Demonstrating opportunities for improved pulse production and nitrogen fixation

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Key messages

- Sowing rate, rather than inoculation, was the main determinant of faba bean dry matter (DM) production.
- It was estimated the faba beans in this demonstration trial fixed between 101–129 kilograms of nitrogen (N) per hectare based on above-ground DM production.
- High harvest indices (HI) in the trial (48.8–64.09%) indicated a considerable amount of the nitrogen fixed was removed in the grain.
- A new DNA test available to measure Group E and F rhizobia in soil accurately predicted the moderate levels of nodulation measured in the trial.
- Inoculation responses are more likely in soils with lower pH (<pH_{ca} 5.0). Where faba beans are sown into acidic layers at depth, the likelihood of inoculation responses will further increase.

Background and aim

As well as generating income, pulses provide significant benefits to farming systems, with nitrogen (N) fixation boosting the supply of this critical nutrient to subsequent crops. However, not all pulses are adequately nodulated, rendering them unable to reach their nitrogen-producing potential, especially on acidic soils.

The demonstration trials in this report were sown as part of a GRDC investment aiming to improve the nitrogen fixation of winter pulse crops and to promote their wider adaptation and adoption. This is the second year of the project, which focussed on the impacts of soil acidity on nitrogen fixation. The project also aims to promote effective inoculation and pulse management practices, and raise awareness and knowledge around pulse nodulation and nitrogen fixation.

A number of organisations across the GRDC Southern Region are involved in the project including: Mallee Sustainable Farming (lead organisation), the South Australian Research and Development Institute (SARDI), AgCommunicators, Bates Ag, Rural Directions, Southern Farming Systems, Birchip Cropping Group, Ryder Ryan Research Pty Ltd, Moodie Agronomy, Riverine Plains Inc, Southern Pulse Extension, SARDI and Trengove Consulting.

In order to demonstrate best-practice inoculation in pulse crops on acid soils in northern Victoria, a demonstration site at Murchison was sown to faba beans. Inoculant treatments were decided in consultation with the host farmer and the nitrogen-fixation project research team.

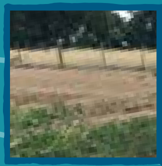
The results from the site have been promoted through the GRDC southern pulse extension project.

Method

The range of inoculation and nutrient treatments are shown in Table 1.

Two sowing rates (140 and 160kg/ha) were also tested to see if there would be any effect on nitrogen fixation or yield. The site was soil sampled on 28 February, 2020, (0–10cm depth) and samples were sent to SARDI for pH and background rhizobia level testing. Background rhizobia level tests were carried out using a plant trap method in pots and using DNA testing to estimate rhizobia number per gram of soil. Soil samples were also collected at 5cm increments down to 20cm to identify the location and extent of any acid soil layers.

Two spray passes (2 x 28m) of sodium molybdate (75g/ha) were applied to a section of the trial, across all treatments by boom spray after sowing, to see if there was any response to molybdenum applied to the soil rather than to the seed. The demonstration trial (un-replicated) was sown at Murchison on 17 May, 2020, using the host farmers' sowing equipment. Nodulation was assessed on 11 August, 2020. Six plants per treatment were dug out from six positions, soaked and rinsed, nodules counted and ascribed a score using the method described in Table 2. Dry matter samples and pod counts were taken on the 21 October 2020 at mid pod fill. Four samples were taken from each treatment, weighed, dried and averaged. Results from the demonstration trial were analysed via simple linear regression using Statistix 8.0. A subsample from the DM cuts will be used to determine the amount of nitrogen in the shoots from symbiotic nitrogen fixation in a process called Nitrogen 15 analysis. This will show how much nitrogen in the faba bean plant came from the atmosphere (i.e. fixed) and how much came from the soil (results not available at the time of publication).



