Lime and lime quality for acid soils

More than two million hectares of land in South Australia are susceptible to soil acidification, a process that degrades the soil and reduces crop and pasture growth. Soil acidification is a natural process but is accelerated by more intensive and productive farming systems. It is a build-up of hydrogen ions in the soil that causes acidity. When the soil pH falls below pH 5.0 (measured in calcium chloride $CaCl_2$) then the productivity of even tolerant crops and pastures starts to fall, toxic amounts of aluminium can be released into the soil, microbial activity starts to decline and nutrients such as phosphorus, magnesium, calcium and molybdenum become less available to plants. For optimum production of most crops and pastures, soil pH should preferably be at or above pH 5.5 ($CaCl_2$).

Lime is the most effective and economical method for the treatment of acid soils. Applications of lime will raise the soil pH and improve crop and pasture production. This information note outlines types of lime materials; lime quality; application and alternative lime materials present in the agricultural areas of SA.

Lime materials

Lime and other liming materials such as dolomite counteract soil acidity by neutralizing acid reactions in the soil. The carbonate component of the lime material reacts with the hydrogen ions in the soil solution and in doing so raises the soil pH. There are various materials that contain carbonate:

- Limestone: crushed and sieved limestone contains mostly calcium carbonate;
- Dolomite: crushed and sieved dolomite rock contains a mixture of magnesium and calcium carbonates. Dolomite is generally harder than limestone and needs to be finely ground to be satisfactory;
- Lime sand: mined from natural deposits, that occur mainly along the coastlines. These do not require crushing and consist mostly of calcium carbonate;
- Shell grit: shell grit was mined and crushed at Port Parham but this has since closed down;
- Lake deposits: unconsolidated calcium carbonate and magnesium carbonate deposits that are present in old lake beds;
- Industrial by products: crushed limestone burnt for industrial purposes produces calcium oxide (burnt or quick lime). Stockpiling and wetting up of calcium oxide converts it to calcium hydroxide (hydrated lime or slaked lime). A by-product from soda ash manufacturing was a hydrated lime marketed as ‘Nutrilime’. These products are very effective as liming materials but can be quite hazardous to use because of their caustic nature. Due to the closure of the soda ash manufacturing plant at Osborne, Adelaide only a small amount of these products are now available.

Figure 1 shows the lime products in South Australia.

