TIPS & TOOLS

SOUTHERN FEEDBASE

Re-inoculating established legume pastures: do I need to and how do I do it?

Root nodules on legumes contain rhizobia, a nitrogen-fixing bacteria, which converts nitrogen from the atmosphere into a form which can be used by the plant. As the legume plant and its nodules senesces and breaks down, the residue provides available nitrogen to the surrounding plants.

Recent surveys of established pastures in southern Australia revealed suboptimal nodulation of legumes.

Legumes need to be adequately (possess a sufficient number) and effectively (right rhizobia strain) nodulated to achieve nitrogen fixation targets of 20–30kg nitrogen/tonne shoot dry matter. A 2019 survey of 225 paddocks in NSW (Hackney et al. 2019) revealed 93% of the pastures in those paddocks were inadequately nodulated.

What is adequate nodulation and why is it necessary?

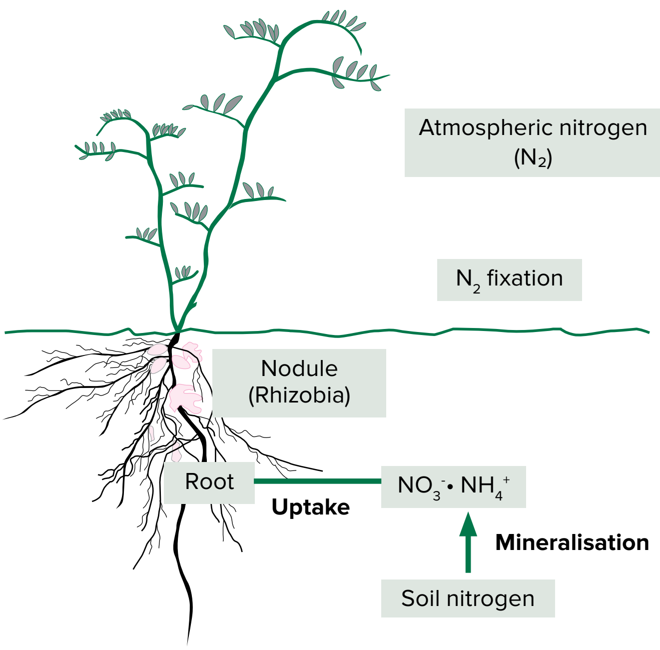
Adequate nodulation is defined (Yates et al. 2016) as 21 to 40 small (<5mm diameter) and/or three to four large (>5mm diameter) pink nodules on the root system of a legume plant which has been carefully extracted from the soil and washed 12 weeks after germination.

It is best to assess nodulation 10–12 weeks after emergence by carefully digging up the plant and gently washing the root system for examination. Do not pull the plant out of the soil, as the nodules can be easily broken off the roots.

If nodulation is inadequate, it is likely the legume will meet its additional nitrogen needs from the soil. It will not build soil nitrogen by biological fixation as an effectively nodulated plant would. When nodulation fails completely, the legume will access all its nitrogen from the soil and will not contribute to building soil nitrogen reserves.

An inadequately nodulated legume, or one which has completely failed to nodulate, will also be less effective in utilising phosphorus and sulphur fertilisers. This will result in overall decreased pasture production. Non-legume plants depend on legumes to respond to applied phosphorus and sulphur to supply nitrogen for their use.

Figure 1: Effective nitrogen cycling via root nodules



Should I re-inoculate inadequately nodulated pasture?

It is important to consider why nodulation is currently inadequate. Failure to identify why nodulation is poor and automatically implementing re-inoculation may result in some short-term benefit, but it is likely nodulation will again quickly fall below optimal levels.

Reasons for poor nodulation include (but are not limited to):

- **Soil acidity.** This is a widespread and increasing issue in southern Australia. Recent surveys of established pasture paddocks in NSW revealed soil acidity to be the main reason for suboptimal nodulation. Legumes and their associated rhizobia differ in their pH tolerance (Table 1). The rhizobia may require 0.5–2.0 pH units higher than its host legume plant to function optimally. For example, sub-clover will grow with minimal restriction down to a pHCa 4.8, but its rhizobia require a pHCa >5.0 for optimal function. Lucerne will grow with minimal restriction down to pHCa 5.0 but optimal function of its rhizobia requires pHCa >7.0. Aside from impacting rhizobia survival, low soil pH can impact host legume root growth, especially if aluminium or manganese are high. Under such conditions, the host legume root systems can become distorted, with fine root hair growth severely affected. Rhizobia gain entry to the host legume via these fine hairs and under acidic soil conditions root hairs are less prolific, or become thickened or distorted, restricting rhizobia entry and reducing nodulation.

