How do I ...

manage soil health to grow good sub-clover?

The issue:	Sub-clover can be the canary in the coalmine for mixed pastures. If your sub-clover looks poor or sparse it can be a sign there is something inadequate in the soil, which will eventually affect the desirable grasses.
The impact:	Reduced sub-clover content means reduced animal production, as clovers are more digestible than other forages, supporting higher consumption and better weight gain. Poor sub-clover also results in decreased soil nitrogen, which restricts desirable grass growth and favours weeds which prosper in low-fertility soils.
The opportunity:	Getting the soil health right increases pasture growth, which leads to improved animal performance.

How do I know if my sub-clover is substandard?

Does your sub-clover have a leaf area smaller than a five cent piece and is the plant bright green with no mottling on the leaves? Is the sub-clover content of your pasture less than 10% in late winter and early spring? If you answered yes to any of these questions you may have an underlying soil constraint affecting sub-clover production.

Larger sub-clover leaves taken from plants next to sheep dung, compared to smaller leaves representing plants away from dung.

Pasture with less than 10% sub-clover in spring can have a hidden soil constraint.

Common soil constraints

Sub-optimal production of sub-clover is difficult to determine. Only under extreme nutritional stress will leaf symptoms appear. More likely ‘hidden hunger’ occurs, meaning the sub-clover plants are not getting all the nutrients they require. Growth is less and weeds that tolerate lower soil fertility compete more aggressively.

The most common soil-related reasons for poor sub-clover growth are phosphorous and molybdenum deficiencies and acidity. Diagnosis starts with a soil test, taken at a depth to 10cm.

Phosphorus

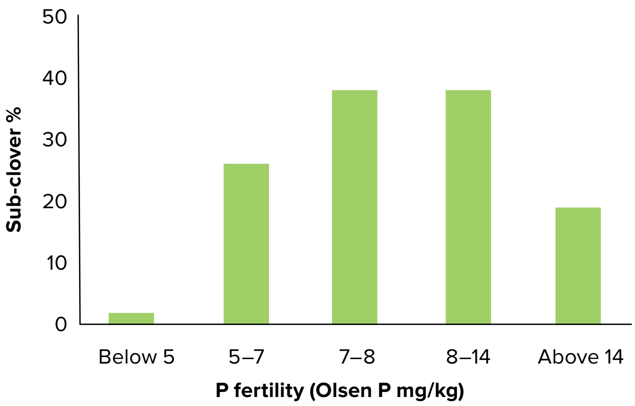
Phosphorus is the first limitation to rule out. If below-minimum soil test values for sub-clover of 8mg/kg (Olsen P) or 14mg/kg at moderate PBI* (Colwell P) are identified, consider phosphorus application. Additionally confirmation of phosphorus deficiency can be made by comparing plant growth in high and low-fertility areas in a paddock.

If the soil test indicates above-minimum phosphorus values, then examine the soil pH. Soil pH ($CaCl_2$) should be above 5.0. If below 5.0, check the nodules on the roots of the sub-clover (see page 5). Nodules can provide additional clues as to the influence of soil pH and adequacy of the trace element molybdenum.

If the nodules are less than ideal, further investigation is required. This can be through pasture test strips by applying lime and/or molybdenum, or submitting leaves for a tissue test.

A long-term phosphate trial near Hamilton, Victoria indicated sub-clover content can be improved by increasing the soil to moderate fertility (7–8 Olsen P or 14–19 Colwell P at a PBI* of 190).[1] Above this, fertility level increases in sub-clover content are only marginally greater (Figure 1).

Figure 1. Sub-clover content in response to P fertility under medium grazing pressure (October 1997).[1]



Note: The grazing pressure was adjusted for the fertility and ranged from 11 DSE/ha at low fertility to 24 DSE/ha under high fertility.

* PBI (phosphorus buffering index) is a measurement of the soil’s ability to ‘lock up’ P. Soils with a high PBI require higher Colwell P targets to compensate for the ‘lock up’ of P to meet plant P demands.

Soil acidity and aluminium

Soil acidity and aluminium toxicity are closely related, however not all soils contain aluminium. The amount within a soil is influenced by its mineralogy. Sands contain little aluminium but ironstone soils or soils with kaolinite clay contain considerable aluminium.

