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Regional Development

GOVERNMENT OF
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GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Field Trials Report 2023

WA Farming Systems Project (DAW2204-003RTX)

Executive summary

Within the Western Australian Faming Systems Project, a program of 15 field trials were conducted in 2023 from Ogilvie in the north to Wittenoom Hills in the south.

Despite a dry season all trials were implemented effectively such that all multi-year trials are set to investigate their associated research questions.

Systems trials

Three large (4-6 hectare) farming systems trials were planted at Northampton, Merredin and Lake Grace. These trials test different crop and pasture rotations, delayed sown cereals and different levels of fertiliser nitrogen. At each site rotations, sowing time rules and nitrogen fertiliser treatments were refined by local research partner groups (Regional Innovation Groups or RIGs). After local input all trials still have the same trial design and many common treatments, i.e., 11 rotations are common between all three sites.

A wide range of biophysical variables that track the influence of the treatments on weeds, plant diseases and soil nitrogen and water were measured at each site. These measurements were centrally coordinated such that the timing and method of observations were the same across sites.

The 2023 results from these trials are quite basic, as expected given that this is the first year of a multi-year trial, where the real interest is in rotational effects. However, we have thoroughly characterised each of the sites and set rotations for following years.

Crop yields and pasture biomass production were low compared to most years, particularly at Northampton and Merredin. For example, wheat yield was 1.6 t/ha at Northampton, 1.0 t/ha Merredin and 3.0 t/ha at lake Grace.

Vetch species and end use trials

A vetch trial series was conducted with eight trials across four sites. Four of these trials assessed current vetch varieties against elite breeding lines. Of the released lines Volga produced equal top yields at most WA sites in 2023 and appears to be a reliable choice for both grain and dry matter production. At the majority of sites new breeding lines matched Volga for yield. At Wittenoom Hills two lines, 37107 and 38866, produced slightly higher yields than Volga. SARDI Vetch Breeder Stuart Nagel advised one of these lines (37107) is set to be released to growers in 2025.

Alongside these variety trials, plots were sown to investigate the role of vetch in the farming systems when utilised in different ways; harvested for grain, cut for hay and green or brown manured. The end use treatments were imposed, and these trials will be sown to wheat in 2024 with nitrogen and soil water monitored closely.

Legacy effect trials

Three legacy effect trials were conducted:

At **Merredin** the effects of safflower and chickpea on a following wheat crop were examined. Safflower had limited break crop effects in a subsequent wheat crop, although interestingly protein was greater than wheat grown on wheat. Yield of wheat after chickpea was ~ 0.5 t/ha greater than wheat after safflower or wheat. In season nitrogen rate had minimal influence on the break crop effect of safflower or chickpea, likely a consequence of the dry 2023 season. The trial will be sown again in 2024 to see if break crop effects persist.

At **Doodlakine** the effect of chickpea on wheat was examined with emphasis on nematodes. Chickpeas did not increase *P. neglectus* levels over the growing season as much as the most susceptible cereal control varieties.

If this result is confirmed it would indicate inclusion of chickpea into existing wheat dominant rotations in Western Australia is unlikely to increase the risk of damage to following cereals from *Pratylenchus neglectus* nematode.

The Doodlakine trial also tested nitrogen rates with results indicating that in low rainfall years farmers growing wheat after chickpea could reduce risk and maximise returns by using low rates of applied nitrogen - or in very low rainfall years choosing not to apply nitrogen.

At **Ogilvie** wheat was sown onto plots of eight different pulses species grown in 2022. Wheat in 2023 averaged 1.3 t/ha at 12.1% protein, with no difference in the yield (P = 0.273) or protein (P = 0.08) of wheat due to the pulse species grown before it. Given growing season rainfall was 130 mm, it is likely that legacy effects may occur in 2024, hence the site will be sown to canola in 2024.

Species x sowing time trials

To address project outcomes of increased system diversity and maximising sowing opportunity a pilot trial investigating species by sowing time interactions was sown at Chapman Valley.

This is a unique trial that tests the response of sowing time of eight pulse species, barley, wheat and canola within the same trial, something not done before. It aligns with the project outputs of investigating diversity within the cropping systems and maximising sowing opportunities.

Growing season rainfall was 170 mm, sowing time 1 was May 24, sowing time 2 was June 14. Mean wheat yield was 2.1 t/ha, barley 2.3 t/ha, legumes ranged 0.7 to 1.9 t/ha and canola 0.7 t/ha. Species responded differently to sowing time, for example canola yield declined more than other species by delayed sowing into June.

The legacy effects of legumes, canola and barley on wheat will be assessed by sowing wheat across all plots in 2024. Additional species by time of sowing trials will commence in 2024.

With the suite of trials implemented in 2023, Research Scientists and Technical Officers have laid the foundation for a successful field component of the project.

Acknowledgements: The Western Australian Farming Systems Project Team; Balwinder Singh, Bella Tyak-White, Brenda Shackley, Dion Nicol, Grace Williams, Imma Farre, Karyn Reeves, Kristy Hunter, Lea Obadia, Mark Seymour, Megan Abrahams, Naomi Simpson, Rod Bowey, Steph Boyce, Sud Kharel, Tinula Kariyawasam, Vanessa Stewart-McGinniss.

Prepared by WAFS Project Research Lead, Martin Harries 21/03/2024

Systems trials

Background

The Western Australian Farming Systems Project (WAFS) commenced in July 2022. A seven-month consultative period ensued to identify research needs within the farming systems space, that align with the outputs of the WAFS project:

- maximise sowing opportunities
- increase diversification in cropping systems
- investigate options for lower greenhouse gas (GHG) emissions.

Medium term (5 year) trials were implemented at Lake Grace, Northampton and Merredin in 2023 to investigate the outputs listed above. Each of these trials is 4-6 hectares including various rotations, nitrogen rates and sowing time strategies. Additionally at each location there is an advisory group of local farmers, consultants and researchers to ensure rotations and agronomy are relevant and consistent with current practices.

Objectives

The goal of these trials was to “establish research sites focused on strategies to increase conversion of rainfall to profit ($/ha/mm) across the crop sequence while managing weeds, diseases and soil fertility and risk”, posing the following questions:

- How does water use efficiency (WUE) and nitrogen use efficiency (NUE) of cereals change relative to each other due to altered rotations, reduced fertiliser nitrogen and their interactions?
- How does rotational WUE, NUE and profit change due to altered rotations, reduced fertiliser nitrogen and their interactions?

By answering the questions, we will show which rotation x N strategy combination is best for:

- WUE cereal and rotation
- NUE cereal and rotation
- Profit cereal and rotation… what was the best treatment to convert rainfall to profit $/ha/mm?

We are also keen to see if we can identify profitable farming systems with lower greenhouse gas (GHG) emissions.

Northampton systems trial

Local research team: Marty Harries, Steph Boyce and Lea Obadia.

Key messages

- We have successfully established a large-scale farming systems trial 5 km east of Northampton.
- The site has been comprehensively characterised, and we have a good understanding of biophysical variables, soils, nutrients, weeds and pathogens.
- 2023 was a decile 1 rainfall, with site yields of canola 1.0 t/ha, lupin 1.2 t/ha and wheat 1.6 t/ha.

Methods

Plots were sown with a DPIRD cone seeder, each plot consisting of 4 seeder runs to be a width of 9 m by 45 m. These main plots were divided into split plots of 9m x 20m (Figure 1). The two edge cone seeder runs were used to monitor soils and take destructive plant samples, leaving the middle two runs (14 rows) for machine harvest.

The split plot design enables each rotation to be grown at two levels of fertiliser nitrogen input. The rationale was that a split plot design increased the power of the statistical analysis of rotation x nitrogen interaction. This enables analysis of the performance of legumes in higher and lower fertiliser nitrogen situations. The higher fertiliser rate was based around current application rates used by farmers. Additionally, APSIM was used to estimate yield from decile 2 and 7 rainfall years at the site. The nitrogen exported in grain from these yields is similar to the high and low amounts being applied. A wide range of crop rotations were included (Table 1).

Within this report statistical analysis was done using Genstat 22nd edition. Treatment structure: Tmt*Nitrogen. Blocking structure: Rep/Row/Nitrogen+ColRep. Hence treatment was a combination of species and sowing time. ANOVA and Fisher's protected LSD were conducted on selected variates.

Figure 1. *Northampton trial July 2023, with main plots and split plot design depicted.*

Treatments

Trial treatments are a combination of a rotation x sowing time x nitrogen fertiliser rate. At Northampton there are 11 rotations ranging from continuous wheat to continuous pasture and various amounts of diversity between these. Most rotations are phased such that each land use in the rotation is grown each year, such that we can better account for seasonal variability. Sowing is in summer (serradella, pasture/wheat/pasture/wheat rotation) or timely/dry (most of the trial) and delayed sown (wheat). Fertiliser is applied at two rates of nitrogen, as described above, with the amounts of other elements kept as close to the same as possible.

Table 1. *Treatment summary*

System	Rot	Sow time	N	Typical sequence	Description
ConW_T_2	ConW	Timely	2	Cer/Cer/Cer/Cer	Continuous wheat
ConW_D_2	ConW	Delayed	2	Cer/Cer/Cer/Cer	Continuous wheat
DivHV2_T_2	DivHV2	Timely	2	Leg/Cer/Leg/Cer	Diverse high value 2
BaseHVL_T_2	BaseHVL	Timely	2	Leg/Cer/Cer/Leg	Baseline
IntBase_T_2	IntBase	Timely	2	Can/Cer/Can/Cer	Intense baseline
DivHV1_T_2	DivHV1	Timely	2	Leg/Can/Cer/Cer	Double break
DivLI1_T_2	DivLI1	Timely	2	LegCover/Cer/LegCover/Cer	Cover crop
DivLI2_S_2	DivLI2	Summer	2	Pas/Cer/Pas/Cer	Annual pasture
DivLI3_T_2	DivLI3	Timely	2	Pas/Pas/Cer/Cer	Double pasture
DivLI4_T_2	DivLI4	Timely	2	Pas/Pas/Pas/Pas	Continuous pasture
Flex_T_2	Flex	Timely	2	Fal/Tac/Tac/Tac	Tactical

Rot = rotation, Int = intense, Flex = Flexible, Div = diverse, Con = continuous, LV = low value, HV = high value, LI = Low input. Cer = cereal, Leg = grain legume, Can = canola, LegCover = legume cover crop desiccated in spring (vetch or lupin), Pas = pasture, Fal = fallow, Tac = tactical, T = timely, D = Delayed, S = summer, N fertiliser nitrogen rate. Nit 2 = decile 2 N replacement, note all treatments in table 1 are also included with decile 7 N replacement.

Agronomy

Sowing

Serradella was sown on 28 March, but only a few plants germinated at this time. The bulk of the trial was sown on 28–29 May, and delayed wheat was sown on 15 June.

Varieties

Emu canola, Jurien lupin, Cavalier medic, Frano and Margarita serradella, Vixen wheat, Studenica Vetch.

Nitrogen

Legumes had 0 or 10 kg/N at seeding with no additional post-emergent. All canola received 49 kg/ha N at sowing and the higher N treatment a further 49 kg/ha post-emergent. All wheat received 37 kg/ha and the high N treatment a further 37 kg/ha post-emergent.

Plots were, as much as possible, managed as per district practice, i.e. no foliar fungicide was applied to cereals or canola in spring due to the dry conditions, with no sign of foliar pathogens at yield limiting levels.

See Appendix A for a more detailed summary of agronomic management.

Location

A 4.5-hectare site was identified east of Northampton (Figure 2). A big thanks to Chris and Jess at Mulga Springs for hosting the trial.

Site	Latitude (dd)	Longitude (dd)	Nearest town
Trial site	-28.3525	114.6965	Northampton

Figure 2. *Trial site adjacent to Horry Rd, 5 km east of Northampton.*

Results

Weather

Annual rain was 202 mm and growing season rain 177 mm. This represents a decile 1 rainfall with long term mean annual rainfall of 480 mm at the closest Bureau of Meteorology site, situated around 15 km west of the trial. There was little summer and autumn rain, the break of season occurred on 26 May (~8 mm), with a further 8 mm the following week (Figure 3).

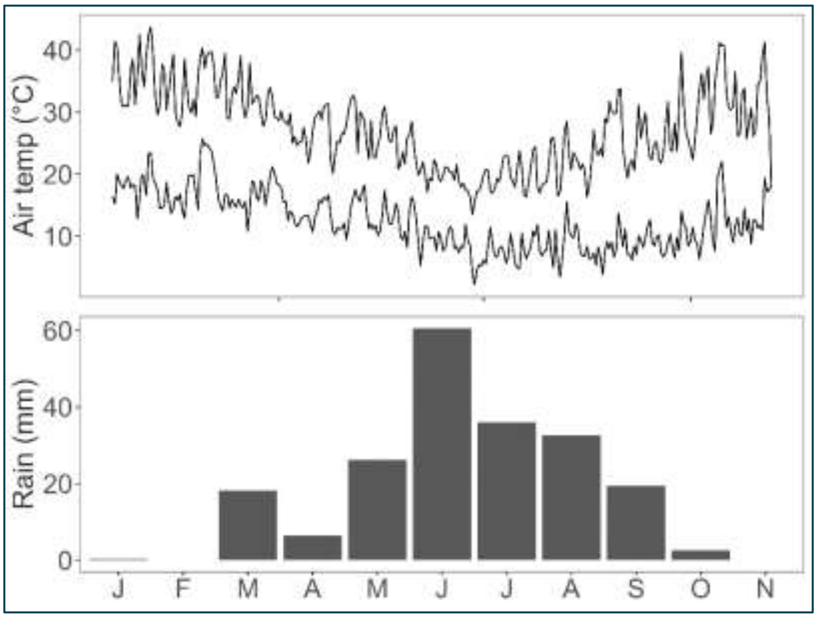

Figure 3. *Site monthly rainfall and min and max air temperatures 2023.*

Soil water

Soil water content was very low in topsoil prior to seeding, but there was moisture at depth (Figure 4). Consequently, it was estimated that there was 38 mm of plant available moisture when sampled on March 28 but most of this was below 30 cm (Table 2). Mean soil moisture content after harvest followed a similar trend (Figure 4) with roughly the same amount in soil as March (Table 2).

Soil content after harvest varied between land uses (Table 3). Gravimetric soil content was greater in fallow throughout the profile and lower for canola, and to a lesser extent wheat, indicating canola and wheat roots were accessing water at this depth to greater extent than the other land uses.

This response was also observed from soil cores taken to measure the lower limit of water extraction for each plant species. Rain exclusion tents were erected in late spring. Whole intact soil cores were taken with all soil collected to 1.5 m. This soil was weighed and dried to determine soil water content. There was less water under canola (58 mm) compared to medic (78 mm), wheat (81 mm), serradella (91 mm), lupin (102 mm) and manured vetch (110 mm). It is likely that root growth was restricted due to the dry season such that water was not extracted at depth for some species, so lower limits will be measured again in 2024.

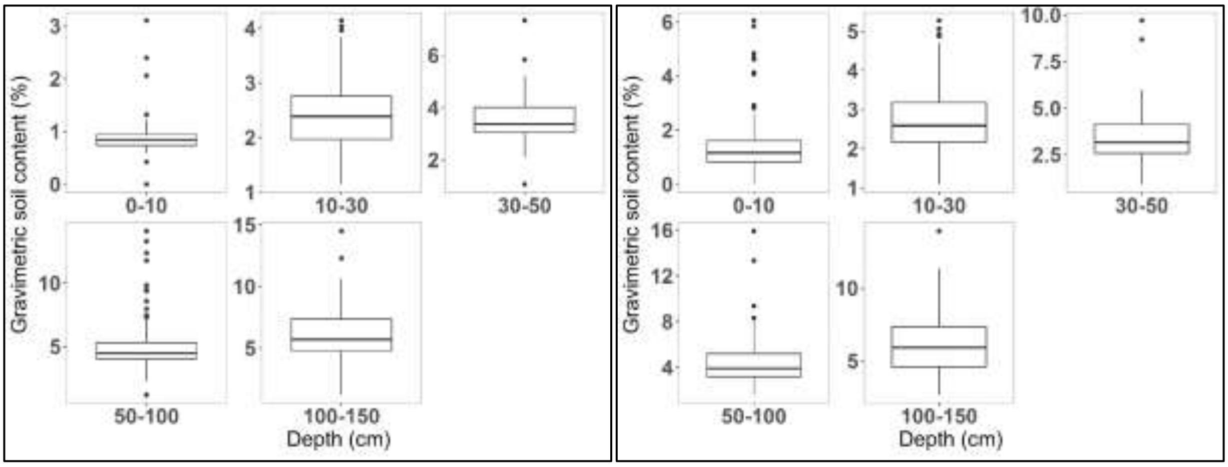

Figure 4. *Mean gravimetric soil content (%) from all plots prior to sowing (left panel) and after harvest (right panel)*

Table 2. *Starting soil moisture, drained upper limit (DUL), lower limit (LL), plant available water content (PAWC) and final soil moisture.*

Depth (cm)	Layer (cm)	March soil water (mm)	DUL (mm)	*LL (mm)	**PAWC (mm)	**Final soil water (mm)
0-10	10	1	11	1	10	2
10-30	20	5	20	4	17	6
30-50	20	10	21	6	15	9
50-100	50	29	61	14	47	25
100-150	50	37	75	20	55	37
Total (mm)		83	188	44	144	80

*Lowest value from all land uses, **mean all crop and pasture plots

Table 3. *Gravimetric soil content (%) of each land use measured after harvest (Oct 19).*

Depth (cm)	Canola	Lupin	Medic	Serradella	Vetch	Wheat	Fallow
0-10	1.4	1.3	1.3	1.5	1.5	1.2	3.7
10-30	2.7	2.8	2.4	3.4	3.5	2.5	4.7
30-50	3.3	3.4	3.2	5.0	4.3	3.2	5.4
50-100	3.6	4.8	5.8	6.2	5.0	3.8	5.7
100-150	5.6	7.0	6.8	6.3	6.8	5.9	7.0
Mean (%)	3.3	3.8	3.9	4.5	4.2	3.3	5.3

Selected soil parameters

Chemical analysis of each plot was taken to a depth of 1.5 m. All elements were at adequate soil concentration or above. Soil pH was lower than observed from earlier site testing at the 10-30 cm soil layer, but at good levels throughout the rest of the profile. This is typical of soils in this region. Lime will be applied in 2024. There was a reasonable amount (88 kg/ha) of mineral N/ha at the site before seeding (Table 4).

Table 4. *Pre-seeding soil analysis.*

Depth (cm)	Nitrate (mg/kg)	Amm (mg/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	pH $CaCl_2$	OC (%)	Nitrate (kg/ha)	Amm (kg/ha)
0-10	18	5	39	230	18	6.4	0.80	28	8
10-30	2	1	16	167	6	4.8	0.30	5	4
30-50	1	1	4	154	5	6.1	0.10	4	3
50-100	1	1	5	170	5	5.6	0.20	8	9
100-150	1	1	4	155	5	5.9	0.20	10	9
Total								55	33

Establishment

Serradella sown on 28 March had a partial germination, with a few plants establishing in each plot. Most plants of all species established after being sown on 28 and 29 May. Canola, lupin and vetch density was ~40 plants/m^2, medic and serradella ~80 plants/m^2 and wheat a bit lower than desired at 125 plants/m^2 (Figure 5).

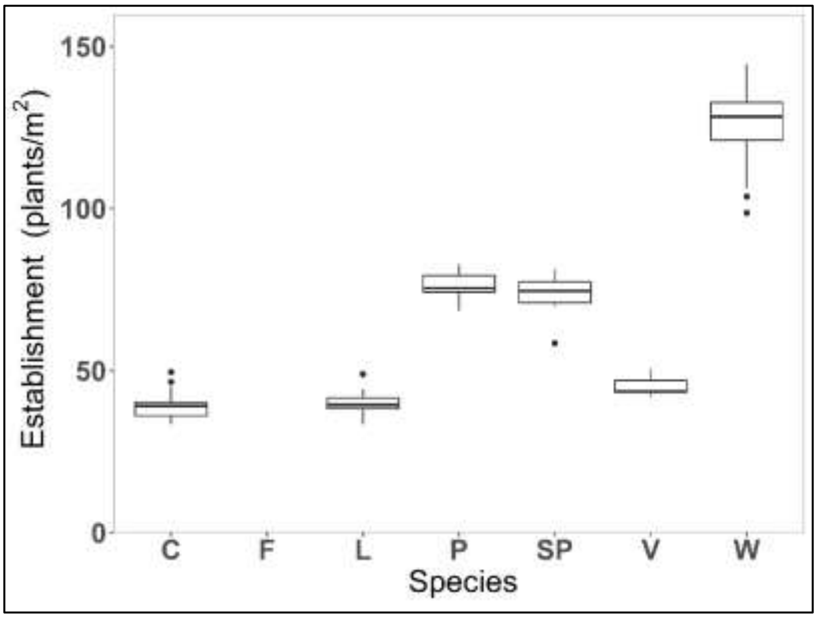

Figure 5. *Establishment of crop and pasture species at Northampton 2023. C = canola, F = fallow, L = lupin, P = Medic, SP= Serradella, V = vetch, W = wheat. Lower, middle and upper lines of boxes are the 1st quartile, median and 3rd quartile, respectively, whiskers extend 1.5 times interquartile range.*

Weeds

Weed counts were taken after seeding, before post-emergent herbicides were applied, and again in spring, around anthesis, after application of selective herbicides. There were no differences in density of weeds measured in autumn between land uses (P = 0.170) or nitrogen levels (*P* = 0.277). There were differences in density of weeds measured in spring between land uses (*P* < 0.001) but no difference between nitrogen levels (*P* = 1.000).

Overall site mean weed density was 2.8 weeds/m^2, comprising of 2.6 broadleaf and 0.2 grass weeds/m^2. Hence, there were very few grass weeds observed and more broadleaf weeds than anticipated, based on crop scouting of the paddock in 2022. The most frequently observed broadleaf weed species were sow thistle, flat weed, wild radish and doublegee, with cape weed, erodium and blue lupin also recorded.

Broad leaf weed density decreased for most land uses from autumn to spring but increased within medic pasture from 3.7 to 11.4 weeds/m^2 and in serradella from 1.5 to 9.2 weeds/m^2, indicating poor in-season control within pastures (Figure 6). This occurred because post-emergent broadleaf herbicides were not applied to pastures, to maximise seed set. After discussion with the RIG, weed seed set was minimised by slashing above the height of pastures in spring, as a simulation of light grazing. The result is not surprising and demonstrates why it is challenging to incorporate pastures into intensive cropping systems. Because the most frequent weeds were ephemeral species (sow thistle and flat weed) it is unlikely to result in large yield losses in other parts of the rotation, as evidenced by effective weed control in crops in 2023. Post emergent broad-leaf herbicides will be applied to regenerating pasture plots in 2023.

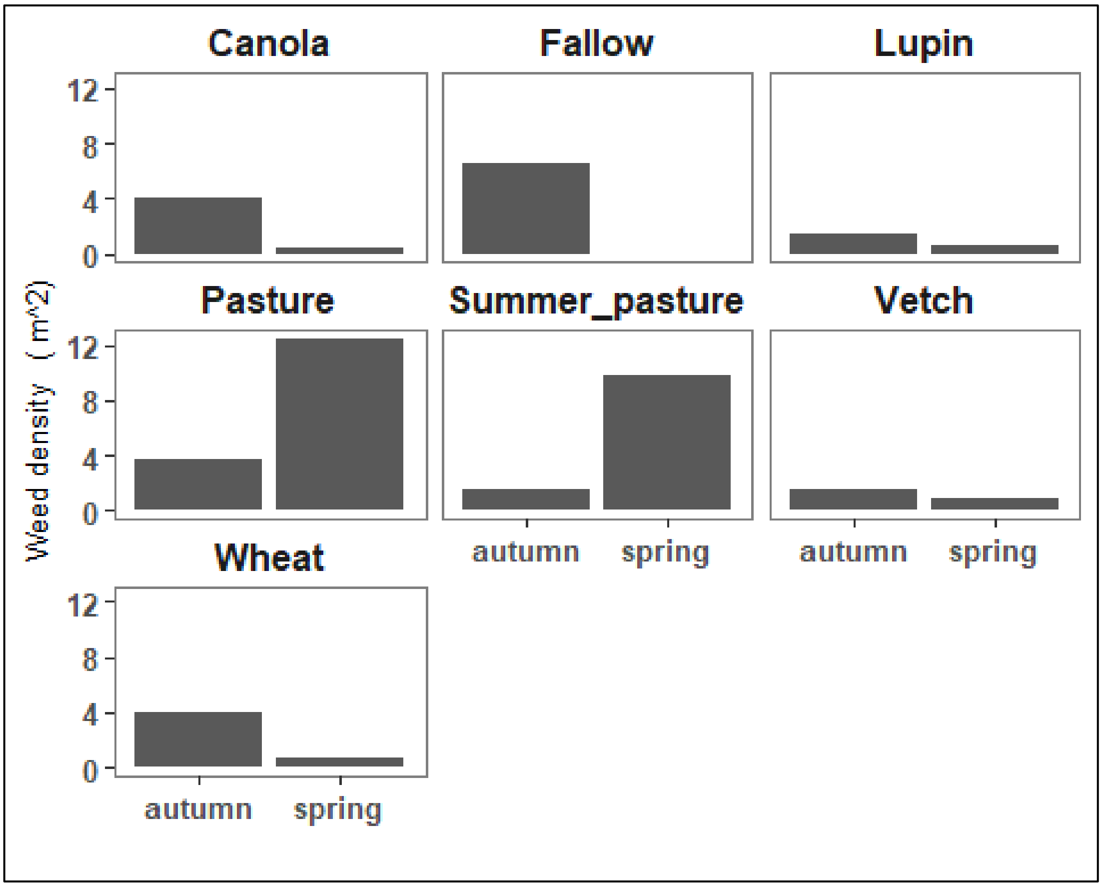

Figure 6. *Weed density within each land use in autumn and spring.*

Pathogens and nematodes

PREDICTA®B sampling was undertaken for each plot in autumn, prior to seeding, and in spring, around anthesis. Cereal cyst nematode, stem nematode, *P. thornei*, and *P. quasitereoides* were not found at the site. For take-all, crown rot, black spot, and *P. neglectus,* > 98% of samples taken in autumn were at levels below detection or low risk of affecting yield (Figure 7). There was more rhizoctonia DNA in soil than anticipated based on sampling of the site in 2022, which indicated rhizoctonia was at a low level. Rhizoctonia in autumn, pre-sowing, did not differ between treatments (P = 0.399). In spring, while mean rhizoctonia soil DNA concentration was low in serradella, results were variable such that there were no differences between treatments (P = 0.667).

Take-all declined across the growing season within all land uses, likely a consequence of low grass weed numbers and dry conditions (Figure 8). Crown rot levels were low and variable from both pre-sowing and spring measurements (Figure 8). This was possibly due to a large stubble/crown load from the previous wheat crop which was slow to decompose under dry conditions. Given the dry year it was not surprising that rhizoctonia soil DNA concentration increased from autumn to spring (Figure 8). These conditions generally slow plant root growth such that a greater proportion of roots remain in the surface soil layers where rhizoctonia is most active. Given that rhizoctonia is present plant roots will be assessed for damage in 2024. The response of *P. neglectus* to various land uses was variable, which is likely because the mean concentration of eggs in each land use was low, lower than the amount considered likely to cause any yield loss. Septoria and pythium had contrasting responses to the season; septoria levels reducing in spring and pythium levels increasing. Free living nematode species detected included: Panagrolaimidae, Mononchida, Mesorhabditinae, Dorylaimida, Cephalobidae, Aphelenchidae and Aphelenchoididae. Three of 6 mycorrhizal fungi species within the PREDICTA®B assay were detected. No foliar pathogens were observed and there were very few reports of foliar pathogens throughout the district.

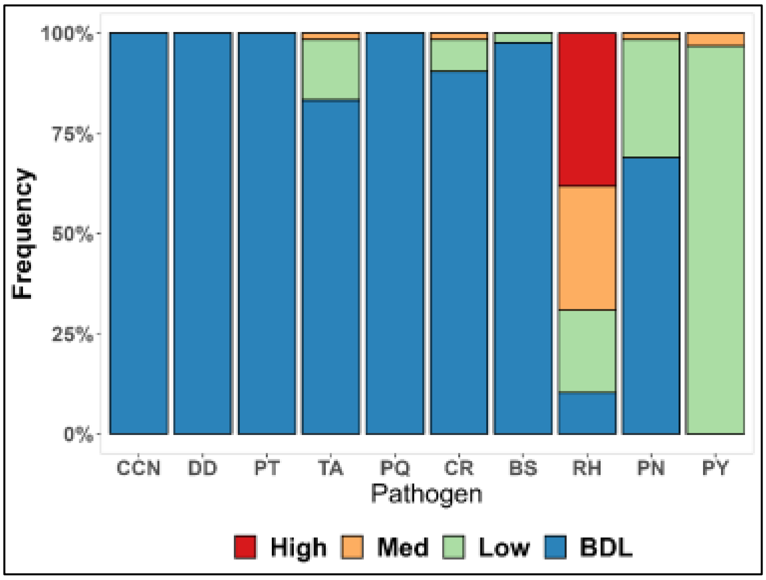

Figure 7. *Frequency of pathogen DNA concentration assays, taken at visit 1 (autumn), within PREDICTA B disease risk yield loss categories (BDL = below detection limit, Low, Med = medium, High), for CCN (cereal cyst nematode, H. avenae), DD (stem nematode, D. dipsaci), PT (P. thornei), TA (take-all, G. graminis var. tritici), PQ (P. quasitereoides), CR (crown rot, Fusarium spp.), BS (black spot, D. pinodes/P. pinodella), RH (R. solani AG-8), PN (P. neglectus) and PY (Pythium Clade F). Note Pythium (PY) and (PT) P. thornei tests are under development and categories represent population density not disease risk.*

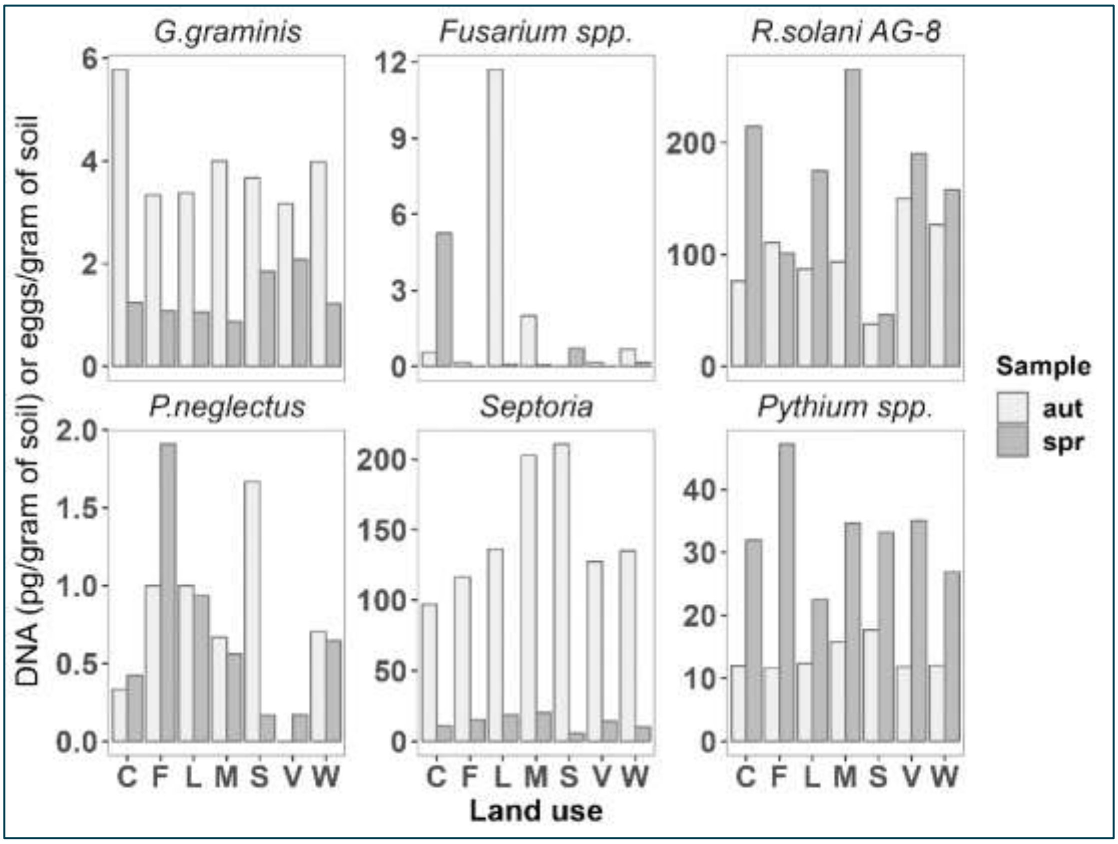

Figure 8. *Amount of DNA of G. graminis var. tritici, Fusarium spp., R. solani (AG-8), , Pythium Clade F, Septoria, or eggs, of P. neglectus in soil when sampled in autumn (aut) and spring (spr) for the land uses of canola (C), Fallow (F), lupin (L), medic pasture (M), serradella (S) Vetch (V) and wheat (W).*

Crop growth

Biomass cuts were taken from each plot twice, once at peak vegetative biomass (late anthesis) and at maturity.