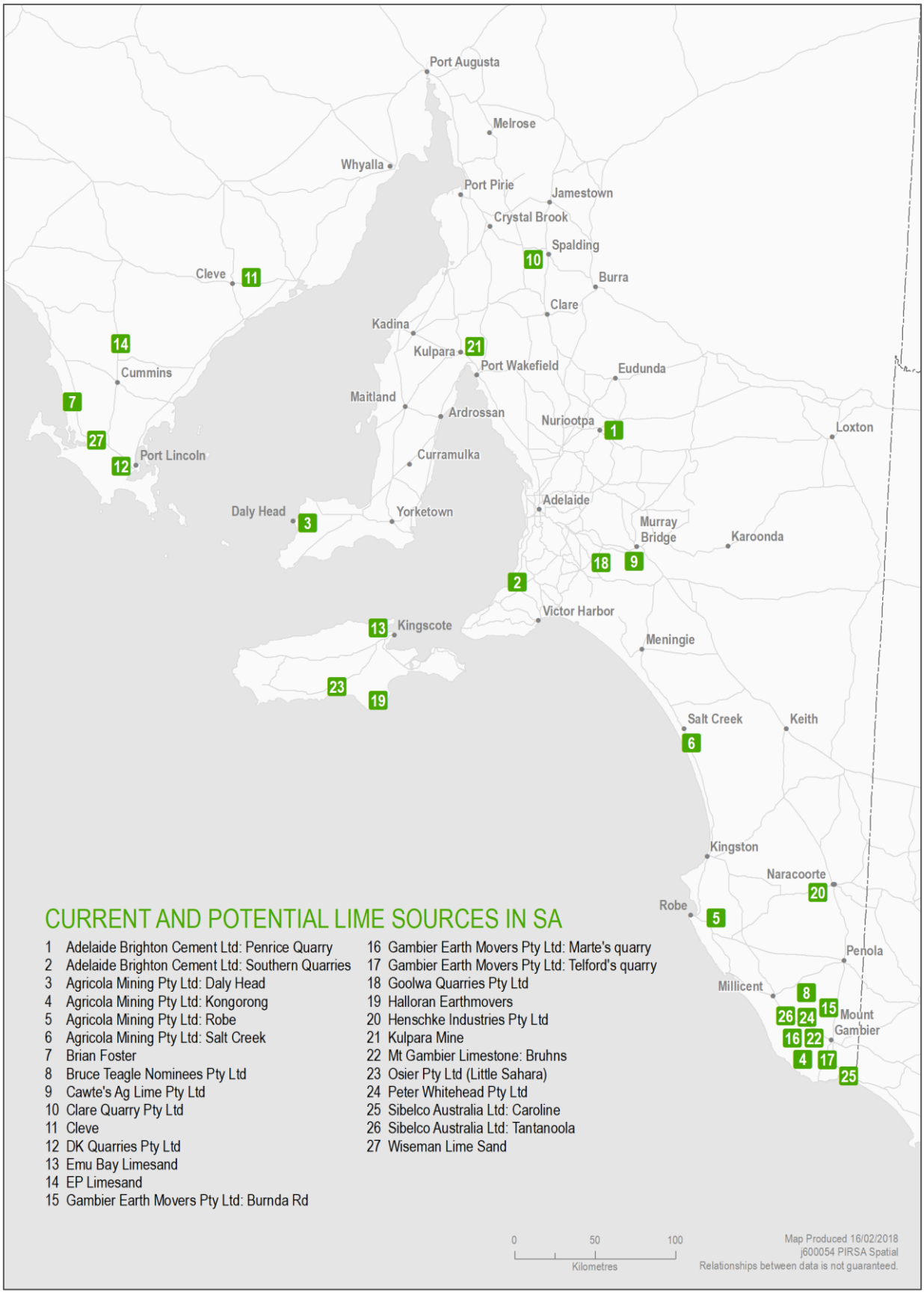

Figure 1: *Location of lime products in South Australia (PIRSA Spatial Information Services)*

Lime quality

A range of tests have been developed to measure lime quality in terms of their effectiveness in counteracting soil acidity. These include the Neutralising Value (purity), particle size (fineness), calcium and magnesium content, and reactivity. Registered agricultural lime suppliers are required to provide a laboratory analysis of the NV, particle size and calcium and magnesium content of their liming products to purchasers.

Neutralising value (NV)

As carbonate is the key agent for neutralizing acid in the soil, the proportion of carbonate in the liming material is important. The NV relates to the amount of calcium carbonate. Pure calcium carbonate is 100%. The higher the NV, the greater the material's capacity to neutralize acid soils. Good quality liming materials should have a NV greater than 80%. Calcium oxide or calcium hydroxide have a NV greater than 100%.

Liming rates are calculated on the basis of 100% purity so if the NV of a product is less than 100% the amount of lime material to be applied has to be increased to provide the appropriate amount of carbonate. For example, if the NV is 60% and the rate of lime required is 2 t/ha then the amount of lime can be increased to 3.3t/ha to provide 100% NV.

Particle size

The finer the liming material, the quicker the lime will react within the soil. However, fine particles are difficult to spread because they tend to block up the spreader and can drift. A mixture of fine and coarse particles will overcome spreading difficulties but the coarser particles will react more slowly. Preferably more than 60% of the lime should pass through a 0.3 mm screen. Lime with a high NV and a small particle size will give the quickest response.

With fine lime, many contract spreaders have a shroud to control the dust. Wetting the lime with 2-4% by weight of water will also minimize the dust.

Effective neutralizing value (ENV)

ENV is a calculation that takes into account particle size and the NV of a liming material. Lime passing through a 0.3 mm sieve is considered 100% effective, lime in the size range of 0.3 to 0.8 mm sieve is considered 60% effective and lime coarser than 0.8 mm is considered only 10% effective. The percentage of the lime through each screen is multiplied by these effective ratings of 100%, 60% and 10% and by the NV of the material, then added together to obtain the ENV. Preferably, ENV should be greater than 65%. ENV is useful when comparing similar materials derived from similar sources such as mined crushed rock or lime sands but there are problems when comparing materials from differing sources such as lake bed deposits compared to crushed rock.