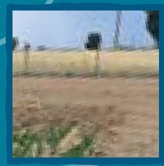


TABLE 1 Site information, soil type, pH, background rhizobia and details of experimental treatments for the faba bean demonstration trial at Murchison, Victoria, 2020

	Demonstration 1		
Pulse crop	Faba beans		
Location	Murchison, Victoria		
Cultivar	Samira		
Soil type	Mixed		
Soil pH ($CaCl_2$) 0–10cm	5.5		
Soil nitrogen (0–60cm)*	140kgN/ha		
Background rhizobia levels	Low levels lentil/faba* bean rhizobia; ~ 284/g soil		
	Treatment	**Sowing rate (kg/ha)**	**Plot size (m)**
	Nil inoculation	140	18m x 660 (1.18ha)
	Acid-tolerant peat inoculant (strain SRDI-969)	140	18m x 660 (1.18ha)
	TagTeam® peat inoculant and molybdenum-treated seed (Mo 250P™ @ 0.7L/t)	140	18m x 660 (1.18ha)
	TagTeam peat inoculant 1	140	18m x 660 (1.18ha)
	TagTeam peat inoculant 2	165	18m x 660 (1.18ha)

* Soil samples were collected for soil nitrogen testing during late May, 2020, from the paddock where the trial was located (Note: samples were not taken from the actual trial site).

TABLE 2 Nodulation scorecard used to assess the number and distribution of nodules from plants collected across the demonstration treatments

	Distribution of effective nodules	
Nodule score	**Crown (top 5cm)**	**>5cm from tap root**
0	0	0
0.5	0	1–4
1.0	0	5–9
1.5	0	>10
2.0	<10	0
2.5	<10	<10
2.75	<10	>10
3.0	>10	0
4.0	>10	<10
5.0	>10	>10

Source: Brockwell and Gault (1977) in AGrow, Final technical report, 2018, southern NSW Trials, Improving nitrogen fixation in lentils.

The plots were harvested using the farmer's header, using a 12m wide section harvested from the middle and along the full length of each treatment.

Results

The paddock at Murchison had a continuous cropping and liming history spanning more than 10 years. Lime was applied at a rate of 2.5t/ha during 2012 and again during 2017. Pulse crops have not previously been grown in the paddock, however sub-clover would have been present prior to 2010. Although the 0–10cm soil test indicated a pH of 5.5, soil pH decreased to 4.4 at the 5–15cm depth, with aluminium (Al) percentage increasing to potentially damaging levels (Figure 1). This indicated the previously applied lime had not moved through the profile into the root zone.

Although faba beans had not previously been grown at the site, pre-sowing tests indicated low background levels of rhizobia in the soil (284 rhizobia/g soil, 0–10cm), which was possibly due the presence of a species that hosts Group E or F rhizobia in the paddock prior to 2010. A moderate level of nodulation (score 2.3) was measured in the uninoculated treatment (Table 3). Nodulation scores for the remaining

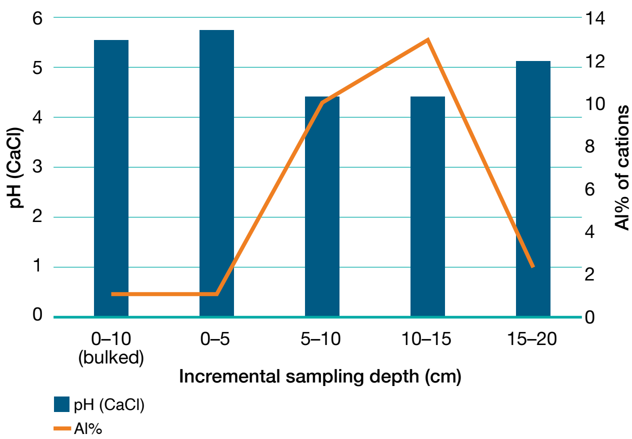


FIGURE 1 Soil test results for the Murchison demonstration paddock showing soil pH and aluminium percentage at different depth increments

Note: The bulked 0–10cm sample shows different pH and aluminium results compared to when the sample was divided into 5cm increments (0–5 and 5–10cm). This is due to lime being concentrated in the top few centimetres of soil and not having moved down the soil profile.

TABLE 3 Faba bean plant density, nodulation score, dry matter production, pod count, yield, estimated nitrogen fixation and harvest index for the faba bean demonstration trial at Murchison, Victoria, 2020

Treatment	Plant density (plants/m²)	Nodule score (1–5)	Dry matter (t/ha)	Pod count (pods/m²)	Yield (t/ha)	Estimate of nitrogen fixed (kg N/ha)#	Harvest index (%)
Nil inoculation	15	2.3	8.07	273	3.94*	129	48.88
Acid-tolerant inoculant (strain SRDI-969)	20	3.8	7.58	231	4.35	121	57.39
TagTeam peat inoculant and molybdenum treated seed (Mo 250P)	20	0.8	7.47	281	4.34	120	58.09
TagTeam peat inoculant 1 (sowing rate 140kg/ha)	27	1.7	6.32	243	4.03*	101	63.76
TagTeam peat inoculant 2 (sowing rate 165kg/ha)	25	2.2	6.99	236	4.48	112	64.09

* Both the nil inoculation and TagTeam peat inoculation 1 (sowing rate 140kg/ha) treatments had wheel tracks (from a spray boom), which would have reduced harvested yield.

