Potassium for high rainfall pastures

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Potassium for high rainfall pastures
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Summary

- Potassium deficiency is most likely for legumes in pastures on sandy soils and in wet years
- Potassium can be redistributed around the farm from paddocks regularly cut for silage/hay to paddocks in which silage/hay are fed out
- Legumes have a higher potassium requirement than grasses
- The soil test for potassium is not particularly reliable
- Tissue testing is probably more useful than soil testing in deciding whether or not potassium fertiliser should be applied to pasture.

Role of potassium in plants

Potassium plays a major role in plant growth. It maintains the solutions in plant cells at ionic strengths suitable for maintaining strong plant walls and for the proper functioning of leaf pores (stomata) and plant processes such as photosynthesis, transport of sugars and enzyme activation.

Potassium does not become a direct part of the plant structure but acts to regulate water balances, nutrient and sugar movement in plant tissue. Plants deficient in potassium cannot use other nutrients and water efficiently. They are less tolerant of stresses such as drought and waterlogging and are more susceptible to pests and diseases.
Soil potassium

Sources of potassium in soil are indicated in Figure 1. The potassium found naturally in soils has come from weathering of soil minerals such as micas (biotite and muscovite) and feldspars. These minerals release potassium into the soil solution as they break down.

Potassium is the main positively charged ion (cation) in the fluid inside plant cells. In soil, cations balance negatively charged sites on the surface of clays, oxides and organic matter. In clays, cations—including potassium—can balance negative charge in internal surfaces not exposed at the surface. These cations are called non-exchangeable cations because they cannot be replaced by other cations in the soil solution as charge balancers on the internal surfaces of clays. These non-exchangeable cations are only released to soil solution as the clay structure is slowly broken down (weathered).

However, cations balancing negative charges on the surfaces of soil constituents exposed to the soil solution (outside surfaces of clays and surfaces of oxides and organic matter) can be readily replaced (exchanged) as balancers of negative surface charge by other cations in soil solution. These are called exchangeable cations.

Cation exchange capacity of soil

The cation exchange capacity of a soil is a measure of the negative charge sites on that soil which are balanced by exchangeable cations. Cation exchange sites are typically balanced by the major soil cations calcium, magnesium, potassium and sodium. The proportion of the major cations that balance the total cation exchange capacity of most productive soils is usually 65–80 per cent calcium, 10–20 per cent magnesium, 3–8 per cent potassium and less than 4 per cent sodium.
Figure 1. Forms of potassium (K) in soil. The K is indicated by the red dots. The Colwell test procedure can only extract soluble K in soil solution and exchangeable K on the surfaces of soil constituents (clays, oxides, organic matter), which is also the only K in soil that plant roots can take up.

Soil potassium taken up by plant roots

Plant roots can readily take up exchangeable potassium and potassium ions present in soil solution but not the non-exchangeable potassium in clays and structural potassium in primary soil minerals.

Major pasture species used in high rainfall pastures

The major pasture species sown into high rainfall pastures are annual ryegrass (*Lolium rigidum*), Italian ryegrass (*Lolium multiflorum*) and a number of annual legumes, particularly subterranean clover (*Trifolium subterraneum*).
How susceptible are clover and ryegrass to potassium deficiency?

Grasses are better able than legumes to use potassium taken up from soil and accumulated in dried herbage to produce dry matter, so they rarely become potassium deficient, whereas legumes are very susceptible to potassium deficiency.

When first cleared for agriculture, most soils in south-western Australia had adequate indigenous potassium for crop and pasture production, the exception being sandy soils in high rainfall (greater than 800 mm annual average) areas. Particularly in wet years, legumes planted on these soils soon showed signs of potassium deficiency, reducing dry matter and seed production and persistence in the pasture.