At the time of the first cut, canola and wheat biomass was approximately double that of the other plant species (Figure 9). There were significant ($P < 0.001$) differences between treatments (Table 5). Additionally high nitrogen biomass across all plots was 3,181 kg/ha compared to 2,858 kg/ha, a significant difference ($P < 0.001$). There was also an interaction effect, with species responding to the different nitrogen rates differently. Canola was the most responsive land use, biomass increasing ~1.4 t/ha from low to high N. Conversely vetch and serradella biomass were greater from the low nitrogen treatment (Table 5).

At maturity the result was similar, large differences ($P < 0.001$) in biomass between species; canola and wheat still with greater biomass than the other species. Lupin biomass had increased from the earlier cut, while pastures contained a similar amount of biomass. There was a difference ($P = 0.002$) in biomass due to nitrogen rate, higher nitrogen with greater biomass (Table 5). While there were numerically different responses of land use to nitrogen rate to that observed in autumn (Table 5), this was not significant ($P = 0.505$). Also note that vetch was brown manured, hence not sampled at harvest.

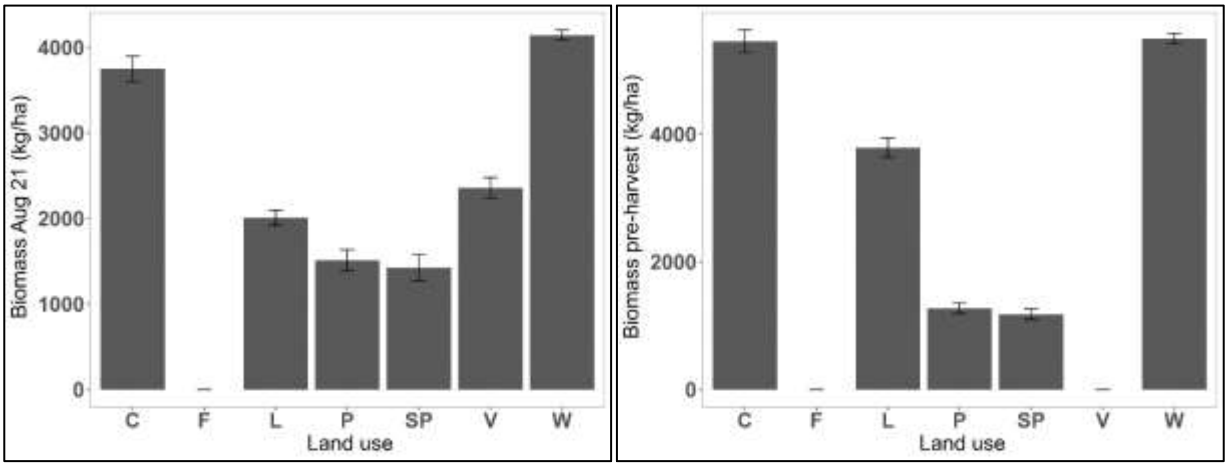

Figure 9. *Dry biomass near anthesis (left panel) and at Maturity (right panel)*

Table 5. *Biomass as effected by fertiliser nitrogen rate and sowing time.*

		Biomass (Aug 21) (kg/ha)				Biomass (Pre-harvest) (kg/ha)			
Land use	**Sowing time**	**High N**	**Low N**	**Mean**	**Fisher of Mean**	**High N**	**Low N**	**Mean**	**Fisher of Mean**
Fallow	None/Timely	0	0	0	a	0	0	0	a
Serradella	Dry/Timely	1410	1441	1426	b	1153	1203	1178	b
Medic	Timely/dry	1670	1353	1512	b	1323	1222	1273	b
Lupin	Timely/dry	2129	1890	2009	c	4033	3541	3787	c
Vetch	Timely/dry	2228	2492	2360	c	0	0	0	a
Wheat	Wet/delayed	3615	3695	3655	d	4925	4678	4801	d
Canola	Timely/dry	4436	3067	3752	d	5817	5086	5451	e
Wheat	Timely/dry	4298	4115	4206	e	5699	5467	5583	e
Mean N		3181 a	2858 b			4186 a	3880 b		

Note Mean N does not equal the mean of the different land used within Table 5 because there were a different number of plots of each land use.

Normalised Difference Vegetation Index (NDVI)

Green area ground cover was measured using handheld NDVI machines fortnightly throughout the growing season. Rates of ground cover accumulation differed between land uses ($P < 0.001$). Canola and wheat had the fastest rates of ground cover accumulation (Figure 10), with NDVI of canola greater than wheat and wheat greater than the other land uses on July 12 (Table 6). There was an increase in NDVI at the higher nitrogen rate ($P < 0.001$) (Table 6) but despite canola showing larger response of NDVI to nitrogen than the other land uses (Table 6), there was no significant interaction ($P = 0.444$). A similar response was observed on July 27 although NDVI of fallow remained stable while the legumes started to increase ground cover (Table 6).

For canola, NDVI results fluctuated throughout the season due to yellow flowers covering the canopy in spring, with NDVI increasing after flowers senesced. The low NDVI for fallow indicates good weed control. The decline in vetch NDVI was after being brown manured in late August.

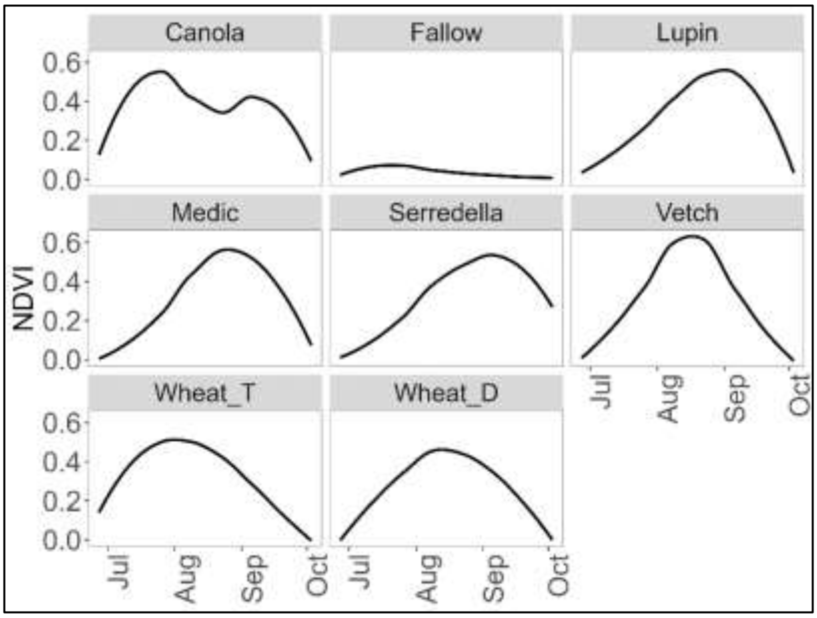

Figure 10. *NDVI of each land use over the growing season.*

Table 6. *NDVI as effected by fertiliser nitrogen rate and sowing time.*

	NDVI 12/7				NDVI 27/7			
	High N	Low N	Mean	Fisher of Mean	High N	Low N	Mean	Fisher of Mean
Serradella Dry/Timely	0.17	0.15	0.16	a	0.36	0.32	0.34	b
Medic Timely/dry	0.19	0.17	0.18	a	0.35	0.36	0.35	b
Fallow None/Timely	0.19	0.17	0.18	a	0.18	0.17	0.18	a
Lupin Timely/dry	0.22	0.19	0.21	a	0.41	0.35	0.38	b
Vetch Timely/dry	0.23	0.21	0.22	a	0.49	0.41	0.45	c
Wheat Wet/delayed	0.23	0.21	0.22	a	0.54	0.47	0.51	c
Wheat Timely/dry	0.50	0.48	0.49	b	0.67	0.62	0.64	d
Canola Timely/dry	0.60	0.54	0.57	c	0.75	0.67	0.71	e
Mean N	0.37 a	0.35 b			0.55 a	0.50 b		

Note Mean N does not equal the mean of the different land used within Table 6 because there were a different number of plots of each land use.

Root assessment

Plants from legume plots were dug from plots on 11 August and nodulation scored using a 0–8 scale; zero = no nodules present and 8 = nodules = extremely abundant. Mean nodulation score ranged from 3.2 for medic, to 4.4 for lupin. Plant tissue was taken at this time and assessed for % nitrogen derived from atmosphere, with results indicating plants were fixing well. Final calculations of amount on nitrogen fixed are yet to be completed.

Plant development

The late break, dry spring and temperatures in excess of 31 degrees in late August restricted growing and flowering periods. Canola flowered first reaching 50% flowering around a week ahead of legume and 10 days ahead of the wheat. The canola cultivar, Nuseed Emu TF, is a series 3 short season phenotype. Wheat was the last crop to flower, with the flowering period curtailed by very warm conditions (Tables 7 and 8).

Table 7. *Date of key plant development stages for each crop or pasture.*

	Sow	Emergence	First flower	50% flower	Last flower	Maturity	Senescence
Canola	29/05/2023	7/06/2023	28/07/2023	16/08/2023	28/08/2023	3/10/2023	12/10/2023
Lupin	30/05/2023	7/06/2023	8/08/2023	22/08/2023	28/08/2023	3/10/2023	11/10/2023
Medic	29/05/2023	7/06/2023	11/08/2023	25/08/2023	30/08/2023	3/10/2023	12/10/2023
Serradella	29/03/2023	7/06/2023	8/08/2023	22/08/2023	4/09/2023	6/10/2023	16/10/2023
Vetch	30/05/2023	7/06/2023	16/08/2023	Brown manured.			
Wheat_T	29/05/2023	7/06/2023	21/08/2023	28/08/2023	1/09/2023	25/09/2023	3/10/2023
Wheat_D	15/06/2023	22/06/2023	25/08/2023	30/08/2023	6/09/2023	3/10/2023	12/10/2023

Table 8. *Days from sowing to plant development stage for each crop or pasture.*

	Sow	Emergence	First flower	50% flower	Last flower	Maturity	Senescence
Canola	29/05/2023	9	60	79	91	125	136
Lupin	30/05/2023	8	70	84	90	127	134
Medic	29/05/2023	9	74	88	93	126	136
Serradella	29/03/2023	70	132	146	159	130	201
Vetch	30/05/2023	8	78	Brown manured.			
Wheat_T	29/05/2023	9	84	91	95	119	127
Wheat_D	15/06/2023	7	71	76	83	110	119

Yield

Yields were well below district average due to seasonal conditions (Table 9) and differed between land uses ($P < 0.001$). Wheat yielded more than lupin or canola and while lupin yielded more on average than canola this was not significant. Overall, there was no difference in yield between nitrogen levels ($P = 0.975$) (Table 9) and hence while canola yield responded more to nitrogen this was not statistically significant. Also, there was no effect of sowing time on wheat yield.

Table 9. *Yield of canola, lupin and wheat as effected by fertiliser nitrogen and sowing time.*

		Yield (kg/ha)			
Land use	Sow time	High N	Low N	Mean	Significance
Canola	Timely/dry	1116	941	1,028	a
Lupin	Timely/dry	1235	1207	1,221	a
Wheat	Timely/dry	1545	1634	1,589	b
Wheat	Wet/delayed	1583	1526	1,554	b
Mean N		1058 a	1059 a		

Note Mean N does not equal the mean of the different land used within Table 9 because there were a different number of plots of each land use.

Grain quality

Protein was reduced at the lower nitrogen rate, with protein in canola and wheat lower at the low nitrogen rate (Table 10). June sown wheat average 12% protein compared to 11.5% for the May sowing, but this was not statically significantly. Lowest wheat protein was observed in the May sow low nitrogen treatment.

Protein increased in canola at the higher nitrogen level.

Table 10. *Protein and oil percentage as effected by fertiliser nitrogen and sowing time.*

Species	N	Sow	Protein (%)	Oil (%)
Canola	N2	Dry/timely	19.6	46.2
Canola	N3	Dry/timely	21.6	44.5
Lupin	N2	Dry/timely	28.2	
Lupin	N3	Dry/timely	28.3	
Wheat	N2	Dry/timely	11.1	
Wheat	N3	Dry/timely	11.9	
Wheat	N2	Wet/delayed	11.8	
Wheat	N3	Wet/delayed	12.2	
LSD			0.94	0.38

Summary

We have successfully implemented and monitored a complex farming systems trial at Northampton. The site has been thoroughly characterised such that we have a detailed understanding of key biophysical variables that are likely to be influenced by the different farming system treatments.

The results from 2023 were impacted by the dry season, with low biomass and yield compared to long term averages for the district. As expected, given that this is the first year of a 5-year trial, the results to date are quite basic. However, all plots grew well enough to ensure that rotational responses can be studied, and we observed responses to nitrogen treatments.

Results will become more informative as rotations/treatments diverge. In particular, it will be interesting to see if fertiliser nitrogen in excess of what was removed in grain carries through to 2023. Similarly, it will be interesting to see if differences in final soil moisture between treatments results in differences in growth and yield in 2024. This will most likely be quite dependent on 2024 seasonal conditions.

Appendix A. Agronomic management summary.

Canola, Emu				**kg or L/ha**
15-May-23	Pre	Insec	Cruiser opti	0.5
	Pre	Insec	Cruiser opti	0.5
	Pre	Fung	Maxam xl	0.4
	Pre	Fung	Maxam xl	0.4
	Pre	Fung	Saltro duo	0.2
28-May-23	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Treflan	1.5
	Sowing	Seed	Cv. Emu	1.9
	Sowing	Fert	Agstar extra	100
	Sowing	Fert	Urea	75
30-May-23	Post	Insec	Dominex	0.2
	Post	Insec	Lorsban	0.2
27-Jun-23	Post	Fert	MAXamFLO	90
28-Jun-23	Post	Herb	Roundup 690	0.9
11-Jul-23	Post	Fert	MAXamFLO	90
12-Jul-23	Post	Herb	Roundup 690	0.9
10-Aug-23	Post	Fung	Miravis Star	1
	Post	Fung	Miravis Star	1
	Post	Insec	Trojan	0.03
6-Oct-23	Post	Herb	Reglone	1.5
13-Oct-23	Harvest			

Fallow				
28-May-23	Pre	Herb	Glyphosate	1
28-Jul-23	Pre	Herb	Glyphosate	1
10/08/2023	Pre	Herb	Glyphosate	2

Lupin, Jurien				
15-May-23	Pre	Fung	Rovral	0.32
29-May-23	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Reflex	0.75
	Pre	Herb	Diuron	0.6
	Pre	Seed	Cv. Jurien	80
	Sowing	Fert	Super potash 5:1	120
	Sowing	Fert	Super phos	80
	Sowing	Fert	Urea	22
30-May-23	Post	Insec	Dominex	0.2
	Post	Insec	Lorsban	0.2

Serradella, Frano/Margarehta				**kg or L/ha**
28-Mar-23	Pre	Insec	Dominex	0.2
	Pre	Insec	Lorsban	0.2
	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Rustler	0.8
	Pre	Herb	Spinnaker	0.7
	Sowing	Seed	Cv. Margarehta	5
	Sowing	Seed	Cv. Frano	5
	Sowing	Fert	Super potash 5:1	
	Sowing	Fert	Urea	
15-Jun-23	Post	Herb	Select	0.33
	Post	Herb	Factor	0.18
	Post	Spray adjuvant	Uptake wetter	0.582
	Post	Spray adjuvant	Uptake wetter	0.24
10-Aug-23	Post	Insec	Trojan	0.03

Wheat, Vixen				
15-May-23	Pre	Fung	Jockey	0.0045
	Pre	Fung	Raxil	1
	Pre	Fung	Raxil	1
29-May-23	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Sakura	0.118
	Pre	Herb	Treflan	1.5
	Pre	Wetter	Sacoa	0.02
	Pre	Adjuvant	Ammonium sulphate	
	Sowing	Seed	Cv. Vixen	100
	Sowing	Fert	Agstar extra banded	100
	Sowing	Fert	MOP	20
	Sowing	Fert	Urea topdressed	50
30-May-23	Post	Insec	Dominex	0.2
	Post	Insec	Lorsban	0.2
27-Jun-23	Post	Fert	UAN	60
30-Jun-23	Post	Herb	Velocity	1
	Post	Herb	Velocity	1
11-Jul-23	Post	Fert	UAN	60
10-Aug-23	Post	Insec	Trojan	0.03
13-Oct-23	Harvest			

Vetch, studenica				

29-Jun-23	Post	Herb	Select	0.33
	Post	Herb	Factor	0.18
	Post	Spray adjuvant	Uptake wetter	0.582
	Post	Spray adjuvant	Uptake wetter	0.24
10-Aug-23	Post	Insec	Trojan	0.03
13-Oct-23	Harvest			

Medic, cavalier				
15-May-23	Pre	Fung	Apron	0.01
	Pre	Fung	Thiram	0.02
29-May-23	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Edge	0.8
	Pre	Herb	Broadstrike	0.03
	Pre	Seed	Medic	10
	Sowing	Fert	Super potash 5:1	
	Sowing	Fert	Urea	
30-May-23	Post	Insec	Dominex	0.2
	Post	Insec	Lorsban	0.2
29-Jun-23	Post	Herb	Select	0.33
	Post	Herb	Factor	0.18
	Post	Spray adjuvant	Uptake wetter	0.582
10-Aug-23	Post	Insec	Trojan	0.03

15-May-23	Pre	Fung	P-Pickle T	0.02
	Pre	Fung	P-Pickle T	0.02
29-May-23	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Sprayseed	1.5
	Pre	Herb	Edge	0.8
	Pre	Herb	Reflex	0.75
	Pre	Herb	Terbyn extreem	0.86
	Sowing	Seed	Cv. Studenica	40
	Sowing	Fert	Super potash 5:1	
	Sowing	Fert	Urea	
30-May-23	Post	Insec	Dominex	0.2
	Post	Insec	Lorsban	0.2
29-Jun-23	Post	Herb	Select	0.33
	Post	Herb	Factor	0.18
	Post	Spray adjuvant	Uptake wetter	0.582
10-Aug-23	Post	Insec	Trojan	0.03
30-Aug-23	Post	Herb	Gramoxone	0.8

Lake Grace systems trial

Local research team: Brenda Shackley, Rod Bowey and Kristy Hunter

Key messages

- A large-scale farming systems trial has been successfully established ~10 km west of Lake Grace.
- The site has been characterised during 2023 so there is a good understanding of biophysical variables such as the soils, nutrients, weeds and pathogens.
- 2023 was a decile 3 rainfall, but with the opportunity to seed in late April the site average yields were 3.4 t/ha for barley, 1.3 t/ha for canola, 3.3 t/ha wheat and 2.5 t/ha for lupin.

Methods

Plots were sown with a Living Farm cone seeder, each plot consisting of 4 seeder runs to be a width of 8 m by 45 m. These main plots were divided into split plots of 8 m x 20 m (Figure 1). The two edge cone seeder runs were used to monitor soils and take destructive plant samples, leaving the middle two runs (16 rows) for machine harvest.

The split plot design enables each rotation to be grown at two levels of fertiliser nitrogen input. The rationale was that a split plot design increased the power of the statistical analysis of rotation x nitrogen interaction. This enables analysis of the performance of legumes in higher and lower fertiliser nitrogen situations. The higher fertiliser rate was based around current application rates used by farmers. Additionally, APSIM was used to estimate yield from decile 2 and 7 rainfall years at the site. The nitrogen exported in grain from these yields is similar to the high and low amounts being applied. A wide range of crop rotations were included (Table 1).

Within this report statistical analysis was done using Genstat 22nd edition. Treatment structure: Tmt*Nitrogen. Blocking structure: Rep/Row/Nitrogen+ColRep. Hence treatment was a combination of species and sowing time. ANOVA and Fisher's protected LSD were conducted on selected variates.

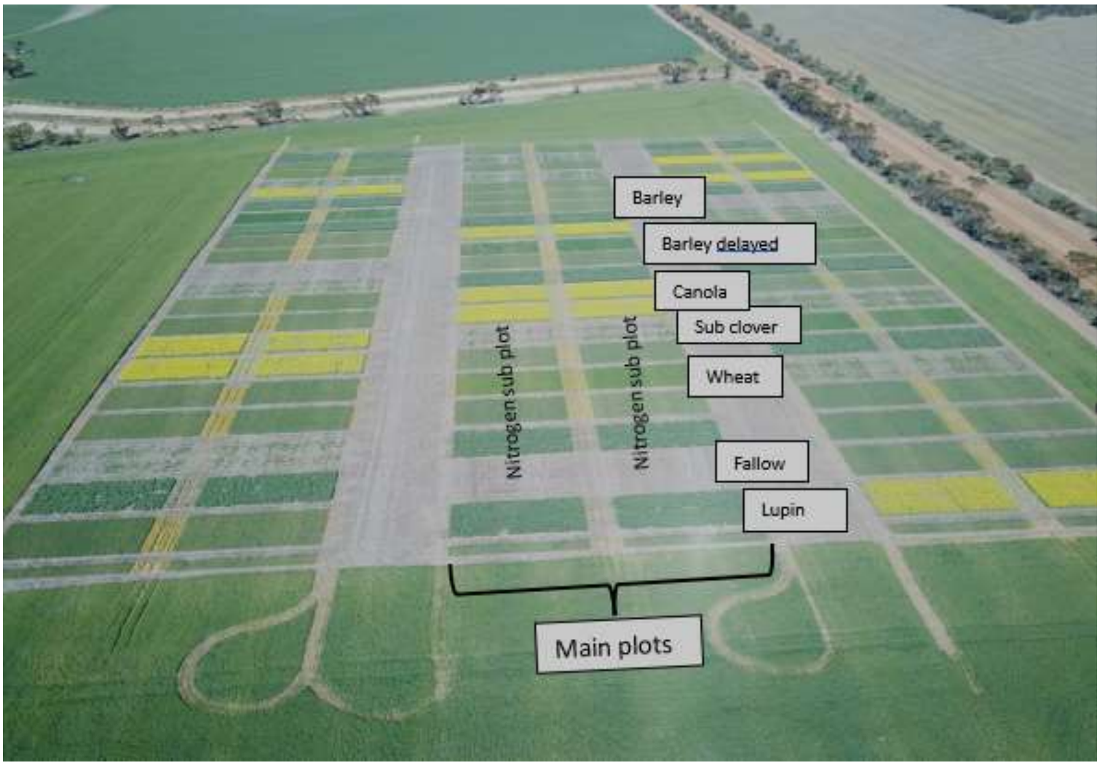

Figure 1. *Lake Grace trial August 2023, with main plots and split plot design depicted.*

Treatments

Trial treatments are a combination of a rotation x sowing time x nitrogen fertiliser rate. At Lake Grace there are 11 rotations ranging from continuous barley to continuous pasture (Dalkeith clover) and various amounts of diversity between these. Most rotations are phased such that each land use in the rotation is grown each year, such that we can better account for seasonal variability. Sowing is 'timely/dry' (late April for most of the trial in 2023) and delayed sown (barley). Fertiliser is applied at two rates of nitrogen, as described above, with the amounts of other elements kept as close to the same as possible.

Table 1. *Treatment summary*

System	Rot	Sow time	N	Typical sequence	Description
ConB_T_2	ConW	Timely	2	Bar/Bar/Bar/Bar	Continuous barley
ConB_D_2	ConW	Delayed	2	Bar/Bar/Bar/Bar	Continuous barley
DivHV2_T_2	DivHV2	Timely	2	Can/Bar/Lupin/Wht	Diverse high value 2
Base_T_2	Base	Timely	2	Lupin/Wht/Bar/Lupin	Baseline
IntBase_T_2	IntBase	Timely	2	Can/Bar/Can/Bar	Intense baseline
DivHV1_T_2	DivHV1	Timely	2	Lupin/Can/Bar/Bar	Double break
DivLI1_T_2	DivLI1	Timely	2	Bmanure/Wht/Bar/Bmanure	Cover crop
DivLI2_S_2	DivLI2	Timely	2	Pas/Bar/Pas/Bar	Annual pasture
DivLI3_T_2	DivLI3	Timely	2	Pas/Pas/Bar/Bar	Double pasture
DivLI4_T_2	DivLI4	Timely	2	Pas/Pas/Pas/Pas	Continuous pasture
Flex_T_2	Flex	Timely	2	Fal/Tac/Tac/Tac	Tactical

Rot = Rotation, Int = Intense, Flex = Flexible, Div = Diverse, Con = Continuous, Base = Baseline, HV = high value, LI = Low input. Bar = Barley, Wht = Wheat, Lupin = grain lupin, Can = Canola, B manure = lupin desiccated in spring, Pas = Pasture, Fal = Fallow, Tac = tactical, T = timely, D = Delayed, N = fertiliser nitrogen rate. Nit 2 = decile 2 N replacement, note all treatments in Table 1 are also included with decile 7 N replacement.

Agronomy

Sowing

The main sowing of barley, wheat, canola, lupin and sub clover was sown on 26 and 27 April, with an excellent germination of canola, as expected for barley, wheat and sub clover but poorer establishment of lupin. The delayed barley was sown 25 May, in dry conditions, germinating with the rain on 1June.

Varieties

The following varieties were used: Maximas CL Plus barley, Catapult wheat, Bonito canola, Jurien lupin and Dalkeith sub clover.

Nitrogen

Lupins and sub clover plots had 0 or 10 kg/N at seeding with no additional post-emergent. All barley, wheat and canola plots received 27 kg/ha N at sowing for the low N treatment or a total of 46 kg N/ha for the high N treatment. A further 23 kg N/ha was applied post-emergent to the high N treatment for barley, wheat and canola, supplying a total of 69 kg N/ha.

Plots were, as much as possible, managed as per district practice. However, no seed dressing for spot type net blotch was applied to the barley seed, hence a foliar fungicide was applied to earlier than many of the barley crops in the area.

See Appendix A for a more detailed summary of agronomic management.

Location

A 4.5-hectare site was identified west of Lake Grace (Figure 2). A big thanks to Kevin Naisbitt at Jenakora for hosting the trial.

Site	Latitude (dd)	Longitude (dd)	Nearest town
Medium rainfall – southern WFS	-33.1399	118.3086	Lake Grace

Figure 2. *Trial site adjacent to Jarring South Rd, ~10km west of Lake Grace.*

Results

Weather

The growing season rainfall was approximately 200 mm (April to October). This represents a decile 3 rainfall with long term median (decile 5) annual rainfall of 342 mm at the Bureau of Meteorology site, situated around 15 km east of the trial in Lake Grace. There was little ‘summer’ rain however the break of season occurred on 1 and 8 April with around 25 mm for each rainfall event, with a further 7 mm the following week. The next significant rainfall event was at the end of May. There were no frost events during spring in 2023.

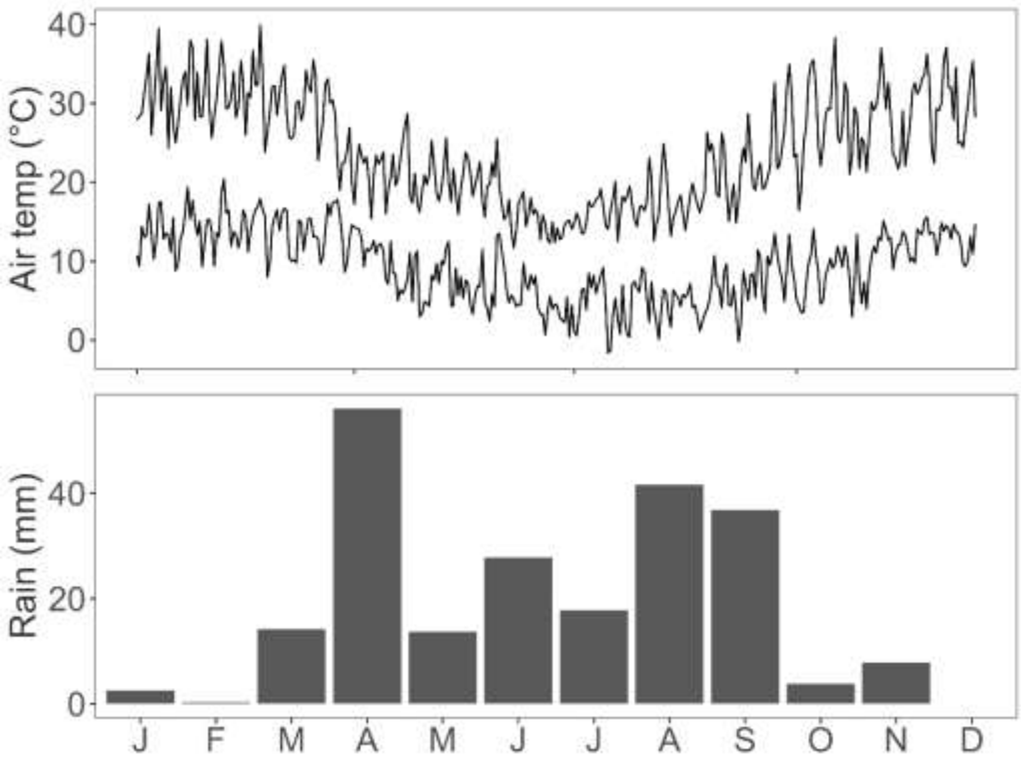

Figure 3. *Site monthly rainfall and min and max air temperatures, combination of Lake Grace patch point data and Hobo data at site from June 2023.*

Soil water

Soil water content was adequate to marginal in the topsoil prior to seeding, with increasing moisture at depth (Table 2). The canola and sub clover were sown slightly deeper with the drying topsoil.

