Economic benefits of nitrogen fixation from legumes in subsequent season crops

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Key findings

- Vetch brown manure fixed the most nitrogen (N) into the soil with a pre-seeding soil N of 107 kg/ha, an increase of 37.9 kg N/ha from 2021. Poor legume growth in 2021 resulted in no increase in soil N from grain legume treatments.
- Barley (5.73 t/ha) and wheat (6.10 t/ha) yielded similarly across all 2021 treatments. Grain quality was also similar in 2021. Protein was low for wheat (10.1%) and barley (10.9%) due to under fertilisation. Test weights were high, and screenings were acceptable.
- Timok vetch had the highest two-year partial gross margin in wheat and barley with $2,202 and $1,777/ha respectively. Brown manured vetch provided the lowest return in both wheat ($1,804/ha) and barley ($1,306/ha) due to no income in the first year and minimal benefit from increased N fixation.

Introduction

Nitrogen is a fundamental element in cropping systems, contributing to vital plant functions of crop growth and development (Leghari 2016). Forms of nitrogen are available from atmospheric, biological and organic fixation of N, therefore appropriate N management practices are important to increase soil N and minimise input costs of N fertilisers for cereal and oilseed crops (Leghari 2016).

Legume crops have been used to fix N into soils for many years to reduce the cost of fertiliser inputs, however, not all legume crops are capable of fixing the same amount of soil N (Farquharson et al 2022). Nitrogen fixation is also affected by biomass production with larger crops typically fixing more N (Seymour et al 2015).

In recent seasons, N based fertilisers including urea and diammonium phosphate (DAP) have increased in cost, putting significant pressure on growers to manage the application of granular fertilisers more efficiently. It has also influenced grower's decision-making when considering an increase in primary production area sown to legume crops.

This two-year trial investigated N fixation of legumes in the medium rainfall zone of the Mid-North region and the economic benefits in a subsequent season's crop (wheat or barley).

Methodology

2021		**2022**	
Seeding date	May 18, 2021	**Seeding date**	June 10, 2022
Crop type	Grain legumes	**Crop type**	Cereal phase
Basal fertiliser	MAP (10:22) + 2% Zn @ 80kg/ha	**Basal fertiliser**	DAP (18:20) + 1% Zn + Impact @ 80 kg/ha
2021 harvest date	November 30, 2021	**2022 harvest date**	December 14, 2022

The trial was a split plot design with three replicates and five treatments. It was managed with the application of pesticides to ensure a weed, insect and disease-free canopy. Plots were assessed for crop biomass (t DM/ha) at hay cutting (50% podding), grain yield (t/ha) and harvest biomass (t DM/ha) in 2021. Plot assessments in 2022 involved pre-seeding soil N (kg N/ha), NDVI (Normalised Difference Vegetation Index) as a measure of crop vigour, grain yield (t/ha) and a partial gross margin ($/ha). Data was analysed using a split plot ANOVA model in Genstat 22nd edition.

Five legume treatments were sown in 2021; Timok vetch, PBA Hallmark XT lentil, PBA Butler field pea and PBA Samira faba bean. A vetch brown manure treatment was also included and was terminated on September 1, 2021 using RoundUp Ultra®MAX + Lontrel® Advanced, followed by a double knock of SpraySeed® on September 29. Genesis 090 chickpea was removed from analysis in 2021 as poor establishment in that year would have influenced available soil moisture and available N for the following year's crop.

The starting soil N in 2021 was 68.7 kg N/ha. In 2022, legume treatments were over-sown with Scepter wheat or Compass barley. The targeted wheat grain yield for wheat and barley in 2022 was 3 t/ha, equating to approximately 120 kg N/ha (based on N efficiency of 40 N/t). Granular urea was applied to all cereal plots, targeting 120 kg/ha N.

Table 1. Pre-seeding N level (kg/ha) in 2022 for each legume treatment and the average amount of N applied (kg/ha) to reach 120 kg N/ha target.

