

Nitrogen Legacy and Rotational Value of Multi-Use Lupin and Vetch

GRDC/Grower Group Alliance/Facey Group

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BACKGROUND

Facey Group has undertaken multiple GRDC-investment research projects to assess the role of legumes in Kwinana West farming systems. Between 2022 and 2024, trials comparing chickpea, faba bean, field pea, and vetch varieties at different sowing times demonstrated that wheat following legumes benefited from improved biomass and yield, with mid-April legume sowing proving more advantageous for the wheat than later plantings. A 2024 vetch demonstration showed that vetch varieties had 6–21% higher protein content than oats and a barley-vetch mix. However, aphid pressure prevented yield comparisons, leaving a critical gap in agronomic data on vetch grain and hay production.

To address the gap, this trial sought to generate further locally relevant insights into vetch performance. The trial also assessed lupins for grain and brown manure, alongside vetch for hay, grain, and green manure, quantifying their total nitrogen contributions to the following cropping year.

AIM

To quantify the profitability, nitrogen legacy, and rotational value of vetch and lupins across multiple end-uses.

TRIAL DETAILS

Property:	Andrew and Melissa Grieve
Location:	Latitude 32°47'43.4"S, Longitude 117°18'38.2"E
Soil Type:	Sandy loam
Crop Variety:	Jurien Lupin Volga Vetch
Sowing Date:	30 April 2025
Seeding Rate:	Lupin 100 kg/ha Vetch 40 kg/ha
Machinery:	9.1 m air seeder with 20.3 cm row spacing and sown at 4 cm deep
Inoculant:	Alosca Group E granules 10 kg/ha – Vetch Alosca Group G granules 10 kg/ha – Lupins
Fertiliser:	Macro Pro Extra 50 kg/ha
Paddock Rotation:	2024 Wheat
Herbicides:	<u>28 April</u> Paraquat 1.5 L/ha Propizamide 1 L/ha Diuron 1.5 kg/ha

02 July
SOA 1%
Clethodim 500 ml/ha
Factor 120 g/ha
Hasten 1%

METHODOLOGY

The trial included three end-use treatments for Volga vetch (brown manure, hay, and grain) and two end-uses for Jurien lupin (brown manure and grain). Treatments were established in randomised paddock-scale strip design and divided into three internal sampling zones (pseudo-replicates) to strengthen measurement robustness under commercial conditions (Figure 1).

Post-emergent broadleaf weed control presented practical challenges across the trial. Due to the differing herbicide tolerances and physiological sensitivities of vetch and lupin, identifying broadleaf herbicide options that provided effective control without compromising crop safety required careful management. Capeweed (*Arctotheca calendula*) was the dominant broadleaf pressure and remained a persistent competitor throughout the season. To minimise interference at harvest, grain yield samples were taken from representative areas within each strip, and the remaining sections were subsequently sprayed out to prevent further weed seed set. After harvest, the remaining non-harvested areas were mowed to prevent them from affecting the post-harvest results and support weed control.

Measurements were collected from each section three times to capture within-strip variability. Assessments included Predicta B, soil bulk density, plant establishment counts, weed counts, Normalised Difference Vegetation Index (NDVI), biomass sampling, plant tissue analysis, nodulation, and harvest yield. The hay treatment was terminated at hay-cut timing, while brown manure strips were terminated using glyphosate and rolled approximately one week later. Grain plots were harvested for yield and quality assessment.

Volga	Jurien	Volga	Jurien	Volga
Manure	Grain	Grain	Manure	Hay
Manure	Grain	Grain	Manure	Hay
Manure	Grain	Grain	Manure	Hay

Figure 1. Trial design in strips representing a crop and end-use, separated into 3 sections to increase sampling robustness.

RESULTS AND DISCUSSION

Table 1. 2025 monthly rainfall statistics from nearest BOM weather station – Narrogin, WA, station number 010614 (mm).

Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
11.2	5.4	42.2	29.2	16.6	37.2	82.2	98.4	39.7	18.0	15.4	0.6	396.1

April had 29.2 mm of rainfall, with 14.8 mm falling early in the month (4 April), followed by little additional rain before seeding. May rainfall was low at 16.6 mm total, with no significant event over 5.0 mm, resulting in limited early-season moisture for rapid establishment. Rainfall increased in June (37.2 mm), July (82.2 mm), and peaked in August (98.4 mm), supporting crop recovery.

Table 2. Pre-sowing soil test and potential mineralizable nitrogen (PMN) results by depth.

Depth	Total mineral nitrogen (kg N/ha)	Potentially mineralisable nitrogen (kg N/ha)	Bulk density (g/cm ³)
0-10	40	3.3	1.21
10-30	34	<2.8*	1.42
30-60	27	<4.5*	1.51

Note: PMN values marked with “<” indicate laboratory results below the analytical detection limit of 1.0 mg/kg N. Reported values have been converted to kg N/ha using measured bulk density. Therefore, results are expressed as maximum estimated values rather than exact concentrations.

Estimate of pre-sowing mineral nitrogen content was 40 kg N/ha in the top 10 cm, 34 kg N/ha at 10–30 cm, and 27 kg N/ha at 30–60 cm. The potentially available portion was low, with a potential mineralisable

nitrogen (PMN) measuring 3.3 kg N/ha in the surface layer and <2.8 kg N/ha below 10 cm. This indicates that only a small proportion of soil N was readily mineralisable at sowing.

Table 3. Average plant establishment and weed density by species and purpose, 4 weeks after sowing.

Species/Purpose	Plant density (plants/m ²)	Weed density (plants/m ²)
Lupin	30	0
Grain	28	0
Manure	32	0
Vetch	28	1
Grain	31	2
Manure	27	1
Hay	26	1
Average	29	1

Vetch established at an average of 28 plants/m², which sits within the expected range of 25–40 plants/m² for a 40 kg/ha sowing rate under typical field emergence (Nutt, 2004). In contrast, lupins averaged 30 plants/m², below the typical target of 50–70 plants/m² for a 100 kg/ha sowing rate (Gladstones, 1998; GRDC, 2020). However, germination was still ongoing, likely delayed by limited early rainfall and soil moisture constraints (Table 3).

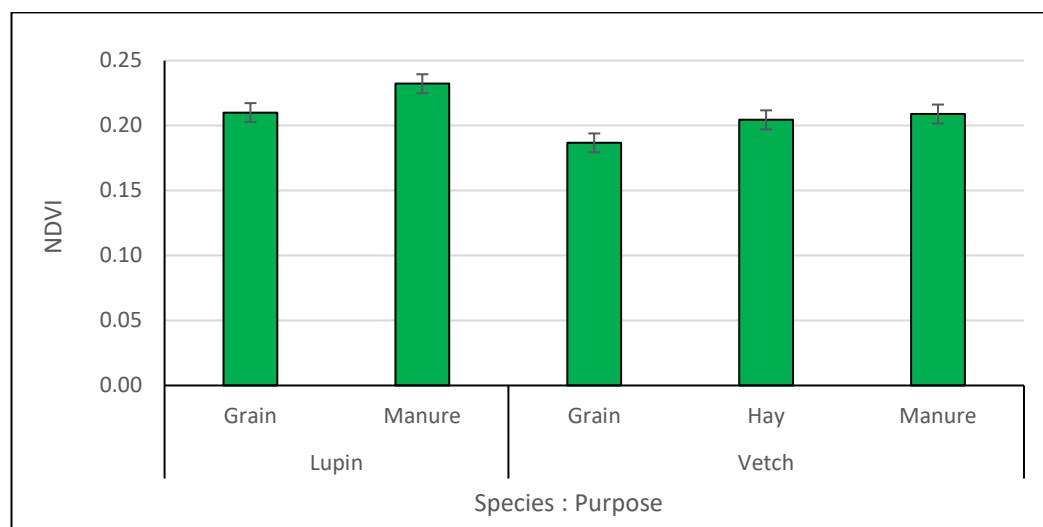


Figure 2. Average NDVI values by species and purpose, 7 weeks after sowing.