Soil samples for moisture and nutrients were taken after harvest (mid-December) but are still to be processed.

Table 2. *Average gravimetric soil content (%) of each depth of soil sampled at seeding (late April).*

Depth (cm)	Gravimetric soil water content (%)
0-10	8.7
10-20	10.1
20-30	13.5
30-50	15.4
50-100	16.2

Selected soil parameters

Chemical analysis of each plot was taken to a depth of 1 m. All elements were at adequate soil concentration or above. Soil pH was lower than observed from earlier site testing at the 0-10 cm soil layer, but at high levels throughout the rest of the profile. Phosphorus and sulphur are lower than expected. There was a reasonable amount (71 kg/ha) of mineral N/ha at the site before seeding (Table 3), this is assuming a bulk density of 1.4 (data not available at this stage).

Table 3. *Average of the pre-seeding soil analysis taken late April.*

Depth (cm)	Nitrate (mg/kg)	Amm (mg/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	pH $CaCl_2$	OC (%)	Nitrate (kg/ha)	Amm (kg/ha)
0-10	32	2	22	245	6	5.5	1.13	45	3
10-20	5	1	4	234	4	7.1	0.31	6	2
20-30	3	1	3	338	6	7.9	0.19	5	2
30-50	2	1	3	480	11	8.1	0.13	3	1
50-100	3	<1	<2	570	29	8.0	0.14	4	1
Total								63	9

Establishment

Seeding 26–27 April into a drying topsoil resulted in slightly lower establishment than desired for barley, wheat, lupin and clover. Canola establishment exceeded the desired 50 plants/m², which may have been a combination a higher establishment than expected and/or the incorrect seeding calibration (Table 4). Delayed barley germinating with the end of May rainfall had a better establishment.

Table 4. *Average establishment of crop and pasture at Lake Grace in 2023.*

Crop	Plant establishment (m²)
Maximus CL Plus barley	126
Maximus CL Plus barley - delayed	143
Catapult wheat	135
Bonito canola	97
Jurien lupin	34
Dalkeith sub clover	41

Weeds

Quadrat counts in autumn, after seeding and before selective herbicide application, indicated there were very few weeds at the site. Four weed species were observed;

natural clover (0.7/m^2), ryegrass (0.1/m^2), wild radish (0.1/m^2) and volunteer canola (0.1/m^2).

Weeds were not counted in spring due to the low number and research staff availability. Some turnip and radish plants did persist in the plots sown to crop, while sow thistle was observed in spring in some fallow and sub clover plots. These were removed by hand, as this was easier than spraying. A spray will be added to the economic analysis to capture this. By harvest, more sow thistle, melon and Afghan thistle were present in the bare areas between the reps and plots. These were sprayed out.

Pathogens and nematodes

PREDICTA®B sampling was undertaken for each plot in autumn, prior to seeding, and in spring, around anthesis. Cereal cyst nematode, stem nematode, *P. thornei*, take-all, and *P. quasitereoides* were not found at the site (Figure 4). For black spot, *P. neglectus* and pythium there were no samples with soil DNA at concentrations associated with high yield loss risk. There were a small proportion of plots in which rhizoctonia and crown rot DNA in soil were at levels that could cause high yield loss, if conditions were conducive to these pathogens.

Take-all declined across the growing season within all land uses except wheat, indicating a low level of grass weeds, as measured at the site (Figure 5). Crown rot levels were low and decreased in all land uses from autumn to spring. Rhizoctonia increased in most land uses but declined in the fallow plots. *P. neglectus* increased in wheat and canola but declined in fallow, lupin and medic pasture. Septoria was low and variable, indicative of the dry season which was not conducive to Septoria. Pythium increased under lupin more than the other land uses.

Free living nematode species detected included: Panagrolaimidae, Mononchida, Mesorhabditinae, Dorylaimida, Cephalobidae, Aphelenchidae, and Aphelenchoididae. Three of six mycorrhizal fungi species within the PREDICTA®B assay were detected.

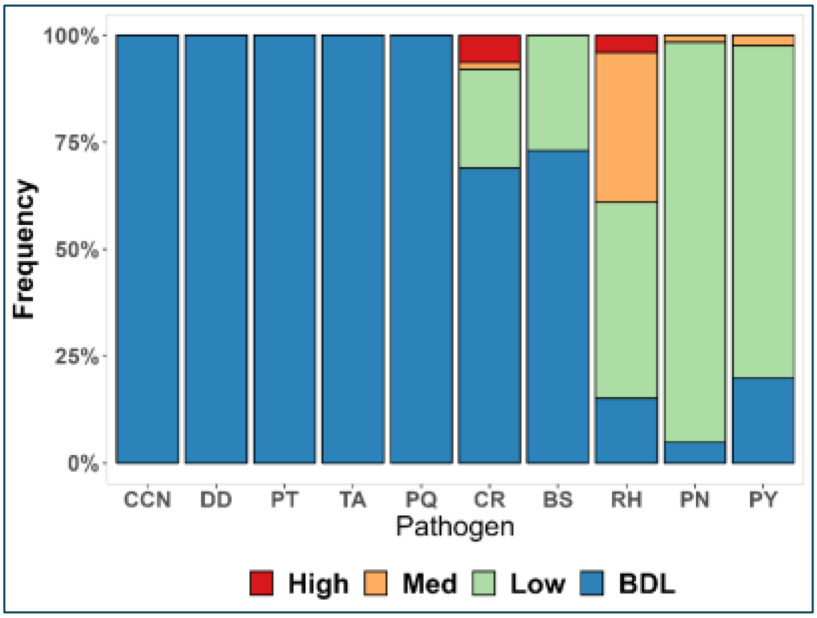

Figure 4. *Frequency of pathogen DNA concentration assays, taken at visit 1 (autumn), within PREDICTA B disease risk yield loss categories (BDL = below detection limit, Low, Med = medium, High), for CCN (cereal cyst nematode, H. avenae), DD (stem nematode, D. dipsaci), PT (P. thornei), TA (take-all, G. graminis var. tritici), PQ (P. quasitereoides), CR (crown rot, Fusarium spp.), BS (black spot, D. pinodes/P. pinodella), RH (R. solani AG-*

8), PN (P. neglectus) and PY (Pythium Clade F). Note Pythium (PY) and (PT) P. thornei tests are under development and categories represent population density not disease risk.*

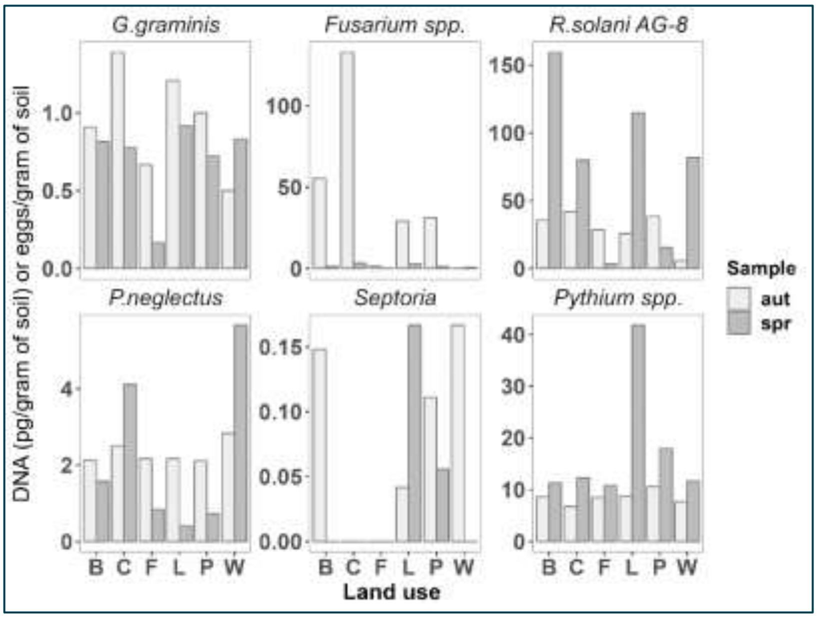

***Figure 5.** Amount of DNA of G. graminis var. tritici, Fusarium spp., R. solani (AG-8), Pythium Clade F, Septoria, or eggs, of P. neglectus in soil when sampled in autumn (aut) and spring (spr) for the land uses of barley (B), canola (C), Fallow (F), lupin (L), medic pasture (P), and wheat (W).*

Crop growth

Biomass cuts were taken from each plot twice, once at 'peak' vegetative biomass (late anthesis) and at maturity.

Crop biomass at anthesis was significantly higher than the pasture biomass, which was sampled/ reached anthesis over three weeks later (Table 5). Overall, there was a significant difference between the nitrogen treatments ($P < 0.001$), but no significant interaction between species and nitrogen. There was an anomaly with one replicate in the lupin brown manure land use, which reduced the response to nitrogen. Barley which was sown later was the most responsive at the first cut, biomass increasing ~1.2 t/ha from low to high N, closely followed by wheat sown late April. Conversely pasture biomass was greater from the low nitrogen treatment (Table 5).

At maturity the result was similar, large differences ($P < 0.001$) in biomass between species, barley, wheat and lupin with greater biomass than canola. Pasture was not measured at this stage. There was a significant difference ($P < 0.001$) in biomass due to nitrogen rate, higher nitrogen with greater biomass, except for lupin (Table 5). For the late April sown barley and canola, the difference in biomass due to higher nitrogen was higher than the first cut at over 1.4t/ha. While the biomass difference due to nitrogen for wheat and the late sown barley was still significant at maturity it was lower (~0.7t/ha).

Table 5. *Biomass of crop and pasture at anthesis and maturity in response to nitrogen rate and delayed sowing for barley (Lake Grace 2023).*

Land use	**Sowing time**	**Anthesis biomass (kg/ha)**			**Pre-harvest biomass (kg/ha)**		
		High N (69kg N/ha)	Low N (27kg N /ha)	*Difference*	High N (69kg N/ha)	Low N (27kg N/ha)	*Difference*
Barley	Timely	5501	4663	*838*	7729	6308	*1421*
	Delayed	5312	4081	*1231*	6115	5367	*748*
Wheat	Timely	5745	4570	*1175*	8294	7674	*620*
Canola	Timely	3910	3153	*757*	5690	4197	*1493*
		High N (10kg N/ha)	Low N (nil)		High N (10kg N/ha)	Low N (nil)	
Lupin	Timely	5057	4661	*396*	6589	6719	*-130*
Lupin (Brown manure)	Timely	5059	5023*	*36**			
Pasture	Timely	1445	1539	*-94*			

* Anomaly in one rep

NDVI

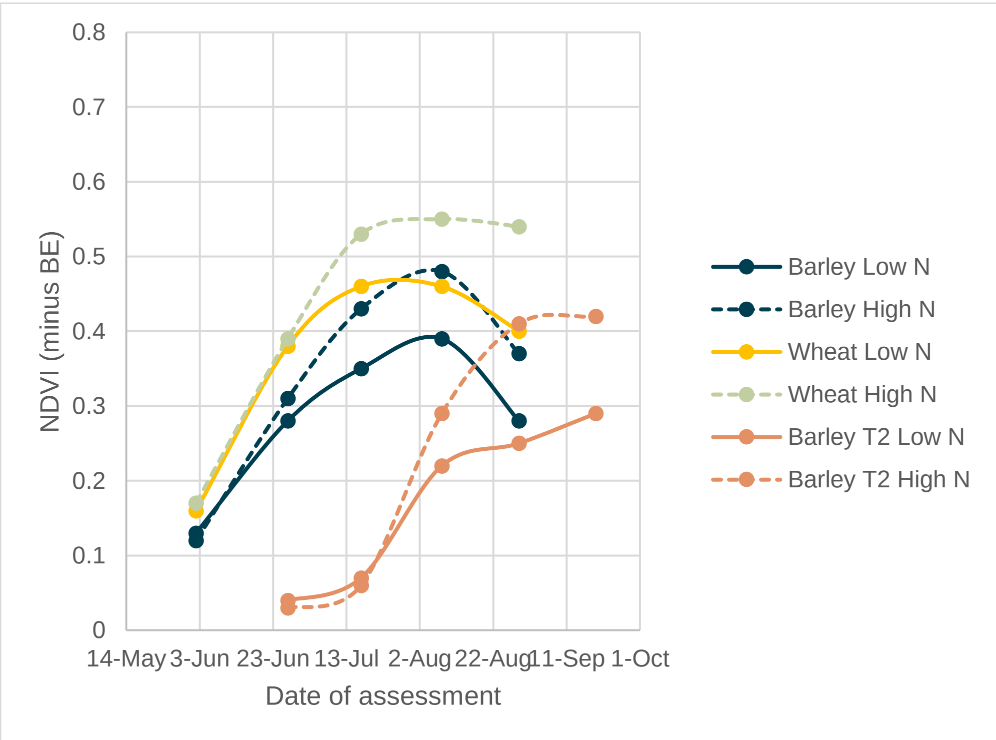

Figure 6*: NDVI assessments over time for barley and wheat at the farming systems site, Lake Grace 2023 (sown April 26 or May 31). Low N = 27kg N/ha and High N = 69kg N /ha*

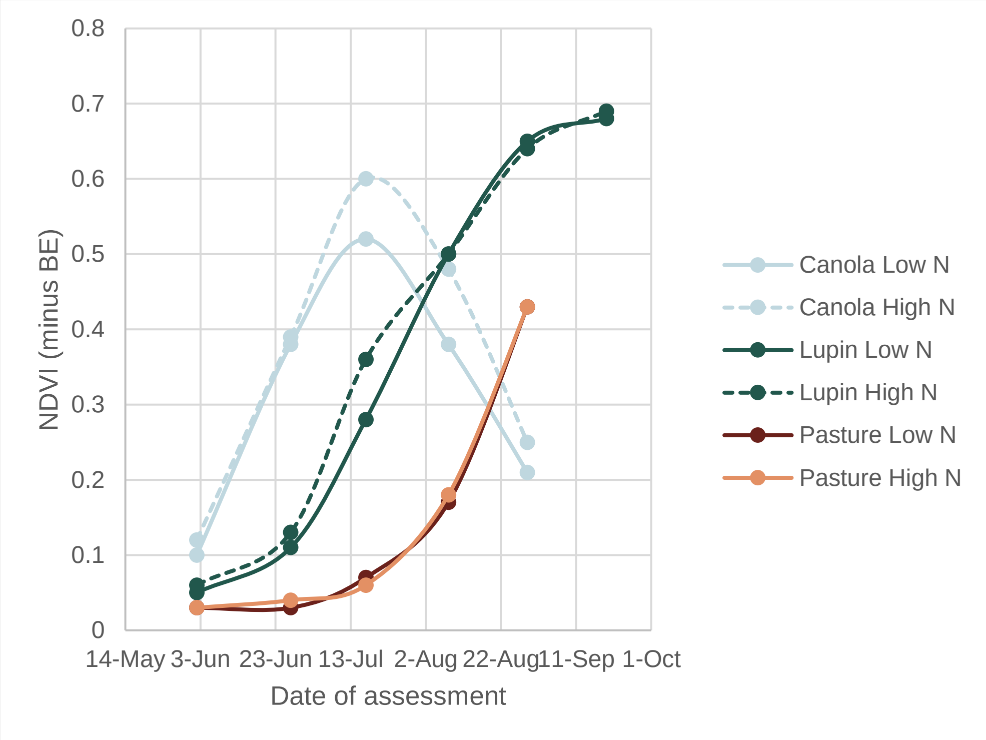

***Figure 7**. NDVI assessments over time for canola, lupin and pasture at the farming systems site, Lake Grace 2023 (sown April 26). Low N = 27kg N/ha for canola or nil and High N = 69kg N /ha or 10 for lupin and pasture.*

Green area ground cover was measured using handheld NDVI machines every three weeks through the growing season. Rates of ground cover accumulation differed between species. Canola, wheat and barley had the fastest rates of ground cover accumulation (Figures 6 and 7), while lupins were slower to accumulate cover, they had a higher peak. Pasture was the slowest to accumulate ground cover. There was an increase in NDVI at the higher nitrogen rate for barley, wheat and canola where an additional 42 units of N were applied.

Root assessment

Lupin and pasture plants were dug from plots on 19 and 24 July respectively and nodules scored using a 0–8 scale; zero = no nodules present and 8 = nodules extremely abundant. Mean nodulation score ranged from 4.6 for sub clover to 5.9 for lupin. Root weights ranged from 4.8 g for sub clover to 18.5 g for lupin.

Plant tissue was taken at anthesis and assessed for % nitrogen derived from atmosphere, results not yet available to indicate how well plants were fixing. Final calculations of amount on nitrogen fixed will also be completed once the results are available.

Plant development

With the good start to the season, soil moisture at depth, mild temperatures and frost prior to flowering (early July), growth was not restricted in 2023. Maturity was hastened by the end of the season with the last effective rain on 14 September. Canola and lupins were the first to reach 50% flowering at the start of August (Tables 7 and 8). It was noted that a bulk lupin crop adjacent to the trial site had a quicker development with a higher plant density but similar sowing date.

Table 6. *Date of key plant development stages for each crop or pasture (Lake Grace, 2023).*

	Sow	Emergence	First flower	50% flower	Last flower	Maturity
Barley	26/04/2023	1/05/2023	Z59 = 25/08/2023			3/10/2023
Barley-delayed	25/05/2023	7/06/2023*	Z59 ~ 19/09/2023			20/10/2023
Wheat	26/04/2023	2/05/2023	29/08/2023	4/09/2023		18/10/2023
Canola	27/04/2023	2/05/2023	26/07/2023	9/08/2023	26/08/2023	10/10/2023
Lupin	27/04/2023	8/05/2023	25/07/2023	1/08/2023	8/08/2023	18/10/2023
Pasture	27/04/2023	3/05/2023	15/09/2023			

**: germination with rain on 31st May*

Table 7. *Days from sowing to plant development stage for each crop or pasture (Lake Grace, 2023).*

	Sow	Emergence	First flower	50% flower	Last flower	Maturity
Barley	26/04/2023	5	121			160
Barley-delayed	25/05/2023*	7*	117			148
Wheat	26/04/2023	6	126	131		175
Canola	27/05/2023	5	90	104	121	166
Lupin	27/05/2023	11	89	96	103	174
Pasture	27/05/2023	6	141			

**: germination with rain on 31 May*

Mineralised nitrogen (N)

Soil samples (0–10cm) were collected from each plot and assessed for nitrate and ammonium nitrogen levels from seeding and then roughly every 3 weeks during the season. Final nitrate and ammonium nitrogen levels were taken after harvest but are not available at the time of the report.

Figures 8 and 9 show the total N over the season for each treatment with total N the additional of nitrate plus ammonium N multiplied by the estimated bulk density of 1.44. Before maturity or the end of the season, the total N ranged from over 40 kg/ha for fallow, ~30 for pasture, above 10 for lupin and below 10 for the cereal and canola land uses.

The results in figures 8 and 9 may be influenced by the different number of plots per treatment, i.e. high for barley but low for fallow and wheat, with canola, lupin and pasture in between. However, there are some interesting responses with the additional nitrogen treatment (high N) on the total N over the season, suggesting there may be some interaction with microbes and N mineralisation.

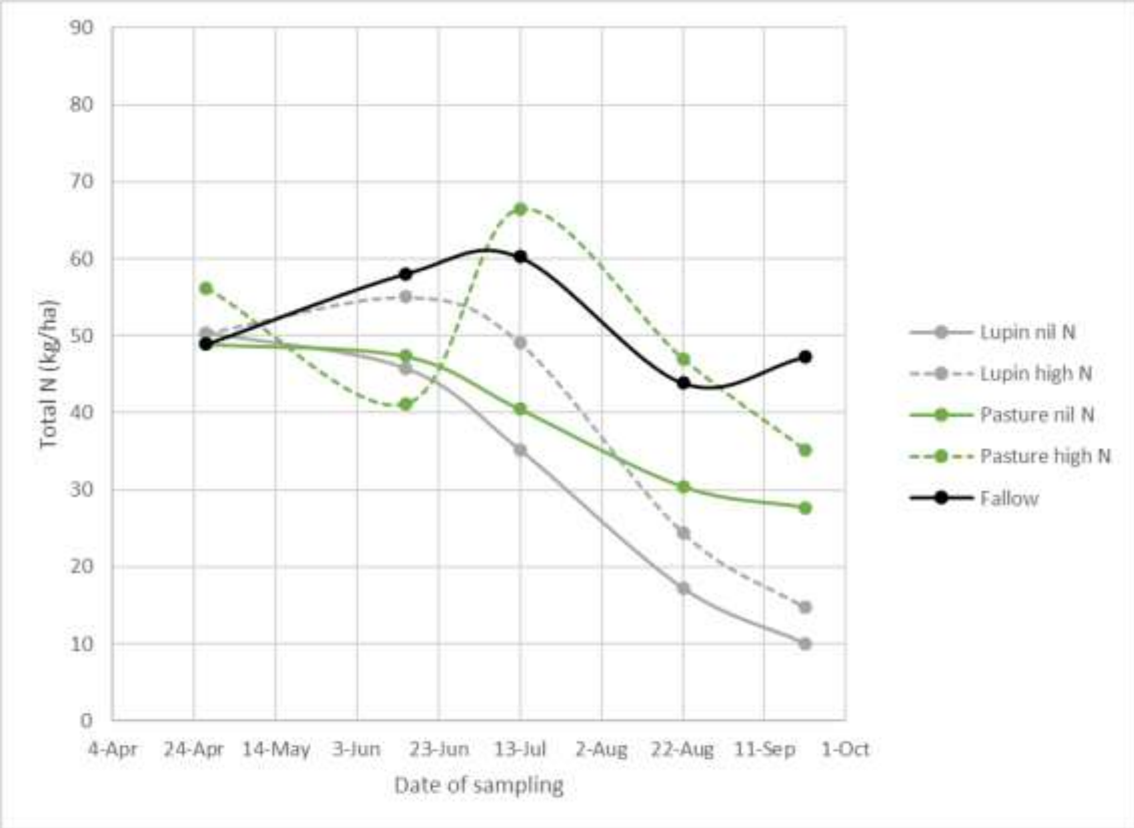

Figure 8*. N available (kg N/ha) for lupin, pasture with nil and high N treatment and fallow system at the start and during the season (Lake Grace 2023, assuming 1.44 BD)*

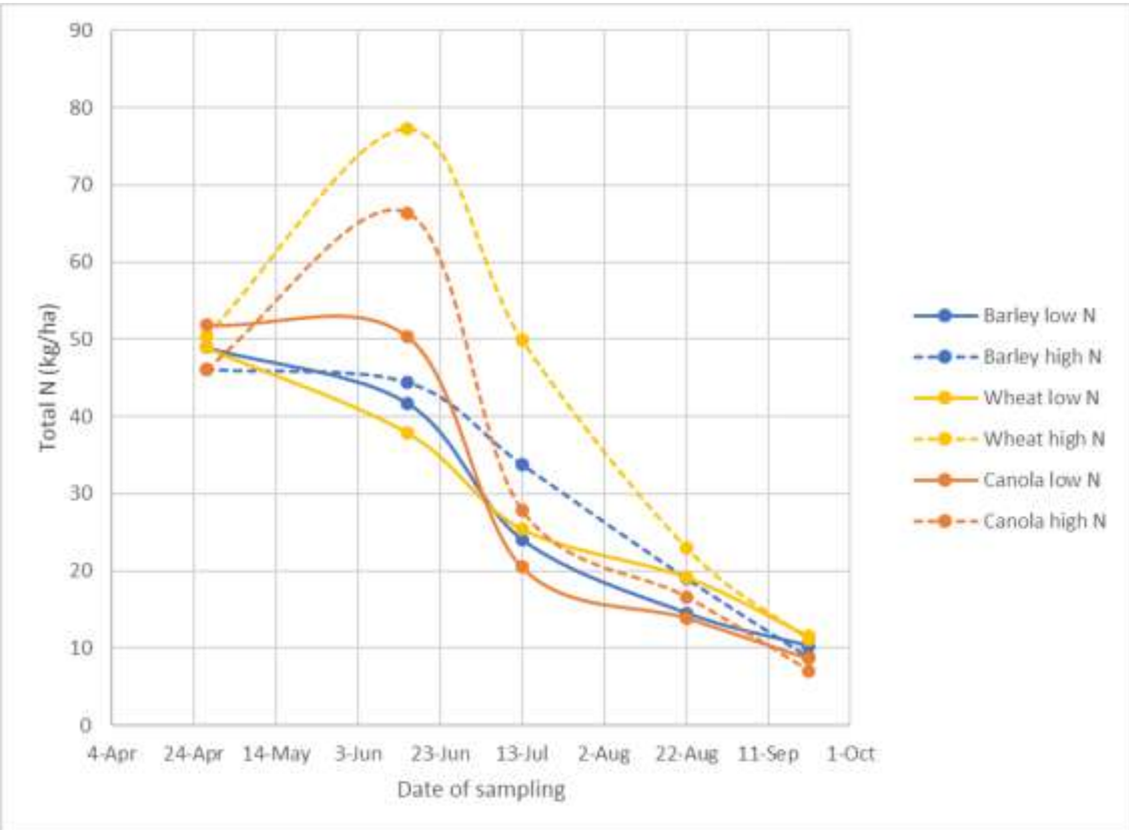

Figure 9*. N available (kg N/ha) for the cereal and canola crops and N treatments at the start and during the season (Lake Grace 2023, assuming 1.44 BD)*

Yield

Yields were above the district average, supported by the good start to the season and the late April seeding (Table 8). Barley sown 'timely' yielded the highest (average 3.43 t/ha) but was not significantly higher yielding than wheat (average 2.99 t/ha). Both barley and wheat sown 'timely' (late April) yielded significantly higher than barley delayed (end of May). All cereal crops yielded higher than lupin or canola. Note that most of the canola in the district was sown early to mid-April.

There was a significant difference in yields between nitrogen levels for the cereal crop. Canola was responsive to the additional nitrogen, but this was not statistically significant. Lupins had no response to the 10 units of nitrogen applied at seeding.

Pasture seed yields are still to be assessed.

Table 8. *Grain yield response of barley, wheat, canola and lupin and wheat to additional nitrogen and delay in sowing time (Lake Grace 2023).*

Land use	Sowing time	Yield (kg/ha)		
		High N (69kg N/ha)	Low N (27kg N/ha)	Difference
Barley	Timely	3818	3042	776
	Delayed	3214	2767	447
Wheat	Timely	3591	3103	488
Canola	Timely	1354	1174	181
		High N (10kg N/ha)	Low N (nil)	
Lupin	Timely	2459	2463	-4

Grain quality

Grain quality for all crops were assessed as per CBH receival standards. Even with high nitrogen input of 69 units, Maximus CL Plus barley and Catapult wheat sown late April achieved protein levels below what is required from the optimum grades of Malt or APW. Germ end staining was also an issue for Maximus sown late April, hence the barley could only be received as Feed. Maximus sown later was within the protein requirement for Malt and germ end staining below the maximum limit of 30.

Table 9. *Grain quality response of barley, wheat, canola and lupin and wheat to additional nitrogen and delay in sowing time (Lake Grace 2023).*

Land use	Nrate (kg N/ha)	Protein (%)	Hectolitre wt (kg/hl)	Oil (%)	Retention (%, >2.5mm)	Screenings (%, <2mm)	Germ end staining (BPM)	Grain wt (mg)
Barley	27	8.5	76.4		98		43	46.7
	69	9.1	76.4		98		46	46.5
	Difference	*0.6*						
Barley T2	27	9.9	71.9		89		13	42.4
	69	10.6	71.4		87		15	41.1
	Difference	*0.7*						
Wheat	27	7.7	84.7			0		44.5
	69	8.2	84.5			0		42.3
	Difference	*0.5*						
Canola	27	15.7		48.6				

	69	17.3		46.6					
Lupin	0	26.4							
	10	26.3							

BPM = Black Plastic Measure with maximum of 30 for Malt

Summary

We have successfully implemented and monitored a complex farming systems trial at Lake Grace. The site has been characterised such that we have a basic understanding of key biophysical variables that are likely to be influenced by the different farming system treatments.

The results from 2023 were impacted by the good start to the season, the opportunity to sow relatively early and no low temperatures during flowering. As expected, given that this is the first year of a 5-year trial, the results to date are quite basic. However, all plots grew well enough to ensure that rotational responses can be studied, and we observed responses to nitrogen treatments.

Results will become more informative as rotations/treatments diverge. In particular, it will be interesting to see if fertiliser nitrogen in excess of what was removed in grain carries through to 2023. Similarly, it will be interesting to see if differences in final soil moisture between treatments results in differences in growth and yield in 2024. This will most likely be quite dependent on 2024 seasonal conditions.

Merredin systems trial

Local research team: Dion Nicol, Grace Williams and Bella Tyak White

Key messages

- We have successfully established a large-scale farming systems trial on DPIRD's Dryland Research Institute 5 km west of Merredin.
- The site has been comprehensively characterised, and we have a good understanding of biophysical variables; soils, nutrients, weeds and pathogens.
- 2023 was a decile 1 rainfall, with site yields of canola 0.40 t/ha, chickpea 0.40 t/ha, early sown wheat 0.85 t/ha and late sown wheat 0.55 t/ha.

Methods

Plots were sown with a DPIRD cone seeder, each plot consisting of 5 seeder runs to be a width of ~10m by 36m. These main plots were divided into three split plots of 10m x 10m with a gap between them (Figure 1). The edge cone seeder runs were used to monitor soils and take destructive plant samples. The middle two runs were used for machine harvest.

The split plot design enables each rotation to be grown at three levels of fertiliser nitrogen input. The rationale was that a split plot design increased the power of the statistical analysis of rotation x nitrogen interaction. This enables analysis of the performance of legumes in higher and lower fertiliser nitrogen situations. The lowest fertiliser rate was a nil treatment. The other two rates were based around current application rates used by farmers and were also informed by estimating nitrogen requirements to achieve yield potential in decile 2 and 7 rainfall years at the site. A wide range of crop rotations were included (Table 1).

