

Impact of Legume Rotations on Soil Nitrogen and Crop Performance

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KEY MESSAGES

- Soil nitrogen (kg/ha) levels were significantly higher in plots following a legume crop compared with those following a cereal crop.
- Wheat grown on legume stubble had significantly higher total nitrogen (%) than wheat grown on cereal stubble.
- 2025 wheat yields were significantly higher when grown on legume stubble, with green manured serradella, vetch and lupins giving the highest yield response.

AIM

To assess how integrating a legume rotation within a cereal-based system influences soil nitrogen dynamics and overall productivity.

BACKGROUND

The cultivation of grain legumes provides nutritious food, improves soil health, and reduces nitrogen fertiliser in farming systems. Significant increases in domestic and international demand for Western Australian grain legumes are forecast due to burgeoning global populations, improvements in market access, as well as our geographic advantage. However, grain legumes currently contribute in a small and diminishing way to the profitability of Western Australian farming systems due to concerns about their reliability and profitability.

In 2024, Liebe Group implemented a time of sowing trial to compare the performance of legumes and cereal crops across two sowing dates. This trial was conducted in Maya, on a deep yellow sandy soil that had regular liming activity, resulting in a pH of 6.4 in the top 10 cm but still sub-soil acidity remained an issue at 10-20 cm where pH measured 4.6.

Treatment 1 was sown on the 9th May 2024 under marginal soil moisture conditions (TOS 1). Although 14 mm of rain had fallen at the start of the month, the topsoil had started drying out by sowing. In contrast, time of sowing 2 (TOS 2) was sown on 6th June 2024 into moisture and was then followed by a 30 mm rainfall event two days later. The following crops were sown in 2024; lupin, vetch, chickpea, serradella, canola, wheat (Calibre, Tomahawk and Denison) and barley (Maximus and Buff).

In 2025, Vixen wheat was sown over each of those plots to compare the impact of a legume rotation on the subsequent cereal crop.

TRIAL DETAILS

Trial location	Elserae Agriculture, Maya
Plot size & replication	10 m x 1.5 m x 3 replications
Soil type	Deep yellow sand
Paddock rotation	2024 treatments, 2023 canola, 2022 wheat, 2021 lupins
Sowing date	21/05/2025
Sowing rate	75 kg/ha Vixen wheat
Fertiliser	21/05/2025: 70kg/ha MAP 13/08/2025: 60 L/ha UAN
Trial management	21/05/2025: 3 L/ha SE14, 400 ml/ha Uniform fungicide injected with water banded away from seed, 35g/ha Logran, 80 g/ha Lontrel, 100 ml/ha Voraxor, 1 L/ha Mateno PSPE: 1 L/ha of Pyrinex
Growing season rainfall	293 mm
Harvest date	28/11/2025

TREATMENTS

Stubble Treatment (2024 crop type)					
1	Calibre wheat	5	Buff barley	9	CBA Captain chickpea
2	Tomahawk wheat	6	Battalion canola	10	Volga vetch
3	Denison wheat	7	Frano serradella (Green manured)		
4	Maximus barley	8	PBA Jurien lupin		