With an average NDVI of 0.21 at seven weeks after sowing, canopy development was below the typical 0.30–0.50 range expected during active vegetative growth (Tucker, 1979; Raun et al., 2001), indicating slower early biomass accumulation. Differences between species and end-uses were minor, with Jurien lupin averaging 0.22 compared to 0.20 for Volga vetch. Lupin manure plots recorded the highest NDVI (0.23), while vetch grain plots were lowest (0.19), suggesting only small variations in early canopy development across treatments.

Nodulation

Table 4. Nodulation score results (0-10 scale), at mid-late vegetative stage (14 weeks after sowing).

Species/Purpose	Nodulation Score
Lupin	5
Grain	6
Manure	4
Vetch	3
Grain	4
Hay	3
Manure	2
Grand Total	4

Nodulation scores indicated that lupins were likely fixing more atmospheric nitrogen, while vetch nodulation may have been constrained. Lupin showcased a higher nodulation performance of 5, with grain plots highest at 6 and manure sections at 4, suggesting generally effective rhizobia activity. In contrast, Vetch scored 3, a sign of moderate nodulation, with the manure section reaching 2 only.

Peak biomass, plant nitrogen concentration, and fixation capacity

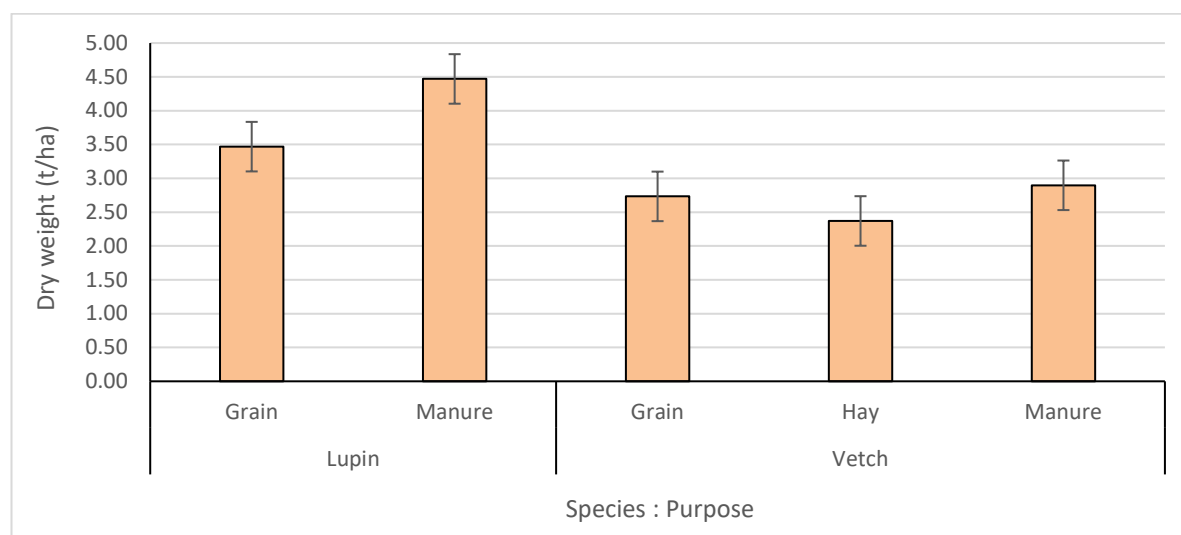


Figure 4. Plant biomass by species and purpose at peak biomass timing.

At peak biomass, average dry matter production across the trial was 3.19 t/ha. Lupins produced higher biomass than vetch, averaging 3.97 t/ha compared with 2.67 t/ha for vetch, which is consistent with their greater vegetative growth potential under Mediterranean conditions (Peoples et al., 2009). Within lupins, the manure treatment was highest at 4.47 t/ha, followed by grain at 3.47 t/ha. For vetch, biomass ranged from 2.37 t/ha (hay) to 2.90 t/ha (manure).