Leaching causes potassium deficiency in clover in high rainfall pastures on sandy soils

Sandy soils usually have low cation exchange capacity in the plant root zone. In high rainfall areas, pasture plant roots do not grow deeper than 20–40 cm, largely because the major pasture species are relatively shallow rooting and winter waterlogging restricts rooting depth. In wet years in sandy soils, potassium is leached below the root zone and legumes become potassium deficient, although ryegrass is usually able to access sufficient potassium. Consequently, annual applications of potassium fertiliser are generally required for production and persistence of legumes, especially in wet years.
Potassium fertilisers

The cheapest and most commonly used potassium fertiliser for high rainfall pastures is potassium chloride (muriate of potash, 50 per cent potassium and 50 per cent chloride).

Potassium sulphate (sulphate of potash, 41.5 per cent potassium and 17 per cent sulphur) is more expensive than potassium chloride and is generally only used on horticultural crops that are sensitive to chloride.

Timing of application

The best time to apply potassium fertiliser is about three weeks after annual pasture has emerged at the start of the growing season and when plants have developed sufficient roots to minimise leaching.

Potassium fertiliser is also often applied in late winter–early spring to pasture set aside to produce silage or hay.

Redistribution of potassium in silage and hay

Silage generally contains about 2.5 per cent potassium and hay about 1.5 per cent. Therefore, a tonne of silage contains about 25 kg potassium and a tonne of hay about 15 kg. Using these values, 5 t/ha silage would remove about 125 kg potassium/ha while a 5 t/ha hay crop would remove about 75 kg /ha. High yielding silage and hay crops can remove sufficient potassium to induce deficiency in legumes growing in these paddocks in subsequent years. On the other hand, feeding this silage/hay back to animals on the farm can lead to high levels of potassium in the paddocks in which it is fed. Potassium is redistributed around a farm from paddocks cut for silage/hay to paddocks in which silage/hay are fed out.

In loamy or clay soils, cation exchange capacities and levels of soil potassium are typically larger than for sandy soils, so more than one silage or hay crop may be required to induce deficiency.
Redistribution of potassium by grazing animals

Cattle and sheep urine contains a lot of potassium. When cattle or sheep graze pasture, they redistribute the potassium in the pasture they consume in urine patches that can occupy up to 20 per cent of a paddock.

Most sandy soils used for crops and pastures are now potassium deficient

Although potassium fertiliser was initially only applied to high rainfall pastures on sandy soils, removal of potassium in grain of crops and cereal hay has depleted soil potassium reserves. As a result, potassium deficiency has become common in sandy soils for cereal and canola crops and in legume pastures grown between the crops. These soils cover about 75 per cent of the almost 18 million hectares used for agriculture in south-western Australia. It is now generally profitable to apply fertiliser potassium to cereal and canola crops, and legume-based pastures, on soils where soil and/or tissue testing indicates a likely response.

Like ryegrass, lupin crops rarely become potassium deficient.

Importance of pasture management

Pasture is generally the cheapest source of feed on grazing properties and it has always been profitable to use as much pasture as possible.

Rotational grazing is the most effective way of increasing pasture use by grazing animals. This involves delaying grazing until ryegrass plants have produced three leaves per tiller. How a pasture is managed can affect its composition and therefore how much potassium it needs. The lower the legume content of a pasture, the less potassium it needs. Although the composition of a pasture can change over a growing season and between seasons, intensively grazed pastures which are regularly
top-dressed with nitrogen fertiliser tend to lose their legume content and become grass dominant.

Because ryegrass is better than legumes at using potassium taken up from soil and accumulated in pasture herbage, ryegrass dominant pastures need less potassium fertiliser than legume-ryegrass pastures.

Too much potassium can induce magnesium deficiency in lactating dairy cows

Per unit of potassium taken up from soil and accumulated into pasture dry matter, ryegrass produces more dry matter than clover. That is, once potassium has been accumulated into herbage, ryegrass uses it more effectively than does clover. Therefore, ryegrass requires less potassium than clover so fertiliser potassium requirements for ryegrass are less than for legumes.

If too much potassium fertiliser is applied to a ryegrass-dominant pasture, the concentration of potassium in the herbage can be as high as 4 to 6 per cent.

