INOCULATING LEGUMES IN ACIDIC SOILS

FACT SHEET

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

NATIONAL
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Considerations for inoculation when growing legume crops in acidic soils

KEY POINTS

- **Application of rhizobia as an inoculant is often required to support legumes to nodulate and fix nitrogen on acid soils.**
- **Rhizobia (except lupin rhizobia) are sensitive to low pH. Their ability to survive at ideal rates for nodulation is reduced in acidic soils with a pH below 5.5$_{CaCl_2}$.**
- **Growers are advised to double the inoculation rate when sowing legumes into very acidic soils to ensure adequate rhizobia numbers are present when seeds germinate.**
- **Legume nodulation may be suboptimal below pH 5.5 and lime application should be considered to increase soil pH for grain legumes and crops other than lupin.**

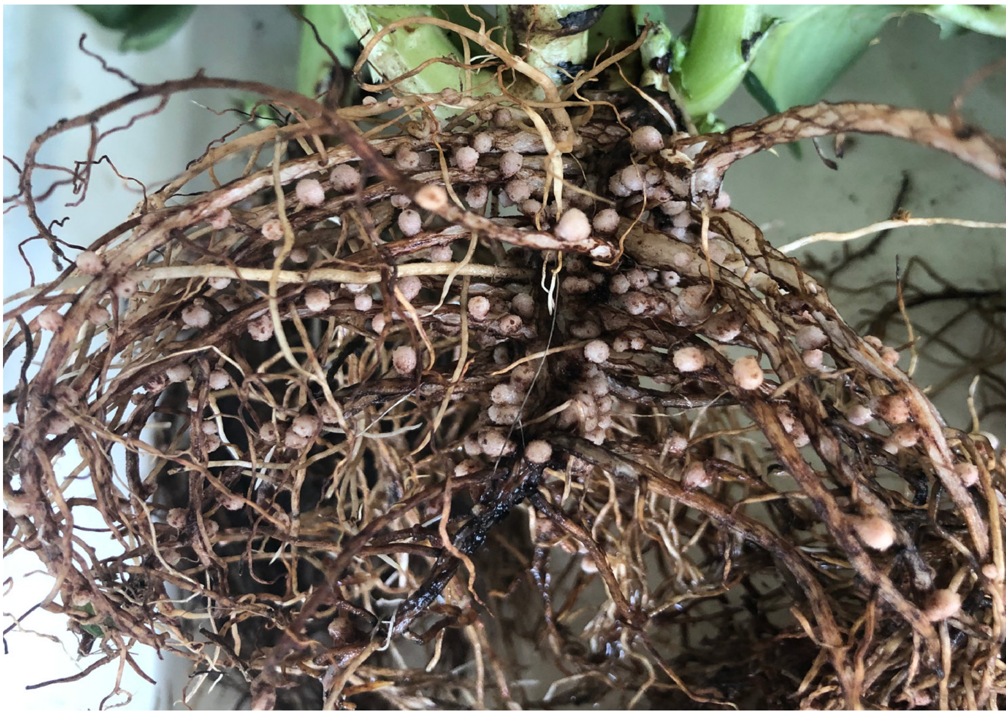

Photo: AgCommunicators.

Introduction

Growing grain legumes in a crop rotation can contribute more than 100 kilograms per hectare of 'fixed' nitrogen to the soil for the benefit of future cereal and canola crops in the paddock. The nitrogen fixation process requires rhizobia (root nodule bacteria) to be present in adequate numbers in the soil to enable nodulation on the legume's root system as the plant grows. In acidic soils, adequate levels of rhizobia are less likely to be present, and rhizobia will need to be added to the seed or soil at sowing, using an inoculant.

The rhizobia that nodulate legumes in the E and F inoculation groups (field pea, faba bean, lentil and vetch) and N inoculation group (chickpea) are sensitive to soil acidity, especially below pH 5.5$_{CaCl_2}$ (i.e. pH measured in calcium chloride). Lupin rhizobia are more tolerant of acidic soils (Table 1).

Expansion of the areas being sown to pulses that are sensitive to soil acidity is presenting issues with nodulation and at times, plant establishment and growth due to the increasing prevalence of acidic soils. In these areas, especially where grain legumes are grown for the first time or have been infrequently grown, they are likely to benefit from rhizobia inoculation. When sowing into acidic soils, particularly when combined with dry sowing and pesticides applied to seed, the survival of rhizobia and the success of nodulation and subsequent performance of the pulse crop can be significantly reduced.