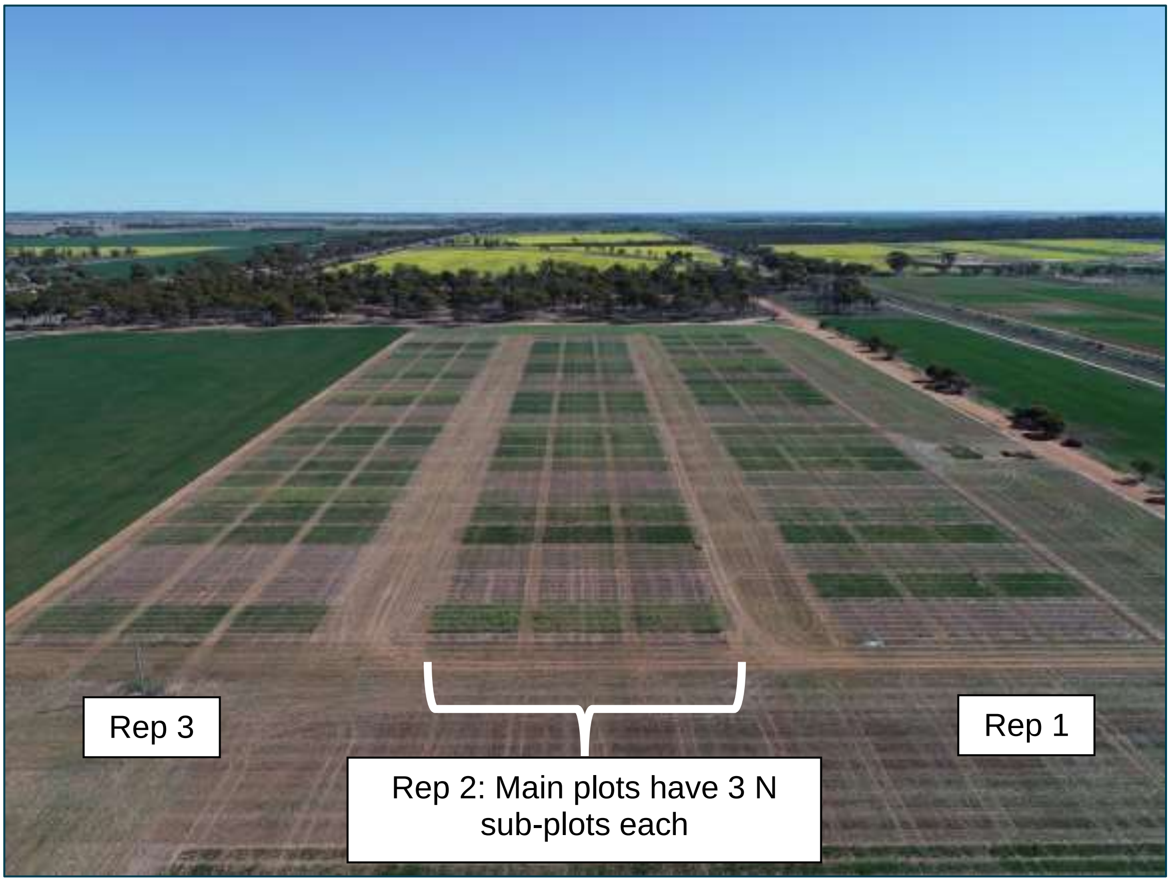

Figure 1. *Merredin trial August 2023, note three replicates of main plots replicate all rotations and these main plots contain three sub-plots (the three nitrogen rates).*

Treatments

Trial treatments are a combination of a rotation x sowing time x nitrogen fertiliser rate. At Merredin there are 16 rotations ranging from continuous wheat to continuous pasture and various amounts of diversity between these. Most rotations are phased such that each land use in the rotation is grown each year, so we can better account for seasonal variability. Sowing is early (lucerne, canola, vetch) or timely/dry (most of the trial) and a delayed sown wheat. Fertiliser is applied at three rates of nitrogen, as described above, with the amounts of other elements kept the same.

Table 1. *Treatment summary*

System	Rot	Sow time	N	Typical sequence	Description
ConC_D_0	ConC	Wet/delayed	0	Cer/Cer/Cer/Cer	Monoculture wheat
ConC_T_0	ConC	Dry/timely	0	Cer/Cer/Cer/Cer	Monoculture wheat
ConP_T_0	ConP	Dry/timely	0	Pas/Pas/Pas/Pas	Continuous pasture
DivHv1_T_0	DivHv1	Dry/timely	0	Leg/Cer/Leg/Cer	Diverse high value
IntBase_T_2	IntBase	Timely	0	Cer/Can/Cer/Can	Intense baseline
DivHv2_T_0	DivHv2	Dry/timely	0	Cer/Leg/Cer/Can	Diverse high value
DivHv3_T_0	DivHv5	Dry/timely	0	Cer/Leg/Can/Cer	Double break
DivLv1_T_0	DivLv1	Dry/timely	0	LegCover/Cer/LegCover/Cer	Cover crop
DivLv2_T_0	DivLv2	Dry/timely	0	Pas/Cer/Pas/Cer	Annual pasture
DivLv3_T_0	DivLv3	Dry/timely	0	Pas/Pas/Cer/Cer	Phase pasture
DivL4_T_0	DivLv4	Dry/timely	0	MS/Cer/MS/Cer	Diverse crop

System	Rot	Sow time	N	Typical sequence	Description
DivLv5_T_0	DivLv5	Dry/timely	0	Lu/Lu/Cer/Cer	Diverse mixed farm
DivLv6_T_0	DivLv6	Dry/timely	0	Lu/Lu/Tac/Tac	Diverse mixed farm
Flex_T_0	Flex	None/Timely	0	Fal/Tac/Tac/Tac	Tactical
SimC1_T_0	SimC1	None/Timely	0	Fal/Cer/Fal/Cer	Simple crop
SimC2_T_0	SimC2	None/Timely	0	Fal/Can/Cer/Cer	Simple crop

Rot = rotation, Int = intense, Flex = Flexible, Div = diverse, Con = continuous, Sim = simple, LV = low value, HV = high value, LI = Low input. Cer = cereal (wheat), Leg = grain legume (chickpea), Can = canola, LegCover = legume cover crop desiccated in spring (vetch), Pas = pasture (subclover), Fal = fallow, Ta = tactical (decided annually), T = timely, D = Delayed, S = summer, N fertiliser nitrogen rate. N 0 = nil N fertiliser, all treatments in Table 1 are also included with decile 2 and decile 7 N rates.

Location

A 6-hectare site was identified on DPIRD's Merredin Research Station.

The soil is a common Merredin series soil which originally supported Salmon Gum vegetation. The top 10 cm is sandier and more acidic than the rest of the profile. While a surface (0-10cm) pH level of 5 is common for these soils 10 cm is usually increasingly alkaline with depth. It has been classified as a Red Sandy Earth (WA soil group) or Haplic Mesotrophic Red Kandosol (Australian soil classification).

Figure 2. Soil pit within the trial paddock used for soil characterisation in 2023.

Agronomy

Sowing

Canola, vetch, lucerne were sown on 14 April.

Timely wheat, chickpea, multispecies (chicory, sub clover, tetraploid ryegrass, tillage radish, vetch), pastures and re-sown lucerne on 5 May.

Delayed wheat 15 June.

Nitrogen

At the nil N rate nitrogen was not applied to any crop or pasture.

At the low (decile 2) nitrogen rate 23 kg/ha was applied to wheat and canola, with none applied to legumes. This was applied at sowing.

At the higher (decile 7) nitrogen rate 64 kg/ha was applied to wheat and canola, with none applied to legumes.

The same amount of P and S was applied to all plots, 8 kg/ha.

Plots were, as much as possible, managed as per district practice; however, herbicide applications were simplified to avoid errors when applying pre-sowing herbicides and manage carryover issues for future rotations.

Results

Weather

Annual rain was 198 mm. Growing season rain 125 mm. This represents a decile 1 rainfall. There was little summer rain but around 50 mm was received in the last week of March. This, along with small rains in April, enabled the April 15 sowing. While over 30 mm was received in May the vast majority of this occurred in the last few days of May. Spring was dry with maximum daily air temperatures peaking over 30 degrees from late August onwards (Figure 3).

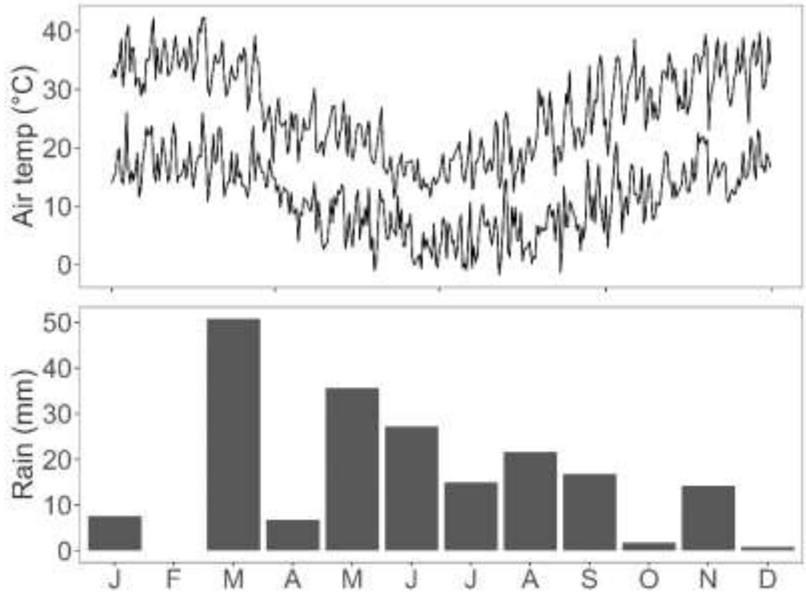

Figure 3. *Site monthly rainfall and min and max air temperatures 2023.*

Selected soil parameters

Chemical analysis of each plot was taken to a depth of 1 m. Soil test parameters indicate that the fertility of the site is generally similar to district soil test results (pers. observation) with organic carbons of ~0.9%, low soil test nitrogen (N), moderate Colwell P, high Colwell K. The surface concentrations of sulphur are low. However, it is important to consider that the concentrations of S increase with depth and may not limit growth.

(Table 4).

Table 4. *Pre-seeding soil analysis.*

Depth (cm)	Nitrate (mg/kg)	Amm (mg/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	pH $CaCl_2$	OC (%)
0-10	9	2	39	379	6	5.1	0.90
10-20	4	2	6	268	7	7.5	0.40
20-30	2	1	5	220	18	8.0	0.30
30-50	1	1	4	241	61	8.3	0.20
50-100	5	1	3	313	111	8.4	0.20

Establishment

Plant establishment for most species was lower than ideal due to dry conditions during germination.

At the first sowing time (14 April) conditions were drying rapidly following the late-March, early-April rain. Vetch established strongly, while the smaller seeded lucerne failed to establish at this time and was re-sown in May.

Due to the difficult conditions at seeding a hybrid canola cultivar was used. Out of interest a comparison of open pollinated, Cv. Bonito, and Hybrid, Cv. Emu, was sown at the west end of the trial. Bandit did not establish in these conditions and didn't emerge until May and June. Emu established with plant densities within the target range (Figure 5). These plots also provided the trial a buffer for protection from birds.

The main sowing time targeted rainfall forecast the following weekend. Windy conditions followed, drying furrows rapidly. Consequently, seedlings were slow to emerge with some seedlings emerging from the rainfall at the end of May/start of June. As a result of this, and more favourable conditions in June, the delayed wheat treatment established at over twice the density of May sown wheat. However, this was still below the target density of 100-120 plants/m^2 (Figure 4).

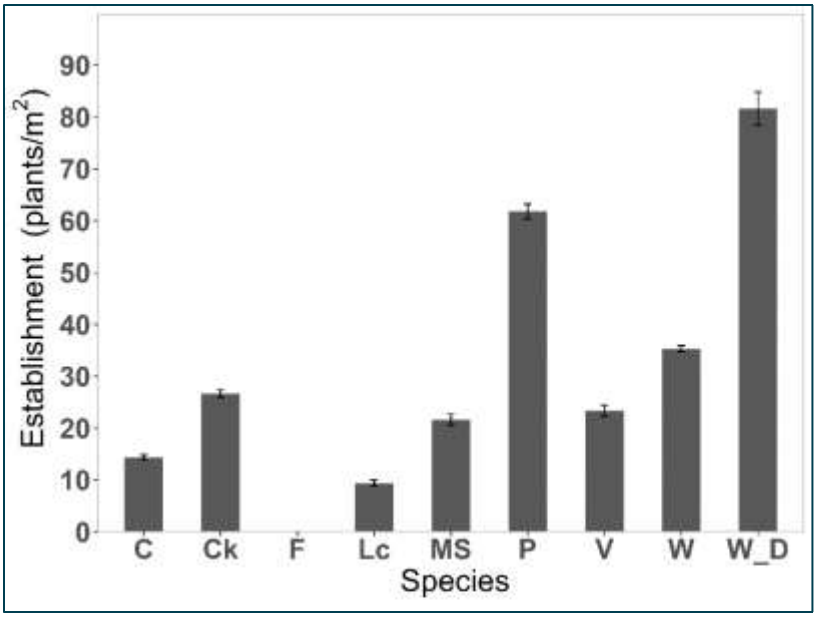

Figure 4. *Establishment of crop and pasture species at Merredin 2023. C = canola, Ck = Chickpea, F = fallow, Lc = Lucerne, MS = Multi species, P = Medic, V = vetch, W = wheat W_D = delay sow wheat.*

Establishment for the multi species treatments were: chicory 1 p/m^2, subclover 10 p/m^2, tetraploid ryegrass 4 p/m^2, tillage radish 3 p/m^2 and vetch 4 p/m^2

Weeds

Weed counts were taken after seeding, before post-emergent herbicides were applied, and again at harvest. There were ~20 weed species observed, most of these were ephemeral species that will not impact yield, such as ice plant, sow thistle, etc. The density of weeds at the Merredin site is very low and numbers of weeds declined with in-season control, such that very few weeds were observed in harvest weed counts (Figure 5).

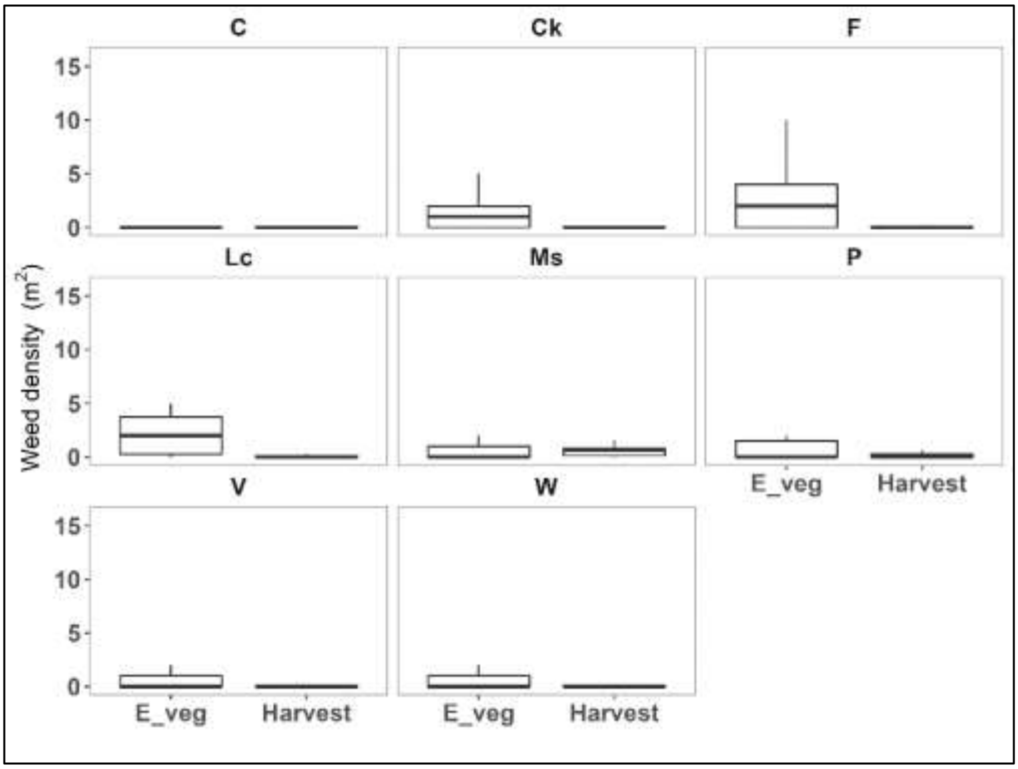

Figure 5. *Weed density within each land use in at early vegetative stage(E_Veg) and harvest. C = canola, Ck = Chickpea, F = fallow, Lc = Lucerne, MS = Multi species, P = Medic, V = vetch, W = wheat.*

Pathogens and nematodes

PREDICTA®B sampling was undertaken for each plot in autumn, prior to seeding. Cereal cyst nematode, stem nematode, Take-all, and *P. quasitereoides* were not found at the site. *P. thornei*, black spot, rhizoctonia, *P. neglectus*, and pythium were only detected at low yield loss risk level. Crown rot was detected in over half of the plots with a small percentage within the high-risk category. Hence, to date, soil DNA testing indicates crown rot is the only pathogen at the site which may impact yield (Figure 6).

Eight free living nematode species were detected along with three mycorrhizal fungi. No foliar pathogens were observed and there were very few reports of foliar pathogens throughout the district.

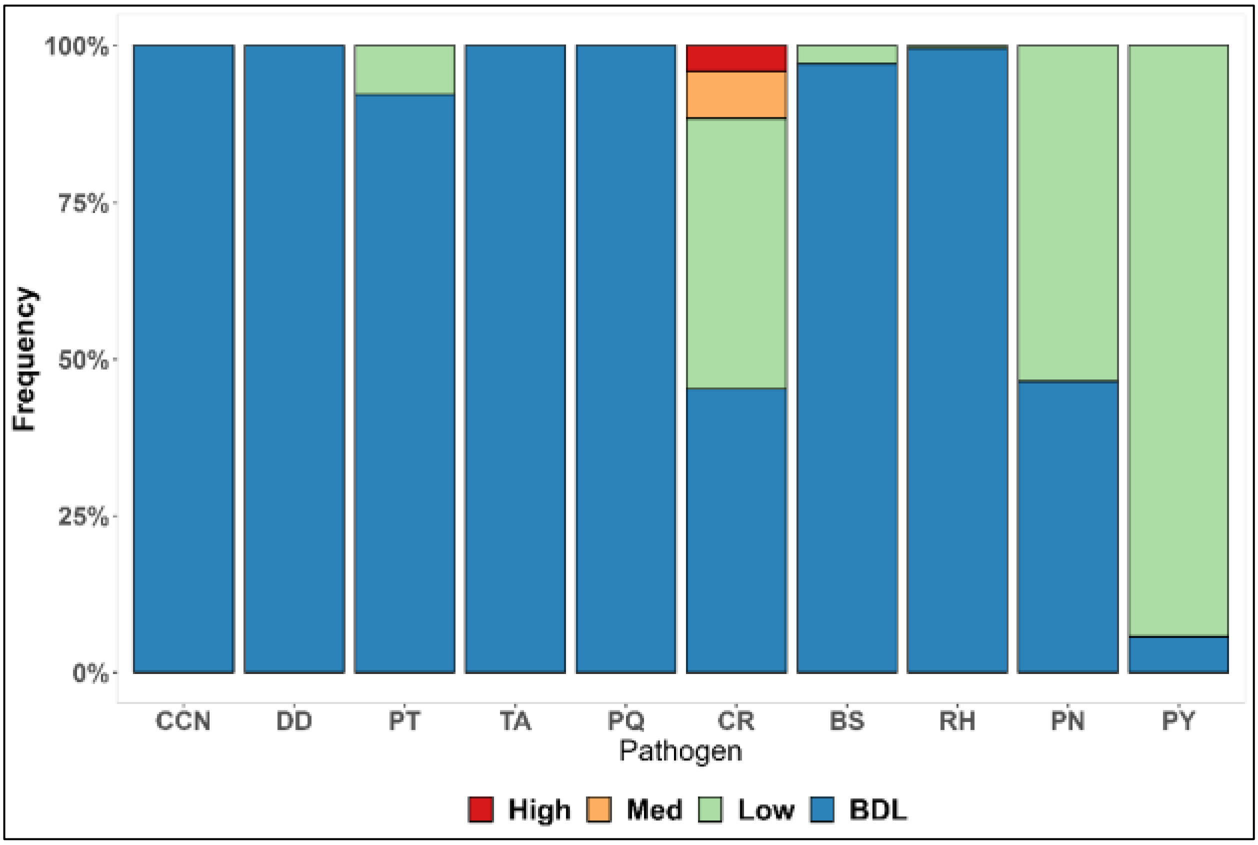

Figure 6. *Frequency of pathogen DNA concentration assays, taken in autumn, within PREDICTA B disease risk yield loss categories (BDL = below detection limit, Low, Med = medium, High), for CCN (cereal cyst nematode, H. avenae), DD (stem nematode, D. dipsaci), PT (P. thornei), TA (take-all, G. graminis var. tritici), PQ (P. quasitereoides), CR (crown rot, Fusarium spp.), BS (black spot, D. pinodes/P. pinodella), RH (R. solani AG-8), PN (P. neglectus) and PY (Pythium Clade F). Note Pythium (PY) and (PT) P. thornei tests are under development and categories represent population density not disease risk.*

Crop growth

Each species was cut at an appropriate date to reflect their peak biomass (Figure 7). These dates were:

- Multispecies 18/09/23
- Canola, Lucerne, Pasture and Vetch 28/09/23
- Chickpea 11/10/23
- Wheat 12/10/23 to 02/11/23

Lucerne had two additional cuts prior to each mowing, though its biomass would not be commercially viable, mowing aids in weed control and reducing water use to improve summer survival.

Delayed wheat had almost 700 kg/ha less biomass at its peak compared to the May sown wheat. Vetch had over 3,600 kg/ha of biomass at its peak, prior to brown manuring, and far exceeded the other broadleaf crops and pasture legumes.

For the multi-species mix the dominant components at the time of peak biomass cuts were tillage radish and sub clover, with ~700 kg/ha and 650 kg/ha dry weight respectively; the other components with ~20 kg/ha dry biomass each. Within the multispecies mixture, the plants such as chicory grew after these cuts were taken. The site was mown later in the season but in future seasons would require mowing more than once to manage seed set and increase nutrient turnover.

Increased fertiliser nitrogen increased peak dry matter of wheat and canola but had little effect on the multi species mix or legumes (Figure 8).

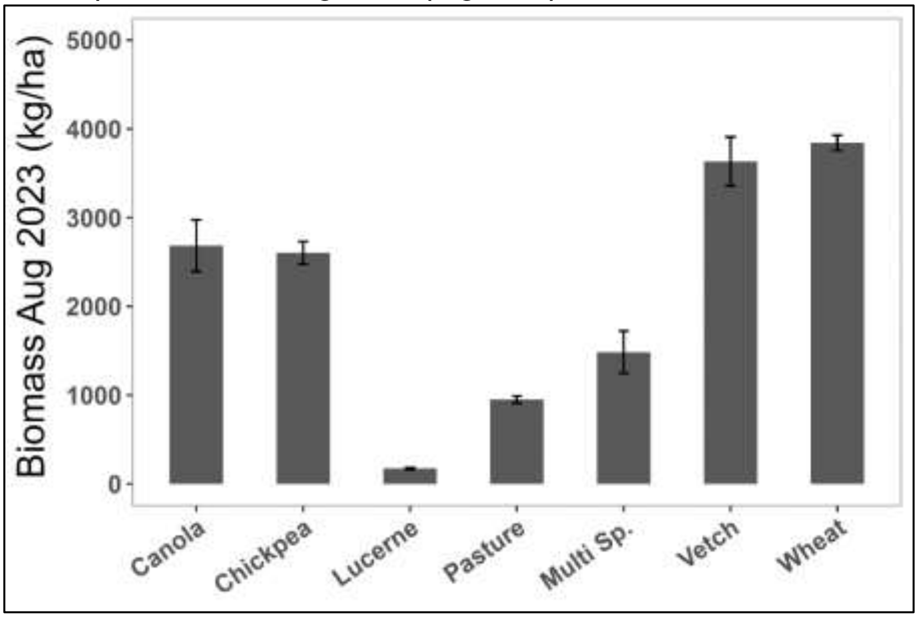

Figure 7. *Dry biomass near anthesis of each land use.*

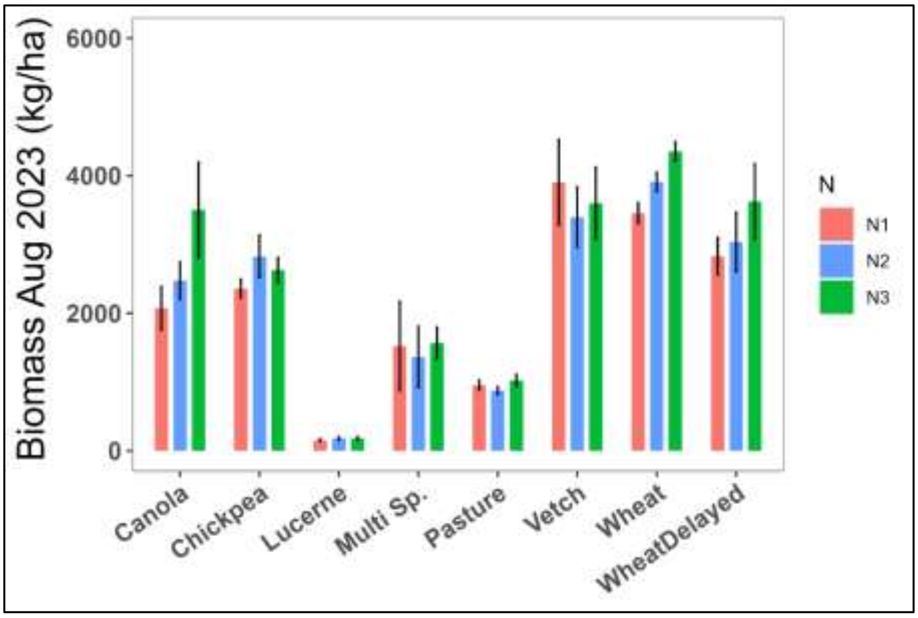

Figure 8. *Dry biomass near anthesis of each land use.*

Normalised Difference Vegetation Index (NDVI)

NDVI was measured over several dates in August and September and in general remained low due to the dry conditions and low plant densities (Figure 9). For example, typically wheat NDVI would be expected to peak at 0.6 or more. Most species showed relatively stable NDVI across the assessment period with some exceptions. Groundcover is the major factor driving NDVI and this was greatest in the vetch and pasture treatments as indicated by the higher NDVI. The vetch declined after mid-August due to dry conditions with the rapid decrease at the final assessment indicating the spray-topping (brown manure cover crop treatment) taking effect. The desiccation of the vetch was delayed due to the prevailing windy conditions at this time which threatened neighbouring plots. The NDVI of the pastures increased rapidly across the assessment period until early September which is commonly observed with annual pasture legumes such as medics. Canola was podding during these measurements and due to terminal drought stress, declined slightly in the NDVI. Chickpea had lower NDVI than vetch and pastures but gradually increased through the assessment period. May sown wheat NDVI declined while the June sown wheat increased converging to a low value of 0.2. The NDVI values for the multispecies were higher than expected considering the amount of biomass, with tillage radish likely contributing most to ground cover. Lucerne NDVI remained low throughout the year. For lucerne second year spring growth is expected to be the peak biomass production for this species, which can support a large root system and utilise deeper soil water (the purpose of this treatment).

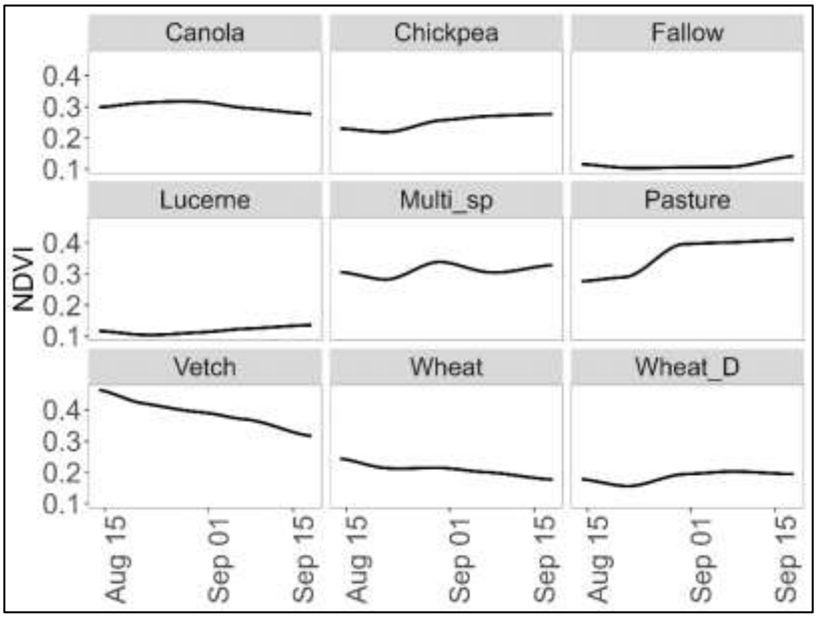

Figure 9. *NDVI of each land use, averaged across all treatments for each species from mid-August to mid-September. LSD 0.02.*

Yield

Grain yields were low overall due to dry seasonal conditions (Table 5, Figure 10). May sown wheat yielded 300 kg/ha more grain than the delayed (mid-June) wheat. Despite the early sowing, and establishment of canola, drought stress limited biomass of both canola and chickpea with grain yields averaging less than 400 kg/ha.

Table 5. *Yield of canola, lupin and wheat as effected by fertiliser nitrogen and sowing time.*

		N0 (0 kg/ha)		N2 (23 kg/ha)		N3 (64 kg/ha)		
Species	Sow time	Mean (kg/ha)	s.e.	Mean (kg/ha)	s.e.	Mean (kg/ha	s.e.	Mean (kg/ha)
Canola	Apr-14	337	18	382	13	437	17	385
Chickpea	May-05	381	10	407	11	403	13	397
Wheat	May-05	772	9	866	9	908	8	849
Wheat	Jun-15	564	17	446	28	633	18	548
Mean N		640		703		747		697

Note Mean N does not equal the mean of the different land used within Table 9 because there were a different number of plots of each land use.

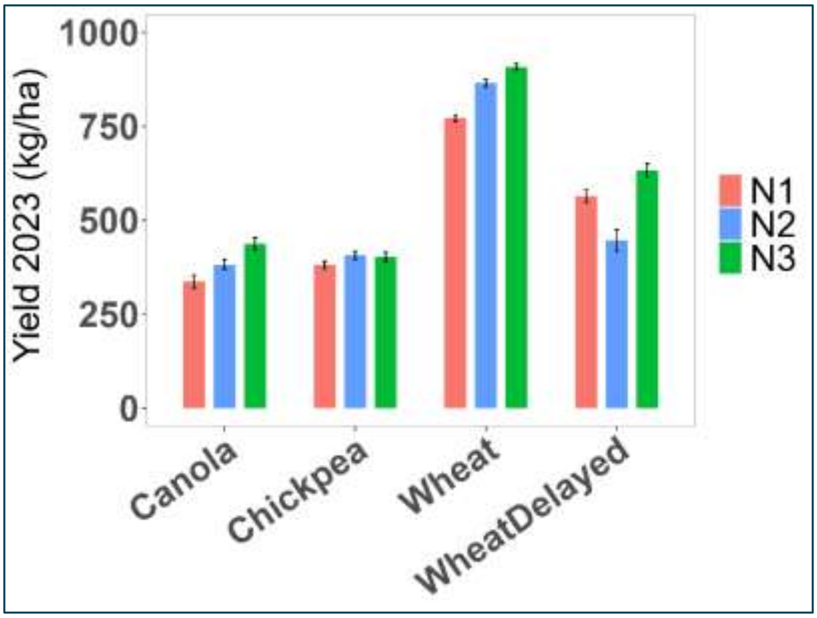

Figure 10. Yield of crop treatments at each nitrogen (N) level: N1= no n fertiliser, N2 = 23 kg/ha on wheat and canola, none for chickpea, N3 =64kg/ha on wheat and canola and none for chickpea.