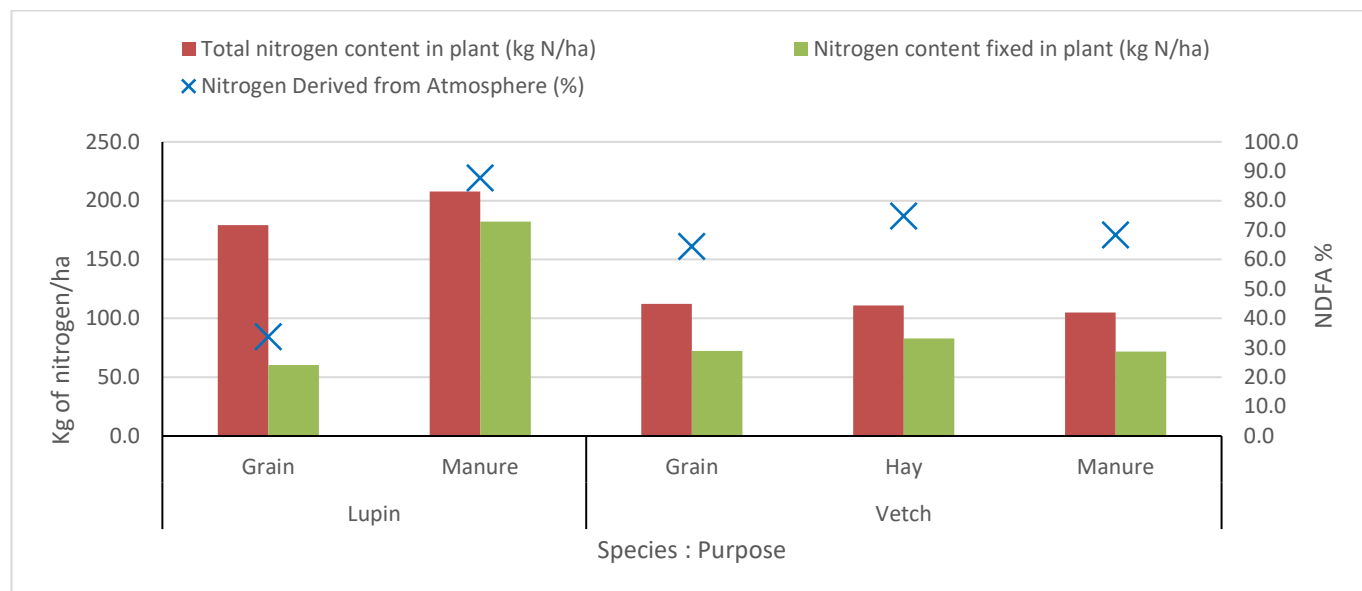


Figure 5. Nitrogen content and percentage nitrogen derived from air (%NDFA) in the plant by species and purpose at peak biomass timing.

Consistent with the biomass results, lupins fixed more nitrogen overall than vetch, averaging 121 kg N/ha compared with 76 kg N/ha for vetch. Although vetch had a higher proportion of nitrogen derived from the atmosphere (%NDFA) at 69%, compared with 61% in lupins, the greater biomass production of lupins resulted in higher total nitrogen fixation per hectare. The highest fixation occurred in lupin-manure sections, which fixed 182 kg N/ha (88% NDFA) from a total accumulation of 208 kg N/ha, while lupin-grain fixed 60 kg N/ha (34% NDFA) despite accumulating 179 kg N/ha. Volga showed more consistent fixation across end-uses, fixing 72–83 kg N/ha (64–75% NDFA).

Grain yield and hay biomass

Table 5. Grain and hay biomass yield by species.

Species/Purpose	Yield/Biomass (t/ha)	Crude Protein (%)	Metabolisable Energy (MJ/kg)
Vetch			
Hay	2.4	24.3	11.74
Grain	1.1	-	-
Lupin			
Grain	3.4	-	-

Lupin yield and harvest index were higher than in vetch, with 3.4 t/ha against the 1.1 t/ha of the vetch (Figure 6). Feed quality samples were taken at the same time as hay cutting. The crude protein of 24.3% and metabolisable energy of 11.74 MJ/kg, reaching above the expected standards at the cutting time of 12–20% crude protein and 8–11 MJ/kg dry matter digestible energy (GRDC, 2018).