When applying inoculant, growers are applying living rhizobia. The more rhizobia that survive between inoculation and plant germination, the greater the potential for prompt and abundant

Photo: Belinda Cay, AgCommunicators.

nodulation. Therefore, the higher the number of rhizobia applied, the greater the chances sufficient rhizobia will survive until needed at plant germination. This is why doubling the recommended inoculant rate can improve nodulation in acidic soils.

Inoculating legumes in acidic soils

Growers sowing legumes into acidic soil conditions where pH_{Ca} in the 0-10cm layer is less than 5.5 have a number of options to consider to increase the chances of growing successful crops. Key considerations include:

START – Is soil acidity likely to limit nodulation?

- Yes → Soil pH_{Ca} <5.5
- Don't know → MEASURE SOIL pH → Soil pH_{Ca} <5.5 or Soil pH_{Ca} >5.5
- No → Soil pH_{Ca} >5.5

Soil pH_{Ca} <5.5 → pH_{Ca} < 4.5 / pH_{Ca} 4.5 to 5.0 / pH_{Ca} >5.0 to <5.5

pH_{Ca} < 4.5 →

ONLY GROW ACID TOLERANT PULSES OR PASTURES

Lime soil to pH 5.5 if planning to grow acid sensitive legumes in future years.

At pH 4.5, nodulation and growth of grain legumes other than lupin will be severely compromised. Consider acid tolerant legumes e.g. lupin, serradella and sub-clover.

*Group E/F (field pea, faba bean, lentil & vetch) and Group N (chickpea) rhizobia will not be present in adequate numbers, regardless of legume history in paddock. If growing these pulses, apply inoculant at double rate, but plant growth will be compromised even if nodulation is sufficient.

pH_{Ca} 4.5 to 5.0 →

****INOCULATION REQUIRED, DOUBLE RATE – LIME ALSO REQUIRED**

*Group E/F (field pea, faba bean, lentil & vetch) and Group N (chickpea) rhizobia unlikely to be present in adequate numbers even if a legume in the same inoculation group has been grown in the previous 4 years.

Apply inoculant at double rate.

Lime soil to pH 5.5 for improved crop growth (except lupin).

pH_{Ca} >5.0 to <5.5 →

****INOCULATION REQUIRED** if a legume from the same inoculation group has not been grown before. Consider applying inoculant at double rate.

INOCULATION may be REQUIRED even if a legume from the same inoculation group has been grown before but residual rhizobia are not present in *sufficient numbers for adequate nodulation.

Consider liming to bring soil pH to 5.5.

Soil pH_{Ca} >5.5 →

****INOCULATION REQUIRED** if a legume from the same inoculation group has not been grown before, double rate may be beneficial.

INOCULATION may not be required if a legume from the same inoculation group was grown in the last four years and was well nodulated. If there are *sufficient rhizobia in soil then dry sowing and seed applied fungicides are unlikely to constrain nodulation.

* Number of E/F rhizobia in soil can be measured using PREDICTA rNod provided by SARDI, tests for Group G and S, and N are under development.

** Where inoculation is required, avoid direct contact between rhizobia and seed applied pesticide treatments.

TABLE 1. Sensitivity of key rhizobia to pH_{Ca}, where red is sensitive and green is optimal.

Rhizobia	Host legume	pH 4	pH 5	pH 6	pH 7	pH 8
Bradyrhizobium spp	Cowpea, lupin, serradella	light green	green	green	orange	red
Bradyrhizobium japonicum	Soybean	orange	light green	green	green	orange
Rhizobium leguminosarum bv. *trifolii*	Clovers	orange	light green	green	green	green
Rhizobium leguminosarum bv. *viciae*	Pea, faba bean, lentil, vetch	red	orange	green	green	green
Mesorhizobium ciceri	Chickpea	red	orange	green	green	green
Sinorhizobium spp.	Medics	red	red	orange	green	green

Photo: Liz Farquharson.

Beans grown at Wanilla in trials showing the difference between nodulation failure (left) and successful nodulation (right).

Care must be taken if growers intend to inoculate seed which has been treated with pesticides. Where pesticide application is necessary, the inoculant is best applied to seed as close to sowing as possible and sown into moist soil. Alternatively, granular inoculant may provide a better option as this reduces direct exposure of the rhizobia to the pesticide.