Crop type	**Average N pre-seeding (2022)** (kg/ha)	**Average N applied** (kg N/ha)	**Granular urea applied** (kg/ha)
Lentil (Hallmark XT)	50.5	69.5	151.2
Field pea (Butler)	55.3	64.7	140.6
Faba bean (Samira)	67.8	52.2	113.5
Vetch (Timok)	67.4	52.6	114.3
Vetch brown manure (Timok)	106.6	13.4	29.1

Results and discussion

Legume yields in 2021

Dry conditions in 2021 resulted in below average grain yields for all legumes at Hart. Lentil was the lowest yielding legume in 2021, averaging 0.67 t/ha. Faba bean, field pea and vetch performed similarly, with yields of 1.09 t/ha, 1.12 t/ha and 1.06 t/ha, respectively (Figure 1).

The vetch brown manure treatment was terminated prior to seed-set.

Field pea and vetch had higher levels of biomass at hay cutting, producing 4.26 and 3.91 t DM/ha respectively (Table 2). At harvest, all varieties produced similar levels of crop biomass, therefore minimal differences in fixed soil N would be expected (Farquharson et al 2022).

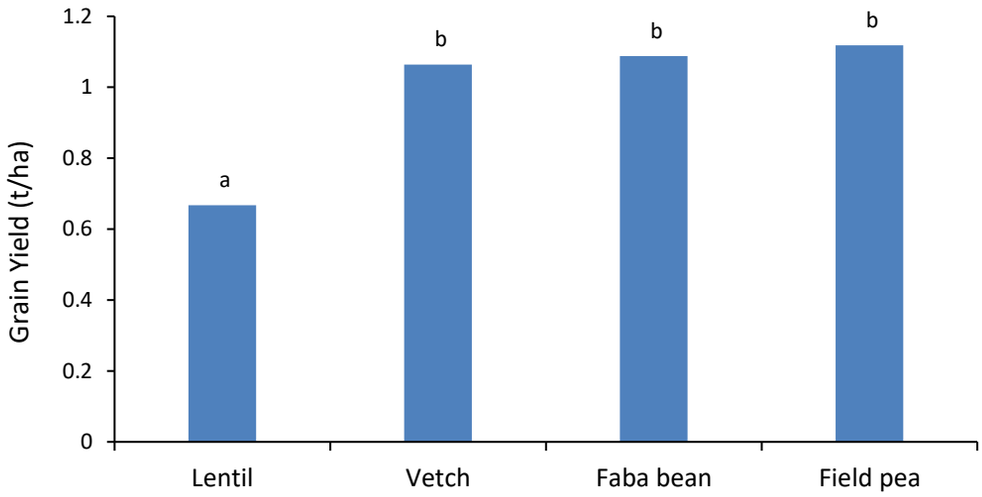

Figure 1. Grain yields at Hart in 2021 for grain legume crops.

Table 2. Biomass production (t/ha) for legume varieties at Hart in 2021. Varieties for each cut timing with the same letter are not significantly different. Shaded values indicate the highest performing treatment.

Variety	2021 Biomass Production	
	Hay cut (t/ha)	**Harvest Cut** (t/ha)
Lentil	2.18[a]	4.52
Faba bean	2.99[ab]	5.65
Vetch	3.91[bc]	4.20
Field pea	4.26[c]	5.20
LSD (P≤0.05)	**1.23**	**NS**

Soil N fixation

Crops with greater biomass typically fix more N into the soil (Farquharson et al 2022). Biomass production in a drier year, as observed at Hart in 2021, was low, therefore N fixation was reduced. Similar or decreased levels of soil N in grain legume treatments, when compared to background levels measured in 2021 (Figure 2), were a result of grain removal and low levels of N fixation in-season due to lower yield potential. The only legume treatment which increased soil N was the vetch brown manure of 106.6 kg N/ha prior to seeding in 2022. This was an increase of 37.9 kg N/ha, when compared to 2021 pre-seeding levels, as a result of no N removal from the terminated vetch.

