Inoculating pasture legumes with rhizobia (root nodule bacteria) is standard practice for many growers, but a national survey carried out during 2013 highlighted several opportunities for growers to maximise the potential benefits by following practical guidelines to optimise the delivery of rhizobia.

**Legumes (crops and pasture combined) are estimated to fix almost 3 million tonnes of nitrogen each year in Australia, which is worth around $4 billion.**

This amount of fixed nitrogen makes a substantial (around 50%) contribution to the estimated 6Mt of nitrogen required annually for grain and animal production. Most of this comes from pastures, which grow across 10 times the area sown to pulse crops.

The fixed nitrogen contributions made by legumes vary considerably with species and situation (e.g. soil type, seasonal rainfall and crop management). Nitrogen fixation generally increases with the amount of pasture biomass. It follows that effective management, leading to vigorous plant growth, will favour higher fixed-nitrogen inputs.

In southern Australia, legume growth is strongly influenced by the amount of water the pasture can access from a combination of stored soil moisture and growing season rainfall (GSR). Management practices that optimise water use efficiency (WUE) and keep soil nitrate concentrations low will favour legume growth and nitrogen fixation.

In addition to increased nitrogen fixation with increased plant biomass, nitrogen fixation is greater when existing soil nitrate levels are below 50kg/ha. Nitrogen fixation virtually ceases at soil nitrate levels above 200kg/ha, although fixation levels again vary with species and situation.

While the legume uses the nitrogen it fixes for growth, any root and shoot residues remaining after grazing contribute to total soil nitrogen for use by non-legumes in the pasture and by subsequent crops.

### Building the nitrogen bank

Inoculating legumes can be a cost-effective way to increase soil nitrogen reserves for following non-legume crops and pastures. Using some basic rules of thumb and a risk–benefit framework can ensure a strategic and targeted approach to legume inoculation. (Photo: Catriona Nicholls)

1. **Inoculating legumes with rhizobia (root nodule bacteria) can deliver substantial fixed nitrogen (N) inputs to pastures and subsequent crops.**
2. **Strategic use of rhizobial inoculants is an effective way to maximise nitrogen inputs from legumes.**
3. **In situations where suitable rhizobia are absent, such as where there is no legume history or hostile soil conditions prevail, inoculation is essential.**
4. **Mixing rhizobial inoculants with fertilisers, trace elements and pesticides is not recommended.**

### When to inoculate?

High numbers of effective rhizobia on the seed are important to ensure prompt nodulation and that the applied rhizobia can compete with the less-effective rhizobia that are already present in many soils.

It is common to purchase seed that has already been inoculated (see box below), but where seed has not been pre-inoculated and inoculant is applied immediately before sowing, it is possible to deliver larger numbers of rhizobia on the seed and improve the chance of a response to inoculation.

Most producers have probably heard the phrases “if in doubt, inoculate”, “inoculation is cheap insurance” and “always inoculate when sowing”. While such an approach might be appropriate where information on prior legume use and soil conditions are limited, such generic messages can cause producers to become cynical about the need for inoculation, and do little to aid their understanding of where inoculation is essential, desirable or least likely to be of benefit.

### Check the expiry period

Always check that seed falls within inoculation expiry dates. These are recommended by the Australian Inoculants Research Group as six months for lucerne, six weeks for annual clovers and two weeks for white clover. Seed purchased inside these expiry periods is more likely to meet the minimum industry standard of: 1000 and 500 rhizobia per seed for medium and small pasture seeds, respectively.
It is possible to adopt a more strategic approach to legume inoculation by using some basic rules of thumb. A risk–benefit approach with respect to the likelihood of obtaining a positive response to inoculation can assist in decision making, by first considering legume species, paddock inoculation history and soil type.

After making the decision to inoculate, it is worth maximising the chances of success by following the recommended application methods for the different inoculant products available — inoculation failure is generally difficult and expensive to remedy.

**Mixing rhizobia with fertilisers and pesticides is generally not recommended, as rhizobial survival when mixed with these additives is often poor.**

**Likelihood of inoculation response**

Several factors contribute to the likelihood of a response to inoculation. There are many different pasture species sown across southern Australia and 10 different legume pasture inoculants on the market. Some pasture legumes (e.g. biserrula and sulla) are specific in the rhizobia they need for nodulation, so it is important to use right inoculant (see Table 1).

