HOW LIME OR GYPSUM CAN IMPROVE pH OR SOIL STRUCTURE

Lime or gypsum applications can be cost-effective ways for growers to improve soil pH or structure.

Lime is used to neutralise soil acidity while gypsum is used to supply soluble calcium and improve soil structure.

The anion in lime (usually carbonate) neutralizes acid and increases soil pH. Because calcium is the main mineral in most limes, it is often assumed calcium neutralizes acidity but this is not the case. Most limes are highly insoluble in water so they only dissolve when they react with acid in the soil. If lime is added to soil with pH above 7.0 (measured in calcium chloride) the lime remains almost inert.

In contrast to lime, the main reason for applying gypsum is to supply soluble calcium. Calcium in gypsum improves soil structure by replacing sodium (and sometimes magnesium) on the exchange surfaces of clays. With the exception of sands, soil structure is determined largely by relationships between positively charged cations and the slightly negative charge that clay particles have on their surfaces.

On poorly structured (non-sandy) soils, sodium (and to a lesser extent magnesium) can dominate the exchange sites. The calcium in gypsum is relatively soluble so it can displace sodium and modify clay structure. Gypsum does not require acid in the soil to dissolve.

What does lime contain?
Limes generally contain carbonate, oxide, hydroxide and/or silicate forms of calcium and/or magnesium. Limes used in agriculture such as limesand and limestone are mostly calcium carbonate, with smaller amounts of magnesium carbonate. Lime quality varies significantly, with neutralizing values and particle size distribution the key quality issues.

Neutralizing value compares a lime’s ability to neutralize acidity with that of pure calcium carbonate, which is given a standard value of 100. But the laboratory determination of a lime’s neutralizing value does not always reflect its capacity to change soil pH. This is why particle size distribution is the second key measure of lime quality.

Neutralizing lime
Lime dissolving is a chemical reaction and smaller particles of lime are more easily dissolved by acid in the soil. Lime particles react and neutralize acidity immediately adjacent to them (see figure below). When this has occurred there is insufficient acidity near the particle for further neutralization. For this reason, it is better to have many, complete neutralizations of smaller lime particles than fewer incomplete reactions with larger lime particles.
While neutralizing value and particle size of lime are important for effectiveness, the costs of lime, transport and spreading also need to be considered when determining the most cost-effective lime.

Limes work when calcium carbonate is dissolved by acids in the ‘soil water’ and splits into calcium ions and carbonate ions (see figure below).

Carbonate combines with hydrogen ions (which are the cause of soil acidity) forming carbon dioxide and water. All neutralising is performed by carbonate, so the calcium applied in lime does not affect soil pH. Dissolution of calcium carbonate into calcium and carbonate ions is more rapid at low pH because there is more acid available to dissolve the lime.
Dissolution is almost impossible under alkaline conditions so if lime were applied to a soil with moderate to high pH, the calcium carbonate would remain largely insoluble. Calcium would not be available to plants and the lime would have little impact on soil pH or soil structure.

**What does gypsum contain?**

Gypsum, as an agricultural mineral, consists of calcium sulphate. Gypsum has no neutralizing value and little or no effect on pH when applied to soil.

Unlike calcium in lime, the solubility of calcium in gypsum is not affected by pH (see figure below) so gypsum provides a soluble source of calcium if sodium needs to be displaced in neutral to alkaline soils.

Soils that have more than 5–6 per cent of the cation exchange capacity occupied by sodium are called sodic. Depending on other soil characteristics (mainly salt and organic matter contents), sodic soils can be unstable.

Symptoms of unstable soil structure include hard setting, cloddiness, surface crusting and poor workability. These occur when sodium dominates the exchange sites because aggregation of clay particles is reduced.

![Diagram showing solubility of calcium in lime and gypsum](image)

**Solubility of calcium in lime alters with pH but solubility of calcium in gypsum is not affected by pH.**

**Repairing sodic soils**

The aim of applying gypsum to sodic soils is to aggregate clay particles by displacing sodium ions on clay surfaces with calcium ions. The relative proportions of exchangeable sodium and calcium are less important in sandier soils because there are few clay particles to aggregate and soil structure cannot be improved anyway.

It is unusual for soil to be both sodic and acidic because sodium-saturated clays tend to dissociate in water, releasing free sodium ions and leaving free charges on clay, which are hydrolyzed.

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Except for some saline soils (where alkaline hydrolysis is suppressed), lime is not usually a suitable source of soluble calcium to displace sodium.

**Calcium supply**

Limes and gypsums can both be considered sources of calcium for plants. Calcium from lime is only available to plants after the lime has dissolved. In contrast, calcium in most gypsum dissolves quickly in soil water and is available to plants.

On most agricultural soils, applying either lime or gypsum just to supply calcium is likely to be uneconomic. This is because for broadacre crops and pastures there is no evidence that calcium is limiting plant growth.

The few reports of calcium deficiencies are generally associated with plant availability in relation to soil moisture and root growth, rather than insufficient soil supply. This situation could change slowly in future but other nutrients are likely to be of more immediate concern. Currently, calcium applied in lime or gypsum is a bonus but a bonus of limited value for plant nutrition.

**Where to apply lime and gypsum**

Carry out soil tests to identify if lime or gypsum is required and to estimate application rates. If pH is less than 5.5 (calcium chloride), it is recommended that growers apply lime.

Rates required depend on the buffering ability of the soil (the capacity to resist pH change) and the specific demands of the crops and pastures grown.

In general, clay soils are more buffered than loams so they require more lime to achieve the same increase in soil pH. Loams in turn are more buffered than sands.

Sodicity identified by soil testing is a guide to gypsum requirement but not a guarantee that a soil is unstable and/or that there will be a response to gypsum. In addition, use paddock observations (such as workability, crusting, run-off) and direct tests (such as dispersion tests). An experienced adviser should be used to assist with any decisions on applying gypsum.

If topsoil samples do not indicate a need for lime or gypsum it can be worthwhile to collect samples further down the soil profile (10–20 cm and 20–30cm). Soil samples from deeper in the profile can identify acid layers and a need for lime not identified from topsoil samples.

Similarly, assessing the subsoil for both sodicity and structural problems is often worthwhile. Taking time to seek local expertise is always recommended.