As soil pH declines below pH ($CaCl_2$) of 4.8, any aluminium present starts to precipitate from a harmless solid into a toxic soluble form which harms root growth. Roots and root hairs become stunted, affecting nutrient and water access. While sub-clover is one of the few legume species considered tolerant to aluminium, if the pH drops below 4.5 growth will be affected.

There are three common methods for testing and assessing soil aluminium: KCl, $CaCl_2$ and % exchangeable cations. Each has different threshold values (Table 1).

Table 1: Critical concentrations of aluminium where sub-clover yields are reduced by 10%.[2]

Aluminium KCl method (mg/kg)	Aluminium $CaCl_2$ method (mg/kg)	Aluminium % of cation exchange capacity*
50	4	13

* At medium electrical conductivity of 0.07 to 0.23 ($EC_{1:5}$ dS/m).

Healthy sub-clover plant roots (left) versus root stunting (right) caused by high soil aluminium.
Image courtesy of Centre for Rhizobium Studies, Murdoch University

Soil acidity and molybdenum

Sub-clover will grow at a pH ($CaCl_2$) as low as 4.2, but production will be reduced by up to 30% and nitrogen fixation from nodules will be poor and reduced by 25% to 42% in comparison to soils limed to pH 5.3.[4]

Of the three sub-clover sub-species grown commercially in Australia, two *(yanninicum* and *subterraneum)* prefer slightly to moderately acid soils, with an ideal pH ($CaCl_2$) in the range of 5.0–6.0. The third sub-species *(brachycalycinum)* evolved on soils that were typically neutral to alkaline pH ($CaCl_2$) of 6.0–8.5, however newer varieties have shown to be more adaptable to slightly acidic soil types, pH > 5.2 ($CaCl_2$).

Soil molybdenum decreases as soil pH declines. A soil pH ($CaCl_2$) of less than 5.0 will result in lower molybdenum levels, especially in light-textured soils with low clay content. Unfortunately, soil testing is not a reliable method to determine molybdenum deficiencies because it is only required in small amounts (0.5 to 10mg/kg). Tissue testing is a more accurate way of determining molybdenum status (see below – *How do I take plant tissue samples for testing?*).

How do I take plant tissue samples for testing?

Tissue sampling kits can be obtained from testing laboratories, some retail merchandise outlets and agronomists.

Spring, before the sub-clover flowers, is the best time to collect material for tissue testing as there is more plant material to sample. Laboratories commonly require between 70 and 200 grams of pure sub-clover, which is equivalent to a large paper bag.

A suggested method of sampling is to take a 'toe cut' of the pasture (about the size of your palm) using clean hand shears. Repeat along a transect 30 times, combining the sample into a large paper bag. Do not use plastic bags as the sample sweats and starts to decompose. If the samples show signs of soil contamination, wash the samples while fresh. Ensure you use deionised water (minerals removed).

Once collected, sort the sample, carefully removing the sub-clover leaves and their leaf stems (petioles) from other species. Wear plastic gloves to prevent contaminating the sample. Keep the sample cool and send by Express Post to avoid delays.

'Toe cut' of pasture samples for tissue tests, using gloves and clean cutters.

Presence of nodules

Ideally a sub-clover plant should have at least 20 small pink nodules up to 2mm long (see below – *How do I know if sub-clover roots have productive nodules?*). If the nodules are large – greater than 5mm – then three nodules/plant will be sufficient to provide the same level of nitrogen fixation.

An example of good nodulation, with more than three large pink nodules on this sub-clover plant.

It is not uncommon to examine sub-clover plants and find no nodules, yet the plant appears healthy and growing well. These plants are not fixing nitrogen, instead they are using soil nitrogen just like the grasses.

Don't be fooled. The sub-clover content in this pasture was good, but on inspection had no nodules.
Image courtesy of Sue Briggs

How do I know if sub-clover roots have productive nodules?

Examining the nodules on sub-clover roots is a useful diagnostic tool. Sub-clover roots should contain pink-coloured nodules. The pink colour signifies the presence of rhizobia bacteria that is fixing nitrogen.

Healthy pink nodules on left side, which will fix nitrogen, versus white, ineffective nodules on the right side.
Image courtesy of Ross Ballard, PIRSA

Other soil issues which could affect sub-clover content

Potassium, calcium and boron are important in sub-clover seed production.