Faba beans are capable of fixing approximately 27 kg of N per tonne of biomass produced, whereas lentils and field peas are capable of fixing approximately 24 kg of N for every tonne of biomass produced (Farquharson et al 2022). These values can change depending on the growing season and performance of varieties. A trial in the Riverine planes observed vetch fixing higher levels of N per tonne of biomass when compared to faba bean and field pea (Glover et al 2012).

Pre-seeding N did not account for crop residue that would contribute N during the growing season.

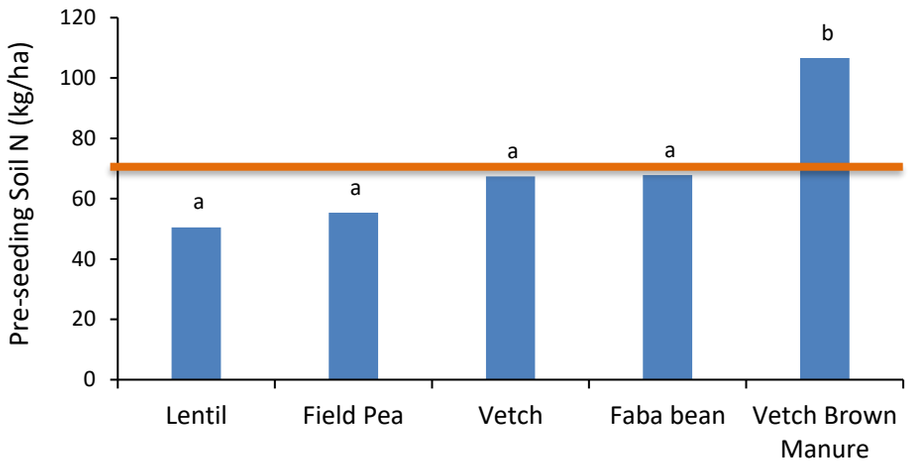

Figure 2. Pre-seeding soil N level at Hart in 2022. Pre-seeding soil N in 2021 is represented by the orange line (68.7 kg N/ha).

2022 crop yield

At Hart in 2022, no yield differences were observed for cereal crops, with wheat yields ranging from 6.06 - 6.15 t/ha and barley from 5.45 – 5.94 t/ha (data not shown). This was expected as each plot was fertilised in-crop with granular urea to 120 kg N/ha. The vetch brown manure treatment could contribute to crop yield increases with early termination, resulting from higher available soil water if seasonal conditions were dry (Ferrier et al 2013).

2022 grain quality

Grain quality for wheat was similar with protein (%), test weight (kg/hL) and screenings of 10.1%, 85.8 kg/hL, and 3.5%, respectively. All treatments met ASW1 receival standards. Barley quality was also similar for protein and retention (Table 2). Test weight and screenings were variable, resulting from previous legume treatments. Barley sown after vetch was observed to have lower test weight and higher screenings, and sown after the vetch brown manure treatment, it recorded a lower test weight. Differences observed for these two treatments were negligible and did not affect receival standards, with all treatments meeting Malt 1 requirements.

Table 2. Grain quality characteristics for Compass barley following legume treatments at Hart in 2022. Shaded values indicate best performing treatments. Values with the same letter are not significantly different.

2021 treatment	**Protein** (%)	**Test Weight** (kg/hL)	**Retention** (%)	**Screenings** (%)
Lentil	11.3	68.2^{abc}	96.8	0.9^{a}
Field pea	10.7	68.6^{bc}	97.4	0.7^{a}
Vetch	11.3	67.6^{a}	96.7	1.1^{b}
Faba bean	10.4	68.6^{c}	97.6	0.6^{a}
Vetch brown manure	11.0	67.9^{ab}	97.0	0.8^{a}
LSD (P≤0.05)	**NS**	**0.63**	**NS**	**0.24**

Gross margin analysis

The legume rotation producing the highest two-year partial gross margin for wheat and barley was vetch, with returns of $2,202/ha and $1,777/ha, respectively (Figure 4). This was due to higher grain yield and prices for vetch in 2021.