When the concentration of potassium exceeds about 4 per cent, magnesium deficiency (hypomagnesia) can be induced in lactating dairy cows, immediately reducing milk production and killing some cows.

Fertiliser potassium should only be applied to ryegrass dominant pastures when, at the three leaf growth stage, a tissue test shows the concentration of potassium is less than 2 per cent.

Soil testing for potassium

Soil testing is used to estimate whether or not a soil contains enough potassium for pasture production in the next growing season.

The soil test procedure used for phosphorus testing is also used to test for potassium and uses a 10 cm soil sample.
Soil test potassium calibrations for clover and ryegrass

The only comprehensive study of soil test potassium for high rainfall pastures was undertaken by W. J. Cox between 1972 and 1974 and these results are still used to provide advice to farmers.

In this study, pasture samples to measure dry matter yield were separated into clover and ryegrass while still green so there are separate calibrations for each pasture species. Results are shown in Figure 2 for clover and Figure 3 for ryegrass.

Clover showed many responses to applied potassium (Figure 2), whereas ryegrass rarely responded (Figure 3). In addition, responses to applied potassium were smaller for ryegrass than clover.

Clover never responded to applied potassium when the soil test was greater than about 100 mg/kg (= 100 ppm) and always responded when the soil test was less than about 30 mg/kg (Figure 2). However, when the soil test was between about 30 and 100 mg/kg, clover sometimes responded and sometimes it didn’t (Figure 2). For clover, the soil test was unreliable in the approximate 30 to 100 mg/kg range and this was not improved by considering soil test potassium measured for soil samples collected at 10-20, 20–30 or 30–40 cm, other soil test potassium procedures or soil properties.

Recommendation for legumes

As insurance against potassium deficiency reducing legume production and persistence, the only recommendation from the Cox study is to apply fertiliser potassium when the potassium soil test is less than about 100 mg/kg. However, this means that fertiliser potassium will be applied to many soils when none is required. Tissue testing through the growing season will provide more accurate information on whether or not potassium fertiliser should be applied.
Figure 2. Relationship between clover dry matter increases (responses) to applied potassium (K) fertiliser and Colwell soil test potassium for the top 10 cm of soil.

Figure 3. Relationship between ryegrass dry matter increases (responses) to applied potassium (K) fertiliser and Colwell soil test potassium for the top 10 cm of soil.
If the tissue test shows less than 2 per cent potassium, it is likely that the pasture will benefit from an application of potassium fertiliser.

**Recommendation for ryegrass**

There were too few ryegrass responses to applied potassium in the Cox study to confidently determine critical soil test potassium values for ryegrass. Ryegrass mostly accessed enough potassium for dry matter production, regardless of the soil test (Figure 3).

**Problem of urine patches for soil testing potassium**

In a long-term experiment (2002 to 2007), six rates of potassium were applied three weeks after pasture emerged each year and the pasture grazed by lactating dairy cows. The cows were on the 15 metre by 20 metre plots only while grazing pasture in the section of the paddock where the experiment was located, between the morning and afternoon milkings during the six growing seasons. No silage or hay was cut and no cows were present on the plots outside the growing season. Soil samples were collected each February to measure soil test potassium using the standard procedure.

Soil test potassium was very variable (Figure 4, Table 1), attributed to varying proportions of soil samples collected between and within cow urine patches, which contain a lot of potassium. This is a problem for all grazed pastures, particularly intensively grazed ones.

**Soil potassium testing for high rainfall pastures**

Both the Cox study and long-term field experiment have shown that soil testing for potassium is unreliable for predicting when to apply fertiliser potassium to high rainfall pastures when the soil test is between about 30 and 100 mg/kg.
Figure 4. Relationship between Colwell soil test potassium (K) and the rate of K applied Autumn each year measured on soil samples collected February each year.

Table 1. For experiment on Rodwell farm, near Boyanup, Colwell soil test potassium (K) for 6 replications of the 6 potassium rates

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<th>K applied (kg/ha per year)</th>
<th>Colwell soil test K (mg K/kg soil)</th>
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Further reading