Soil water post-harvest

Each species and the fallow were sampled from the N3 treatment. These were taken on 10 November prior to the site receiving any summer rainfall. These results showed an increase in soil moisture throughout the profile under fallow plots compared to the other treatments (Figure 11). Most species followed a similar pattern with moisture increasing as depth increased to 50 cm, with some variation in moisture at depths of more than 50 cm. Late sown wheat had used more moisture in the 0–50 cm depths than other species/treatments, however, it had one of the higher moisture contents below 50 cm. Soil water was measured in a small subset (fallow, wheat, vetch) in February to capture the declining soil water contributed from summer rainfall and all plots (n = 243) will be measured again at seeding.

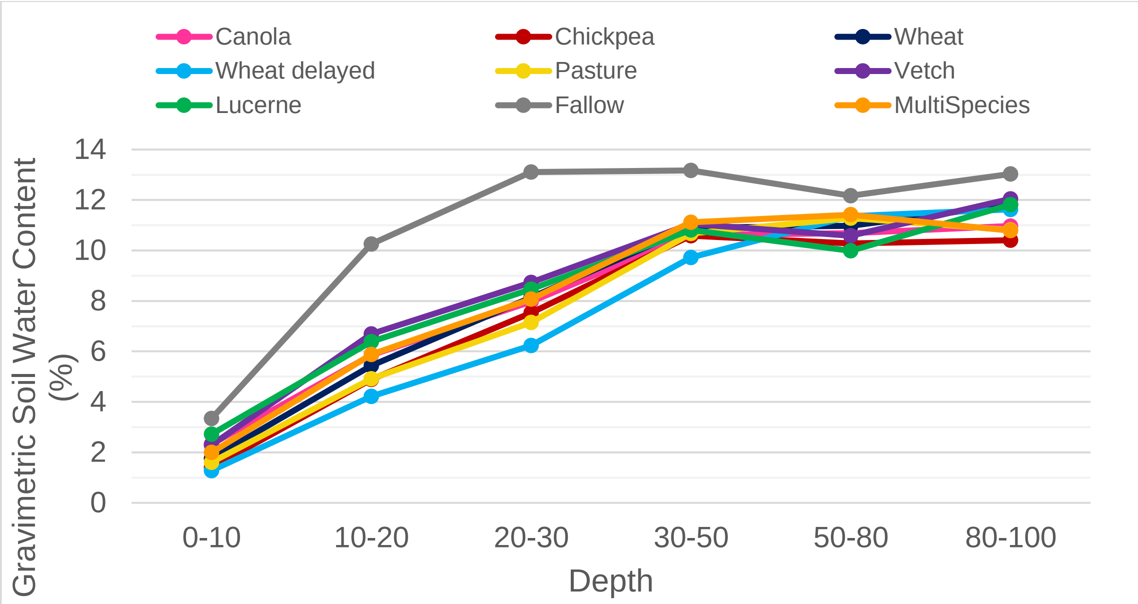

Figure 11. Gravimetric soil water content post-harvest.

Summary

The 2023 season was largely used to set up and characterise the Merredin long term trial site and collect baseline data. With the challenges of recruiting project members for Merredin, reducing the team's capacity, and the relatively dry season in 2023, planning and logistics were challenging with fewer germination opportunities and suitable soil sampling conditions, coupled with prolonged windy weather that increases the risk of damaging susceptible crops and pastures in the neighboring plots. All of this said, the rotations were established, and we have a good understanding of the site. The results from the dry season demonstrates the challenges for integrating break crops on heavy soils in the region. Additional measurements will be taken in 2024 to capture the legacy of the rotations.

Appendix A. Agronomic management summary.

Date	Crop	Crop Growth Stage	Event
14/04/2023	Canola, lucerne, vetch	Seeding	Seeding
05/05/2023	Wheat, Chickpea, multi species	Seeding	Seeding
15/06/2023	Delayed wheat	Seeding	Seeding
04/05/2023	Various	Pre seeding	Roundup Ultra Max (lt/ha), Rate: 2, Total: 9 Treflan (lt/ha), Rate: 2, Total: 9 Chlorpyrifos 500 (lt/ha), Rate: 0.2, Total: 0.9 Alpha Duo (lt/ha), Rate: 0.2, Total: 0.9
12/09/2023	Chickpea	Podding	Aviator Xpro (ml/ha), Rate: 0.5, Total: 0.5
28/07/2023	Canola	Vegetative	Roundup Ready with Plant shield 690 (gm/ha), Rate: 1.3, Total: 1.3
07/09/2023	Vetch	Flowering	Hammer (lt/ha), Rate: 0.05, Total: 0.05 Roundup Ultra Max (lt/ha), Rate: 3, Total: 3
28/08/2023	Canola	Podding	Transform (ml/ha), Rate: 0.1, Total: 0.1
31/07/2023	Wheat	All 540 wheat plots	Bromicide MA (lt/ha), Rate: 1.4, Total: 2.8 Adigor (lt/ha), Rate: 0.05, Total: 0.1 Chlorpyrifos 500 (lt/ha), Rate: 0.2, Total: 0.4 Axial (lt/ha), Rate: 0.6, Total: 1.2
31/07/2023	Chickpea	Vegetative	Uptake -Wetting agent (%/ha), Rate: 1, Total: 1 Factor (gm/ha), Rate: 100, Total: 100 Select (lt/ha), Rate: 0.5, Total: 0.5 Ammonium sulphate - Redox -Used as a Spray ADJUVANT (%/ha), Rate: 1, Total: 1 Chlorpyrifos 500 (lt/ha), Rate: 0.2, Total: 0.2 Aviator Xpro (ml/ha), Rate: 0.6, Total: 0.6
28/09/2023	Multi	Flowering	Chlorpyrifos 500 (lt/ha), Rate: 1, Total: 1
31/07/2023	Pasture	Vegetative	Uptake -Wetting agent (%/ha), Rate: 1, Total: 1 Select (lt/ha), Rate: 0.5, Total: 0.5 Chlorpyrifos 500 (lt/ha), Rate: 0.2, Total: 0.2 Ammonium sulphate - Redox - Used as a Spray ADJUVANT (%/ha), Rate: 1, Total: 1 Factor (gm/ha), Rate: 100, Total: 100
14/07/2023	Wheat and canola	Vegetative	Flexi N (lt/ha), Rate: 100, Total: 100
07/09/2023	Fallow	None	Hammer (lt/ha), Rate: 0.05, Total: 0.05 Roundup Ultra Max (lt/ha), Rate: 3, Total: 3

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Vetch variety and end use/legacy effects

Research team: Mark Seymour and India Warren-Hicks.

Key messages

- Volga was a reliable grain and dry matter choice in 2023.
- A new line 37107 performed well throughout WA and out yielded Volga at Wittenoom Hills.
- The dry spring impacted seed yield at all sites and there appeared to be no stored water following vetch cut for hay, manured or harvested for grain in 2023.
- Dry matter, seed yield and residual nitrogen varied widely between sites.
- Manure treatments left between 50 and 450 kg N/ha for following crops.
- Crops will be sown in 2024, to further investigate legacy effects from the 2023 treatments.

Background

The South Australian vetch breeding program has a small footprint in Western Australia. In most years there is only one germplasm evaluation trial in WA. With more farmers in WA growing vetch there is a demand for better local information on grain production, hay production and biomass at green/brown manuring time (early pod set). With support from DPIRD's Variety Sowing guide project we expanded the vetch variety testing to four sites – Wittenoom Hills, Merredin, Lake Grace and Northampton. At each site we tested 12 vetch lines and with support from the WAFS project we also included extra plots of Volga and RM4. The extra plots were either manured, cut for hay or harvested for grain in 2023 and in 2024 we will monitor the legacy effects for following cereals or canola.

Objectives

Evaluate vetch germplasm and determine legacy effects of vetch grown for grain, hay or manured for the following crop.

Location and site information

Table 1. *Trial information*

	Northampton	Merredin	Lake Grace	Wittenoom Hills
Latitude (dd)	-28.329011	-31.493562	-32.938584	-33.444466
Longitude (dd)	114.532797	118.227122	118.467531	122.152200
Soil type	Red loam	Sandy loam over loamy clay at 15cm	Gravelly duplex	Shallow sandy duplex (APSoil 462)
pH (0-10cm)	6.2	5.6	5.3	6.0
Sowing date	15 May	12 May	30 May	28 April
Emergence counts	14 June	-	-	23 May
Manure and Hay dates	8 September	9 September – Volga 27 September – RM4	2 September	21 September
Manure method	Brown manure	Brown manure	Green manure – whipper snipper	Green manure – whipper snipper
Maturity cuts	2 October	10 October	1 November	18 October
Harvest date	31 October	1 November	2 November	6 November
Soil water harvest	-	-	-	9 November

Methods

Variety trial – 12 lines (see *Table 2*), Blocking - Rep/ColRep, 4 replicates

End use trial – 2 lines (Volga, RM4), Blocking - Rep, 4 replicates

Treatments

Table 2. *Treatments – Variety trial.*

Treatment	Variety/Line	Days to Flowering*	Degree days to 50% flowering*
1	37107	119	1364
2	38397	122	1414
3	38818	118	1350
4	38819	119	1350
5	38849	116	1330
6	38864	119	1364
7	38866	119	1364
8	Morava	131	1513
9	Studenica	107	1219
10	Timok	119	1364
11	Volga	112	1274
12	RM4	137	1597

*As per Wittenoom Hills 2023

Table 3. *Treatments – End use trial.*

Treatment	Variety 2023	End use 2023	2024
1	Volga	Grain	Wheat or Canola
2	Volga	Manure	Wheat or Canola
3	Volga	Hay	Wheat or Canola
4	RM4	Grain	Wheat or Canola
5	RM4	Manure	Wheat or Canola
6	RM4	Hay	Wheat or Canola

Agronomy

Table 4. *List of inputs*

	Northampton	Merredin	Lake Grace	Wittenoom Hills
Fertiliser - seeding	AGNP 80 kg/ha		SOP 33 kg/ha + All Phos 66 kg/ha	Superphos 100 kg/ha
Micronutrients	28th July - EzyFlow Nano Zinc 1 L/ha + 1 $MnSO_4$ 4 kg/ha	9th August - SoluMANG 4 L/ha + EzyFlow Nano Zinc 1 L/ha		
Herbicide				
Knockdown	Glyphosate 1.2L/Ha		26th May - Glyphosate 450 2.5L/ha + Terrad'or 20g/ha + Hasten 1%	
IBS	15th May - Terbyne Xtreme 0.75 kg/ha + Reflex 1.0 L/ha + Edge (Propyzamide 90% ai) 0.75 kg/ha	11th May - Terbyne Xtreme 0.8 kg/ha + Reflex 1.0 L/ha + Rustler (Propyzamide 90% ai) 1.1 kg/ha	Reflex 1 L/ha + Terbyne Xtreme 860g/ha + Rustler 1 L/ha	28th April - Reflex (fomesafen 240g/L) at 1.5 L/ha + Ultro (carbetamide 90% ai) 1.7 kg/ha.
Post-emergent	21st June - Ecopar 800 ml/ha + Wetter 1000 200 mL/ha 6th July - Select Xtra 330 mL/ha + 180 g/ha Factor + 1% Hasten		28th June Clethodim 360 300mL/ha + Hasten 1% 23rd August - Clethodim 360 300mL/ha + Encode (500 g/kg butroxydim) 70g/ha + Hasten 1%	26th May - 330 mL/ha Clethodim + 160 g/ha Factor + 0.5% Uptake + 1% Ammonium Sulphate
Desiccation		18th October Reglone 3 L/ha		Roundup 1.7 L/ha + Sharpen WG 30 g/ha + Hasten 1%
Insecticide	Lorsban 200 mL/ha, Dominex 200 mL/ha		30th May - Chlorpyrifos 400mL/ha + Alpha Forte 120mL/ha	
	10th August – Trojan 30 mL/ha	6th July – Lemat (omethoate) 100 mL/ha	11th Nov - Trojan 30 mL/ha	
		29th Sept - Kaiso-240EG (lambda-cyhalothrin 250g/L) 38 g/ha		
Fungicide	10th August - Miravis Star 1 L/ha		30th August - Veritas Opti 350mL/ha	17th July Miravis Star 750 mL/ha
				9th August – Veritas 1 L/ha

Results

Northampton

The trial was sown 15 May and emerged evenly. Wild radish was widespread, and we were pleased to see that Ecopar applied post-emergent (21 June) did an excellent job in reducing the population. Despite low rainfall in 2023 the vetch grew well producing around 5 t/ha of dry matter. The most widely grown vetch in WA is Volga, and it produced equal top dry matter and grain yield (1.7 t/ha) at Northampton in 2023. The earliest flowering (Studenica) and the latest flowering (Morava) common vetch varieties produced the equal lowest dry matter and seed yield.

End use treatments were modified at this site. As the farmers was concerned about woolly pod vetch setting seed on his paddock, we converted the RM4 grain treatment into RM4 green manure (GM) which took place (8 September) – the same time as hay treatments were imposed on both Volga and RM4. Thus at Northampton with RM4 we can compare green and brown manuring.

Unfortunately, due to an unforeseen error the Volga BM treatments were not sprayed but were left to mature and then harvested for grain. Therefore, we will eliminate Volga BM from subsequent analysis in 2024.

Between the hay treatments being imposed on 8 September and harvesting of the rest of the plots on 31 October, less than 3 mm of rainfall was recorded at Northampton.

In terms of residual N for the following crop – RM4 manure treatments are calculated to have left 132 kg N/ha in above and below ground plant material. This is approximately 80kg N/ha more than that left behind by the Volga vetch harvested for grain treatments and approximately 90 kg N/ha more than the RM4 hay treatment. It will be interesting to evaluate how much of that plant-based N becomes available to the crop in 2024 and the scale of any increase in yield in 2024.

Merredin

Merredin had a drier than average growing season in 2023. April to October rainfall in 2023 of 118 mm was roughly half the long-term average of 222 mm.

The trial was sown into dry conditions on 11May, and the seed bed was quite cloddy. Rolling occurred post emergent and this helped flatten out the soil bed a little bit. Fortunately, June was a relatively wet month, but July–October rainfall was below average and, consequently, the vetch struggled to reach full canopy closure and growth and yields were limited.

The brown manure and hay treatments were imposed at the correct time prior to seed being set (Volga - Sept 5 and RM4 Sept 27), at which time they had both produced around 1–1.3 t/ha of top dry matter. The dry spring did not allow for much further growth with the highest final total dry matter vetch ranging from 1.2 to 2.3 t/ha. From the time of manuring/hay cutting Volga to harvest, the site received only 16 mm of rainfall and for RM4, between hay/manure treatments being imposed and harvest, only 2 mm was received. Hence the hay and manure treatments are unlikely to have led to much extra stored water. Due to the relatively low growth at Merredin in 2023 the biological nitrogen produced at this site was noticeably lower than other sites. The manure treatments are estimated to have left behind 50 to 60 kg N/ha for the following crop, whilst hay and grain treatments left less than 25 kg N/ha. Near sowing in 2024 we will core each plot to determine if there is any difference in stored water or mineral N.

Volga produced equal top seed yield at Merredin in 2023. The earlier flowering variety Studenica had its best performance in WA in 2023 at Merredin – elsewhere its yield was not competitive. The late flowering common vetch variety Morava was visually struggling to set pods in the dry spring and its seed yield reflected this struggle. In these tough conditions no new breeding line outperformed Volga in terms of seed yield or total dry matter production.

Lake Grace

Trial was sown 30 May, which was a bit later than we wanted given the good rainfall received at this site in April. The plants emerged well but initially there was a high population of volunteer grass, which was eventually controlled and by the end of August the trial looked good.

Volga at Lake Grace in 2023 produced equal top seed yield. The later maturing Morava and RM4 produced lowest seed yields.

Hay and manure treatments were imposed on 28 September at which time Volga had produced about 5.6 t/ha of dry matter and RM4, 3.5 t/ha. Between the hay and green manure treatments being imposed and the rest of the plots being harvested on 1 November the nearest weather station at Kulin received 2 mm of rain. Therefore, differences in stored water between the hay/manure treatments and harvested treatments are likely to be related to extra water extracted from the soil profile by plants continuing to grow with RM4 producing an extra 2.5 t/ha of biomass and Volga 2 t/ha from 28 September to harvest. Volga manure and hay treatments are calculated to have left behind twice as much nitrogen as their respective RM4 treatments. This is reflective of the relatively late sowing time on 30 May suiting RM4 which is more likely to have benefited from an April sowing. We will assess mineral N and soil water prior to sowing in 2024.

At the end of the year biomass was similar for all varieties, albeit our dry matter sampling indicated across-site/plot/sampling variability, and we probably need to move towards sampling more of the plot or mowing more of the plot for a more accurate dry matter assessment of hay and final dry matter production.

Wittenoom Hills

The trial was sown into excellent moisture conditions and all lines of vetch grew well. At the end of July nodulation was scored. The nodulation was excellent and even across the site with large fan nodules found on all plants. The site scored 7 on the pulse nodule rating system. There were no crown nodules, hence why no rating above 7 was given. Dr. Ron Yates (DPIRD) commented the absence of crown nodules could be due to the application of pre-emergent herbicides, as they prevent crown nodulation.

Three dry matter (DM) cuts were done on each variety throughout the season. The first cuts were taken at the end of July and had an average dry matter of 1.9 t/ha. The second was taken at the end of August with 4.8 t/ha. Lastly, harvest cuts were taken on18 October. At all three times there was no significant difference between varieties – probably expected in the good conditions at Wittenoom Hills in 2023. The Volga and RM4 samples from the July (DM1) and August (DM2) cuts were sent to Agrifood NSW for feed testing. RM4 DM2 sample had issues being analysed (high ash) so we did not receive results for the sample. Volga and RM4 sampled at the end of July had very similar results other than neutral detergent fibre with Volga at 30% and RM4 at 22.5%. This could be due to Volga being a faster maturing variety, whilst RM4 was still in its vegetative phase.

The trial was harvested on 6 November and all plots harvested well other than RM4; hence we have excluded RM4 from our statistical analysis of grain yield. The numbered SARDI lines in this trial all looked showy in the trial and yielded well with two of SARDI's numbered lines outyielding Volga at 1.9 t/ha. One of the SARDI lines which produced more yield than Volga was 37107. At Wittenoom Hills early in the year we observed 37107 to be one of the more vigorous lines. Stuart Nagel (SARDI vetch breeder) has noticed 37107 to have good performance on lower pH soils and our experience indicates it also performs well on more neutral to alkaline soils, and it shows promise as a good all-round grain and hay variety. 37107 is set for release to Australian growers in 2025.

End use trial

Due to high winds when we went to impose manure treatments, we changed brown manure treatments (BM) to green manuring (GM) using a whipper snipper. The GM and hay treatments were imposed on both Volga and RM4 on 21 September. At this stage Volga had been flowering for more than 35 days and RM4 only 10 days. Volga was starting to form small seeds in the pods (flat pod stage) whilst RM4 had flowers to small embryos. Volga had more time to go through stem extension than RM4 therefore the Volga had higher biomass 8 t/ha at GM/hay cutting than RM4 (6 t/ha). By the end of the year RM4 (10 t/ha) produced similar biomass to other vetches, including Volga (9.5 t/ha). Therefore, it seems reasonable to assume that if we delayed cutting/GM RM4 a bit later it may have had similar biomass to Volga – albeit in situations where farmers do not want RM4 to set seed they may well cut/manure at a similar stage to what we did in 2023 at Wittenoom Hills.

When we estimated the nitrogen balance from our end use treatments, we found green manuring Volga produced the highest biological nitrogen 461 kg N/ha. However, as we manured RM4 slightly early it left less biological N (257 kg N/ha). Because the RM4 was so late maturing and unproductive as a grain crop, we calculated that it produced the second highest nitrogen (291 kg N/ha) for following crops in 2024, leaving much more N behind compared to Volga harvested for grain (110 kg N/ha). Volga cut for hay left 154 kg N/ha - nearly double what RM4 left behind.

Between hay and GM treatments being imposed and the trial being desiccated for harvest, only 9 mm of rain fell. Therefore, the site was very dry when we cored to depth for nutrient and soil water assessment just after the trial was harvested. There was no plant available water in the soil profile, and we observed no differences between any of the treatments. We will assess the plots closer to sowing in 2024, and it will be interesting to see if the differences in ground cover (hay – barest, grain plots – in-between, green manure highest ground cover) will have any effect on maintaining soil water if we do receive rainfall over the summer months.

As expected, at harvest the soil cores showed no apparent differences between mineral nitrogen (mg/kg). Hopefully we will pick up some differences closer to seeding in 2024 as the biological nitrogen becomes mineralised.

Rainfall

***Table 5**.* *Monthly and seasonal rainfall 2023 for vetch sites in 2023 – long term averages in parentheses.*

	Northampton	Merredin	Lake Grace[1]	Wittenoom Hills
Jan	7	8	3	9
Feb	10	0	0	8
Mar	16	23	30	11
Apr	27	35	68	54
May	42	10	8	15
Jun	66	53	93	114
Jul	66	15	16	26
Aug	64	22	43	43
Sep	30	17	25	22
Oct	18	2	2	17
Nov	12	14	14	16
Dec	5	1	0	9
Annual	211 (363)	198 (326)	309 (370)	344 (484)
April to Oct	199 (312)	153 (245)	255 (287)	291 (356)
May to Oct	194 (285)	118 (222)	187 (268)	237 (317)

1 – Kulin rainfall used for Lake Grace

Table 6 *Hay dry matter of vetch (t/ha) in 2023 .*

	Northampton (8 September)	Merredin (9 Sept – Volga and 27 Sept RM4)	Lake Grace (28 Sept)	Wittenoom Hills (18 Sept)
RM4	5.1	1.3	3.5	5.9
Volga	5.2	1.0	5.7	8.0

Yield

Table 7. *Seed yield (t/ha) of vetch in 2023.*

Variety/Line	Northampton		Merredin		Lake Grace		Wittenoom Hills	
37107	1.6	cde	0.41	b	1.0	def	2.1	d
38397	1.4	bcd	0.43	b	0.8	c	1.8	b
38818	1.6	de	0.44	b	0.9	cd	2.0	cd
38819	1.6	de	0.47	b	1.1	fg	1.9	c
38849	1.6	de	0.41	b	1.0	def	2.0	cd
38864	1.5	bcde	0.39	b	1.0	def	2.0	cd
38866	1.5	bcde	0.39	b	1.0	ef	2.1	d
Morava	1.0	a	0.17	a	0.7	b	1.5	a
RM4	0*	-	0.23	a	0.4	a	1.3*	-
Studenica	1.4	b	0.45	b	0.9	cde	1.8	b
Timok	1.4	bc	0.42	b	1.0	cde	1.9	c
Volga	1.7	e	0.39	b	1.2	g	1.9	c
P	<0.001		<0.001		<0.001		<0.001	
LSD	0.2		0.11		0.1		0.1	

* Due to poor harvestability - RM4 not included in seed yield analysis.

Table 8. *Total dry matter of vetch at maturity (t/ha) in 2023.*

Variety/Line	Northampton (2 October)		Merredin (10 October)		Lake Grace (1 Nov)		Wittenoom Hills (18 October)
37107	5.9	c	2.0	def	7.8	a	10.0
38397	4.7	ab	2.3	f	7.5	a	9.4
38818	5.5	bc	1.7	abcde	6.8	a	9.5
38819	5.2	bc	2.0	ef	7.0	a	10.0
38849	5.0	bc	1.7	bcde	6.4	a	8.3
38864	5.1	bc	1.3	ab	7.2	a	9.7
38866	5.0	bc	1.8	bcde	6.2	a	10.0
Morava	4.4	ab	1.5	abc	6.0	a	10.2
RM4	-#		1.3	a	5.9	a	10.1
Studenica	3.7	a	2.1	ef	7.6	a	8.9
Timok	4.9	bc	1.6	abcd	7.1	a	8.6
Volga	5.2	bc	1.8	cdef	7.4	a	9.5
P	0.042		0.002		0.789		0.836
LSD	1.1		0.5				

RM4 removed from trial earlier in season to avoid seed set as per farmers instructions.

Table 9. *Nitrogen balance – Total Nitrogen (kg N/ha) following 2023 vetch treatments Note- root factor added as per Peoples et al. (2017), Unkovich and Pate (2000) and Unkovich et. al (2010). Hay treatments N balance estimates from below ground factor only.*

	Northampton	Merredin	Lake Grace	Wittenoom Hills
RM4 Grain	-#	36	117	318
Volga Grain	69	48	96	169
RM4 manure	132	47	150	252
Volga manure	-#	57	318	453
RM4 Hay	42	3	48	81
Volga Hay	24	18	102	145

*Root multiplication factor for vetch = 1.47 (studies indicate 32% of total N produced by vetches is below ground at maturity). # Treatment did not occur.

Note usually 40% of RON total is available in the following year.

Table 10. *Plant available soil water (mm) in top 100cm at Wittenoom Hills (9th November 2023).*

End use	PAWC (mm)
RM4 Grain	1
Volga Grain	0
RM4 BM	1
Volga BM	0
RM4 Hay	0
Volga Hay	1

Conclusions

All sites experienced a dry May, wet June and dry spring. Plant growth varied widely between sites with Merredin struggling to produce 2 t/ha of dry matter and seed yields less than 0.5 t/ha. In terms of overall plant growth, Northampton and Wittenoom Hills looked good all year whilst Lake Grace was the surprise package and, after a slow start, continued to look more impressive as the season went on. Plant biomass at maturity ranged from 5 t/ha at Northampton, 7 t/ha at Lake Grace, peaking at 9–10 t/ha at Wittenoom Hills. However, the dry spring impacted seed yield at all sites with harvest index ranging from as low as 13% at Lake Grace, 20% at Wittenoom Hills, 22% at Merredin and 27% at Northampton.

Given the wide range in biomass in the experiments we calculated a wide range in the biological nitrogen likely to be left over for following crops from a low of 15 kg N/ha following RM4 hay at Merredin to 461 kg N/ha following manured Volga at Wittenoom Hills.

In 2024 we will sow cereals or canola (site dependent) on top of the 2023 plots, with the plots being big enough to include at least 2 nitrogen application treatments. In 2024 we will sample the soil near sowing and the crops during the growing season to assess nitrogen availability and uptake and attempt to provide a more detailed nitrogen balance. Of particular interest will be the comparison between manure and hay treatments to see if the extra N left behind after manuring can lead to extra yield in 2024. Coring at Wittenoom Hills after harvest indicated the soil was completely dry after all treatments. The dry spring in 2023 may limit treatment differences in stored water at the other three sites. However, it is possible the manure treatments may form a better mulch and help capture and retain summer rain, and we will core all sites close to sowing in 2024 to measure any differences.

Volga consistently produced equal top yields at most WA sites in 2023 and appears to be a reliable choice for both grain and dry matter production. At the majority of sites new breeding lines matched Volga for yield and at Wittenoom Hills two lines 37107 and 38866 produced slightly higher yields than Volga. SARDI vetch breeder Stuart Nagel advised one of these lines (37107) is set to be released to growers in 2025. Stuart has seen 37107 perform well on lower pH soils and farmers who were shown it at WA field days in 2023 appeared keen to try some once it is available.

References

Peoples, M.B., Swan, A.D., Goward, L., Kirkegaard, J.A., Hunt, J.R., Li, G.D., Schwenke, G.D., Herridge, D.F., Moodie, M., Wilhelm, N. and Potter, T., (2017). Soil mineral nitrogen benefits derived from legumes and comparisons of the apparent recovery of legume or fertiliser nitrogen by wheat. *Soil Research*, *55*(6), pp.600-615.

Unkovich, M. J., and Pate, J. S. (2000). An appraisal of recent field measurements of symbiotic N2 fixation by annual legumes. *Field Crops Research*, *65*(2-3), 211-228.

Unkovich, M. J., Baldock, J., and Peoples, M. B. (2010). Prospects and problems of simple linear models for estimating symbiotic N 2 fixation by crop and pasture legumes. *Plant and Soil*, *329*, 75-89.

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Measuring the break crop effect of safflower on wheat in comparison to chickpea.

Researchers: Grace Williams, Dayna Hutchinson.

Key messages

- Crop type preceding wheat had a larger impact on wheat crop growth, grain yield and quality than in season nitrogen rate.
- Safflower had limited break crop effects in a subsequent wheat crop, with equivalent results in most crop growth, grain yield and quality parameters as wheat following wheat.
- Yield of wheat after chickpea was ~ 0.5 t/ha greater than wheat after safflower or wheat.
- In season nitrogen rate had minimal influence on the break crop effect of safflower or chickpea in a subsequent wheat crop. Interactions between break crop type and nitrogen rate were also minimal, likely a consequence of the dry 2023 season.
- The trial will be sown again in 2024 to see if break crop effects persist.

Background

Super high oleic (SHO0 safflower emerged in recent years as a potential new crop option for Western Australian broadacre farming systems. Growers in the eastern wheatbelt had specific interest in this new type of safflower due to its tolerance to drought, heat, sodicity and salt as well as low input requirements and the suitability of current standard machinery used in producing cereals/canola for managing safflower.

As safflower would be a new species in an eastern wheatbelt rotation, it also represents opportunities as a break crop. This may include the potential to reduce cereal diseases, as a non-crop host. Safflower may also be able to utilise or improve soil resources not currently accessed by traditional crops, such as using its deep tap root to access unused sub-soil moisture and create better soil structure from root channels. This concept needs investigation as most knowledge of growing safflower in Australia comes from its use as a minor crop in the eastern states rather than Western Australian environments or systems.

Observations from growers trialling safflower in the eastern wheatbelt in 2022 raised concerns with its suitability. Issues with the crop during the season included low yields, likely due to diseased seed supplies, limited agronomic packages, difficulty harvesting with optimum timing extending harvest beyond the typical period for the eastern wheatbelt.

A small plot trial was conducted at the Merredin Research Station in 2022 to investigate and compare the production of safflower to an alternative break crop option, chickpea, and the most widely grown crop in the eastern wheatbelt, wheat. This created an opportunity to investigate further the potential break crop effects of safflower on a subsequent wheat crop in the 2023 season.

Objectives

- Investigate the effects of growing break crops of SHO safflower or chickpea in the eastern wheatbelt on growth, grain yield and quality of a subsequent wheat crop.
- Determine if break crop effects of SHO safflower or chickpeas are influenced by increasing nitrogen rates in the following wheat crop.

Methods

In July 2022, a randomised small plot trial was sown on a clay loam soil at the Merredin Dryland Research Station. This trial contained three treatments, representing three different crop types: SHO safflower, chickpea cv. Captain and wheat cv. Scepter, with each treatment replicated three times. The trial was blocked by crop type for management purposes (Figure 1). All plots received 80 kg/ha compound fertiliser (Agras) at seeding. These plots were harvested in early January 2023.

Figure 1: *Trial design 2022.*

On 22June 2023, Vixen wheat was sown across all plots under 5 different nitrogen rates, 0 kg/ha, 12.5 kg/ha, 25 kg/ha, 50 kg/ha and 100 kg/ha. In combination with the crop types grown in 2022, this created 15 treatments in 2023 (Table 1). The trial design for 2023 appears in Figure 2.