To raise the soil pH quickly it would be best to use a lime with a high ENV. To maintain the soil pH then a lime with a lower ENV would be adequate.

The particle size is determined on a dry sieving and then the ENV is calculated from the particle size. Some lime sources such as the Agricola products (from old lake beds) react differently with wet sieving. These products are dispersive and break into small particles when wet. With wet sieving these products can have twice the ENV compared to dry sieving. These products are more reactive in the short term but over time will be similar to other lime products. More work needs to be carried out with wet sieving on other lime products.

Calcium and magnesium content

Calcium and magnesium content of liming materials can be important in the selection of liming products. Dolomites have a higher magnesium content while limestones and lime sands have higher levels of calcium. Some horticultural plants can be sensitive to very high or very low levels of calcium and magnesium. Prolonged use of one type of product can lead to an abundance of one nutrient and inducing deficiencies of others. In areas where livestock suffer from grass tetany (low magnesium) then applying dolomite as a liming material may increase soil magnesium levels.

Other tests

Some other tests sometimes used in lime analysis include the Resin Suspension Neutralisation test and porosity. The Resin Suspension Neutralization method assesses the ability of a lime sample to alter the pH of a weak acid solution. This test, however, is not currently available through commercial soil testing laboratories.

Porosity assesses the effectiveness of liming material. Using a scanning electron microscope CSIRO researchers have found that some lime products such as those formed from coral have a 'honey comb' particle structure that greatly increases the surface area and its effectiveness. Mount Gambier limestone is one such liming material.

Application

Rate of lime to raise the soil pH

The amount of lime required to treat soil acidity depends on a number of factors such as the current soil pH; desired or target soil pH; soil texture and lime quality. The aim should be to raise the top-soil to around pH 5.5 ($CaCl_2$).

The following equation gives a guide to the lime requirement:

Lime requirement (t/ha) = (target pH – current pH) x soil texture factor.

Texture factor and lime required to raise the soil pH by 1 unit:
Loam to clay loam 4; Sandy loam 3: Sand 2:

For example: to raise a sandy loam soil of pH 4.8 ($CaCl_2$) to pH 5.5 ($CaCl_2$)

(5.5 – 4.8) x 3 = 2.1 tonnes of lime per hectare is required.

More lime is required to raise the soil pH in clays than in sands so it is important to know the soil's texture.

It is recommended that the maximum amount of lime applied at any one time should be no more to raise the soil pH by 1 unit. This is particularly important on sands and sandy loams as over-liming may induce trace element deficiencies, if they are marginal such as manganese and zinc.

If more lime is required on these soil types to raise the soil pH to 5.5 ($CaCl_2$) then the application will need to be split. Apply an application now and then another application in about 4 years time.

On soils with low organic carbon levels (less than 0.5% for sand: less than 0.7% for sandy loam and less than 1.2% for cays) the application rate of lime should be reduced by 25%.

The lime requirement calculation is based on a pure lime or an NV of 100 %. If the NV of the material to be used is less than this, then higher rates of lime can be used.

Rate of lime to maintain the soil pH

Table 1 shows the impact of farming system on the annual acidification rate. Once the soil pH is at an optimum level then lime is still required to counteract soil acidification from farming practices. For example, in a continuous cropping system 250 kg of lime is required per year to maintain the pH level. More than 1 tonne of lime will be required every four years.

Table 1: Farming system impact on annual acidification rates

Land use system	**Typical acidification rate** (kg lime/ha/year to balance soil acidity)
Low to medium intensity grazing	50 - 100
High intensity grazing – regular hay cuts	150
Crop – pasture rotation – low production	100
Intensive cropping – some pasture , high nitrogen inputs	200
Continuous cropping – high nitrogen inputs	250+

A 'maintenance lime rate calculator' prepared by PIRSA consultants can be used to estimate the amount of lime required for a paddock to offset soil acidification over a period of time. The calculator takes into account soil texture, rainfall, crop rotation, product removal and fertiliser inputs. This is available on the http://agex.org.au/project/soil-acidity/ web-site.

