Rhizobial inoculation can boost crop performance

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Key points

- During 2010, the effect of inoculation on faba beans and lupins was examined in a grower's paddock at Culcairn, NSW that had not grown pulses for at least 10 years. Inoculation increased faba bean grain yield by 1t/ha and increased the amount of shoot nitrogen fixed by both legumes by 130–180kg N/ha.
- The numbers of rhizobia decline in the soil over time, and growers need to consider whether to inoculate pulses based on paddock history and length of time since growing the last legume crop.
- Concentrations of soil mineral nitrogen in 2011 were higher following the inoculated legumes than either the uninoculated treatments or following canola or wheat. But while the grain yields of wheat grown after either faba bean or lupin were significantly higher than after wheat, there was no interaction with added nitrogen fertiliser suggesting that the improvements in yield were not associated with enhanced nitrogen supply.

Background

Legume roots are capable of developing a symbiotic relationship with rhizobial bacteria in the soil. Rhizobia in legume root nodules can fix atmospheric nitrogen (nitrogen gas) and convert it into a form that can be used to support plant growth. The amount of nitrogen fixed is strongly related to legume biomass production. Legumes can fix between 100 to 200kg nitrogen/ha in a growing season when the correct rhizobia are present in high numbers in the soil. It is important to note that correct species of rhizobia must be present. Since the legume species grown in Australia are exotic and the necessary rhizobia for nitrogen fixation do not occur naturally in Australian soils, inoculation with cultures of rhizobia is essential the first time a legume or pulse is grown. However, the population of rhizobia is known to decline in the soil over time if legumes are not regularly sown. At numbers of less than 100 rhizobia per gram of soil, inoculation is usually considered to be necessary to ensure adequate nodulation and sufficient nitrogen fixation to support plant growth. Based on data collated by Ross Ballard (SARDI) from numerous Australian published studies on numbers of soil rhizobia capable of forming nodules on chickpeas, peas or lupins, it will likely be necessary to re-inoculate with rhizobia if it has been more than six years since the last legume crop to ensure the legume will be able to fix nitrogen. A study was undertaken during 2010 to investigate the effect of rhizobial inoculation on nitrogen fixation and crop performance in different environments.

Aims

To assess the impact of rhizobial inoculation on the growth, nitrogen fixation and grain yield of faba beans and lupins in a paddock with no recent history of growing legumes, and to determine whether there was any subsequent effect of the inoculation treatment on soil mineral nitrogen and grain yield by a following wheat crop.

Method

During 2010, the effect of inoculation on faba beans (*Farah*) and lupins (*Jindalee*) were examined in two separate blocks at Culcairn, NSW where pulses had not been grown for at least 10 years. The seeds sown into half the legume plots were inoculated using appropriate commercial peat inoculants, and nodulation, nitrogen fixation, shoot biomass and grain yield were subsequently assessed with and without inoculation. Each treatment was replicated six times. Replicated plots of canola and wheat were included as non-legume controls (only data for nil nitrogen fertiliser presented).

During May 2011 soil samples (0–1.7m) were collected for measurements of soil mineral nitrogen, and wheat (Lincoln) was sown over the previous year's treatments. Each experimental plot was split for plus (50kg nitrogen/ha as urea) and minus nitrogen fertiliser, and grain yields were determined at the end of the growing season.

Results

There were large differences in root nodulation between the inoculated and uninoculated treatments in both species, but the effect was most marked for faba beans where nodules were only occasionally found on lateral roots of the

uninoculated plants, whereas there was profuse nodulation of the crown of the tap root with inoculation (data not shown). The results outlined in Table 1 indicated there were large, significant increases in shoot dry matter, the amounts of nitrogen fixed over the growing season (increased by 5–9 fold), and the amount of shoot nitrogen fixed per tonne of dry matter accumulated (increased by 3–4 fold) for both the faba beans and the lupins due to inoculation. Inoculation also significantly improved grain yield in faba beans by more than 50%, but there was no measurable effect on lupin yield (see Table 1). The additional 1.0 tonne of faba beans grain harvested was worth around $400/ha and was achieved at a cost of about $4/ha in rhizobial inoculant.