Good clover growth in urine patches (areas often high in potassium) may indicate the pasture's responsiveness to potassium. Maintain minimum Colwell K soil test levels: above 120mg/kg in sands and 160mg/kg in clays.

When soil test levels of calcium fall below 3 meq/100g, seed production of clover is compromised. Soils are rarely deficient in calcium, but deficiency has been found on coastal sandy soils.

Boron deficiency can be found on alkaline soils and induced with liming acid soils, as it is closely associated with high calcium levels. Boron deficiencies have been found to be the cause of poor sub-clover persistence in Gippsland and NSW. It is difficult to detect visually, as losses in dry matter production will not be obvious, but seed development will be compromised, resulting in low-weight, unviable seed.

Unfortunately a tissue test is not always reliable, as legumes can adjust tissue growth to meet demand, so the sample appears within acceptable range.[2] Conducting seed and germination tests might be more informative.

Sulphur deficiencies and residual herbicides can also affect nodulation. Surveys in southern and central NSW found more than 93% of paddocks were deficient in clover nodulation and 73% of these paddocks also had low sulphur levels.[5] Sulphur deficiency may be found where high-analysis phosphorus fertilisers have been used e.g. MAP/DAP. Sulphur levels should be maintained above S (KCl) 6mg/kg.

The residual herbicides found to affect nodulation have been mainly Group B sulfonyl urea herbicides such as chlorsulfuron, triasulfuron methyl and clopyralid.[6] These have either been used in prior crops, or in recent weed control (Paterson's curse or thistles) and have not degraded in the soil due to insufficient rainfall or high soil pH caused by recent liming.

Root diseases can be another hidden problem caused by soil-borne pathogens, resulting in seedling and biomass losses over autumn and winter. These can be diagnosed through observation of plant roots or by using a PREDICTA® B test. More information on root diseases can be found in the MLA fact sheet: Root diseases of sub-clover.

More information on diagnosis of poor sub-clover can be found in the MLA fact sheet: How do I determine why my sub-clover is underperforming?

Healthy white and much-branched sub-clover plant roots on the left and reduced root branches, pruned tap roots and presence of brown lesions (middle and right). *Images courtesy of Richard Simpson, CSIRO*

How do I fix the soil deficiencies?

Having determined what nutrients or soil conditions are affecting sub-clover production, decisions can be made on strategies to overcome them. Prioritise paddocks that have more sub-clover and desirable grasses.

Phosphorus is commonly applied regularly at or after the autumn break. Sulphur and potassium can be applied with P fertiliser blends or separately if more cost-effective. Once deficiencies have been corrected, maintenance applications will be required most years. For example, 0.7–1.2kg P/DSE, or 10kg P or K/ha/year, or 7kg S/ha/year will generally be required. More may be needed if there is a history of hay or silage production from that paddock. (Maintenance fertiliser inputs are those that balance the removal of soil nutrients.)

Lime to rectify acidic soils is generally applied every eight to 12 years, depending on the soil pH and the acidification rate of the soil. Maintaining soil pH around pH 5.0 in the top 10 centimetres of soil removes most production constraints. Keeping soil pH above 5.5 creates enough alkalinity to not only treat the top 10cm but to leach below, addressing any subsurface acidity issues.

Molybdenum and other trace elements are required in small quantities, so need to be applied less frequently. Liming acid soil will generally make molybdenum more available, so it is unadvisable to apply both products in the same year.

If molybdenum is required, then apply molybdenum at a rate of 50–100 grams/ha every seven to 10 years. Beware excess molybdenum application may induce a copper deficiency in livestock where marginal copper conditions exist. If the copper status of the soil is unknown, copper can be applied with molybdenum as a safeguard.

If these treatments do not result in a sub-clover response after two years, then other underlying constraints may be present. Learn more from the MLA fact sheet: How do I determine why my sub-clover is underperforming?

TOP TIP

Fertiliser or lime test strips are a fantastic visual indicator of which culprit or culprits is having the greatest impact on growth. It could be that all three (P, S, K) are limiting, which is why all nutrients are applied to one strip and then each is omitted from a strip to see which has the biggest influence on plant response.[7]

Phosphorus versus phosphorus plus molybdenum fertiliser strips indicate a response to molybdenum.

More information

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MLA website:

How do I manage root disease in sub-clover pastures?

How do I determine why my sub-clover is underperforming?

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