Table 1. *2023 trial treatments.*

Treatment	Crop Sequence	Nitrogen Rate (kg/ha)
1	Wheat on Wheat	0
2	Wheat on Wheat	12.5
3	Wheat on Wheat	25
4	Wheat on Wheat	50
5	Wheat on Wheat	100
6	Wheat on Safflower	0
7	Wheat on Safflower	12.5
8	Wheat on Safflower	25
9	Wheat on Safflower	50
10	Wheat on Safflower	100
11	Wheat on Chickpea	0
12	Wheat on Chickpea	12.5
13	Wheat on Chickpea	25
14	Wheat on Chickpea	50
15	Wheat on Chickpea	100

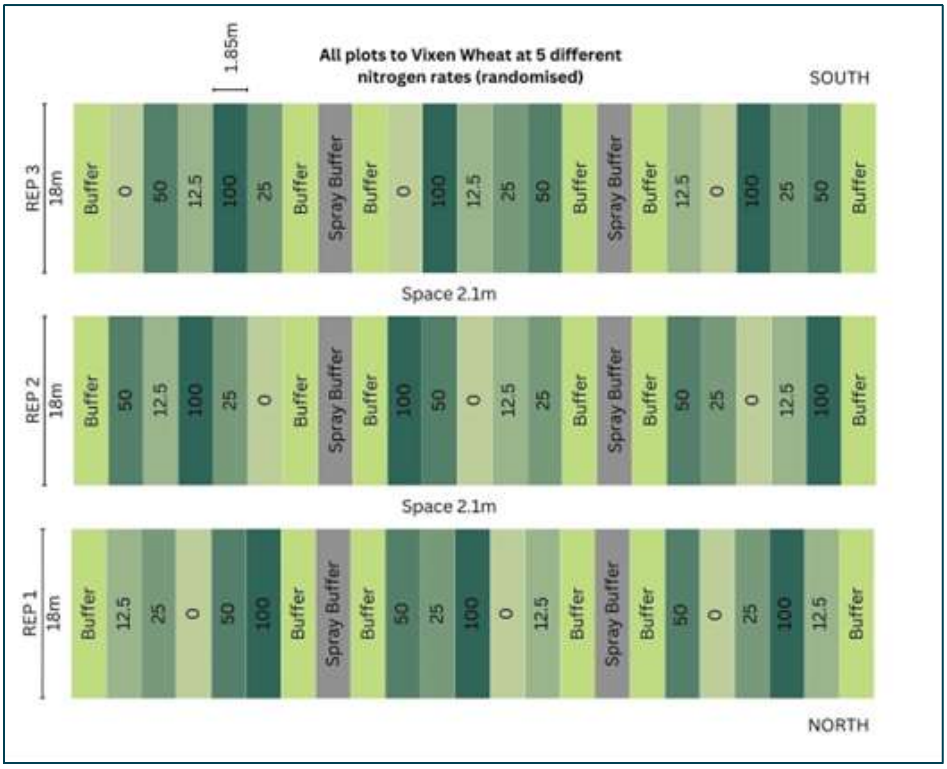

Figure 2: *Trial design 2023.*

Measurements were conducted throughout the season to collect data on wheat growth. This included NDVI, whitehead counts, harvest index, grain yield and grain quality (protein, grain weight, screenings). Data analysis was conducted using GenStat Version 22 software.

Location

	Latitude (dd)	Longitude (dd)	Nearest town
Trial Site	-31.503899	118.214320	Merredin WA

Results

The 2022 growing season in Merredin had very favourable conditions with decile 9 rainfall (359 mm annual total, 269 mm growing season total). Due to the maturity length of the safflower, the trial plots were not harvested until January 2023. At harvest, safflower yielded an average of 1.18 t/ha, chickpea averaged 1.31 t/ha and wheat averaged 2.73 t/ha (Figure 1).

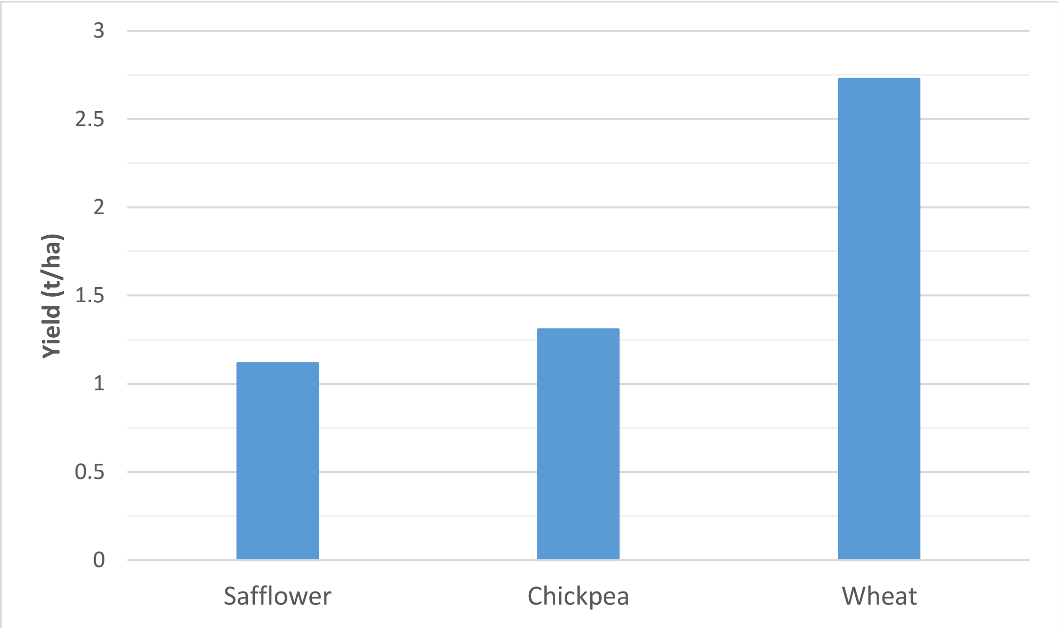

Figure 3: *Grain yield (t/ha) of Safflower, Chickpea and Wheat grown in first year of trial in 2022, harvested January 2023.*

Rainfall for Merredin during 2023 was well below average, with the area receiving a total of 203 mm for the year, with 158 mm of this falling in the April to October growing season. This equated to decile 1 rainfall for both the growing season (April–October) and year in total (January–December) (Figure 4).

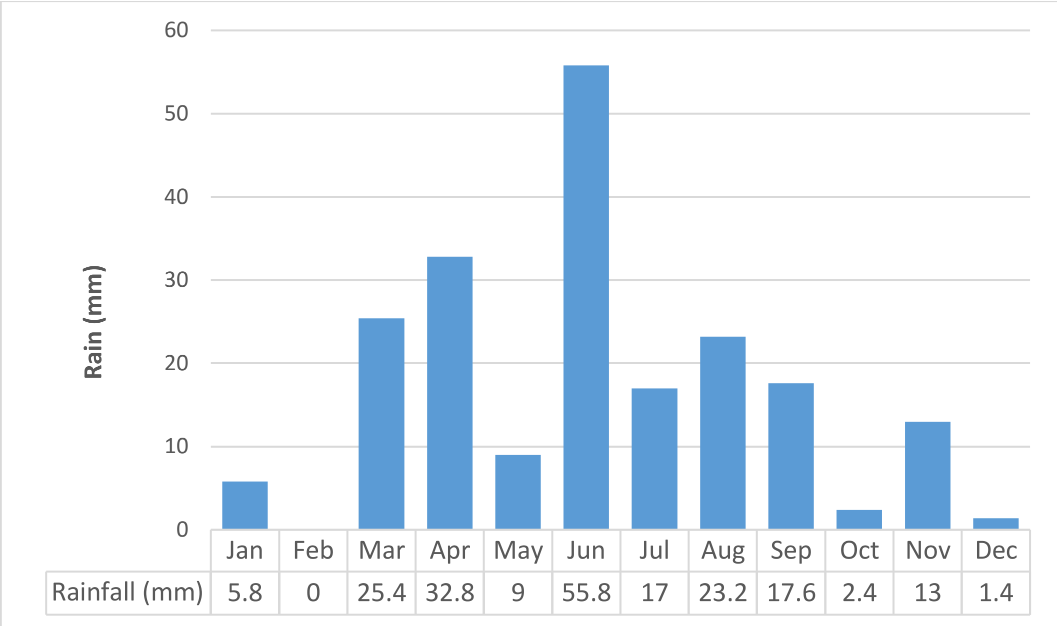

Figure 4: *Total monthly rainfall (mm) for Merredin, 2023. Source: DPIRD Weather Station ME003.*

NDVI measured on 6 September showed a significant difference in average NDVI readings between either break crop type or nitrogen treatment (Figure 5). Break crop type irrespective of nitrogen showed a significant difference between all crops, with wheat following safflower having the lowest NDVI and wheat following chickpea the highest, potentially due to differences in residual soil N from the different crops. A rate response was also evident in increasing NDVI reading when considering nitrogen treatment alone with nitrogen rates at 50 kg/ha or above.

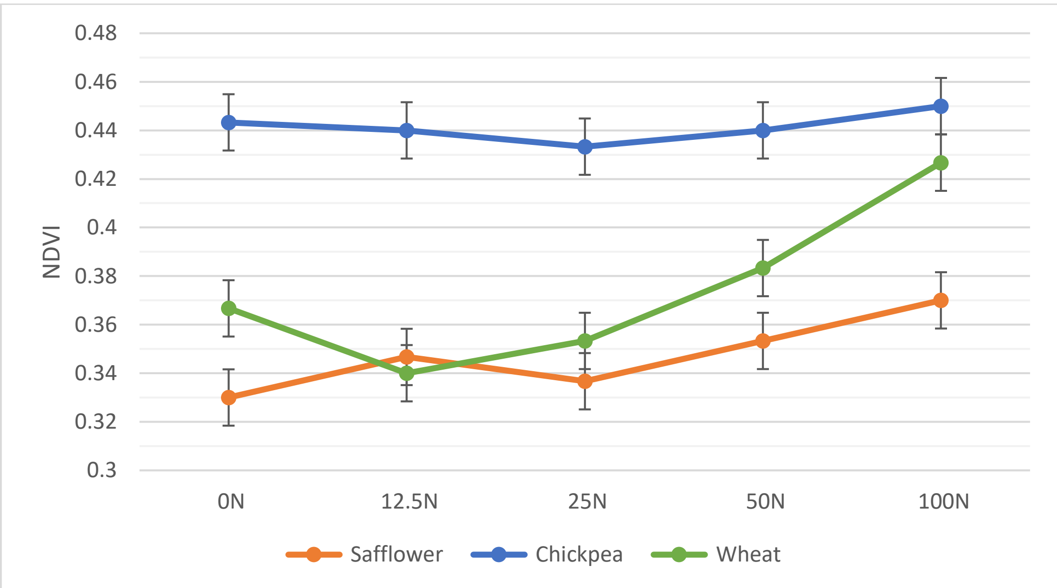

Figure 5: *NDVI readings of Wheat following Safflower, Chickpea or Wheat at different nitrogen rates measured on 06/09/23 using a Trimble Greenseeker. Error bars represent significant difference between crop type (F pr. <0.001, LSD 0.0232).*

For whiteheads when looking at break crop type independent of nitrogen rate, no crop type was significantly different to the others. However, increasing nitrogen rate significantly increased whitehead numbers irrespective of crop type. The 100N treatment averaged across crop types had significantly higher whiteheads than the 25N treatment, however, was similar to all remaining rates. Some crop type x nitrogen interactions were observed in whitehead numbers, where 100N Wheat had the highest number of whiteheads overall and was significantly higher than 0N wheat, 0–25N chickpea and 25N safflower.

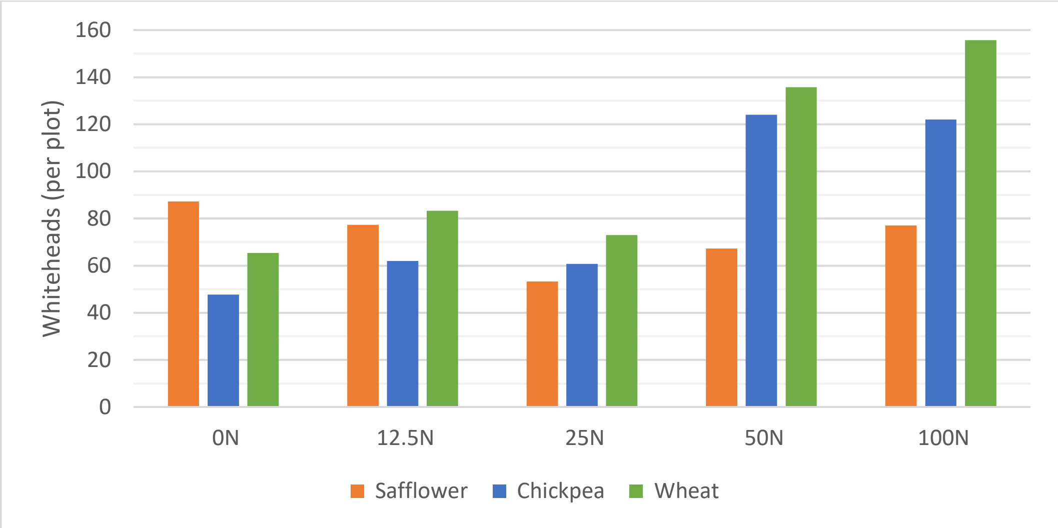

***Figure 6**: Total number of whiteheads per plot in Wheat following Safflower, Chickpea or Wheat at different nitrogen rates measured on 06/10/23.*

The number of wheat heads at maturity was significantly affected when looking at average number between crop types irrespective of nitrogen treatment (Figure 7). Similar to the trends seen in NDVI, significant differences were evident between the three crop types with wheat following safflower having the lowest number of heads and wheat following chickpeas the highest. There was also a small response to nitrogen treatment evident, where the 100N treatment (irrespective of crop type) had an increased number of heads, however, this was only significant in comparison to the 12.5N treatment.

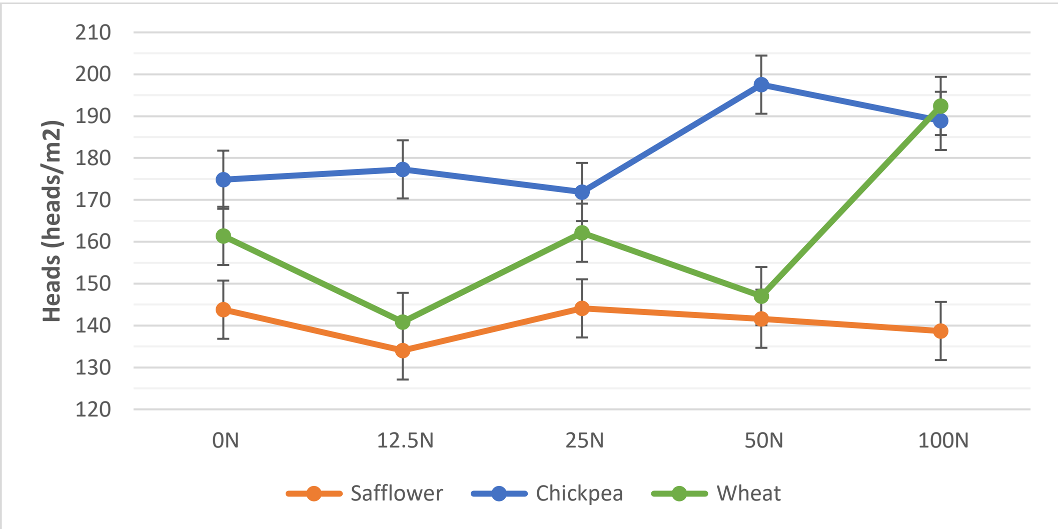

***Figure 7:** Total number of heads per square meter in Wheat following Safflower, Chickpea or Wheat at different nitrogen rates measured on 02/11/23. Error bars represent significant difference between crop type (F pr. 0.021, LSD 13.89).*

Wheat following chickpea had significantly higher harvest index compared to the other crop type treatments with a considerable increase at the 50N nitrogen rate (Figure 8). No significant differences were found between nitrogen rates or when crop type and nitrogen treatment were combined.

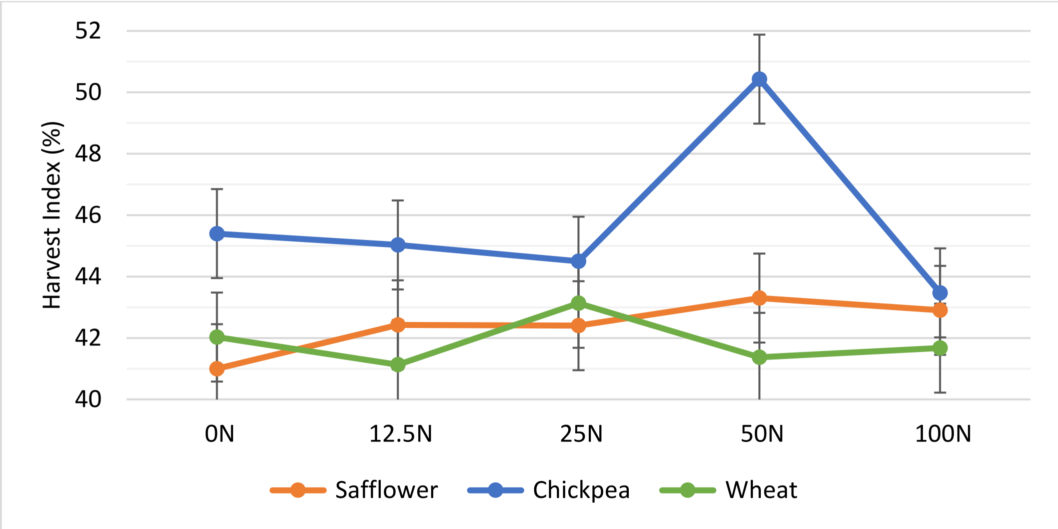

Figure 8: *Harvest Index of Wheat following Safflower, Chickpea or Wheat at different nitrogen rates measured on 02/11/23. Error bars represent significant difference between crop type (F pr. 0.021, LSD 2.898).*

Wheat yield was significantly higher following chickpea compared to safflower or wheat, with up to 579 kg/ha yield benefit (Figure 9). No yield effect was observed between nitrogen rates across the three crop types combined, nor was it significant when looking at each crop type individually. This was despite a decline in yield at the highest N rate for chickpea but not for wheat grown after safflower or wheat. It is unlikely nitrogen responses would have been evident in grain yield in the 2023 season due to the lack of rainfall throughout the growing season limiting yield.

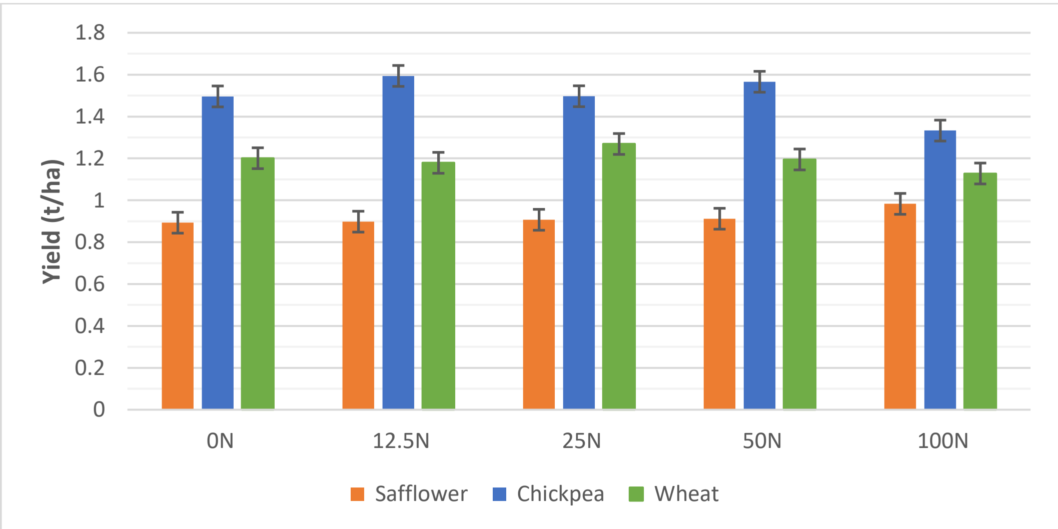

Figure 9: *Harvested grain yield (t/ha) of wheat following safflower, chickpea or wheat at different nitrogen rates measured on 16/11/23. Error bars represent significant difference between crop type (F pr. <0.001, LSD 0.0998).*

Irrespective of nitrogen treatment, wheat following safflower had significantly higher protein of 13.7% compared to either chickpea or wheat which averaged 12.9% and 12.4% respectively (Figure 10). In contrast to the observations seen in grain yield, a slight rate response was evident when looking at nitrogen rate alone (however not when looking at break crop x nitrogen), with a significant increase seen at 50N and again at 100N. No significant differences in protein were seen for the crop type x nitrogen interaction, although protein looked to be less responsive to N rate after chickpea than after wheat or safflower.

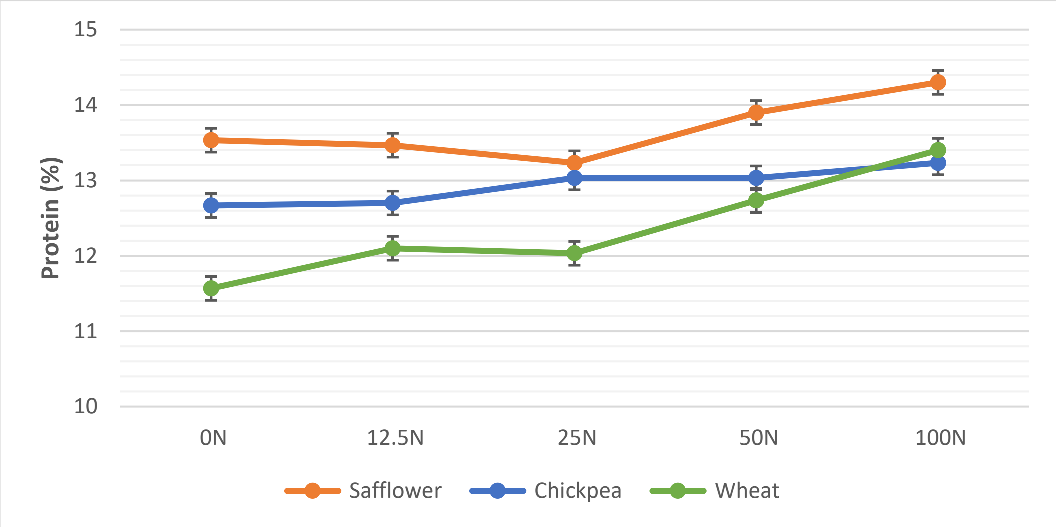

Figure 10: *Grain protein (%) of Wheat following Safflower, Chickpea or Wheat at different nitrogen rates. Error bars represent significant difference between crop type (F pr. <0.001, LSD 0.316).*

Hectolitre weight differed significantly due to break crop type, with wheat following chickpea having a higher average hectolitre compared to the other two treatments (Figure 11). This suggests plumper grain was produced in wheat following chickpea which was confirmed by a significant increase in 1000 seed weight for wheat following chickpea compared to the other two crop treatments (Figure 12). No significant differences were observed in either of these parameters for nitrogen rate or crop type x nitrogen rate.

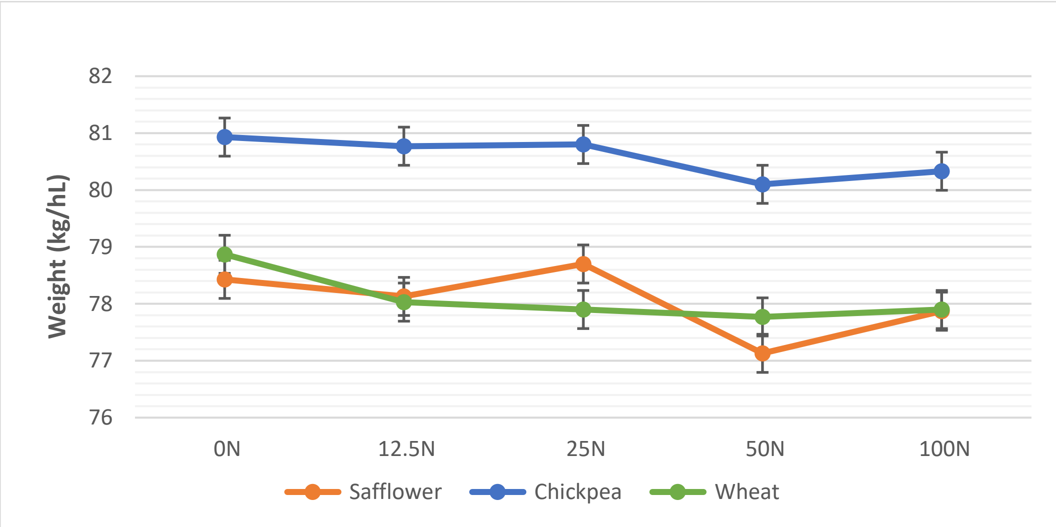

Figure 11: *Grain hectolitre weight (kg/hL) of Wheat following Safflower, Chickpea or Wheat at different nitrogen rates. Error bars represent significant difference between crop type (F pr. <0.001, LSD 0.67).*

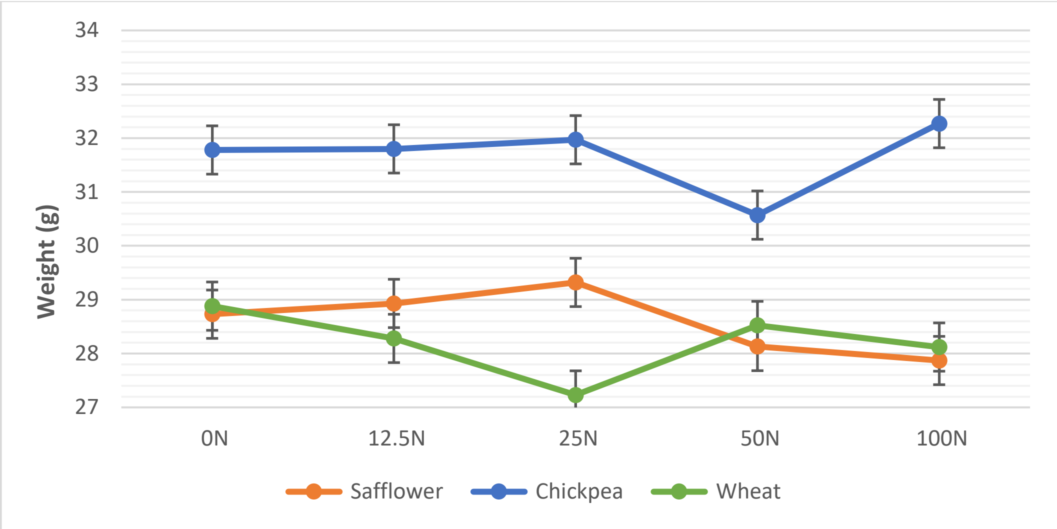

Figure 12: *Weight of 1000 seeds (g) of Wheat following Safflower, Chickpea or Wheat at different nitrogen rates. Error bars represent significant difference between crop type (F pr. <0.001, LSD 0.897).*

Similar to other grain quality parameters measured a significant influence on wheat grain screenings was seen by crop type, however surprisingly not in nitrogen rate or crop type x nitrogen. Screenings significantly increased in wheat following safflower and, to a greater extent, wheat following wheat compared to chickpea. This supports observations from hectolitre and seed weight which correspond to plumper grain in wheat following chickpea.

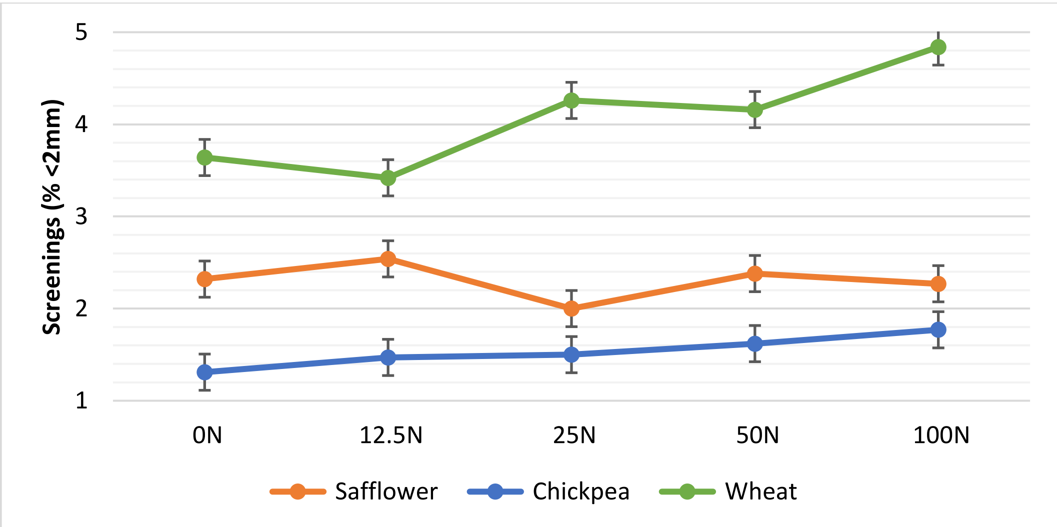

Figure 13: *Screenings (%) less than 2mm from hectolitre measure of Wheat following Safflower, Chickpea or Wheat at different nitrogen rates. Error bars represent significant difference between crop type (F pr. <0.001, LSD 0.393).*

Summary

In the favourable 2022 season wheat yielded substantially more than safflower or chickpea. In 2023 wheat grown after chickpea yielded around 0.5 t/ha more than wheat grown after wheat or safflower. This was a result of a greater number of heads and larger grain after chickpea. 2023 was a dry year and there were few responses to nitrogen.

Despite many significant differences in grain quality which favoured wheat following chickpea, wheat following safflower would have achieved a higher receival grade through the CBH group (Western Australia's grain receival and handling co-operative). This treatment met the requirements for the H1 grade, rather than the H2 grade met by the wheat following wheat or chickpeas, due to its protein levels above 13% and would have attracted a higher premium.

This trial will be resown again in 2024, as it is likely that carryover effects from break crops may persist beyond the dry 2023 season.

Acknowledgements

The original trial was instigated by Greg Shea in 2022, report reviewed by Marty Harries.

Chickpea legacy effects at Doodlakine: Nematodes

Researchers: Mark Seymour (DPIRD Crop Science and Grain Production, Esperance) and Carla Wilkinson (DPIRD Crop Protection - Nematodes, South Perth).

