Dryland Legume Pasture Systems: Medic nodulation and nitrogen fixation

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Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2018: Strand medic or trigonella
2017: Scepter wheat
Soil type
Red sandy loam
Soil test
$pH_{(H20)}$ (0-10 cm) 8.3
Plot size
5 m x 1.5 m x 4 reps x 25.5 cm row spacing

Key messages

- **The nodulation of strand medic was below potential, but was not increased by inoculation.**
- **Trigonella formed more nodules than medic, but in the end PM-250 strand medic was more productive and fixed the most N.**
- **Legume inoculation (2018) increased wheat grain protein (2019). The increase could not be attributed to any measure of legume performance.**

Why do the trial?

There are reports of low grain protein levels in wheat following medic pastures and many observations of poor medic nodulation. Previous work has shown that rhizobial inoculation can improve the nodulation of medics in the SA and Victorian Mallee, and that more generally about 50% of the populations of medic rhizobia in soils are sub-optimal in their nitrogen (N) fixation capacity.

This trial aimed to:

- Determine if inoculation can improve medic nodulation at Minnipa,
- Quantify the amount of N fixed by different legumes,
- Assess impacts on the following wheat crop.

How was it done?

The trial commenced in 2018 at Minnipa in paddock S8. It was a factorial experiment (inoculation × legume) arranged in a fully randomized block design, with four replications.

There were three inoculation treatments (no rhizobia applied, or standard and high rates of inoculation) and four legumes. The legumes were Herald strand medic, representing an 'old' medic, PM-250 strand medic, representing a 'new' medic, Z-2447 medic, a medic with potential improvements in N-fixation capacity, and trigonella, a new aerial seeded legume that is also nodulated by medic rhizobia. The high rate of inoculation was applied as a double rate of recommended label rates of peat inoculant on seed and supplemented with inoculated glass micro-beads also inoculated at double rate and sown at 10 kg/ha with the seed. Standard and high rates of inoculation delivered on average 10,000 and >30,000 rhizobia per seed, respectively. Nodulation, root and shoot dry-matter (DM) production and N-fixation were measured.

In 2019, the plots were over-sown with wheat (cv. Scepter). Wheat grain yield and grain protein were measured.

What happened?

In the pasture year (2018) significant differences in nodulation and N-fixation were measured amongst the legume species (Table 1). However, inoculation even at the high rate, did not improve legume nodulation, N-fixation or DM production (data not shown).

Trigonella had about 4 times the number of nodules (17 per plant), compared to the three medics whose nodulation was similar (≤ 5 nodules per plant). Among the 540 medic plants assessed, 76 plants (14%) had no nodules and 21 plants had ≥15 nodules. Medic nodulation was not increased by inoculation.

Although trigonella had the most nodules and was the most efficient legume for N-fixation (65% N-fixation and 27 kg fixed N/t shoot DM), it did not fix more nitrogen overall because it was less productive. PM-250 and Herald strand medics fixed most N (9.8 and 7.5 N kg/ha respectively), not accounting for root contributions (+8% DM).

Table 1. Nodulation, herbage production, total shoot N and N-fixation of four legumes sown at Minnipa, 2018.

Legume	Nodulation (No./plant)	Production (kg/ha)	Total N (kg/ha)	N-fixation (%)	N-fixed (kg N/t shoot DM)	N-fixed (kg/ha)
Herald medic	5.0	326	13.0	56	22.4	7.5
PM-250 medic	4.4	408	16.0	61	24.1	9.8
Trigonella	17.0	171	7.4	65	27.4	4.8
Z-2447 medic	4.4	252	10.0	49	19.8	5.0
LSD (P=0.05)	*0.7*	*58*	*2.4*	*3*	*1.6*	*1.6*

Table 2. Effect of legume inoculation treatment (2018) on the yield and protein content of Scepter wheat in 2019.

Inoculation rate	Grain yield (t/ha)	Grain protein (%)
Not inoculated	3.02	12.7
Standard inoculation	2.74	13.1
High inoculation	2.60	13.3
LSD (P=0.05)	*ns*	*0.4*

In the wheat (2019), responses were due to inoculation rate (Table 2) rather than legume type (data not shown). Wheat grain protein was significantly greater (13.3%) in the high inoculation rate treatment, compared to no inoculation (12.7%). Wheat grain yield was not significantly affected by treatment, however showed a trend of decreasing yield (–14%, P=0.099) as inoculation rate increased.

What does this mean?

Legume DM production, nodulation and N-fixation

The results demonstrate the importance of legume DM production to the total amount of N fixed. Although legume production was low in 2018 due to late establishment (27 June) and low growing season rainfall (150 mm), it was still a strong determinant of the amount of N-fixed. PM-250 produced most DM (408 kg/ha) and fixed the most N (9.8 N kg/ha). Trigonella was the least productive legume and fixed the least N.

Medic nodulation was low, but not improved by inoculation. Similarly, other measures of legume N-fixation were not improved by inoculation. This is consistent with the current understanding that at Minnipa and in similar environments where soil pH_{CaCl} is >7 (alkaline) and where large backgrounds of annual medic persist, the likelihood of an inoculation response is low.

Although strand medic forms fewer nodules than many other legume species, nodule number (mean of 4.5 nodules/plant) was below potential. Numerous plants had no nodules. Other plants had 20 nodules, providing an indication of what is possible. The lack of inoculation response points to factors other than rhizobial deficiency as the cause of poor nodulation. SU-herbicide residues were unlikely to be the cause since PM-250 is tolerant. A possible explanation lies in the level of available soil N at the site (61 mg/kg soil N, 0-10 cm), since medic nodulation is known to be sensitive to moderate levels of available soil N.

Neither of the new legumes (trigonella or Z-2447) provided an advantage over the PM-250 and Herald. Breeder's line Z-2447 was neither well nodulated or productive. Other medic lines selected for improved N-fixation capacity combined with agronomic performance are being tested.

Wheat crop impact

Wheat grain protein level was greater and yield trended lower, following legume inoculation. This result suggests there was an unmeasured impact of legume inoculation in the previous year.

A negative relationship between grain yield and grain protein is well established and generally thought to be a consequence of extra carbohydrate (yield) in the grain diluting the protein content and vice versa. Since there was no evidence of increased legume growth with inoculation, neither excessive available soil N or water use seem likely to have limited grain yield, although they were not measured. Further, if available soil N or water were implicated, significant effects of legume type should also have occurred, since differences in legume production were substantial. The high rate of inoculation may have affected some aspect of the soil microflora.

Whilst the relative economic benefit of grain yield and protein will depend on grain prices and grade premiums, the trend of reduced grain yield and inability to measure an inoculation response in the legumes, leads us to conclude that inoculation of medic provides no value at Minnipa. The fact that inoculation responses have been measured on Mallee soils in the SA/Vic Mallee may be the result of their lower pH. Further investigation is needed to understand the basis of low nodulation in medic.

Acknowledgements

The Dryland Legumes Pasture Systems project is supported by funding from the Australian Government Department of Agriculture as part of its Rural R&D for Profit program, the Grains Research and Development Corporation, Meat and Livestock Australia and Australian Wool Innovation. The research partners include the South Australian Research and Development Institute, Murdoch University, the Commonwealth Scientific and Industrial Research Organisation, the WA Department of Primary Industries and Regional Development, and Charles Sturt University, as well as grower groups. Project code: RnD4Profit-16-03-010.