Estimated nitrogen fixation based on 16kg nitrogen per tonne of DM produced.

treatments ranged from 3.8 (rhizobia strain SRDI-969 treatment), to less than 1.8 for the TagTeam peat and molybdenum seed treatments.

Plant densities approximated targeted figures of 20 plants/m² for sowing rates of 140kg/ha and 25 plants/m² for the sowing rate of 165kg/ha. Plant density was lowest in the uninoculated treatment, but was not significantly correlated with nodulation overall.

Dry matter production ranged from 6.32–8.07t/ha and was significantly and inversely correlated with plant density (R^2=0.96, P=<0.01), but not nodulation. Grain yield was not significantly correlated with either density or nodulation.

There were no observed differences in yield or DM from applying molybdenum to either seed (Table 3) or as a post-sowing spray (based on visual paddock assessments).

Observations and comments

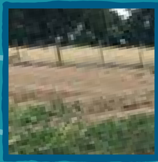
There was a significant inverse relationship between plant density and maximum DM production, which was unexpected. Disease levels were low in the paddock and the reduction in DM production with higher plant density in this trial may have been due to soil type variability across the paddock as the treatments moved from east to west, rather than a result of plant density *per se*.

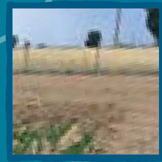
Nitrogen 15 isotope analysis of the faba beans and a reference plant (lupin) was not completed before publishing. As a result, the rate of nitrogen fixation was estimated based on 16kg N/tonne of above-ground DM (Glover *et al*, 2013). The estimated amount of nitrogen fixed in treatments ranged from 101–129kg N/ha (with actual results to be confirmed using nitrogen 15 analysis). The high harvest indices in the demonstration trial indicated a considerable amount of nitrogen fixed was removed in the grain.

Molybdenum is an important micronutrient in the nitrogen fixation process and it is less available in acid soils. The seed-applied molybdenum treatment had the lowest nodule count, which raised questions about the compatibility of the form of molybdenum applied and the rhizobia. Further investigation is needed, as this is a common practice in the region.

While there was some variation in nodulation across treatments, the demonstration trial showed that there was no benefit during 2020 from applying rhizobia (pending nitrogen fixation results) because there was no significant correlation between nodulation and DM or yield. In part, this was due to the presence of a low background level of rhizobia, which resulted in moderate nodulation in the untreated control. In this trial, the level of nodulation and levels of background rhizobia were sufficient to support faba bean growth, but this is unlikely to be the case at lower pH and rhizobia levels as found in other trials (see below). Available soil deep soil nitrogen (0–60cm) also may have moderated any symbiotic responses, as research indicates plants will access easy-to-source nitrogen before fixing nitrogen.

Acid-tolerant rhizobia (Group F for faba beans and lentils) are being trialled to verify their performance across a range of environments before they are released to pulse growers. Although the acid-tolerant rhizobia used in this demonstration resulted in effective nodulation, they did not increase yield, but have done so in other trials where background rhizobia are absent and where average soil pH in the top 10cm is below pH 5.0.





Soil testing for E and F rhizobia number in soil is now available through SARDI. In both years of demonstration trials (2019 and 2020), background soil testing corresponded well to actual nodulation results observed in the field and this indicates background rhizobia testing could provide growers and advisors with accurate information regarding the requirement for inoculation. The test may also have application in understanding how acid layers, such as those measured in this trial at a depth of 5–15cm, affect rhizobia number and subsequent nodulation. Where beans are sown and germinate in the acidic layer, inoculation is more likely to be beneficial.

References

Glover *et al*, 2013, *Break crops in cropping systems: impacts on income, nitrogen and weeds in Research for the Riverine Plains*, 2013.

Acknowledgements

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