COMPARING NITROGEN RETURNS FROM DIFFERENT LEGUME ROTATIONS FOR A MAIZE CROP AT HOWLONG

Results from the Riverine Plains and GRDC Irrigation Discussion Group maize focus paddock

KEY MESSAGES

- **A demonstration trial at Howlong highlighted how poultry manure applied at 6t/ha, a high-density legume mix brown manure and adzuki bean rotation can provide significant amounts of nitrogen to the following maize crop (105 kg N/ha, 130 kg N/ha and 169 kg N/ha respectively).**
- **In contrast to other rotations, a high-density legume mix made into silage significantly reduced the amount of nitrogen available to the following maize crop (54 kg N/ha) due to removal (offtake) of nitrogen in the silage.**
- **Brown manuring a high-density legume mix was significantly less profitable than harvesting high density legume as silage, even when the additional nitrogen fixed by the brown manure over a six-month period was taken into account.**
- **A nitrogen budget is useful for determining how much nitrogen to apply — for a 20 t/ha maize crop, the total nitrogen requirement is 512 kg N/ha. A deep soil nitrogen test taken after a legume crop allows farmers to more accurately calculate the requirements for the following maize crop.**
- **Poultry manure can also be a source of nitrogen and other nutrients including potassium, sulfur and phosphorus for irrigated crops, but these won't all be available in the year of application.**

BACKGROUND

Nitrogen input costs are a significant expense for farmers, especially when growing high-yielding irrigated crops such as maize, which have a large overall nitrogen requirement. For example, a 20 t/ha maize requires 512 kg N/ha, with about half the nitrogen requirement removed with the grain and the other half remaining in the crop residue.

Previous work by Riverine Plains through the Grains Research and Development Corporation's (GRDC) Irrigated Discussion Group project investment, identified that local farmers are interested in alternatives to synthetic nitrogen inputs for high yielding irrigated crops, including nitrogen from sources such as legumes and animal manures. While some local irrigated farmers currently make use of animal manures for crop nutrition, legume crops are not commonly used, mainly because of their yield instability under irrigation. Animal manures are commonly used overseas as a source of nutrition for grain crops and the idea to trial poultry manure on crops originated with an overseas study tour to America, organised by AgNVet.

This trial concept arose from previous nitrogen discussions that took place within the Riverine Plains and GRDC Irrigation Discussion Group meetings.

AIM

This demonstration trial aimed to quantify the nitrogen supplied by legumes, including a high-density legume mix brown manure crop, high-density legume mix silage and an adzuki bean fallow for the following maize crop.

DEMONSTRATION DETAILS

Location	**Howlong**
Crop type	**Maize**
Irrigation system	**Overhead spray (pivot) irrigation**

METHOD

Two case study paddocks at Howlong were selected to compare the amount of nitrogen supplied by different legume crops.

One paddock was sown to adzuki beans in the summer of 2022–2023 before being sown to Pioneer P1837, a hybrid maize for feed grain or silage, on 1 November 2023.

The other paddock was sown to a high-density legume mix of 40 kg/ha of Volga vetch, 7.5 kg/ha of Persian clover and 7.5 kg/ha of Tetila Rye on 27 April 2023. An inoculant was applied, along with MAP at a rate of 50 kg/ha. The high-density legume mix paddock was then split into two, with one section cut for silage (sold standing to a contractor) and the other section sprayed-out (brown manured) on 6 September 2023. The brown manure was then incorporated to a depth of 20 cm using a Horsch Tiger on 20 October 2023 and strip tilled, before also being sown to P1837 hybrid feed grain or silage maize on 30 October 2023.

The maize paddocks were both pre-spread with 6 t/ha poultry manure and received two applications of urea (first application of 600 kg/ha, second application 200 kg/ha), totalling 800 kg urea/ha. The poultry manure provided 105 kg N/ha, while the urea provided 368 kg N/ha. This meant the total nitrogen applied through both sources was 473 kg N/ha, or 92 percent of the requirements of a 20 t/ha maize crop.

The adzuki bean, high-density legume mix silage and high-density legume mix brown manure paddocks were sampled for deep soil nitrogen (DSN) on 17 October 2023, just prior to spreading of the poultry manure and the maize crop being sown. The samples were incremented in 30 cm segments to a depth of 0–90 cm, with the sample sites being GPS referenced. The DSN sample sites from October 2023 were then retested on 21 May 2024 after the maize was harvested to compare changes in nitrogen status.

RESULTS & DISCUSSION

Table 1 shows that at the October 2023 sampling date (pre-sowing), the highest DSN nitrogen levels were found in the adzuki bean paddock (169 kg N/ha), followed by the high-density legume mix brown manure paddock (130 kg N/ha), with the high-density legume mix silage section having the lowest soil nitrogen (54 kg N/ha) of the three comparisons.

For the high-density legume mix paddock, the lower rates of soil nitrogen in the silage section can be attributed to higher rates of product and nitrogen removal compared to the brown manure crop, which retained its biomass within the paddock.

