production and profitability.

Conclusions and recommendations

More intensive and productive farming systems with higher nitrogen use, with grain and pasture legumes in the rotation and higher yields are increasing the rate of soil acidification. Soil pH should be monitored at least every five years and lime applied on a regular basis to counteract the rate of soil acidification.

If the soil pH level has fallen and needs to be lifted then lime should be applied to raise the pH to or above the critical pH level and prevent the development of surface and sub-surface acidity.

Using lime to prevent and treat soil acidification is important to maintain productive, profitable and sustainable farming systems.

For further information contact your local Rural Solutions SA consultants

Phone: 1300 364 322 **Email: info@ruralsolutions.sa.gov.au** **Web: www.ruralsolutions.sa.gov.au**