Lime and soil acidity (7-15)

What is lime?
In the New Zealand context lime refers to ground limestone (CaCO$_3$). However other materials applied to New Zealand soils also have a liming affect; notably dolomite (CaCO$_3$.MgCO$_3$), Reactive phosphate rocks (RPR) and dairy farm effluent (DFE). Burnt lime (CaO) and hydrated lime (Ca(OH)$_2$) are rarely used in the broad-acre situation.

What does it do?
The active ingredient in lime is the carbonate not the calcium (Ca). Ca deficiency does not occur in New Zealand because the soils are geologically young and there is 20% Ca in superphosphate. Consequently there is plenty of Ca in New Zealand soils (see also Farmfact 7-2 Determining nutrient requirements).

It is the carbonate that reacts with and neutralizes the acidity in the soil.

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\text{CaCO}_3 + 2 \text{H}^+ \text{ (acid) } \rightarrow \text{Ca}^{2+} + 2 \text{OH}^- \text{ (alkali)}
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What does lime do?
Liming, by increasing the soil pH, has many effects on the soil:

1. At low soil pH levels (< 5.5) aluminum (Al) and manganese (Mn), which are normally part of the soil minerals become plant available. Small amounts of these elements are toxic to pasture plants and especially clovers. Liming soils with an initial pH below 5.5 eliminates this problem. Soils with a pH > 5.5 will have no available Al and Mn.
2. Soil microbial activity is optimized at pH levels around 6.0. Thus liming soils can increase the biological activity and hence nutrient cycling in the soil. For example it has been shown that liming enhances the breakdown of organic N in the soil releasing a flush of plant available N.
3. The plant availability of molybdenum (Mo) increases as the soil pH increases. Thus liming soil that are deficient in available Mo can significantly increase clover growth by increasing the amount of plant available Mo (Mo is required in small amounts for the process of clover N fixation).
4. Increasing the soil pH can, on some soils, decrease the availability of zinc (Zn) and manganese (Mn). This is why over-liming (liming to soil pH levels to > 6.5) can have detrimental effects on plant growth, particularly on coarse soils.
5. Liming can also increase the availability of phosphorous (P) on some soils (the drier sedimentary soils). This is referred to as the P sparing effect of lime. This effect is not large enough to decrease fertiliser inputs in the long-term.

Why do we need lime?
There are many biochemical reactions in the soil that generate acid (H$^+$). For example the microbial breakdown of soil organic matter to ammonium and then to nitrate (the nitrification process) produces acid. So does the leaching of clover-fixed nitrogen. Some fertilisers produce acid when they dissolve in the soil.

The net effect of all the acid-producing reactions in that the soil pH declines over time. The rate of acidification increases with the increasing pasture production and so for most dairy farms, 400-500 kg/ha of ground limestone is required annual to ‘mop up’ this acidity.

July 2012
Research shows that it does not whether lime is applied in small amounts often or large amounts infrequently. The reason for this is the lime is sparingly soluble – it takes about 12-18 months to fully dissolve in the soil and it has a long residual effect. For this reason the general practice on dairy farms is to apply 2-2.5 tonnes/ha of lime every 4-5 years.

**Optimal pH**

The optimal soil pH depends on the soil (mineral or peat) and the crop. On mineral soils, trials show that as the soil pH increases the pasture response to liming declines. At soil pH 5.0 annual pasture responses to liming are about 10%, at pH 5.5, about 5.0% and if the initial soil pH is in the range 5.8-6.0 the pasture will not respond to additional inputs of lime (see figure below). In other words the optimal soil pH for clover-based pastures on mineral soils is 5.8-6.0. Liming above this can have detrimental effects as discussed above.

A soil pH of 5.8-6.0 is also suitable for most crops (brassicas and maize). However lucerne is sensitive to soil acidity and requires a soil pH of > 6.5.

Peat soils are very different from mineral soils. In their virgin state they do not contain the Al and Mn minerals present in mineral soils and hence can be operated at much lower soil pH levels. Also, unlike mineral soils, the soil pH declines with increasing soil depth. For these reasons the optimal pH on unimproved peats is 5.0 (0-75mm) and 4.5 (75-150 mm). It is important that the lime is worked into the soil – the deeper the better.

As the peat develops and mineralizes it becomes increasingly like a mineral soil and the Anion Storage Capacity (ASC – the ability of the soil to retain phosphorus and sulphur) increases from < 20 up to about 60. Once the ASC reaches about 60 the developed peat should be treated just like a mineral soil (i.e. optimum pH 5.8-6.0). When a developed peat is reworked then additional lime should be applied to counter the new acid peat brought to the surface.

**Lime requirements**

As a rule of thumb 1 tonne/ha ground lime will increase the soil pH by 0.1 pH units. Thus 5 tonnes/ha lime is required to increase the soil pH on a mineral soil from 5.5 to 6.0. The optimum pH 5.8-6.0 should be maintained by the application of 2-2.5 tonne/ha lime every 4-5 years.

During their development peats require large amounts of lime – 10-15 tonnes/ha of lime should be worked as far down as possible into the topsoil to achieve a minimum pH of about 5.0. With more developed peats the topsoil pH should be maintained in the range 5.5-6.0.

**Further reading**