The segmented soil tests also showed that most of the nitrogen was in the top 30 cm at all three sites. However, the adzuki paddock had a more even spread of nitrogen across the soil profile than the high-density legume mix paddocks. There was an interval of around six months between adzuki harvest and DSN sampling, which likely facilitated the breakdown of residue and subsequent release and movement of nitrogen through the profile.

The maize grown in the adzuki bean paddock yielded 16 t/ha, compared to the high-density legume mix silage and brown manure rotations, which both yielded 19.1 t/ha. The lower yields in the adzuki bean rotation were attributed to poorer maize germination, possibly due to the paddocked being overworked, as well as under-watering part of the paddock. The yields in the under-watered section were sub 10 t/ha, whereas the rest of the paddock yielded on par with the yields in the high-density legume mix rotation.

There was no difference in maize yield between the high-density legume mix silage and brown manure crops. A 20 t/ha maize crop requires approximately 512 kg N/ha and there was an ample supply of nitrogen to achieve the target yield in both the silage and brown manured sections. Because nitrogen was not limiting, no yield response was seen to the additional nitrogen available in the brown manured section (the farmer did not reduce nitrogen application rates, despite the higher amounts available).

It's also likely that warm, wet conditions over spring 2023 and summer 2024 increased mineralisation rates in all paddocks, increasing the supply of nitrogen to the subsequent maize crop.

After the maize crop was harvested, follow-up DSN testing showed the highest nitrogen levels in the high-density legume mix brown manure rotation (313 kg N/ha), followed by the adzuki bean rotation (133 kg N/ha), with the lowest nitrogen found in the high-density legume mix silage rotation (90 kg N/ha). Despite the high application rates of poultry manure and in-crop urea, there was a decrease in total nitrogen between maize sowing and harvest for the adzuki bean rotation in the 0-30cm segment, suggesting that the maize crop drew on soil nitrogen reserves in this layer. Poultry manure can take one to two seasons to fully breakdown, so it's likely that not all nitrogen from the manure was available at the time of testing. In comparison, the high-density legume mix brown manure rotation showed a substantial increase in soil nitrogen to 60cm between maize sowing and harvest, likely due to the breakdown of the high-density legume mix residue over the summer, and the subsequent release of mineralised nitrogen back into the soil. The high-density legume mix silage also showed a slight increase in soil nitrogen between sowing and harvest, although not to the same extent as the brown manured crop.

Table 1 Deep soil nitrogen and subsequent maize yield results from three different legume treatments at Howlong.

		DSN PRE-SOWING OCT 2023	DSN POST-HARVEST MAY 2024	MAIZE YIELD 2024
Rotation	**DSN sample depth (cm)**	**(kg N/ha)**	**(kg N/ha)**	**(t/ha)**
Adzuki beans 2022–2023, maize 2023–2024	0-30	79	36	16.0
	30-60	58	58	
	60-90	32	40	
Total (0-90 cm) nitrogen		169	133	
High-density legume mix brown manured 2023, maize 2023–2024	0-30	90	223	19.1
	30-60	14	68	
	60-90	25	22	
Total (0-90 cm) nitrogen		130	313	
High-density legume mix silage 2023, maize 2023–2024	0-30	25	43	19.1
	30-60	11	29	
	60-90	18	18	
Total (0-90 cm) nitrogen		54	90	

GROSS MARGINS - LEGUMES

For the high-density legume mix silage and brown manure treatments, the cost of the seed mix was $160/ha, while the legume inoculant cost $40/ha. MAP cost $68/ha and the cost of sowing the paddock was $35/ha.

The high-density legume mix silage was sold standing, yielding 6.35 t/ha. Once the costs of seed and sowing were considered, the gross margin was $808/ha (Table 2).