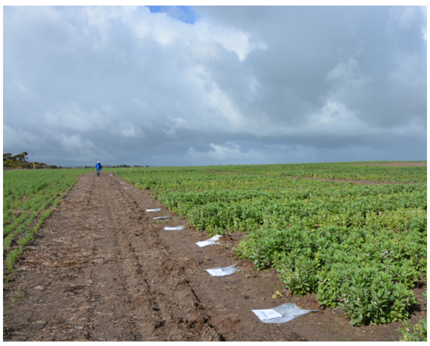

Photo: AgCommunicators.

Soil pH – how low is too low?

Critical soil pH varies for the different legume / rhizobia combinations. Field pea, faba bean, lentil, vetch and chickpea and their rhizobia are more sensitive to low pH than lupin and its rhizobia. Annual medics and lucerne are even more sensitive than the grain legumes to low pH.

In general, soil pH below 5.5 creates a hostile environment for the acidic sensitive species of rhizobia needed for nodulation and nitrogen fixation. These conditions can also directly affect plant roots and the availability of nutrients for a wide range of crops.

When pH is 4.5 or lower, liming is highly recommended to bring levels up to around 5.5. This will assist in decreasing toxic levels of available aluminium to ensure good legume root growth and provide an environment conducive for nodulation in addition to benefiting canola and cereal crops in the rotation.

A pH of 4.5 is too low for most legumes and soils should be limed to increase pH above this level. For legumes in the E and F inoculation groups (pea, bean lentil and vetch) nodulation will be reduced to near zero at pH below 4.5 even with best practice inoculation, so liming is critical for these crops to be reliably grown. More tolerant crop and pasture species (lupin and serradella) may be better options on very acidic, lighter textured soils if liming is not possible.

Identifying acidic soils

Soil acidity can be determined through analysis by commercial soil testing laboratories or alternatively by using soil pH test kits available from gardening centres. The latter are useful to provide general guidance on soil acidity levels and to quickly understand if pH varies down the soil profile. Soil pH test kit results should be backed up with careful soil sampling and laboratory analysis.

Traditional soil sampling strategies, testing to 10 centimetre depth, can sometimes lead to the misdiagnosis that acidity is unlikely to be an issue for legume symbioses. This can occur because although average soil pH to 10cm depth may be neutral, there may be distinct alkaline and acidic zones within or below the top 10cm of the soil profile.

Subsurface acidity and stratification are emerging as serious constraints in areas where pulses are being grown. Stratification is where a very acidic zone develops (usually below 5cm) under a neutral top soil layer. Traditional sampling and mixing of the 0-10cm layer might indicate acceptable pH, but this masks the acidic zone. If the pulse seed is sown in the acidic zone, low pH will have consequences for nodulation and will retard the root penetration of acid-sensitive plants.

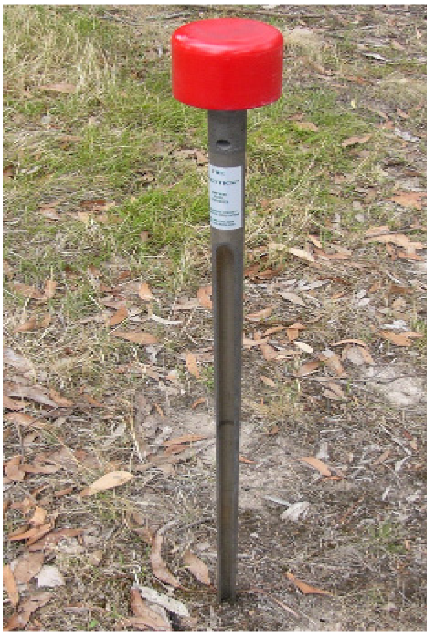

Photo: Tree Logic Tools.

A 'dig-stick' can be used to get a soil core to test pH and identify acidic soil conditions.

Where subsurface acidity is likely, growers are encouraged to sample soils in increments of 5cm to a depth of 25cm in order to diagnose potential stratification issues. A soil core to 25cm depth can be readily obtained from most soils using a 'dig-stick' allowing the pH to be determined by application of the pH kit chemicals down the length of the core. Alternatively digging a hole with a sharp shovel to 30cm depth allows for the application of the pH indicator kit chemicals down the vertical face of soil profile to quickly show variations in pH. NOTE: pH indicated by the kit will be 0.5 to 1.0 units higher than pH in $CaCl_2$.

Apart from impacts on rhizobia and nodulation, root growth and uptake of water and nutrients are reduced under acidic conditions, and low pH can also result in toxic levels of aluminium which severely impairs root growth (Table 2). These constraints are best corrected with the application of lime to increase soil pH.