  Research has shown significant increases in legume nodulation and nitrogen fixation where liming is used to increase soil pH (Evans et al. 1988; Unkovich et al. 1996). In addition to liming, regular inoculation with the current commercial inoculant group will provide (in many cases) improved soil acid tolerance (Yates et al. 2021).

- **Herbicides and herbicide residues.** Many herbicides can have direct effects on the capacity of a legume to nodulate, maintain nodules throughout the growing season and reach nitrogen fixation targets. Similarly, the residues of herbicides used in previous years can also pose a problem for formation of nodules and the capacity of these to function and attain expected nitrogen fixation targets. Sulfonylurea herbicides (Group B) and clopyralid and dicamba (Group I) are particularly problematic in terms of persistence in the soil and can negatively impact legume nodulation. Herbicide and herbicide residues can impact both the host plant root system and rhizobia, impeding nodulation or, if nodulation does occur, impeding nodule function and the amount of nitrogen fixed.

  Herbicides are important for controlling weeds and it is critical to adhere to directions on herbicide labels to minimise potential damage.

- **Climatic conditions.** Rhizobia populations vary through the year and usually reach their lowest levels in summer and early autumn as hot, dry conditions result in population decline. Under reasonable seasonal conditions, rhizobia numbers usually rebound quickly following autumn rainfall. However, if prolonged drought conditions are experienced then the population may be depleted significantly. Where legumes regenerate in marginal moisture, nodulation may be reduced or delayed due to low rhizobia numbers and/or slow root development. In such conditions, re-inoculation is often highly responsive.

Top-dressing with clay granules. Image courtesy ALOSCA Technologies Pty Ltd.

- **Soil texture.** In a free-living state (not in a nodule), rhizobia need access to moisture and nutrients for survival. Coarse-textured soils are less able to maintain high rhizobia populations over time due to reduced capacity for moisture retention and, in some cases, lower nutrient availability. These soils are often highly responsive to re-inoculation. In contrast, soils with higher clay content can generally support higher rhizobia populations over time due to their capacity to maintain better moisture and nutrient supply. Where large populations of rhizobia persist in the soil there can be considerable range in their effectiveness as the characteristics of the population change over time (genetic drift). Often high clay content soils are less responsive to re-inoculation due to competition from the background rhizobia population.

What is the solution?

In situations where soils are strongly acidic (pHCa <5.0), re-inoculation is unlikely to offer a long-term solution to poor nodulation for species such as sub-clover, annual medics and lucerne. Liming to increase soil pH is likely to be a more effective long-term solution and will also increase the efficiency of use of inputs such as phosphorus and sulphur fertilisers. Interestingly, where acidity is the issue, correction of acidity alone through liming has resulted in a significant increase in nodulation and nitrogen fixation of subterranean clover without the need for any further intervention (Evans et al. 1988; Unkovich et al. 1996).

Where liming is not an option, consideration may need to be given to use of more acid-tolerant legumes such as serradella and biserrula. However, even these acid-tolerant species have reduced capacity for nitrogen fixation where pHCa <4.5. If you are contemplating using more acid-tolerant legume species, it is also critical to consider their adaptability to other soil constraints. For example, neither serradella nor biserrula tolerate waterlogging.

Options for re-inoculation

There are several methods for re-inoculation, each offering varied success.

Drilling-in inoculant

1. Drilling of inoculated seed into existing stands is a relatively effective means of delivering rhizobia. Peat-inoculated seed is drilled into moist soil, preferably just prior to emergence of the host legume. This strategy also enables more legume seed to be delivered to the existing pasture, potentially increasing legume populations. To be effective, this strategy requires moist soil as there is rapid desiccation of peat-delivered rhizobia in dry soils and seed should be sown within 12 hours of peat application. Use of disc sowing machinery for drilling will result in less disturbance of existing pasture, especially when perennial grasses are part of the mix.
2. Granular inoculants may be drilled alone or with seed into existing pastures. Granules differ in their capacity to be used under dry soil conditions. Granules with a high moisture content are unsuitable for sowing into dry soils as they will rapidly desiccate. Low-moisture clay granules are better suited to dry soil situations.

Spreading inoculants

Producers will often spread inoculated seed over existing pastures in the hope of introducing new inoculant, but rhizobia death under these conditions is high due to the drying effects of wind and temperature and the direct effects of UV light. Spraying of inoculants is most unlikely to result in successful inoculation for the same reasons.

Surface application of low-moisture granules has been proposed as a mechanism for re-inoculation. However, the success of this practice is yet to be independently verified.