RESULTS

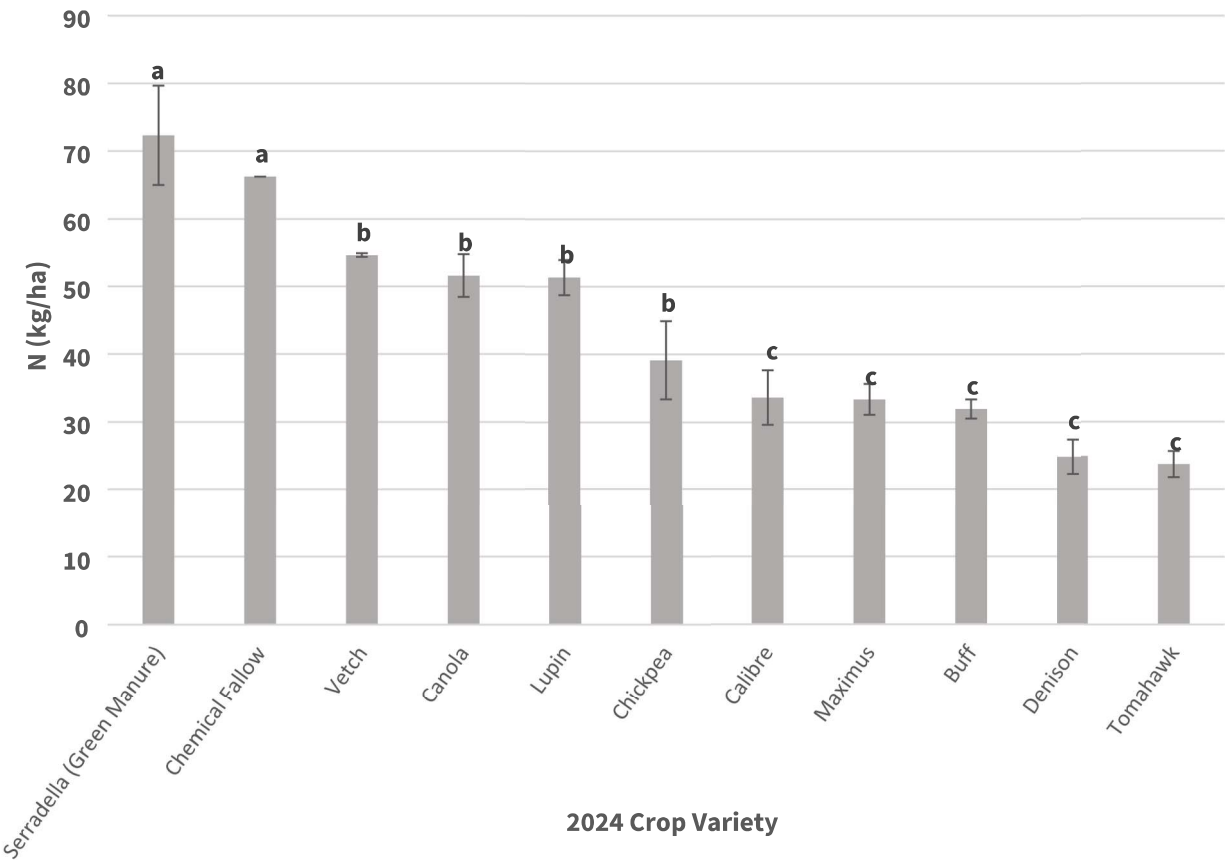


Figure 1. Total 0-30 cm Nitrogen (kg/ha) soil sample results from late April 2025 sampling. Treatments are along the X axis and are the 2024 crop type/variety. Time of sowing (TOS) had no significant effect on mineral N and thus values are averaged across TOS. Letters signify significant differences, LSD = 4.85.

Pre-sowing soil sampling shows plots following a legume crop contained higher concentrations of soil N (kg/ha) compared with those following a cereal crop ($p < 0.05$), with green manure serradella sown in early June fixing the most nitrogen. 2024 time of sowing had no significant effect on mineral N (kg/ha), and there was no treatment $\times$ TOS interaction.

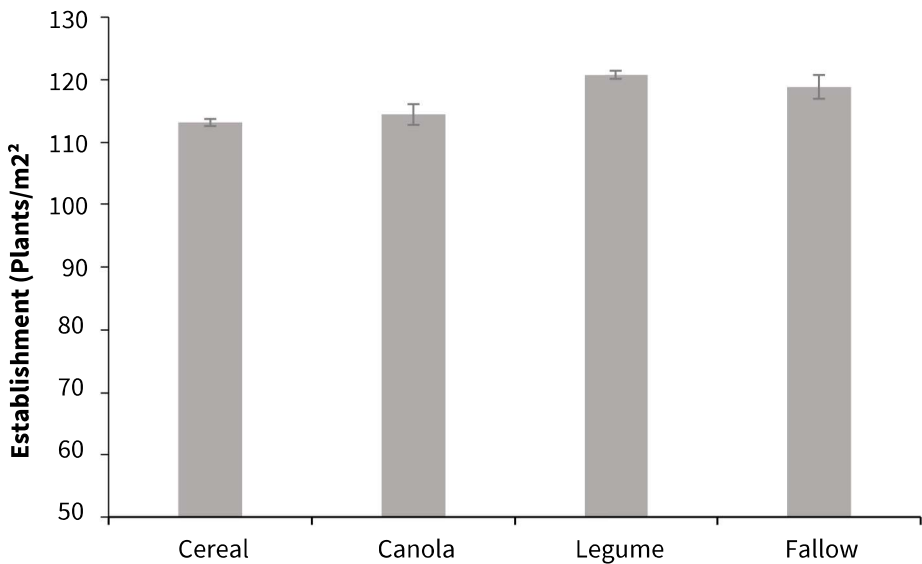


Figure 2. Established wheat plots (plants/m²). The target density was 165 plants/m² from a sowing rate of 75 kg/ha Vixen wheat. Data was collated by 2024 land use (x-axis) for assessment.

Canola and Pulses

The legume-wheat rotation showed statistically higher plant densities than the cereal-wheat rotations ($p < 0.05$). There were no differences between the other treatments or between time of sowing treatments from 2024.