Spreading

Lime is applied by broadcasting material using a spreader. These typically carry 5 to 16 tonnes and are towed behind a tractor or mounted on a truck (Figure 2). Due to the finer particle size the spreading width for lime is much less than for granulated fertilisers. Care needs to be taken that the lime material is evenly spread across the paddock so checking the distribution pattern of lime from the spreader is important.

***Figure 2**: Spreading lime in the Lower North*

Incorporation

As lime does not move quickly through the soil, mixing it in the topsoil with tillage will improve its effectiveness. Finer and better quality products may move more quickly through the soil profile having an increased impact on the lower layers.

If lime is broadcast on the surface and not incorporated (with a no-till farming system) it will move very slowly down the soil profile and generally only moves about 2.5 cm per year. Lime therefore can elevate the pH in the soil surface layers and can have limited effect below the top layer. If the underlying layers are quite acidic then an 'acid throttle' can be created in the main root zone. The 'acid throttle' can stunt rooting depth, development and nodulation and restrict plant's uptake of water and nutrients. It will take about four years for the lime to move about 10 cm down the profile if it does not become fully neutralised beforehand. The 'acid throttle' effect was observed with faba beans in 2017 at the lime trial at Wirrabara. If planning to sow pH sensitive crops such as faba beans or lentils then lime should be incorporated into the soil well before seeding.

Avoid spreading lime onto emerging crops and pastures particularly if conditions are dry as this may burn the tips of emerging plants.

Comparing lime sources

When comparing lime sources, the purchase price, lime quality (NV), freight costs and mileage and the spreading costs need to be taken into account.

PIRSA consultants have developed a decision support tool 'Lime Cheque' that takes into account the lime quality (NV), cost of lime, distance from the lime source (freight) and spreading costs and then compares the cost of liming using different liming products and calculates the most cost-effective lime source to use. This is available on the http://agex.org.au/project/soil-acidity/ web-site.

Cost - benefit

Applying lime to acidic soils can significantly improve crop and pasture yields. The short term response to lime can be profitable and long term viability is ensured by the restoration and maintenance of soil productivity. Economic responses have been achieved with most field crops and the cost of lime is often reimbursed in the first few years. The benefits of liming in addressing soil acidity can last for more than 5 years so the cost of applying lime can be spread over that period.

Soil acidification processes will continue to occur and it is recommended that the soil pH be monitored following lime applications and maintenance applications of lime applied to prevent soil pH falling below the target pH 5.5 ($CaCl_2$).

Alternative materials

There are a number of alternative materials to applying lime that can neutralise soil acidity. Some of these are listed below.

Clay spreading

Clay that contains free lime can act as a liming agent. While clay is commonly used to treat water repellent sands, a clay containing 5% limed applied at 150 t/ha can provide 7.5 t/ha lime. There are now examples of sites that were clayed decades ago which have become acidic again due to the soil acidification processes.

Sodium bicarbonate in neutral to alkaline clays without free lime can also have a liming effect however, over time, the carbonate will leach down the soil profile.

Irrigation water

Irrigation water sourced from old marine limestone aquifers is often highly alkaline. These aquifers are common in the South East, Southern Mallee and in other districts.

Biochar

Many biochars are considered to have an alkaline reaction and neutralising effect in the soil however, this is dependent on the source material for the biochar and how it was processed.

Composts and manures

Compost adds large amounts of cations and anions to the soil which can potentially react with hydrogen ions to have a neutralising effect. However, straw from animal sheds containing manure can contain significant amounts of ammonia and when applied directly to soils the conversion of ammonia into nitrate can lead to soil acidity.

Manufactured fertilisers

Manufactured fertilisers that produce alkalinity include calcium nitrate.

Summary

Applying lime or other liming materials is an effective and economical way to improve soil pH, soil microbial activity and to maintain crop and pasture productivity.

The type of lime material, quality and amount required all need to be considered. The benefits of the most commonly available forms of lime can last for about 5-6 years while some of the alternative materials might last for much longer. Soil pH should be checked on a regular basis after the application of any liming material and further applications be applied as required to maintain soil pH and crop and pasture productivity.

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