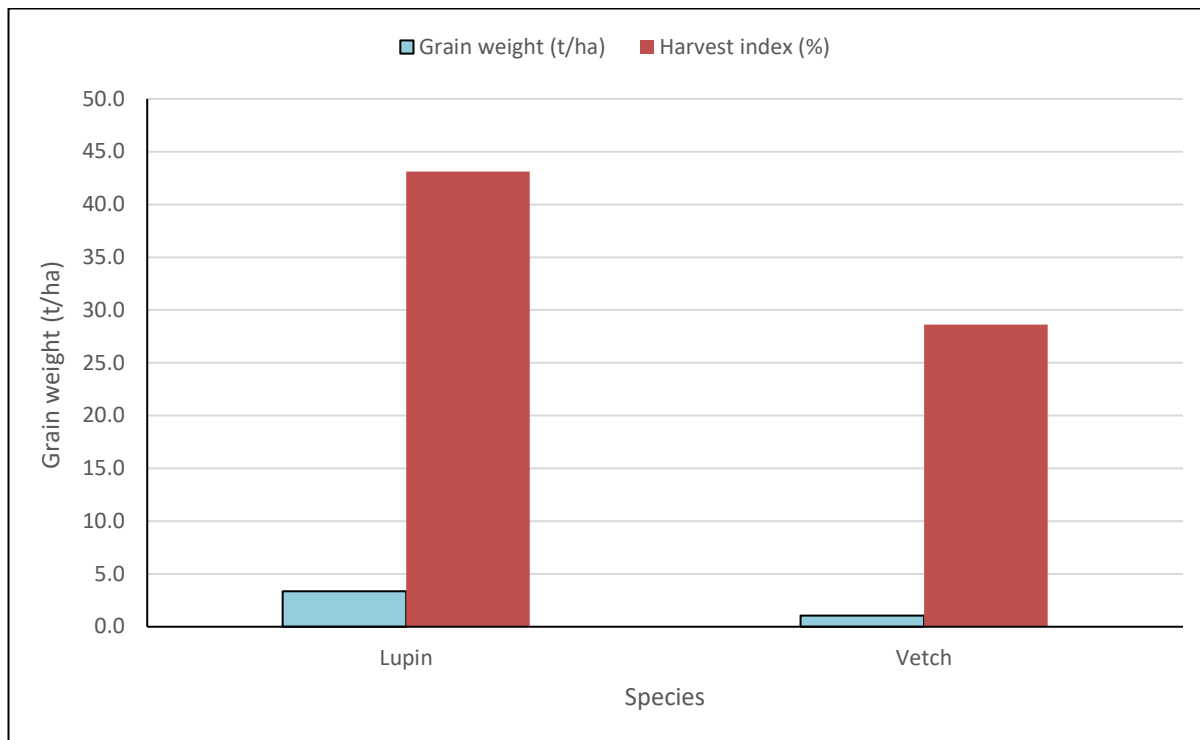


Figure 6. Grain yield and harvest index by species at harvest.