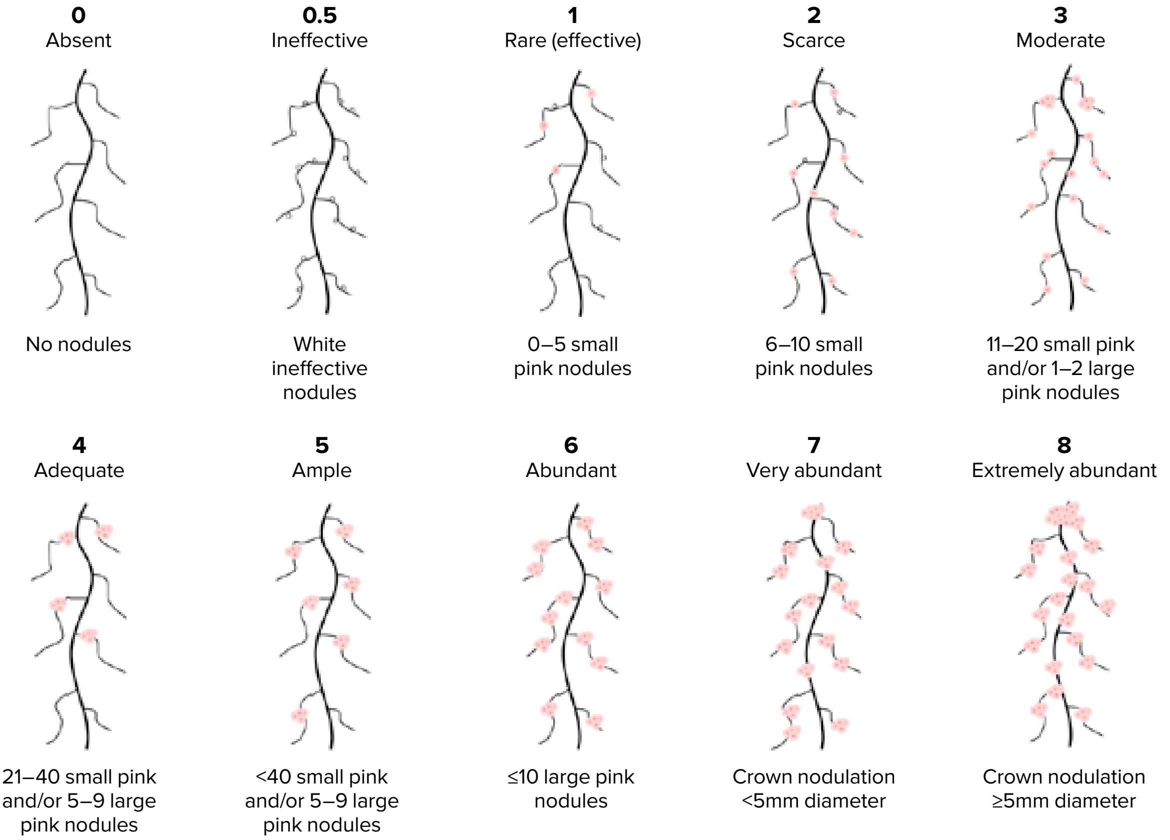
Table 1: Sensitivity of key rhizobia and their host plant to soil pH ($CaCl_2$)*

Pasture species	Host plant/inoculant tolerance	pH4	pH5	pH6	pH7	pH8
Sub-clover	Plant	Poor function / Suboptimal function / Optimal function	Optimal function	Optimal function	Optimal function	Optimal function
	Inoculant (Group C)	Poor function / Suboptimal function	Adequate function	Optimal function	Optimal function	Suboptimal function
Lucerne/annual medics	Plant	Poor function / Suboptimal function	Optimal function	Optimal function	Optimal function	Optimal function / Suboptimal function
	Inoculant (Group AL/AM)	Poor function	Poor function	Suboptimal function	Optimal function	Optimal function
Biserrula	Plant	Suboptimal function / Optimal function	Optimal function	Optimal function	Optimal function	Suboptimal function
	Inoculant (Group BS)	Poor function / Suboptimal function	Optimal function	Optimal function	Optimal function	Optimal function
Serradella	Plant	Optimal function	Optimal function	Optimal function	Optimal function	Optimal function / Suboptimal function
	Inoculant (Group G/S)	Suboptimal function / Adequate function	Optimal function	Optimal function	Suboptimal function	Poor function

Optimal function   Adequate function   Suboptimal function   Poor function

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

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 et al. 2016

Conclusion

Re-inoculation of existing legume-based pastures should not be undertaken without first identifying the reasons for inadequate nodulation. Failure to identify the reasons for current poor nodulation could result in limited success of re-inoculation.

Need further help?

Talk to your local advisor or agronomist to develop a plan for optimising the response from pasture sowing.

Information: mla.com.au/extension-training-and-tools/feedbase-hub/

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