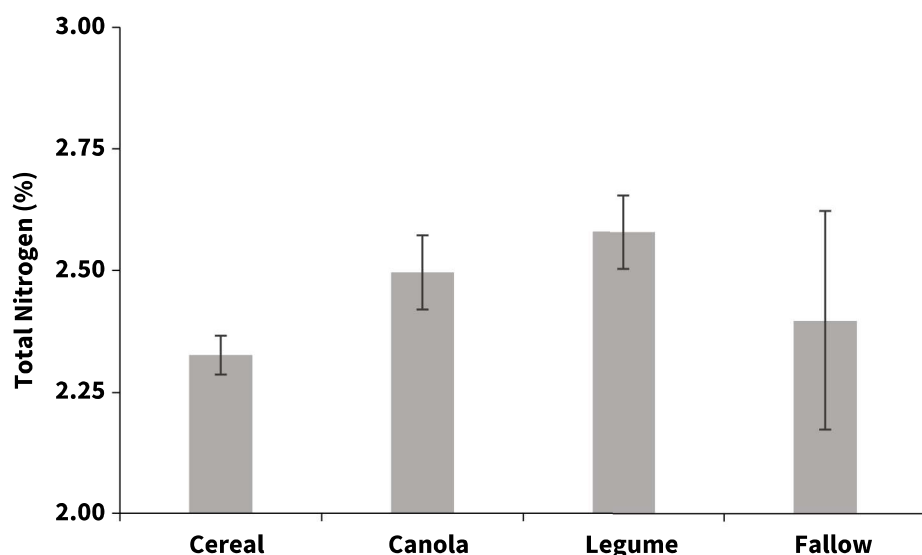


Figure 3. Total Nitrogen (%) from tissue samples of wheat collected on the 12th of August before any top-up N treatments were applied. Data was collated into crop types (x-axis) and then assessed.

The legume-wheat rotation showed statistically higher total nitrogen (%) than the cereal-wheat rotations ($p < 0.05$). There were no differences between the other treatments or between the May or June sown treatments in 2024.

Table 1. Yield (t/ha), protein (%) and screenings (%) of wheat sown in 2025 after various crop types in 2024. Different letters indicated significant differences. LSDs completed for previous crop type treatments only using Fishers pairwise LSD analysis. *Fallow not included in analyses.

2024 Crop	2025 Wheat Yield (t/ha)	Protein (%)	Screenings (%)
Serradella (Green Manure)	6.13 ^a	10.80 ^a	2.70 ^a
Lupin	5.92 ^a	10.33 ^b	2.80 ^a
Vetch	5.84 ^a	10.22 ^b	2.44 ^b
Canola	5.56 ^b	9.80 ^c	2.56 ^a
Chickpea	5.28 ^b	10.03 ^b	2.25 ^b
Fallow	5.26 [*]	9.90 [*]	1.38 [*]
Maximus	4.48 ^c	9.70 ^c	2.62 ^a
Tomahawk	4.41 ^c	9.65 ^c	2.96 ^a
Buff	4.34 ^c	9.57 ^c	2.69 ^a
Calibre	4.31 ^c	9.68 ^c	2.54 ^a
Denison	4.08 ^d	9.53 ^c	3.30 ^a

There were significant yield differences in the 2025 wheat crop in response to different 2024 crop types ($p > 0.001$). The vetch, lupin and serradella rotations produced significantly higher yields than the canola, fallow and chickpea rotations. The cereal on cereal rotation yielded significantly less than all other rotations.

There were no significant differences between the sowing times of the 2024 crop types or the interaction between 2024 crop type and sowing time. It is worth noting that the crop time of sowing in 2024, was not a statistically significant factor in the 2025 results and therefore data has been averaged across TOS for presentation purposes in this report.

COMMENTS

Soil Nitrogen

Prior to seeding in late April, soil samples were collected from the top 30 cm (in 10 cm increments) from all plots to measure residual nitrogen (N). As expected, plots following a legume crop contained higher concentrations of soil N (kg/ha) compared with those following a cereal crop (Figure 1).

The highest residual N was observed in the serradella stubble treatment (green manured), exceeding 70 kg/ha in the top 30 cm of soil, hence its suitability as a productive pasture species. The next highest residual N levels were recorded in the chemical fallow treatment, likely due to increased soil N mineralisation. In contrast, chickpeas had the lowest residual N levels of the legume treatments, reflecting their low N fixing efficiency (GRDC, 2013).

The cereal and canola treatments left higher amounts of N than expected, likely reflecting the substantial fertiliser applications made in 2024 (135 kg/ha). With the late seasonal break and dry finish in 2024, most treatments did not require such high N inputs. For instance, the June-sown canola yielded 1.26 t/ha, leaving over 55 kg/ha of N in the top 30 cm of the soil.

Plant Density

Vixen wheat was dry sown at 75 kg/ha on the 21st of May 2025 across all plots, including additional chemical fallow plots. The trial germinated after the break of the season in early June, with no plots reaching the target density of 165 plants/m².

The legume-wheat rotation showed statistically higher plant densities than the cereal-wheat rotations ($p < 0.05$) potentially driven by higher N levels in the top 10 cm (Figure 2).