Soil nitrogen response post-harvest

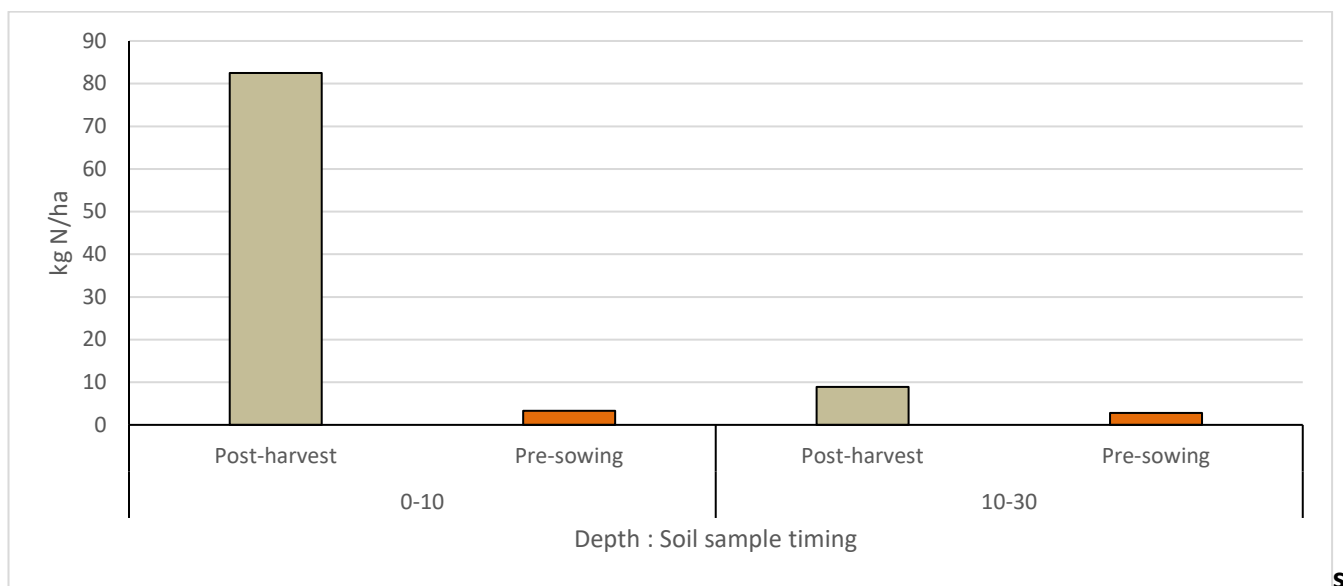


Figure 7. Comparison of the average potential mineralisable nitrogen (PMN) across the trial in kilograms of nitrogen per hectare at pre-sowing and post-harvest.

Post-harvest soil samples were collected at the treatment level. Overall, the inclusion of legumes in the system increased the potential available for next season. In the surface 0–10 cm layer, average PMN increased from 3.3 kg N/ha pre-sowing to 82.5 kg N/ha post-harvest, representing a substantial increase in the biologically active nitrogen pool following the legume phase. In the 10–30 cm layer, PMN increased from 2.8 kg N/ha pre-sowing to 8.9 kg N/ha post-harvest, indicating a smaller but consistent increase at depth (Figure 7).

Table 6. Post harvest soil sample results of potential mineralisable nitrogen in kilograms of nitrogen per hectare after harvest.

Species/Purpose	Potential Mineralisable Nitrogen (kg N/ha)	Bulk Density (g/cm ³)
Lupin		
Grain		
0-10	13.7	1.27
10-30	3.4	1.56
Manure		
0-10	31.2	1.44
10-30	12.23	1.57
Vetch		
Grain		
0-10	<1.4*	1.30
10-30	17.9	1.48
Hay		
0-10	22.1	1.38
10-30	7.9	1.57
Manure		
0-10	53.3	1.38
10-30	<2.95*	1.44

Note: PMN values marked with "<" indicate laboratory results below the analytical detection limit of 1.0 mg/kg N. Reported values have been converted to kg N/ha using measured bulk density. Therefore, results are expressed as maximum estimated values rather than exact concentrations.

PMN differed between species and end-use, mainly in the 0–10 cm layer. In lupin, manure increased PMN to 31.2 kg N/ha (0–10 cm) and 12.2 kg N/ha (10–30 cm) compared with grain at 13.7 and 3.4 kg N/ha, respectively. In vetch, PMN was highest under manure (53.3 kg N/ha at 0–10 cm), followed by hay (22.1 kg N/ha surface; 7.9 kg N/ha at 10–30 cm), while grain was lowest at the surface (<1.4 kg N/ha) but higher at depth (17.9 kg N/ha). Overall, most biologically active nitrogen was concentrated in the surface layer where residues were retained (Table 6).