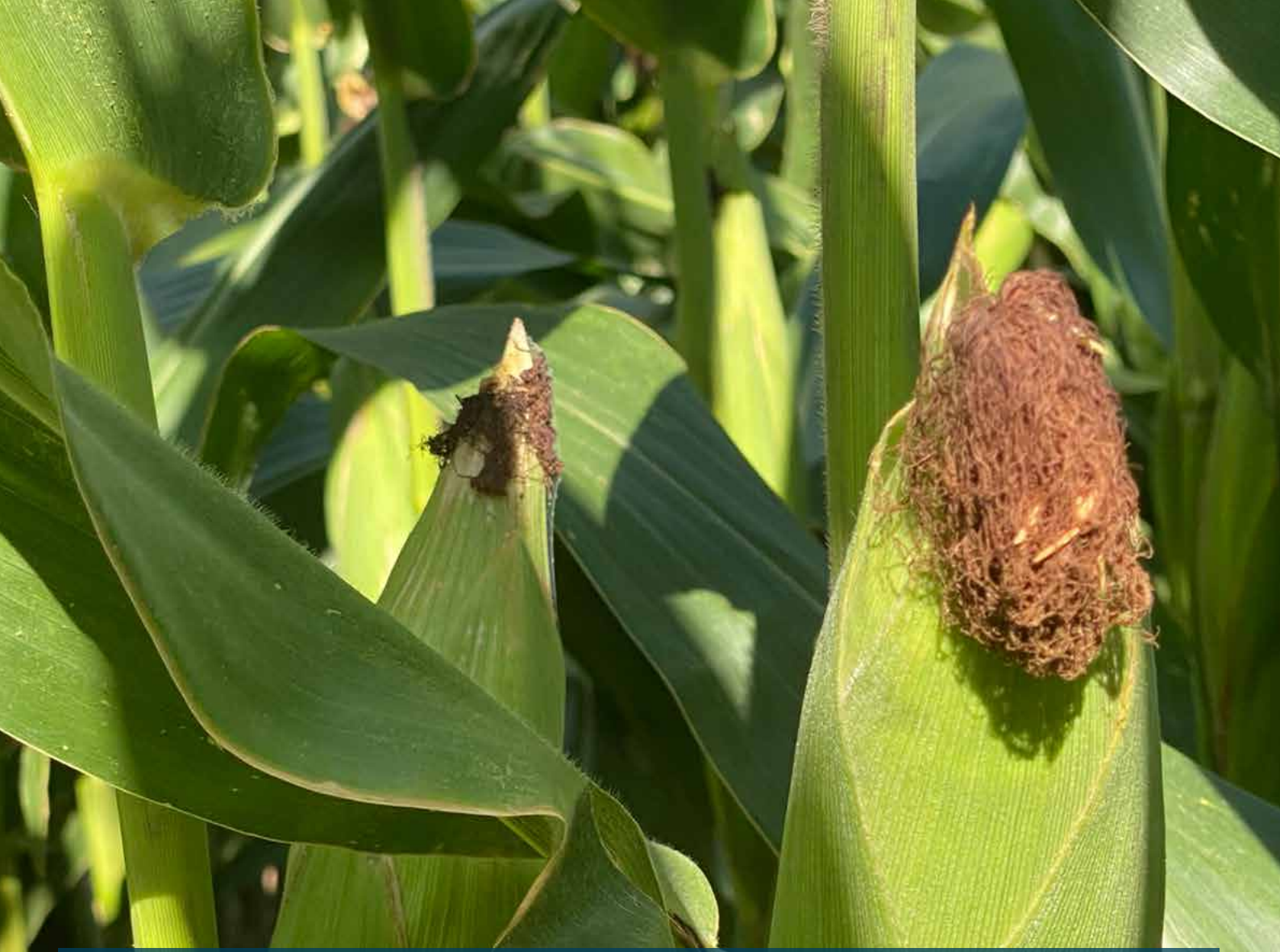
Table 2 High-density legume mix silage gross margin for a standing crop sold at Howlong, 2023.

	DETAILS	$/HA
Income	Silage (6.35 t/ha at $175/t)	1111
Less costs	Sowing	35
	Seed & inoculant	200
	MAP	68
Gross margin		**$808/ha**

The high-density legume mix brown manure crop income was based on the value of the additional nitrogen fixed compared to the silage, as measured in October 2023 and again in May 2024 (Table 3). An additional 76 kg N/ha was added to the soil by the brown manure treatment compared to silage in October 2023, while an additional 223 kg N/ha was added by the brown manure by May 2024. Based on a urea price of $852/t, the value of the nitrogen added to the soil was $553/ha. The costs of the brown manure treatment included seed and sowing of the high-density legume mix, spraying out the brown manure and cultivation using a Horsch Tiger. After costs were considered, the gross margin of the brown manure was $99/ha.

Table 3. High-density legume mix brown manure gross margin at Howlong, 2023

	DETAILS	$/HA
Income		
Additional N compared to silage (Oct 2023)	76 kg N/ha valued at $1.85 kg N	140
Additional N compared to silage (May 2024)	223 kg N/ha valued at $1.85 kg N	413
Income	Total	553
Less costs	Sowing	35
	Seed & inoculant	200
	MAP	68
	Spray out high-density legume mix pasture	51
	Cultivate Horsch Tiger	100
	Total	454
Gross margin		**$99/ha**



CONCLUSION

The demonstration showed that legume crops, such as adzuki beans and a high-density legume mix for silage or brown manure, can contribute significant amounts of nitrogen to an irrigated farming system. It also showed that brown manuring a high-density legume mix provided longer lasting and higher amounts of residual nitrogen compared to high-density legume mix for silage or adzuki beans. This is because brown manuring keeps all the nitrogen in the system, rather than removing it from the paddock through silage or grain.

Although brown manuring can provide significant amounts of nitrogen over an extended period, it means that there is no cashflow in the winter the crop is brown manured. In contrast, a grain crop such as adzuki beans (summer crop) or faba beans (winter crop) can provide some income through grain sales, as well as some residual nitrogen. However, its important farmers also consider the tight timelines between the harvest of a winter crop and the sowing of a summer crop (double cropping) such as maize, and how this might affect harvest logistics and time of sowing.

It's recommended farmers do a nitrogen budget, based on their target yield and maize protein, as well as a deep soil nitrogen prior to sowing. This information can be used to guide nitrogen decisions.

If using animal manures, it's important to get a nutrient analysis, to understand the amount of nutrient applied. Consider also that not all the nutrient is available in the year of application.

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