Key messages

- New provisional root lesion nematode (RLN), *Pratylenchus neglectus*, resistance ratings for chickpea cultivars are MS to MR – which is more resistant than Scepter wheat (S).
    - Inclusion of chickpea into existing wheat dominant rotations in Western Australia is likely to reduce the risk of damage to a following cereal crop from *P. neglectus* nematode.
    - Chickpea varieties more resistant to *P. neglectus* can be used to manage nematode populations in infested paddocks.
    - Starting levels of *P. neglectus* in Scepter wheat in 2023 were low and not expected to cause yield loss (SARDI Broadacre Soilborne Disease Manual)
- In 2022 chickpea grew well and produced acceptable yield of ~ 1.3 t/ha.
- In 2023 wheat yield after chickpea was 300 kg/ha higher than wheat yield following wheat or barley
    - Similar yield gains were found following fallow.
    - Chickpea-wheat sequence produced higher gross margins than fallow-wheat.

Background

In 2022 we conducted an experiment that looked at the multiplication rate of *Pratylenchus neglectus* in varieties of wheat, barley, triticale, chickpea and under fallow on a grower property near Doodlakine. By the end of 2022 the *P. neglectus* levels ranged from 2 nematodes/g of soil under fallow to 6 nematodes/g soil under Scepter wheat. In 2023, we evaluated the effect of the range of *P. neglectus* levels on the yield and nematode multiplication of Scepter wheat following the 2022 cropping treatments. We also evaluated the economics of a chickpea-wheat rotation versus wheat- wheat, barley-wheat and fallow-wheat rotations.

Objectives

Evaluate the effect of the crop species and fallow on nematode levels, yield and financial returns for a following wheat crop in a low rainfall environment.

Location and site information

Location; decimal degrees; -31.608900, 117.877500.

Soil type red loam

Table 11 *2022, 2023 and long-term average monthly rainfall (mm) at Doodlakine.*

	2022	2023	Mean
Jan	0	1	19
Feb	0	0	15
Mar	53	15	17
Apr	32	42	21
May	32	12	34
Jun	41	45	37
Jul	36	13	41
Aug	40	27	37
Sep	39	18	22
Oct	23	1	17
Nov	10	23	17
Dec	3	10	13
Annual	310	206	280
May to Oct	211	114	186

Table 212. *Soil test CSBP 2023 (8 days after sowing in Wheat N0 2023) – Chickpea 2022 plots and N tests for Barley 2022.*

		Depth (cm)			
Depth		0-10	10 to 30	30 to 50	50 to 110
Colour		DKBR	BR	LTBR	LTBR
Gravel	**%**	5	5	5-10	5-10
Texture		2.5	2.5	2.5	2.5
Ammonium Nitrogen	**mg/kg**	2	3	< 1	< 1
Nitrate Nitrogen	**mg/kg**	8	4	3	4
Phosphorus Colwell	**mg/kg**	12	2	< 2	< 2
Potassium Colwell	**mg/kg**	684	636	846	1050
Sulfur	**mg/kg**	5.3	4.6	5.6	39.8
Organic Carbon	**%**	0.37	0.23	0.13	0.12
Conductivity	**dS/m**	0.09	0.14	0.355	0.811
pH Level (CaCl2)		6.7	8	8.3	8.6
pH Level (H2O)		7.5	9	9.8	10.1
DTPA Copper	**mg/kg**	0.7	0.51	0.64	0.75
DTPA Iron	**mg/kg**	12.1	6.6	7.2	7.7
DTPA Manganese	**mg/kg**	8.16	1.93	1.5	1.56
DTPA Zinc	**mg/kg**	0.84	0.2	0.14	0.13
Exc. Aluminium	**meq/100g**	0.035	0.053	0.063	0.052
Exc. Calcium	**meq/100g**	8.79	13.12	7.89	5.22
Exc. Magnesium	**meq/100g**	4.51	7.5	9.51	7.27
Exc. Potassium	**meq/100g**	2.1	2.09	2.32	2.7
Exc. Sodium	**meq/100g**	0.36	0.97	4.24	9.73
Boron Hot CaCl2	**mg/kg**	2.36	4.12	10.83	13.2
Total Nitrogen	**%**	0.09	0.07	0.06	0.05
Chickpea 2022					
Mineral N	**kg N/ha**	15	31.5	13.5	36
Total N content	**kg N/ha**	1350	3150	2700	45000
Barley 2022					
Mineral N	**kg N/ha**	13.5	9	4.5	18
Total N content	**kg N/ha**	1200	3150	2250	45000

Methods

Species/variety trial 18 lines in 2022 (see **Error! Reference source not found.**), Blocking - Rep/Species, 6 replicates.

All plots in 2023 were sown to Scepter wheat at a seeding rate of 80 kg/ha and received 50 kg N/ha. Crop inputs and timing of events in **Error! Reference source not found.**.

Table 3 *Event Diary*

Date	Details
18/05/2023	Knockdown - Roundup Ultra Max 3 L/ha + Triclopyr 0.16 L/ha + Hammer 0.05 L/ha + MSO 0.05%
26/05/2023	Nematode sampling of every plot
7/06/2023	Seeding, Scepter 80 kg/ha. Superphosphate 97 kg/ha.
7/06/2023	Alpha Duo 0.2 L/ha + Mateno Complete 1 L/ha + Chlorpyrifos 500 0.2 L/ha + Sprayseed 2 L/ha + Treflan 2 L/ha
15/06/2023	Nitrogen applied and soil cores taken
1/08/2023	MCPA LVE 0.45 L/ha + Velocity 0.8 L/ha
7/11/2023	Whole tops total dry matter at maturity and %N in whole tops
8/11/2023	Harvest and Grain samples
15/11/2023	Nematode sampling of every plot

Results

2022

Chickpeas did not increase *P. neglectus* levels over the growing season as much as the most susceptible cereal control varieties (Calingiri and Scepter) which indicates that chickpeas have some resistance to *P. neglectus* (Figure 1).

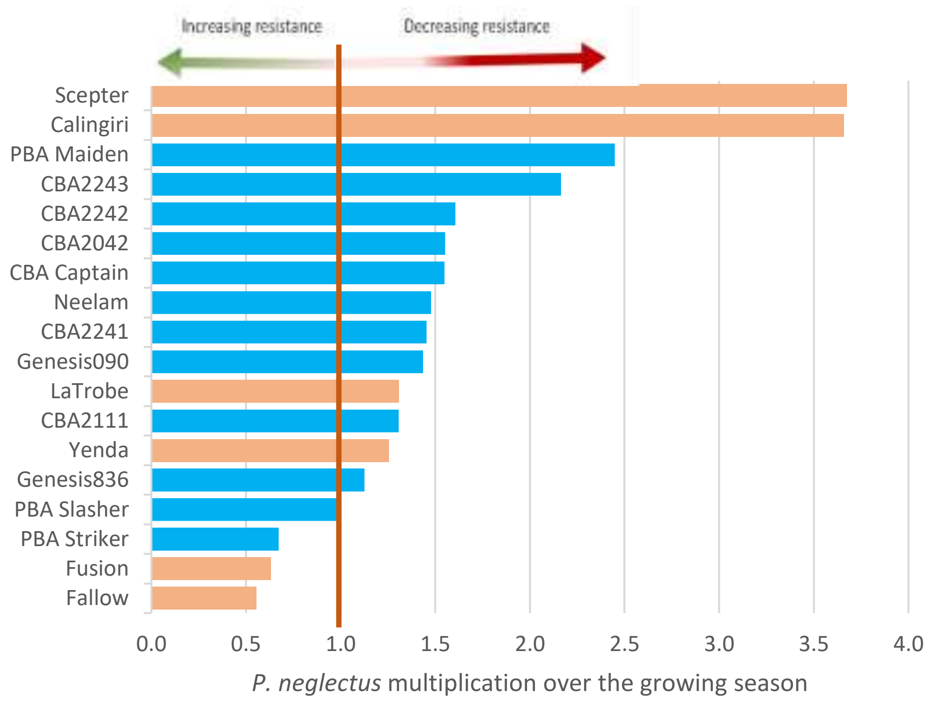

Figure 1. *Doodlakine 2022- Pratylenchus neglectus multiplication after a growing season of different chickpea varieties (reps=6). Orange bars are cereal control varieties or fallow and blue bars are chickpea test varieties.*

There was a range of resistance ratings in chickpeas grown in WA. Ratings for resistance of chickpeas to *P. neglectus* at Doodlakine were combined with ratings from a sister trial at Dalwallinu to give an average rating for each variety (Table 5). From provisional ratings PBA Striker is the most resistant chickpea variety screened. Please note - a robust rating for *P. neglectus* resistance requires at least five successful screening tests (with at least three in the field).

Table 4. *Chickpea resistance ratings 2022.*

No.	Crop 2022	Variety 2022	Resistance rating[1]
1	**fallow**	**Fallow**	**RMR**
2	**triticale**	**Fusion**	**RMR*p***
3	chickpea	PBA Striker	MR*p*
4	chickpea	CBA 2042	MRMS*p*
5	chickpea	PBA Slasher	MRMS*p*
6	**wheat**	**Yenda**	**MRMS**
7	chickpea	CBA Captain	MS*p*
8	chickpea	CBA 2111	MS*p*
9	chickpea	CBA 2242	MS*p*
10	chickpea	Neelam	MS*p*
11	**barley**	**LaTrobe**	**MS**
12	chickpea	CBA 2241	MSS*p*
13	chickpea	CBA 2243	MSS*p*
14	chickpea	Genesis 090	MSS*p*
15	chickpea	Genesis 836	MSS*p*
16	chickpea	PBA Maiden	S*p*
17	**wheat**	**Scepter**	**S**
18	**wheat**	**Calingiri**	**SVS**

Provisional resistance ratings of chickpea varieties to root lesion nematode species Pratylenchus neglectus, based on field screening at Dalwallinu and Doodlakine in 2022. 1R=resistant - nematode numbers will decrease when this variety is grown. MR = Moderately resistant - nematode numbers will slightly decrease when this variety is grown. MS = Moderately susceptible - nematode numbers will slightly increase when this variety is grown. S = Susceptible - nematode numbers will increase greatly when this variety is grown and p= provisional rating

Barley was the most productive species in 2022 (Tables 6 and 7).

Table 5. *2022 Key results - Species*

Crop22	Grain yield (kg/ha)	Protein (%)
Barley	3476	8.3
Chickpea	1318	21.6
Fallow	-	-
Triticale	2717	7.6
Wheat	2481	8.3

Table 6. *2022 Key results – Species/variety*

Crop22	Variety22	Grain yield (kg/ha)	Protein (%)
Barley	LaTrobe	3476	8.33
Chickpea	CBA Captain	1255	21.43
Chickpea	CBA2042	1388	22.08
Chickpea	CBA2111	1320	22.05
Chickpea	CBA2241	1354	21.57
Chickpea	CBA2242	1285	21.02
Chickpea	CBA2243	1284	22.09
Chickpea	Genesis090	1298	21.32
Chickpea	Genesis836	1342	21.4
Chickpea	Neelam	1429	21.72
Chickpea	PBA Maiden	1267	21.73
Chickpea	PBA Slasher	1315	21.3
Chickpea	PBA Striker	1277	21.78
Fallow	Fallow	-	-
Triticale	Fusion	2717	7.61
Wheat	Calingiri	2455	8.47
Wheat	Scepter	2601	8.15
Wheat	Yenda	2385	8.13
	P	<0.001	<0.001
	LSD	145	0.43

2023

Doodlakine/Merredin had a drier than average growing season in 2023. April to October rainfall in 2023 of 118 mm was roughly half the long-term average of 222 mm. Merredin and Kellerberrin did record a wet April, but the site at Doodlakine did not receive the thunderstorm in early April (Week 13) which, combined with a dry May, resulted in sowing being delayed until the first week of June. Fortunately, June was a relatively wet month, but July–October rainfall was below average; consequently wheat growth and yields were limited.

Nematodes 2023

Pratylenchus neglectus 2023

Pratylenchus neglectus levels at sowing in 2023 were low with average soil levels ranging from 1 nematodes/g soil in 2022 triticale Fusion plots to 5 nematodes/g soil in Scepter wheat and CBA 2243 chickpea (data not shown). After Scepter wheat was grown across the site in 2023 there was a range of end of season *P. neglectus* levels with 2022 triticale Fusion and fallow plots still supporting the lowest levels of *P. neglectus* (Figure 2). For the 2022 chickpea varieties there was a range of *P. neglectus* levels but in general there was no residual effect in the 2023 Scepter of 2022 chickpeas lowering nematode levels compared to the susceptible cereals, Calingiri and Scepter, grown in 2022 (Figure 2).

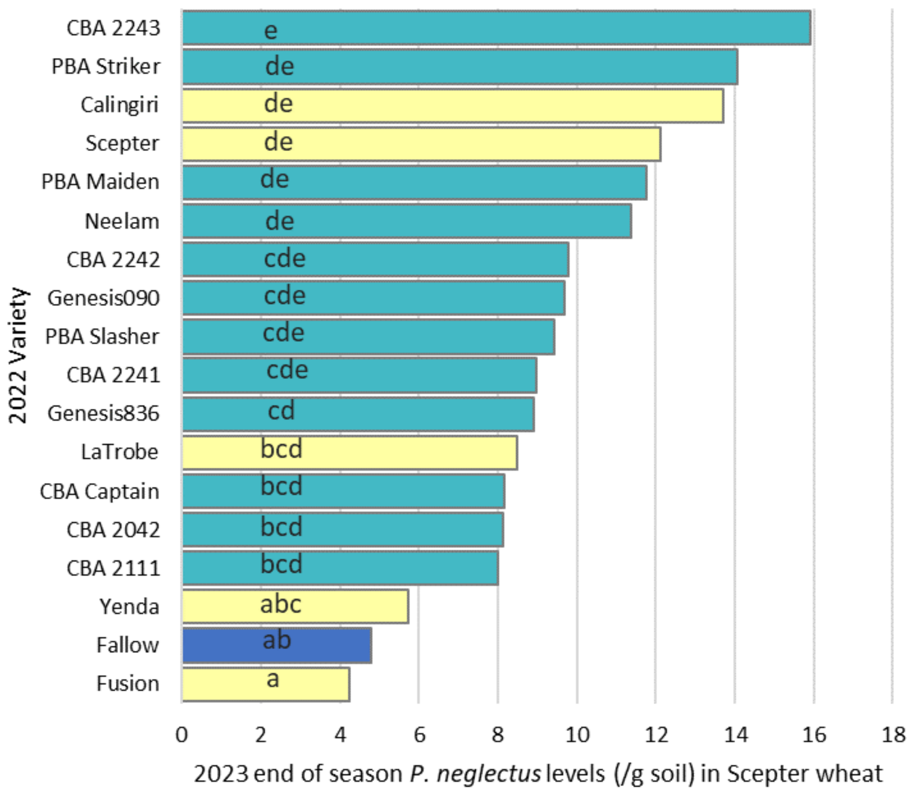

Figure 2. *Residual effect of growing chickpeas on root lesion nematode species Pratylenchus neglectus levels in a subsequent Scepter wheat crop, Doodlakine 2022-2023. Note letters indicate a significant difference between varieties. Significance was determined on Ln transformed data and averages have been back-transformed for this figure.*

There was no difference in the multiplication rate of *P. neglectus* in 2023 between the different crops or fallow in 2022 (Figure 3). If there was a difference in multiplication rate between crops the angle of the slope of the regression line shown in Figure 3 would be different between crops. This indicates that growing chickpeas in 2022 didn't change the soil environment in a way that impacted *P. neglectus* multiplication in the following Scepter wheat crop.

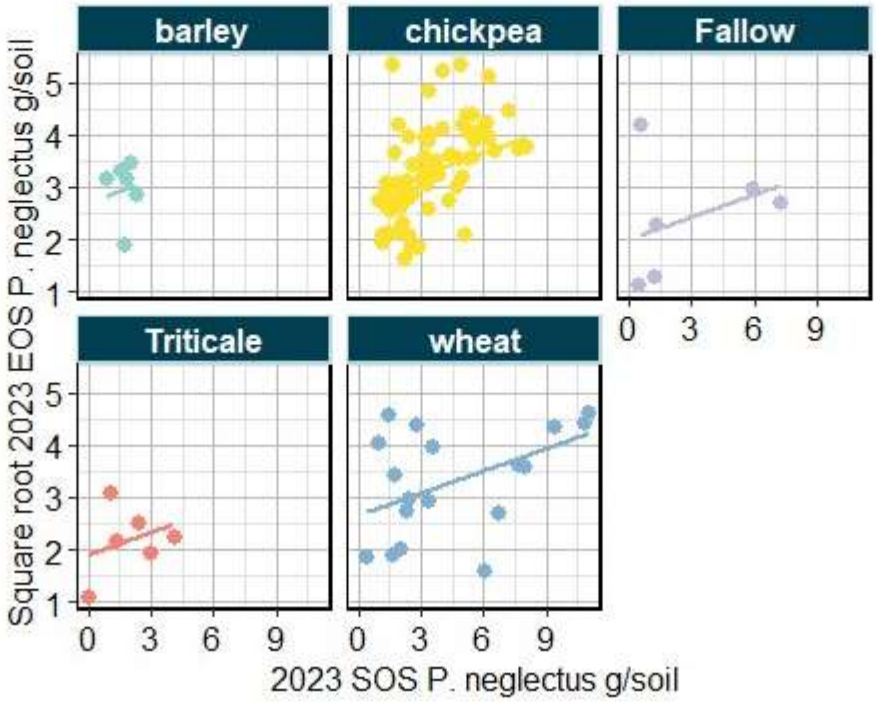

Figure 3. *Effect of 2022 crop type on Pratylenchus neglectus multiplication in the subsequent Scepter wheat sown in 2023, Doodlakine.*

In general, *P. neglectus* multiplication after a chickpea-wheat rotation was the same as a wheat-wheat rotation and a barley-wheat rotation (Figure 4). The best rotations for lowest nematode multiplication were triticale-wheat or fallow-wheat.

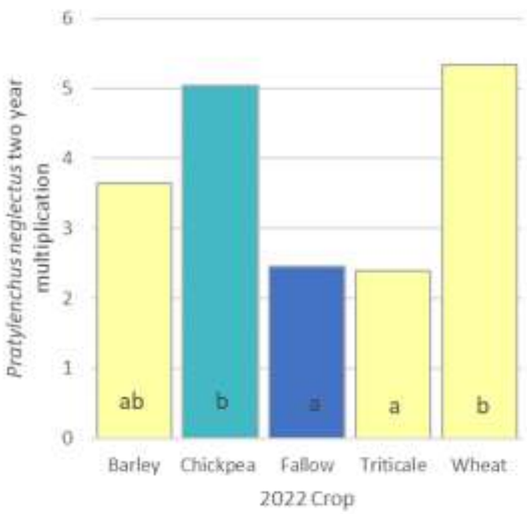

Figure 4. *Pratylenchus neglectus multiplication in different crops in 2022 and Scepter wheat in 2023 over two years, May 2022- November 2023, Doodlakine.*

Grain yield and protein 2023

Wheat yields at Doodlakine in 2023 were highest after chickpea and bare fallow (Figure 5). Although chickpea varieties varied in resistance to *P. neglectus* in 2022 season, creating differing end of season levels, Scepter wheat yields in the 2023 season were similar after all chickpea varieties (Figure 6). Across all species and varieties at Doodlakine in 2023 there was no association between nematode level at the start or end of the year and yield of Scepter wheat (P>0.05). This is likely because nematode levels were low at this site. Grain protein in wheat in 2023 was highest after the bare fallow (>12%) of 2022 and lowest protein (<11%) following barley and triticale (Figure 8). This resulted in all plots of wheat after fallow and a high proportion of plots following chickpea being graded AH grade, whilst wheat following barley, triticale and wheat were more likely to be graded as APW.

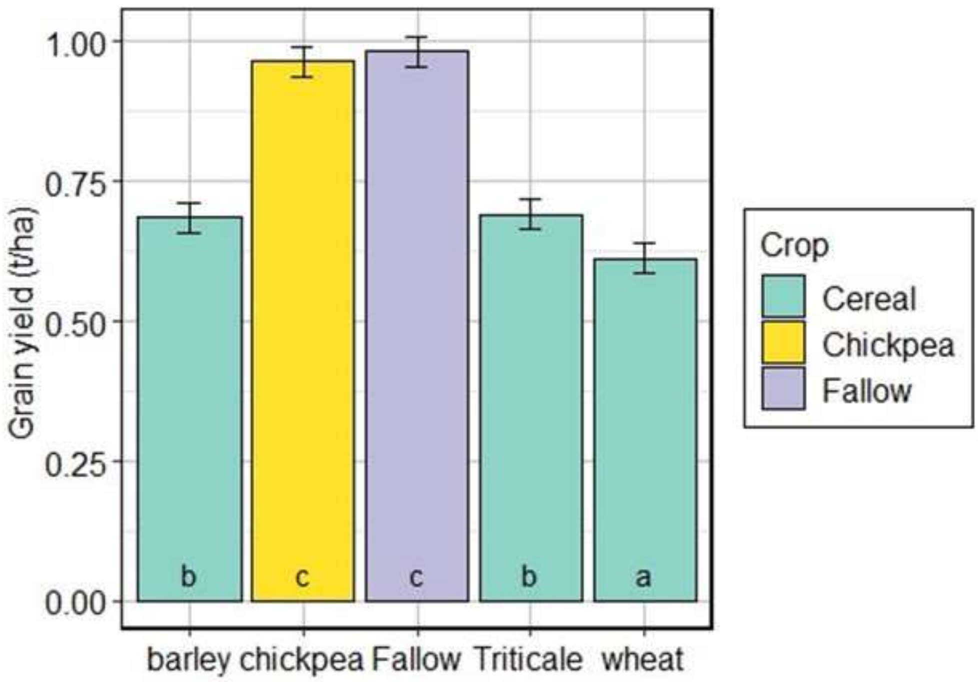

Figure 5 *Grain yield of Scepter wheat at Doodlakine in 2023 following different crop species and bare fallow in 2022.*

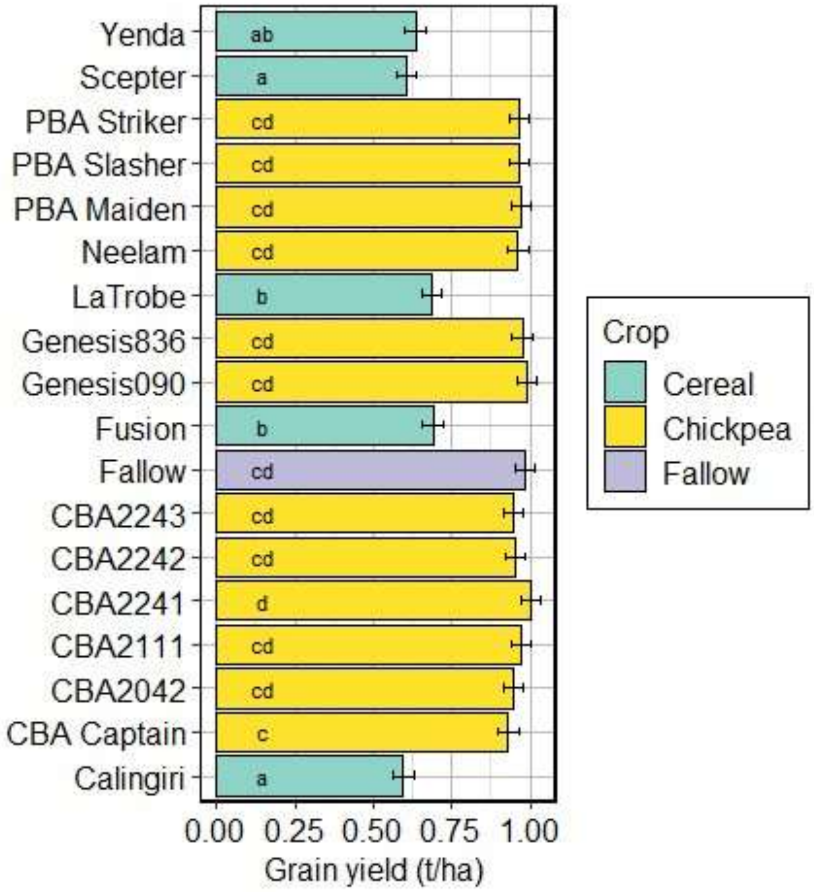

Figure 6. *Grain yield of Scepter wheat at Doodlakine in 2023 following different crop species/varieties and bare fallow in 2022.*

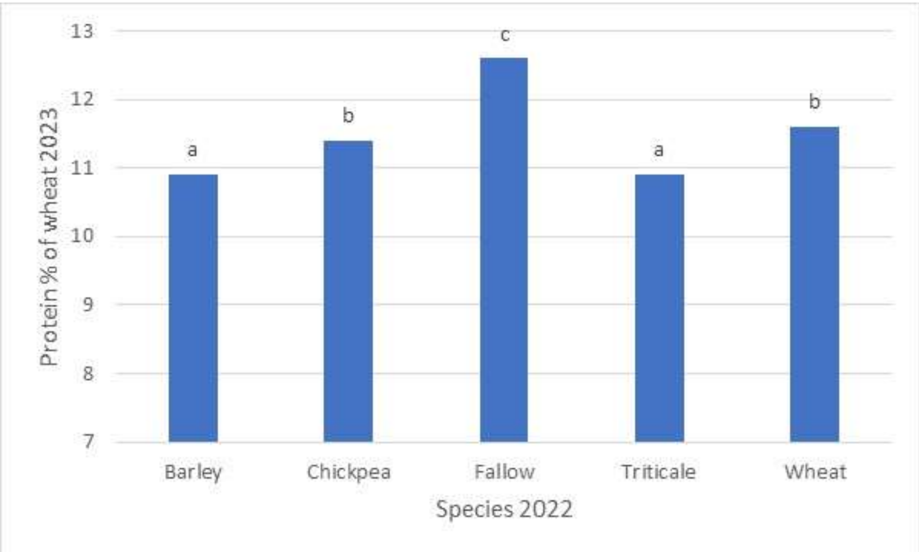

Figure 7. *Protein % of Scepter wheat at Doodlakine in 2023 following different crop species and bare fallow in 2022.*

Gross margins

With a low rainfall year in 2023 the two-year gross margins were heavily influenced by the performance of the crops in 2022 (Table 7). Barley produced the highest gross margins in 2022 of over $700/ha and the highest two-year gross margin of $692/ha. Wheat and chickpea in 2022 produced similar margins of $554/ha and $527/ha respectively, albeit chickpea margins were heavily influenced by grain prices and the recent rebound in chickpea prices helped boost the 5-year average price we used in the analysis. The 300 kg/ha boost in wheat yields from chickpea the previous season and improved grain quality compared to wheat on wheat resulted in a higher two-year gross margin for the chickpea-wheat sequence than wheat-wheat.

Whilst the bare fallow resulted in low nematodes and high yields in 2023 the overall low yield produced by wheat in the dry year of 2023 did not allow fallow to be competitive over two years and choosing to grow chickpea as a break may be a better option in areas where the probability of two good years in a row are low.

Table 13. *Gross margin (GM, $/ha) and grain yields (GY, t/ha), 2023 was Scepter wheat.*

Species 2022	GY 2022	GM 2022	GY 2023	GM 2023	GM over two years
Barley	3.5	760	0.69	-85	692
Chickpea	1.3	527	0.96	20	542
Fallow	-	-60	0.98	30	-30
Triticale	2.7	417	0.69	-84	333
Wheat	2.5	554	0.61	-109	445
P	<0.001	<0.001	<0.001	<0.001	<0.001
LSD	0.1	66	0.05	22	72

Grain prices used were wheat $350/t basis adjusted for grade, barley $310/t, triticale $264/t, chickpea $700/t. Costs were cereals $300/t, chickpea $400/t, fallow $60/t.

Conclusions

Inclusion of chickpea into existing wheat dominant rotations in Western Australia improves potential gross margins compared to wheat-wheat and fallow-wheat rotations. There is a range of resistance of chickpea varieties which can be used to choose a suitable variety to grow in a paddock where *Pratylenchus neglectus* management is a priority. Chickpea varieties tested by Vanstone *et al.* (2008) rated chickpea as susceptible to *P. neglectus.* This new data indicates that the majority of modern chickpea cultivars are provisionally rated MS to MR and hence have better resistance to *P. neglectus* than Scepter wheat which currently dominates the WA wheatbelt. There was no residual effect of growing chickpeas on *P. neglectus* multiplication in the subsequent wheat crop.

Wheat yields were 300 kg/ha higher after chickpea or fallow than after cereals. In this experiment, we were able to measure a range of *P neglectus* following different crop species and bare fallow. However, there was no association between nematode levels and the yield of wheat at Doodlakine in 2023. This may have been because the start of 2023 season *P. neglectus* population levels were low and may not have been at sufficient levels to significantly impact Scepter wheat yields. More experimentation would also be necessary to determine if low seasonal rainfall in the 2023 season impacted nematode multiplication.

In 2022 chickpea grew quite well and produced acceptable yield of ~ 1.3 t/ha. Recent price increases in chickpea, combined with a small yield boost of 300 kg/ha and improved grain quality resulted in the chickpea-wheat sequence being competitive with the wheat-wheat sequence. Whilst fallow also led to a small 300 kg/ha yield boost the lack of any financial returns in year 1 resulted in a poor financial result. If chickpea prices remain high farmers using fallow may like to consider utilising chickpea as the break from cereals in their rotation.

References

Vanstone, V. A., Hollaway, G. J., and Stirling, G. R. (2008). Managing nematode pests in the southern and western regions of the Australian cereal industry: continuing progress in a challenging environment. *Australasian Plant Pathology*, *37*, 220-234.

Acknowledgments

Thanks to Mark Beavon and the Merredin Research Support Team.

Caroline Peek helped organise the plant sampling in 2022.

Sean Kelly (DPIRD Crop protection, South Perth) sampled all plots for nematodes.

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Erin Stevens (DPIRD Esperance) processed the grain samples in 2023.

Thanks to the WA Farming Systems project and DPIRD’s Crop Sowing Guide project for financially supporting this series.

Legacy effects of cereals, chickpea and fallow on following wheat.

Researchers: Mark Seymour (DPIRD Crop Science and Grain Production, Esperance) and Carla Wilkinson (DPIRD Crop Protection - Nematodes, South Perth).

Key messages

- Chickpea-wheat sequence produced similar gross margins to a barley-wheat sequence.
    - Despite barley outyielding chickpea in the first year.
    - Due to increased wheat yield and better grain quality.
    - Provided prices for chickpea remain high.
- This trial indicated that in low rainfall years farmers growing wheat after chickpea could reduce risk and maximise returns by using low rates of applied nitrogen — or in very low rainfall years choosing not to apply nitrogen.
- Starting levels of *P. neglectus* were not high enough to cause significant yield loss in Scepter wheat (2-4 nematodes/g soil; SARDI Broadacre Soilborne Disease Manual)
- There was no effect of increasing N rate or legacy effects of growing CBA Captain chickpea or Hindmarsh barley on *P. neglectus* multiplication.

DPIRD Research Scientist Salzar Rahman inspecting the Doodlakine Species trial in October 2022.

Background

The setup year of this work in 2022 was funded by DPIRD and the second year of trials in 2023 was conducted in collaboration with GRDC.

In 2022 we conducted an experiment that measured the multiplication rate of WA's most common broadacre root lesion nematode (RLN) species, *Pratylenchus neglectus,* in varieties of wheat, barley, triticale, chickpea and under fallow at Doodlakine. In 2023 we evaluated the effect of the range of nematode levels on the following wheat crop – see separate report.