Where subsurface acidity is present, strategic incorporation/tillage can aid the efficacy of lime application for treating subsurface issues; other subsoil constraints (e.g. compaction) should be taken into consideration to maximise treatment impact, along with the risks associated with soil disturbance, such as erosion.

TABLE 2. Crop symptoms at different soil pH (measured in calcium chloride).

If the soil pH is:	
More than 5.5	There will be no problems from soil acidity affecting crop growth and yield, and there could be net movement of lime beyond 10cm depth.
Less than 5.5	The effectiveness and numbers of rhizobia that fix nitrogen (N) on acid sensitive legumes (e.g. lucerne and pulses, but not narrow-leafed lupin) are reduced. Liming increases the persistence and nodulation by these rhizobia, and the amount of N fixed and grain produced.
Less than 5.0	In addition to the effects above, there is a chance of molybdenum deficiency in legumes — check for local advice. Molybdenum is important in the synthesis of amino acids and proteins and a requirement for rhizobia bacteria to fix atmospheric N.
Less than 4.8	In some soils, aluminium (Al) starts to change from a harmless solid into a soluble form which is toxic to root growth. Aluminium tolerance among plant species varies. Reduced root growth means roots are unable to effectively explore soil for nutrients (particularly phosphorus and trace elements) and access stored subsoil water for growth or grain filling. Crop yield is reduced significantly. Reduction in root hairs occurs and so infection by rhizobia (nodulation of legumes) is reduced.
Less than 4.5	The speed of N mineralisation processes (nitrification) slows significantly, resulting in decreased N supply. In most soils Al concentrations increase further and quickly become toxic to most pasture and crop species. The nodulation of rhizobia in acid intolerant or sensitive legumes is reduced.
Less than 3.8	Soil can no longer buffer effectively against pH change and is overcome with acidity. Irreversible soil structural damage may occur.

Adapted from Fenton G (2003). Planning on liming, NSW Agriculture, Acid Soil Action leaflet No 4 (2 ed).

Photo: Pulse Australia.

Acid tolerant rhizobia

Research began in 2015 to develop acid tolerant rhizobia to increase capacity for E and F crops (faba bean, field pea, lentil and vetch) to better nodulate in acidic soils.

Two elite Group E/F strains have been found to increase nodulation compared to the current inoculant strain in field trials where soil pH ranged from 4.6-5.0. It is envisaged the acid tolerant rhizobia could be commercially available in 2022.

Note: references to pH in this document refer to pH measured in calcium chloride ($CaCl_2$)

GRDC RESEARCH CODE

MSF1806-002

FREQUENTLY ASKED QUESTIONS

Why do you recommend double rate for under pH 5.5 $_{CaCl_2}$?

Acidic soils with a pH of less than 5.5 can substantially reduce the survival of rhizobia for most legumes. In such acidic conditions, most legumes will require inoculation each time the crop is grown. Doubling the rate of inoculant can increase nodulation by increasing the number of rhizobia surviving at seed germination in acidic conditions.

How often do I need to inoculate pulse seed if I have acidic soils?

Acidic soils with a pH_{Ca} of less than 5.5 measured in calcium chloride can reduce the survival of rhizobia for most legumes. In very acidic conditions (<4.5), pulses and other crops (apart from lupin) will struggle. Urgently consider a liming program to increase the pH to 5.5.

What can I do to remediate my acidic soil?

Consider a liming and lime incorporation strategy to increase the pH across the whole paddock or in problem zones identified through soil testing to depth at increments. Pasture seeds can be lime pelleted to assist with rhizobia survival in acidic soils.

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USEFUL RESOURCES

GRDC Podcast – The lowdown on subsurface acidity https://grdc.com.au/news-and-media/audio/podcast/the-lowdown-on-subsurface-acidity

GRDC Publication - Legumes in Acidic Soils – Maximising production potential in south eastern Australia https://grdc.com.au/legumes-in-acidic-soils

GRDC Paddock Practices - 10 dos and don'ts when inoculating legumes https://grdc.com.au/news-and-media/news-and-media-releases/south/2020/april/paddock-practices-10-dos-and-donts-when-inoculating-legumes

GRDC Inoculating Legumes – A practical guide https://grdc.com.au/GRDC-Booklet-InoculatingLegumes

GRDC Podcast – introducing pulses to acid soils https://grdc.com.au/news-and-media/audio/podcast/introducing-pulses-to-acid-soils

GRDC YouTube – Optimising pulse nodulation in low pH soils https://youtu.be/R8CZ5rLUgig

MORE INFORMATION

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