How do I assess effective nodulation in legume pastures

The issue:	More than 90% of legume-based pastures surveyed across NSW and WA have inadequate nodulation in their root systems.*
The impact:	Poor nodulation may limit nitrogen fixation, impacting dry matter production, soil nitrogen levels and livestock productivity.
The opportunity:	Improving legume nodulation and nitrogen fixation can increase productivity.

Through nitrogen fixation, pasture legumes can deliver a sustainable input of nitrogen (N) into farming systems. This supports high-quality feed for livestock and soil nitrogen for non-legume pasture components or subsequent crops.

To carry out this important function, legumes must be adequately nodulated and these nodules need to contain an 'effective strain' of rhizobia (the bacteria responsible for converting atmospheric nitrogen to ammonia within the nodule). Finding out the nodulation status of your pasture legumes is a relatively quick and simple process.

Do I have a problem?

The first step to knowing whether legume pastures are fixing nitrogen is to check whether roots are healthy and nodules are present and effective.

Figure 1: A pink legume nodule sliced in half indicating efficient nitrogen fixation

How to assess legume nodulation

Under optimal soil and growing conditions, nodulation occurs relatively early in the growing season.

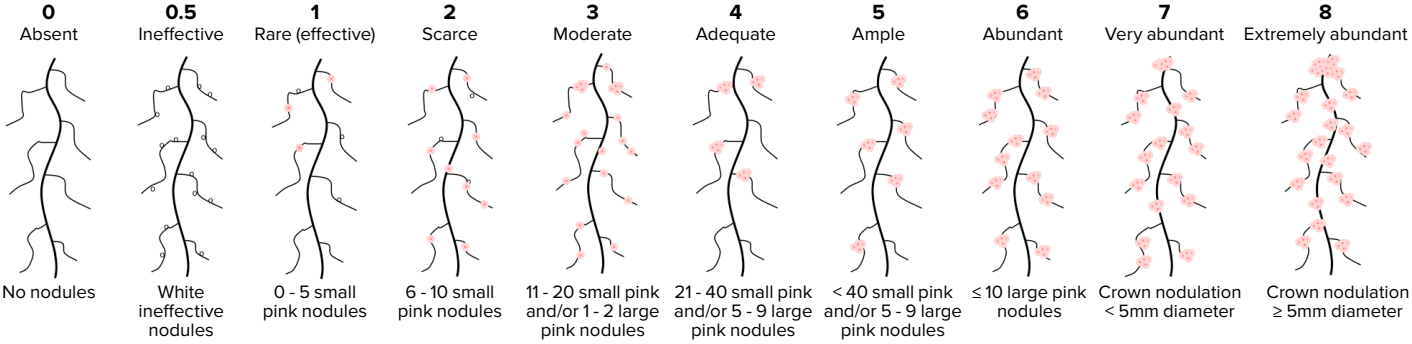
Sampling can generally be carried out 12 weeks after germination (mid to late winter) when soil moisture conditions are favourable. Here's how to do it:

1. Assess a minimum of 15-20 plants. Select plants from a representative area of the paddock.
2. Carefully excavate plants from the soil to a depth of about 30cm using a shovel (don't pull plants out of the soil as this can pull nodules off the root system).
3. Wash the soil from the roots and gently separate plants to assess individual root systems.
4. Assess the number and colour of the nodules using the rating system in Figure 2: An adequately nodulated plant will have a minimum of 20 nodules on the root system and these nodules will be pink in colour due to the presence of leghemoglobin (see Figure 1) if they are effectively fixing nitrogen.

If plants are assessed late in the growing season, effective nodules may appear dark pink to green in colour when cut open.

White nodules can indicate the nodules contain ineffective strains of rhizobia and are poor at fixing nitrogen.

Figure 2: A scoring system can be used to assess legume nodulation for plants growing for a minimum of 12 weeks in paddock situations



Source: Yates RJ, Abaidoo R and Howieson JG (2016) Field experiments with rhizobia. In: Working with rhizobia.

What affects nodulation?

There are three main soil and management factors that can impact on legume nodulation: soil pH, nutrient availability and use of herbicides. Identifying and addressing these factors can improve legume performance, nodulation and nitrogen fixation.

1. Nutrient availability

Legume plants and their associated rhizobia both have specific nutrient requirements for function and growth. Ensuring sufficient availability of key macronutrients, such as phosphorus (P), sulphur (S) and potassium (K), will support legume growth and rhizobia function. Micronutrients, such as molybdenum (Mo) are also critical to nodule formation and function.

High levels of available aluminium (Al) can impede the nodulation process by affecting legume root development and impacting on rhizobia survival.

2. Herbicide use

Residues of some herbicides can adversely impact root development and rhizobia survival. It is critical to observe plant-back periods on herbicide labels to lessen the potential impact.

3. Soil pH

The pH of soil affects not only the plant, but also its associated rhizobia. Plants often tolerate variations in soil pH better than their associated rhizobia (see Table 1 below). For example, sub-clover can grow quite effectively down to a pHCa of 4.2, while the Group C inoculant responsible for nodulating sub-clover has a higher pH requirement for optimal performance. Plants and their associated inoculant group differ in terms of pH tolerance and species. For example, serradella (and its associated rhizobia) have a greater tolerance to lower pH (Table 1), however, plant tolerance is still greater than rhizobia tolerance.

In some cases, it may be necessary to consider applying lime to improve plant growth, rhizobia survival and legume nodulation. Where liming is not possible, consider using a more tolerant legume and its associated rhizobia. Nodulation and nitrogen fixation can also be affected under alkaline conditions, particularly where soil pHCa exceeds 8. Take care when sowing pastures to match pasture species and varieties with their associated rhizobia.

(Note: When choosing species, it is also critical to consider other stressors in addition to soil pH, including availability of key nutrients, presence of toxic plant elements such as aluminium and tolerance to waterlogging)

Table 1: Sensitivity of key rhizobia and their host plant to soil pH($CaCl_2$)*

Pasture species	Plant/Inoculant type	pH4	pH5	pH6	pH7	pH8
Sub-clover	Plant					
	Inoculant (Group C)					
Lucerne/annual medics	Plant					
	Inoculant (Group AL/AM)					
Biserrula	Plant					
	Inoculant (Group BS)					
Serradella	Plant					
	Inoculant (Group S)					

Optimal function Adequate function Sub-optimal function Poor function

Source: Drew et al. 2016, R. Yates (pers. comm.), various government departmental publications

*In-paddock assessments were carried out by: Janelle Jenkins (Riverina LLS), Belinda Hackney (Central West LLS/Graham Centre for Agricultural Innovation), Jo Powells (South-East LLS), Clare Edwards (Central Tablelands LLS), methodology was developed by Ron Yates (DAFWA) and nodule occupancy assessment by Sofie De Meyer (Murdoch University).

More information

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