Plant Tissue Samples

Tissue samples were collected on 12th August to measure total Nitrogen (%) levels. Legume-Wheat rotations contained significantly higher N levels than wheat on cereal stubbles ($p < 0.05$) (Figure 3).

It is worth noting that soil and tissue results did not always align. For example, June-sown serradella (TOS 2) plots had the highest soil N (kg/ha) in the top 30 cm but did not produce the highest tissue N levels (data not presented), highlighting the complexities of soil N cycling and plant uptake. Following tissue sampling, 60 L/ha of UAN was applied across all plots.

Disease

No significant differences in leaf disease or insect pressure were observed between treatments. Cereal aphids and spot blotch were detected at high levels throughout the trial, but were controlled (data not presented).

Yield

The yield results in this trial are primarily a response to soil N levels and highlight the N fixing ability of serradella (green manured), vetch and lupins on this soil type (Table 1). Chickpea in contrast is less suited this soil type and thus fixed less N, although it still provided a yield benefit over that of the cereals. The continuous cereals rotation yielded significantly less than all other treatments despite carry over N in the soil from 2024. Additionally, there was likely a disease break benefit at this site, although this was not measured. There was a yield benefit after the fallow, likely due to an increase in mineralised N in the fallow phase, however this benefit was not enough to offset the loss of the 2024 yield.

Grain Quality

In wheat, increasing nitrogen rates leads to higher grain yields and protein concentrations up to a threshold, beyond which yield plateaus while protein levels continue to increase (Scott, 2022). The serradella plots, which had the highest soil N levels, recorded the highest grain protein content at 10.8% (Table 1), achieving APW1 classification. Overall, the legume plots produced higher protein levels than all other treatments, resulting in APW2 grading, compared with ASW9 for the cereal, canola, and fallow plots, currently a difference of \$20/t. These results highlight the nitrogen-fixing benefit of legume crops in generating residual nitrogen that remains plant-available throughout the growing season, reducing production risk and enabling crops to better capitalise on longer seasonal conditions.

Economic Analysis - 2 year total return

Table 2. Total return (yield x grain price) over the 2024 and 2025 season for each rotation.

2024 Crop	2024 Yield (t/ha)	2024 Grade	2024 Return (\$)	2025 Wheat Yield (t/ha)	2025 Grade	2025 Return	Combined Return (\$/ha)
Canola	2.76	Can1	1879.56	5.56	ASW9	1556.80	3436.36
Lupin	3.34	Lup1	1309.28	5.92	APW2	1841.12	3150.40
Maximus	6.09	MALT1	1893.99	4.48	ASW9	1254.40	3148.39
Calibre	4.76	APW1	1713.60	4.31	ASW9	1206.80	2920.40
Tomahawk	4.68	APW1	1684.80	4.41	ASW9	1234.80	2919.60
Buff	5.77	BFED1	1673.30	4.34	ASW9	1215.20	2888.50
Vetch	1.41		831.90	5.84	APW2	1816.24	2648.14
Denison	4.55	H2	1492.40	4.08	ASW9	1142.40	2634.80
Chickpea	0.90		720.00	5.28	APW2	1642.08	2362.08
Serradella	Green Manured		0	6.13	APW1	1900.30	1900.30
Fallow	-	-	0	5.26	ASW9	1472.80	1472.80

2024 grain pricing is based on a 5 year average 2020-2024 as follows: APW1 \$360, H2 \$328, Malt1 \$311, BFED1 \$290, Lup1 \$392, Can1 \$690, Grain Vetch \$590, Chickpea \$800. (AgExcellence Alliance 2024).

2025 pricing is based on prices taken on the 29/01/2026 including APW 1 \$310, APW 2 \$311, ASW9 \$280 (GrainBrokers 2026).

Table 2 outlines a crude 2-year \$/ha return based on the 2024 crop performance and 2025 wheat yield and grade. The canola rotation provides the highest return per hectare, followed by the Lupin rotation. Green Manured Serradella and the Fallow returned the lowest return per hectare due to no income in the 2024 season. Serradella, being a pasture legume, would likely return an income if it were to be grazed however, this is not considered in this analysis. Fallow would probably only be considered if the paddock had a high weed burden. The aim will be to continue to monitor this site in 2026, to see whether there are ongoing benefits to having the legume in the system.

CONCLUSION

In most cases the inclusion of legumes increased soil nitrogen at sowing, and tissue nitrogen content, yield and protein of subsequent wheat crops, when compared to growing continuous wheat. It would be interesting test other high value legume species on these limed soils, that have traditionally been too acidic for these species.

ACKNOWLEDGMENTS

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FUTHER READING

2024 Trial Article: Evaluation of Sowing Time on Legumes and Cereals Performance - scan QR code to view.

PEER REVIEW

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