Legume inoculation significantly increased the concentration of mineral nitrogen when sowing wheat during 2011 compared with the uninoculated faba bean treatment and the unfertilised canola or wheat grown during 2010 (see Table 2). However, by the end of the growing season there were no interactions in grain yield between legumes that were inoculated or not during 2010, or whether nitrogen fertiliser was applied to wheat or not during 2011, so the data has been combined in Table 3 for ease of presentation. Wheat yields following faba beans or lupins proved to be significantly greater than wheat-wheat, and canola-wheat sequences in the faba beans block, but wheat yield following canola could not be statistically separated from lupin-wheat in the lupin block in a different part of the paddock.

Observations and comments:

Growers need to consider the paddock history and length of time since the last legume when considering whether to inoculate their legume crops. Since rhizobial numbers slowly decline in the soil over time when legumes are not regularly sown, there could be a benefit of inoculation after a prolonged break between legume crops. In addition, rhizobia survive poorly in acid soils, so inoculation is likely to be required more frequently in acid soils. Clearly there was evidence that low rhizobial numbers and sub-optimal nitrogen fixation limited the performance of faba bean at the

TABLE 1 Effects of inoculation on shoot dry matter (DM), grain yield and nitrogen fixation by faba beans or lupins at Culcairn, NSW during 2010

Species	Inoculation	Shoot DM (t/ha)	Grain yield (t/ha)	Shoot nitrogen fixed	
				(kg N/ha)	(kg N/ t DM)
Faba beans	-	5.97	1.75	23	4
Faba beans	+	11.61	2.70	202	17
Lupins	-	7.76	3.50	37	5
Lupins	+	9.18	3.70	169	18
LSD (P<0.05)					
Faba bean x inoculation		2.40	0.44	56	2.6
Lupin x inoculation		NS	NS	56	3.3

TABLE 2 Effects of pulses grown with or without inoculation, or canola and wheat grown with or without nitrogen fertiliser during 2010 on soil mineral nitrogen (0–1.7m) measured in May 2011 at Culcairn, NSW

Species	Inoculation or nitrogen fertiliser	Soil mineral nitrogen (kg N/ha)	Species	Inoculation or nitrogen fertiliser	Soil mineral nitrogen (kg N/ha)
Faba beans	-	203b*	Lupins	-	191ab*
Faba beans	+	252a	Lupins	+	209a
Canola	-	165b	Canola	-	180b
Wheat	-	158b	Wheat	-	120c
LSD (P<0.05)		48			27
*Figures followed by different letters differ significantly					

TABLE 3 Effect of pulses, canola or wheat grown during 2010 on subsequent wheat yields at Culcairn, NSW during 2011

Species	Wheat yield (t/ha)	Species	Wheat yield (t/ha)
Faba beans	5.37a*	Lupins	5.39a*
Canola	4.56b	Canola	4.92ab
Wheat	4.61b	Wheat	4.50b
LSD (P<0.05)	0.66		0.72
*Figures followed by different letters differ significantly			

Culcairn site during 2010 (see Table 1). When considering whether to inoculate pulse crops or not it is useful to keep in mind that while field peas, lentils, faba beans and vetch can nodulate with the same rhizobia species, a different rhizobia species is required for lupins and a different species again for chickpeas. So it is important to look at the time interval between legumes that nodulate with the same rhizobial species.

The increased nitrogen fixation that occurred with inoculation was reflected in measurably higher concentrations of soil mineral nitrogen during 2011 compared with the uninoculated treatments or where either canola or wheat had previously been grown (see Table 2). However, the fact that there was no effect of applications of an additional 50kg fertiliser-nitrogen/ha on subsequent wheat yields during 2011 (see Table 3) implied that the higher grain yields observed after faba beans and lupins were not directly associated with improved nitrogen nutrition.

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