Barley and wheat sown after vetch brown manure resulted in the lowest two-year partial gross margin with cumulative returns of $1,306/ha and $1,804/ha, respectively (Figure 4). This was expected as there was no income during the 2021 season. Alternative uses of vetch, such as grazing, were not included in the partial gross margin analysis.

The advantage of a brown manure vetch prior to wheat or barley was a 40% ($112/ha) and 45% ($147/ha) reduction in urea cost (Table 3 & 4). This would also provide secondary benefits in years where access to fertiliser or labour is limited. Low lentil yields in 2021 also resulted in a lower two-year partial gross margin, performing similar to vetch brown manure.

Brown manured vetch also offers a high level of weed control in preparation for subsequent years' crops. In high weed pressure paddocks, the partial gross margin would be affected due to a reduction in grain yield.

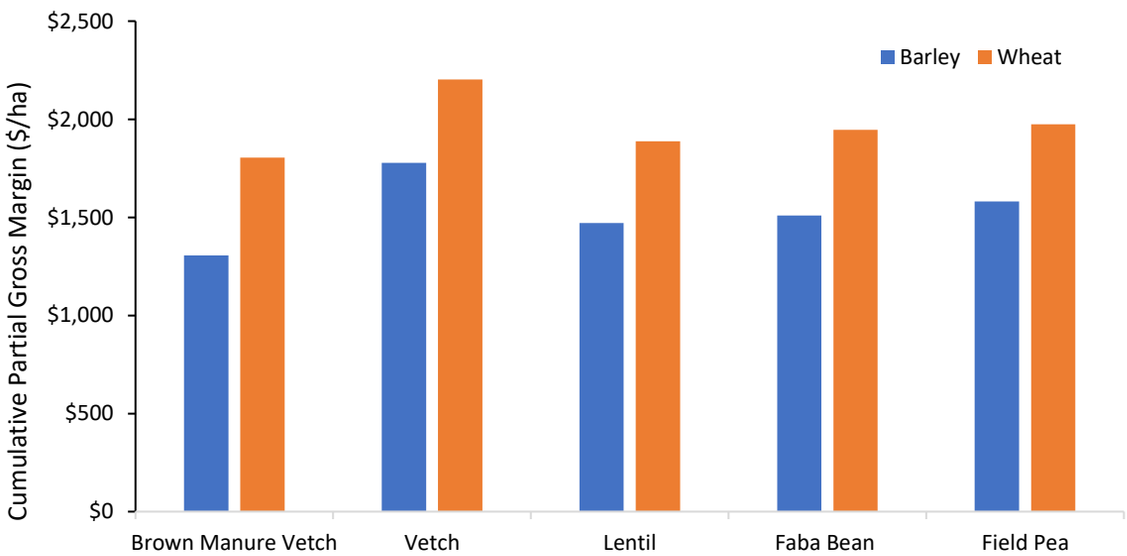

Figure 4. Cumulative partial gross margin analysis ($/ha) for grain legume crops, followed by wheat or barley at Hart. The partial gross margin includes pesticide and fertiliser inputs and seed costs. Operational, contracting and insurance costs were not accounted for. Grain prices for 2021 in addition to seed, pesticide, basal fertiliser and urea costs were based on estimates from the 2021 and 2022 Farm Gross Margin Guide. Barley and wheat prices for 2022 were based on cash prices available at Viterra Snowtown on December 14. ASW wheat was $376/t and Malt 1 barley was $298/t.

The partial gross margin presented is based on one year of legume and cereal data only and is likely to vary depending on seasonal conditions.

Table 3. Partial gross margin ($/ha) for legume crop and Scepter wheat crop at Hart. The 2022 grain price was based on ASW1 at Snowtown on December 14. The 2021 and 2022 Gross Margin and Enterprise Planning Guides were used to estimate input costs.