Where a pasture species with a specific rhizobia requirement is grown for the first time, it is essential to use an inoculant, as there will be no suitable rhizobia present in the soil. A response to inoculation is almost assured. A double rate of inoculant is often used in these situations, to enhance the likelihood of prompt and abundant nodulation.

Even some clovers with fussy rhizobial needs (e.g. gland, bladder and arrowleaf) respond well to inoculation. For more specific recommendations refer to *Inoculating legumes: A practical guide.*

If a pasture or crop legume that uses the same rhizobia has not been grown in the past four years, and soil conditions are hostile (acid, salty or subject to very hot summer temperatures), then the probability of a response to inoculation is moderate. The number of rhizobia tends to decrease under these conditions.

Where acid-sensitive legumes (e.g. lucerne) are sown into acid soils (pH 5.5 or less in CaCl₂) it is essential to inoculate every time a pasture is sown, as the rhizobia that persist in the soil start to lose their capacity to fix nitrogen. This occurs in about 50% of clover and medic pastures.

When renovating these pastures, a top-up with the appropriate commercial inoculant strain can be beneficial. It is not possible to predict where these less effective rhizobia occur and so inoculation is best targeted at pastures performing below expectation. Responses are unlikely to persist past a few years.

**Measuring success**

To determine whether inoculation has been successful, it is important to look below the soil surface and inspect plant roots for healthy nodules. A visual check of root systems is worthwhile to establish if a reasonable number of nodules is present and well-distributed across the root system or whether there has been a nodulation delay or failure.

Carefully breaking open nodules to determine if there is a pink or reddish colour in the nodules will show the nodules are active.

Neither of these visual assessments will indicate the actual amount of nitrogen fixation being achieved: sophisticated scientific techniques are required to measure this. However, understanding the extent of nodulation in the existing pasture can help guide decisions around the need for inoculation in future years.

See the *Assessing legume inoculation to evaluate inoculation success factsheet* for more details.

**Table 1. Inoculant groups for common legume species and the maximum seed treatment rates**

<table>
<thead>
<tr>
<th>Inoculant group</th>
<th>Common name of legume</th>
<th>Seed size</th>
<th>Maximum weight of seed (kg) treated by 250g peat inoculant</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>Lucerne, strand medic, disc medic</td>
<td>Small</td>
<td>25kg</td>
</tr>
<tr>
<td>AM</td>
<td>Burr medic, barrel medic, snail medic, sphere medic, murex medic</td>
<td>Medium</td>
<td>50kg</td>
</tr>
<tr>
<td>B</td>
<td>White clover, red clover, strawberry clover, berseem clover, talish clover</td>
<td>Small</td>
<td>25kg</td>
</tr>
<tr>
<td>C</td>
<td>Subterranean clover, balansa clover, bladder clover, crimson clover, purple clover, arrowleaf clover, rose clover, gland clover, helmet clover, Persian clover</td>
<td>Small-medium</td>
<td>25-50kg</td>
</tr>
<tr>
<td>D</td>
<td>Greater lotus</td>
<td>Small</td>
<td>10kg</td>
</tr>
<tr>
<td>E</td>
<td>Vetch, lathyrus</td>
<td>Large</td>
<td>100kg</td>
</tr>
<tr>
<td>S</td>
<td>French and yellow serradella</td>
<td>Medium</td>
<td>50kg</td>
</tr>
<tr>
<td>Biserrula</td>
<td>Biserrula</td>
<td>Small</td>
<td>10kg</td>
</tr>
<tr>
<td>Lotus</td>
<td>Birdsfoot trefoil</td>
<td>Small</td>
<td>10kg</td>
</tr>
<tr>
<td>Sulla</td>
<td>Sulla</td>
<td>Medium</td>
<td>10kg</td>
</tr>
</tbody>
</table>

There is a low likelihood of response to inoculation in paddocks where: there has been a recent history of inoculation with the appropriate rhizobia (i.e. the correct inoculant group), the soil pH is between 5.5 and 7.5 (in CaCl₂), and recent nodulation and pasture production have been in line with expectations based on GSR.

In long-term clover and medic pastures where legume production falls below expectation, there is still a low to moderate likelihood of inoculation response. In these situations, inoculating may still be worthwhile because the rhizobia that persist in the soil start to lose their capacity to fix nitrogen. This occurs in about 50% of clover and medic pastures.

For further information, please refer to publications found at The University of Adelaide website or contact Dr Maarten Ryder, maarten.ryder@adelaide.edu.au

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