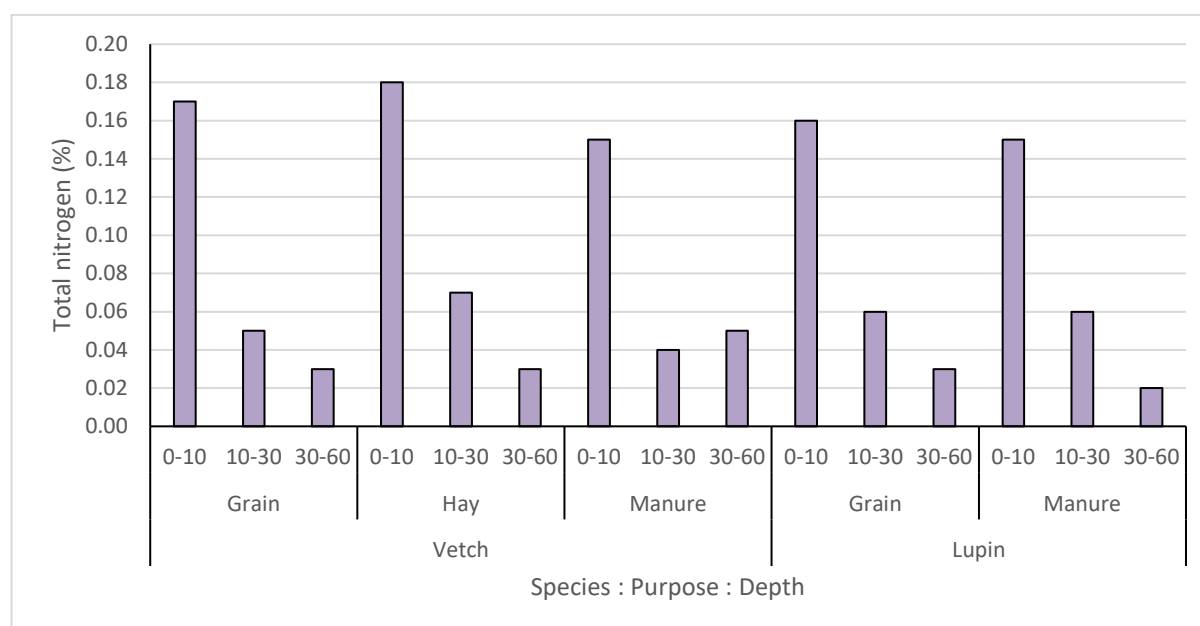


Figure 8. Comparison of the total nitrogen concentration of the soil by species, purpose, and depth post-harvest.

Total nitrogen content in the soil showed small variations among treatments at the surface, with manure having the lowest level (0.15% for lupin and vetch). Vetch-hay had the highest nitrogen concentration with 0.18% (Figure 8).

CONCLUSION

Pre-sowing, the soil had a good level of mineral nitrogen available (74 kg N/ha in the 0 – 30 cm layer) and low soon-to-be available nitrogen (PMN 3.3 kg N/ha at 0–10 cm and <2.8 kg N/ha at 10–30 cm). Despite this, both legumes relied strongly on biological fixation at peak biomass. The specific drivers of this response cannot be confirmed without in-season soil N measurements.

At early flowering, lupins accumulated more plant N largely because they produced more biomass, resulting in higher total N fixed (121 kg N/ha in lupins vs 76 kg N/ha in vetch), even though vetch had a higher proportional reliance on fixation. The difference in lupin nitrogen derived from air (NDFA) between the grain (34%) and manure (88%) sections likely reflects spatial variation in soil nitrogen availability and seasonal influences on fixation intensity, rather than the intended end-use management, as sampling occurred before biomass removal.

Nitrogen tracing by end-use indicates that after harvest/termination, the biologically active N pool (PMN) increased strongly at the surface level. Manure treatments showed the highest increase in N mineralisable potential post-harvest. This was not reflected in Total N (%), as PMN represents nitrogen that has not yet converted into plant-available forms but has the potential to supply nitrogen to the following crop.

Further nitrogen tracing will be undertaken in 2026, as the trial progresses into a cereal rotation. This next phase will evaluate the agronomic response of the following crop and enable a comprehensive economic assessment of the rotational value associated with each legume end-use.

ACKNOWLEDGEMENTS

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