		Vetch brown manure	Vetch	Lentil	Faba Bean	Field Pea
Income	2021 Yield (t/ha)	0	1.03	0.58	0.91	0.92
	Price ($/t)	$ -	$ 500	$ 600	$ 400	$ 380
	2022 Yield (t/ha)	6.09	6.06	6.09	6.12	6.15
	Price ($/t)	$ 376	$ 376	$ 376	$ 376	$ 376
	Total ($/ha)	$ 2,290	$ 2,794	$ 2,638	$ 2,665	$ 2,662
2021 Expenses	Seed Cost	$ 38	$ 38	$ 32	$ 70	$ 57
	Sowing Fert.	$ 48	$ 48	$ 48	$ 48	$ 48
	Pesticides	$ 74	$ 66	$ 175	$ 139	$ 86
	2021 Total ($/ha)	$ 159	$ 152	$ 255	$ 258	$ 191
2022 Expenses	Seed Cost	$ 45	$ 45	$ 45	$ 45	$ 45
	Sowing Fert.	$ 104	$ 104	$ 104	$ 104	$ 104
	Pesticides	$ 178	$ 178	$ 178	$ 178	$ 178
	Urea	$ -	$ 113	$ 169	$ 135	$ 171
	2022 Total ($/ha)	$ 327	$ 439	$ 496	$ 461	$ 497
Final Partial GM ($/ha)		**$ 1,804**	**$ 2,202**	**$ 1,887**	**$ 1,946**	**$ 1,973**

Table 4. Partial gross margin ($/ha) for legume crop and Compass barley at Hart. The 2022 grain price was based on Malt 1 at Snowtown on December 14. The 2021 and 2022 Gross Margin and Enterprise Planning Guides were used to estimate input costs.

		Vetch Brown Manure	Vetch	Lentil	Faba Bean	Field Pea
Income	2021 Yield (t/ha)	0	1.09	0.75	1.27	1.32
	Price ($/t)	$ -	$ 500	$ 600	$ 400	$ 380
	2022 Yield (t/ha)	5.88	5.94	5.76	5.45	5.63
	Price ($/t)	$ 298	$ 298	$ 298	$ 298	$ 298
	Total ($/ha)	$ 1,752	$ 2,315	$ 2,166	$ 2,132	$ 2,179
2021 Expenses	Seed Cost	$ 38	$ 38	$ 32	$ 70	$ 57
	Sowing Fert.	$ 48	$ 48.00	$ 48	$ 48	$ 48
	Pesticides	$ 74	$ 66	$ 175	$ 139	$ 86
	2021 Total ($/ha)	$ 159	$ 152	$ 255	$ 258	$ 191
2022 Expenses	Seed Cost	$ 60	$ 60	$ 60	$ 60	$ 60
	Sowing Fert.	$ 104	$ 104	$ 104	$ 104	$ 104
	Pesticides	$ 86	$ 86	$ 86	$ 86	$ 86
	Urea	$ 37	$ 137	$ 191	$ 115	$ 157
	2022 Total ($/ha)	$ 287	$ 386	$ 440	$ 365	$ 407
Final Partial GM ($/ha)		**$ 1,306**	**$ 1,777**	**$ 1,471**	**$ 1,509**	**$ 1,581**

Conclusion

Urea input was reduced when vetch was brown manured at Hart in 2021 with cost reduced by 40-45% ($112-147/ha), although overall gross margins were similar between legume crops. Due to seasonal conditions, grain legumes did not increase soil N at Hart.

Vetch grain production prior to a cereal crop produced the highest two-year partial gross margins across wheat and barley due to good prices. All legume treatments provided profitable options for growers, even with low grain yields in 2021. Brown manured vetch also provided a profitable option for growers with the added benefit of improved weed control.

The results presented cover two-years of data only and are influenced by seasonal conditions.

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