We had extra plots (buffers) in the 2022 trial, so we took the opportunity to compare the nitrogen and subsequent yield response of wheat following barley compared to wheat following chickpea. We also investigated the effect of different N rates and residual effects of chickpeas and barley on *Pratylenchus neglectus* multiplication in the following Scepter wheat crop. This report concentrates on that aspect of the experiment.

Objectives

Compare the nitrogen response of wheat following barley compared to wheat following chickpea. Measure the effect of nitrogen rate and previous crop; barley or chickpea, on *Pratylenchus neglectus* population levels.

Location and site information

Location; decimal degrees; -31.608900, 117.877500.

Soil type red loam

Table 14 2022, 2023 and long-term average monthly rainfall (mm) at Doodlakine.

	2022	2023	Mean
Jan	0	1	19
Feb	0	0	15
Mar	53	15	17
Apr	32	42	21
May	32	12	34
Jun	41	45	37
Jul	36	13	41
Aug	40	27	37
Sep	39	18	22
Oct	23	1	17
Nov	10	23	17
Dec	3	10	13
Annual	310	206	280
May to Oct	211	114	186

Table 2. Soil test CSBP 2023 (8 days after sowing in Wheat N0 2023) – Chickpea 2022 plots and N tests for Barley 2022.

		Depth (cm)			
Depth		0-10	10 to 30	30 to 50	50 to 110
Colour		DKBR	BR	LTBR	LTBR
Gravel	**%**	5	5	5-10	5-10
Texture		2.5	2.5	2.5	2.5
Ammonium Nitrogen	**mg/kg**	2	3	< 1	< 1
Nitrate Nitrogen	**mg/kg**	8	4	3	4
Phosphorus Colwell	**mg/kg**	12	2	< 2	< 2
Potassium Colwell	**mg/kg**	684	636	846	1050
Sulfur	**mg/kg**	5.3	4.6	5.6	39.8
Organic Carbon	**%**	0.37	0.23	0.13	0.12
Conductivity	**dS/m**	0.09	0.14	0.355	0.811
pH Level (CaCl2)		6.7	8	8.3	8.6
pH Level (H2O)		7.5	9	9.8	10.1
DTPA Copper	**mg/kg**	0.7	0.51	0.64	0.75
DTPA Iron	**mg/kg**	12.1	6.6	7.2	7.7
DTPA Manganese	**mg/kg**	8.16	1.93	1.5	1.56
DTPA Zinc	**mg/kg**	0.84	0.2	0.14	0.13
Exc. Aluminium	**meq/100g**	0.035	0.053	0.063	0.052
Exc. Calcium	**meq/100g**	8.79	13.12	7.89	5.22
Exc. Magnesium	**meq/100g**	4.51	7.5	9.51	7.27
Exc. Potassium	**meq/100g**	2.1	2.09	2.32	2.7
Exc. Sodium	**meq/100g**	0.36	0.97	4.24	9.73
Boron Hot CaCl2	**mg/kg**	2.36	4.12	10.83	13.2
Total Nitrogen	**%**	0.09	0.07	0.06	0.05
Chickpea 2022					
Mineral N	**kg N/ha**	15	31.5	13.5	36
Total N content	**kg N/ha**	1350	3150	2700	45000
Barley 2022					
Mineral N	**kg N/ha**	13.5	9	4.5	18
Total N content	**kg N/ha**	1200	3150	2250	45000

Methods

P. neglectus infected paddock x Crop Species x N rate trial

- Treatment list 2023 in **Error! Reference source not found.**.
    - 2 crop species in 2022 (Chickpea and Barley)
    - Oversow wheat crop in 2023 x 6 Nitrogen rates (0, 12.5, 25, 50, 75 and 100 kg N/ha) in 2023, Blocking – Rep/Species, 6 replicates.
- All plots in 2023 sown to Scepter wheat at a seeding rate of 80 kg/ha.
- Crop inputs and timings in **Error! Reference source not found.**.

Table 3. *Event Diary*

Date	Details
18/05/2023	Knockdown - Roundup Ultra Max 3 L/ha + Triclopyr 0.16 L/ha + Hammer 0.05 L/ha + MSO 0.05%
26/05/2023	Nematode sampling of every plot
7/06/2023	Seeding, Scepter 80 kg/ha. Superphosphate 97 kg/ha.
7/06/2023	Alpha Duo 0.2 L/ha + Mateno Complete 1 L/ha + Chlorpyrifos 500 0.2 L/ha + Sprayseed 2 L/ha + Treflan 2 L/ha
15/06/2023	Nitrogen treatments applied and soil cores taken
1/08/2023	MCPA LVE 0.45 L/ha + Velocity 0.8 L/ha
7/11/2023	Whole tops total dry matter at maturity and %N in whole tops
8/11/2023	Harvest and Grain samples
15/11/2023	Nematode sampling of every plot

Treatments

Table 4. *Treatments – Species x N rate trial (6 replications).*

Treatment	Species 2022	Nitrogen rate (kg/ha) 2023
1	Hindmarsh Barley	0
2	Hindmarsh Barley	12.5
3	Hindmarsh Barley	25
4	Hindmarsh Barley	50
5	Hindmarsh Barley	75
6	Hindmarsh Barley	100
7	CBA Captain Chickpea	0
8	CBA Captain Chickpea	12.5
9	CBA Captain Chickpea	25
10	CBA Captain Chickpea	50
11	CBA Captain Chickpea	75
12	CBA Captain Chickpea	100

Results

Doodlakine had a drier than average growing season in 2023 (Table 14). The farm at Doodlakine did not receive the thunderstorm in early April (Week 13) that nearby sites at Kellerberrin and Merredin reported which combined with a dry May resulted in sowing being delayed until the first week of June. Fortunately, June was a relatively wet month, but July-October rainfall was below average - consequently wheat growth and yields were limited.

Sampling at harvest in 2022 indicated that chickpea grown in 2022 left 82 kg/ha of residual organic nitrogen (RON) in above and below ground residues for following crops and barley 31 kg RON/ha (Table 5). That is, compared to barley, chickpea grown in 2022 left approximately 50 kg N/ha more residual organic nitrogen.

If we assume 40% of that residual organic nitrogen becomes available in 2023 then wheat after chickpea may have 33 kg N/ha available and wheat after barley, 12 kg N/ha (Table) – i.e. wheat after chickpea may have access to an extra 21 kg N/ha. Combined with nitrogen mineralised from soil organic matter (19 kg N/ha – estimated using SYN Excel tool) we calculated wheat after chickpea had access to 52 kg available N/ha and wheat after barley 31 kg N/ha.

Soil sampling to depth on a small number of selected chickpea 2022 and barley 2022 plots near sowing in 2023 indicated that mineral N was low at this site (

		Depth (cm)			
Depth		0-10	10 to 30	30 to 50	50 to 110
Colour		DKBR	BR	LTBR	LTBR
Gravel	%	5	5	5-10	5-10

| | | | | | |) and
|---|---|---|---|---|---|
| **Texture** | | 2.5 | 2.5 | 2.5 | 2.5 |
| **Ammonium Nitrogen** | **mg/kg** | 2 | 3 | < 1 | < 1 |
| **Nitrate Nitrogen** | **mg/kg** | 8 | 4 | 3 | 4 |
| **Phosphorus Colwell** | **mg/kg** | 12 | 2 | < 2 | < 2 |
| **Potassium Colwell** | **mg/kg** | 684 | 636 | 846 | 1050 |
| **Sulfur** | **mg/kg** | 5.3 | 4.6 | 5.6 | 39.8 |
| **Organic Carbon** | **%** | 0.37 | 0.23 | 0.13 | 0.12 |
| **Conductivity** | **dS/m** | 0.09 | 0.14 | 0.355 | 0.811 |
| **pH Level (CaCl2)** | | 6.7 | 8 | 8.3 | 8.6 |
| **pH Level (H2O)** | | 7.5 | 9 | 9.8 | 10.1 |
| **DTPA Copper** | **mg/kg** | 0.7 | 0.51 | 0.64 | 0.75 |
| **DTPA Iron** | **mg/kg** | 12.1 | 6.6 | 7.2 | 7.7 |
| **DTPA Manganese** | **mg/kg** | 8.16 | 1.93 | 1.5 | 1.56 |
| **DTPA Zinc** | **mg/kg** | 0.84 | 0.2 | 0.14 | 0.13 |
| **Exc. Aluminium** | **meq/100g** | 0.035 | 0.053 | 0.063 | 0.052 |
| **Exc. Calcium** | **meq/100g** | 8.79 | 13.12 | 7.89 | 5.22 |
| **Exc. Magnesium** | **meq/100g** | 4.51 | 7.5 | 9.51 | 7.27 |
| **Exc. Potassium** | **meq/100g** | 2.1 | 2.09 | 2.32 | 2.7 |
| **Exc. Sodium** | **meq/100g** | 0.36 | 0.97 | 4.24 | 9.73 |
| **Boron Hot CaCl2** | **mg/kg** | 2.36 | 4.12 | 10.83 | 13.2 |
| **Total Nitrogen** | **%** | 0.09 | 0.07 | 0.06 | 0.05 |
| | | | | | |
| ***Chickpea 2022*** | | | | | |
| **Mineral N** | **kg N/ha** | 15 | 31.5 | 13.5 | 36 |
| **Total N content** | **kg N/ha** | 1350 | 3150 | 2700 | 45000 |
| ***Barley 2022*** | | | | | |
| **Mineral N** | **kg N/ha** | 13.5 | 9 | 4.5 | 18 |
| **Total N content** | **kg N/ha** | 1200 | 3150 | 2250 | 45000 |

) and differences between treatments are likely to be within the margin of error of sampling and margin of error of laboratory testing.

If one chose to ignore the margins of error, then the sampling indicated that chickpea had left more nitrogen behind than the barley treatments. Mineralised nitrogen after chickpea was 60 kg N/ha in the top 50 cm of soil and 27 kg N/ha after barley. Most of this extra N was in the 10 to 30 cm horizon highlighting the value of sampling to depth when tracking nitrogen in rotations. Chickpea roots and nodules are unlikely to be present below 30cm due to elevated boron and salt levels.

Thus, our soil sampling and N balance calculations appear to be similar – with wheat after chickpea likely to have 50 to 60 kg available N/ha and wheat after barley 30 kg N/ha.

Table 5. *Nitrogen balance (kg N/ha) following harvest in 2022.*

Crop 2022	N in dry matter of tops at maturity	N in above and below ground biomass#	N exported in grain	N balance	'Available' Residual organic nitrogen (RON) in 2023
Hindmarsh barley	48	73	42	31	12
CBA Captain chickpea	71	129	47	82	33

Below ground N calculated using published root factors for cereals of 1.52 and chickpea 1.82 as per Peoples et al. (2017), Unkovich and Pate (2000) and Unkovich et. al (2010).
Cereals had 40 kg N/ha applied in 2022 – but we assume 96% of that was available in 2022.
Available soil N = RON * 0.4

2023 was a low rainfall year at Doodlakine and yields of all crops were limited. Wheat after chickpea yielded 0.9 t/ha producing on average 300 kg/ha higher grain yields than wheat after barley (Figure 1). There was no interaction between previous crop species and nitrogen ($P>0.05$) by the end of the 2023 season, with the yield of wheat after chickpea and barley responding similarly to applied N and no rate of nitrogen applied to wheat after barley could match wheat after chickpea with zero nitrogen applied.

The chickpea-wheat sequence not only yielded more than the barley-wheat sequence in 2023 but it also boosted grain protein. For example, to reach 11% protein, wheat following barley required 75 kg N/ha of fertiliser nitrogen, whilst wheat after chickpea produced 11% protein at 25 kg N/ha (Table 15).

Despite the dry year and low wheat yield in 2023 there was a positive financial outcome for wheat following chickpeas at low N application rates (0-50 kg/ha). Wheat produced positive gross margins in 2023 after chickpea due to combination of higher yields, and improved grain quality, whilst wheat after barley had negative gross margins in 2023. However, the higher returns from barley in 2022 ensured that when the financial returns from the barley-wheat and chickpea-wheat sequences were calculated over two years similar overall gross margins from both sequences were obtained (**Error! Reference source not found.** and Table 16).

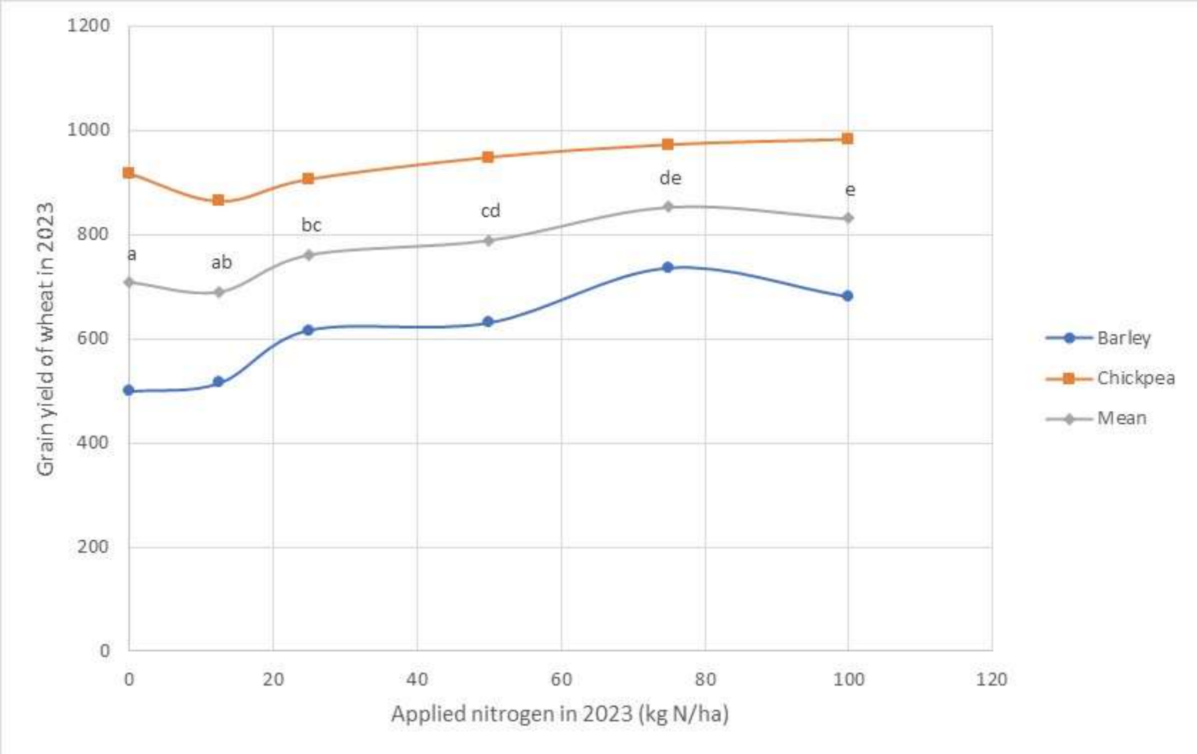

Figure 1 *Grain yield (kg/ha, Nov 11) of Scepter wheat in 2023 following either barley or chickpea in 2022.*

Table 15. *Protein (%) response to applied nitrogen of wheat in 2023 following barley or chickpea.*

N (kg/ha)	Barley 2022	Chickpea 2022	Mean
0	9.5	10.2	9.9
12.5	9.6	10.8	10.2
25	10.5	11.2	10.8
50	10.5	11.6	11.1
75	12.0	12.0	12.0
100	12.4	12.4	12.4
	10.7	11.4	11.1
	P	LSD	
Species	0.01	0.1	
N	<0.001	0.4	
Species*N	0.033	0.6	

Table 16. *Single (2023) and two year (2022-23) gross margins ($/ha) at Doodlakine*.

		2023 Gross margin Wheat after:			Two year Gross margin		
N (kg/ha)	N cost/ha	Barley 2022	Chickpea 2022	Mean	Barley 2022 and wheat 2023	Chickpea 2022 and wheat 2023	Mean
0	0	-87	57	-15	558	664	611
12.5	19	-102	32	-35	507	533	520
25	38	-72	35	-19	612	541	577
50	75	-111	22	-44	550	534	542
75	113	-102	-18	-60	548	470	509
100	150	-151	-44	-97	560	437	498
Mean		-104	14	-45	556	530	543
	P	LSD			P	LSD	
Species	<0.001	7			0.338	47	
N	<0.001	22			0.118	91	
Species*N	0.107	ns			0.155	127	

Pratylenchus neglectus

There was no effect of N rate applied in 2023 or crop grown in 2022 (chickpea or barley) on *P. neglectus* multiplication in Scepter wheat in 2023 (Figure 2). In previous work we have shown that increasing N rate can lead to an increase in root lesion nematode *P. quasitereoides* population levels as more N increases root growth which provides more food for the nematodes. The implications of nitrogen inputs (organic and inorganic), previous cropping combined with low seasonal rainfall on *P. neglectus* levels and soil biota requires further research.

At the beginning of 2023 there was low levels of *P. neglectus* in all plots but there was significantly (P=0.042) more *P. neglectus* in the buffer plots which had grown CBA Captain (4 nematodes/g soil) than buffer plots which had grown Hindmarsh (2 nematodes/g soil) in 2022. At the end of the 2023 season there was still significantly (P=0.049) more *P. neglectus* in the plots where CBA Captain was grown in 2022 (10 nematodes/g soil) compared with the plots where Hindmarsh barley was grown in 2022 (7 nematodes/g soil). Whilst this difference in nematode levels is not large it demonstrates that crop rotation can affect nematode levels for at least a year and hence rotation with more resistant varieties or crops is a key tool for root lesion nematode management.

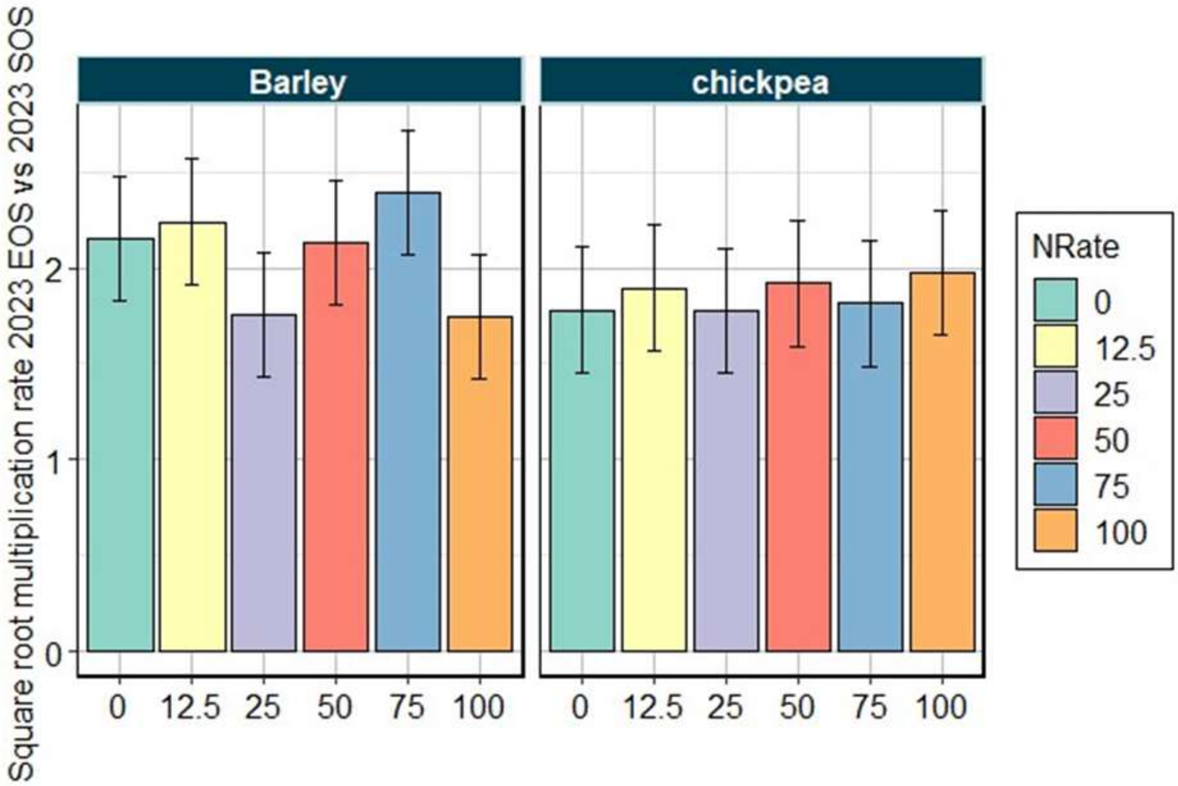

Figure 2. *Effect of previous crop and in crop applied N rate (kg/ha) on Pratylenchus neglectus multiplication in Scepter wheat.*

Conclusions

On a positive note, for chickpea growers, this trial indicated that if prices for chickpea remain high the economics of including chickpea in low rainfall rotations stack up and in low rainfall areas/seasons farmers may maximise returns by applying very low rates of fertiliser nitrogen to their wheat crops following chickpea.

The dry season, low starting levels of *P. neglectus* and effect of different crop on soil biology may have affected factors such as nutrient availability, competition in the soil for resources and predation of plant parasites. These aspects need further research.

References

Peoples, M.B., Swan, A.D., Goward, L., Kirkegaard, J.A., Hunt, J.R., Li, G.D., Schwenke, G.D., Herridge, D.F., Moodie, M., Wilhelm, N. and Potter, T., (2017). Soil mineral nitrogen benefits derived from legumes and comparisons of the apparent recovery of legume or fertiliser nitrogen by wheat.*Soil Research*,*55*(6), pp.600-615.

Unkovich, M. J., and Pate, J. S. (2000). An appraisal of recent field measurements of symbiotic N2 fixation by annual legumes.*Field Crops Research*,*65*(2-3), 211-228.

Unkovich, M. J., Baldock, J., and Peoples, M. B. (2010). Prospects and problems of simple linear models for estimating symbiotic N 2 fixation by crop and pasture legumes. *Plant and Soil*,*329*, 75-89.

Acknowledgments

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Thanks to the WA Farming Systems project and DPIRD’s Crop Sowing Guide project for financially supporting this series.

Pulse species legacy effects, Ogilvie

Research team: Mark Seymour, Steph Boyce, Marty Harries, Lea Obadia.

Key messages

- In 2022 four of eight pulse species grown in 2022 yielded over 1.5 t/ha.
- Narrow leaf lupin had the greatest yield of 2.6 t/ha and vetch the lowest at 1.2 t/ha.
- Chickpea establishment, biomass and yield were lower than expected.
- In 2023 there were no statistically significant difference in wheat yield sown into different pulse species residues, but yield of wheat was greatest after field peas, 1.58 t/ha, and least after kabuli chickpea, 1.18 t/ha.
- Wheat protein ranged from 12.5% (following albus) to 11.4% (following chickpea).
- Screenings were above 5% after faba bean, and below 5% on all other residues.
- Wheat will be sown again in 2024, to further investigate legacy effects from the 2022 sown pulses.

Background

The amount of biological nitrogen being added to Western Australian farming system has reduced substantially in the past few decades due to a reduction in legume pasture area and quality and a reduction in area of grain legume crops sown (Kirkegaard *et al.* 2011; Harries *et al.* 2015). For around a decade high intensity cropping systems with few legumes have been used in many paddocks and there is concern that this is drawing down soil nitrogen (Angus *et al.* 2020; Harries *et al.* 2021).

Consequently, growers are looking to include legumes in farming systems more frequently and need information on which legumes perform best and how each legume species impacts the following cereal crops. By investigating legacy effects of pulses their performance can be assessed in a farming systems context.

Objectives

The objective was to test several pulse species against each other in the northern agricultural region. This is to identify which is best adapted to this location.

Wheat was sown over each plot to assess the effect of pulse species on yield and quality of the following wheat crop.

Location

Ogilvie, Warakirri Farms on a red sandy loam with gravel at around 30 cm.

Table 1. Trial location

	Latitude (dd)	Longitude (dd)	Nearest town
Trial Site	-28.17869	114.699872	Northampton

Methods

A small plot trial sown with DPIRD equipment. Plots were 20 m long by 2.0 metres wide.

Three replicates of the treatments arranged in randomised complete blocks (Figure 1).

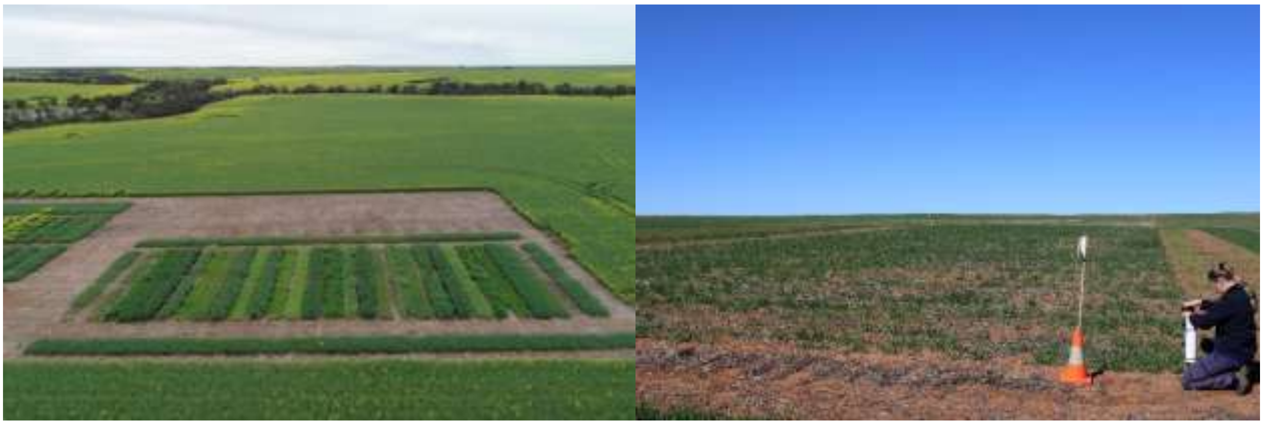

Figure 1. *Left various pulse species sown in 2022. Right, variable establishment of wheat in the dry 2023 season.*

Treatments

In 2022 the trial included 8 pulse species. In 2023 these plots were over-sown with wheat, Cv. Scepter (Table 2).

Table 2. Trial treatments by year.

Treatment	2022 Sp.	2022 Cv.	2023
1	Desi chickpea	CBA Captain	Wheat
2	Kabuli Chickpea	Genesis 090	Wheat
3	Narrow leaf lupin	PBA Jurien	Wheat
4	Albus lupin	Amira	Wheat
5	Lentil	PBA Highland XT	Wheat
6	Faba bean	PBA Marne	Wheat
7	Field pea	PBA Butler	Wheat
8	Vetch	Studenica	Wheat

Agronomy

Pulses 2022

Inputs
Herbicide
• Knockdown: Glyphosate 1.2L/Ha
• IBS: Terbyne Xtreme 0.9 kg/ha + Reflex 1.0 L/ha + Rustler (Propyzamide 500) 1.0 L/ha
• Post-emergent: 500 mL/ha Select + 180 g/ha Factor + 1% uptake + 1% Ammonium Sulphate
• No broadleaf post emergent herbicides were applied because there is nothing available for this range of species.
Insecticide
• Kockdown: Lorsban 200 mL/ha, Dominex 200 mL/ha
• IBS: Lorsban 200 mL/ha, Dominex 200 mL/ha
• Post: Lorsban 300 mL/ha, Dominex 300 mL/ha (25/7/2023)
Fungicide
• Post: Bravo® Weather Stik® 720 1.0L/ha (16/6/2022)
• Post: Bravo® Weather Stik® 720 1.5L/ha (7/7/2022)
• Veritas Opti® 400 mL/ha (19/7/2022, 15/8/2022 and 12/9/2022)
Fertiliser
• Seeding: AGNP 80 kg/ha

Note: Because 2022 was a wet year and we wanted to test pulse species yield potential fungicides were applied every 3-4 weeks, to ensure fungal pathogens did not limit yield

Wheat 2023

Inputs
Herbicide
• Knockdown: Glyphosate 1.2L/Ha
• Pre-seeding: Sakura 118 g/ha
• Post emergent: Velocity 0.8 L/ha, MCPA LVE 0.45 L/ha
Insecticide
• Pre-seeding: Lorsban 200 mL/ha, Dominex 200 mL/ha
Fertiliser
• Seeding: Agstar extra 70 kg/ha (~10 units of N) + Urea 50 kg/ha (23 kg/ha)
• No additional nitrogen was applied due to the low yield potential season and preceding pulse crops.

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Results

2022

Annual rainfall was 373 mm. Growing season rain was ~309 mm, taken from patch point data (Figure 2), with rain received at regular intervals resulting in an above average season throughout the district.

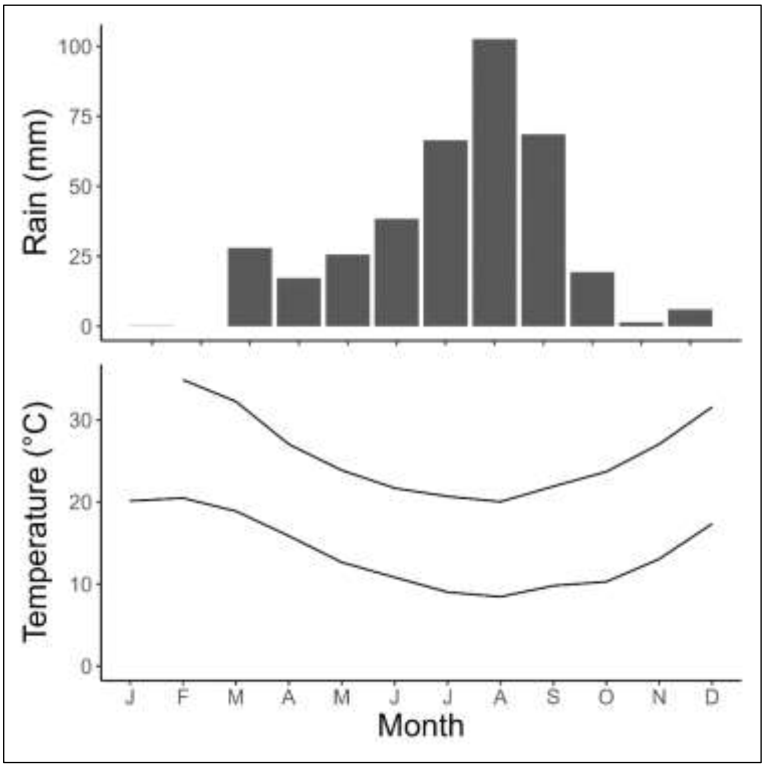

Figure 2. *Rainfall and minimum and maximum temperatures at the trial site in 2022. Patch point data (-28.178688, 114.700047) 20/04/2022 to 31/9/2022.*

Establishment density was lower than anticipated for some species, notably chickpea. While a favourable season enabled chickpeas to recover and branch, such that full canopy cover was achieved, final dry matter prior to harvest of chickpeas was lower than expected, relative to other species (Table 3).

Nodulation was scored using a 0–8 scale; zero = no nodules present and 8 = nodules = extremely abundant. Nodulation of chickpea was low when assessed on 22 August while nodulation of faba bean was greater than the other species (Table 3).

The range in yield between the pulse species was large. Lupin yielded the most at 2.6 t/ha while vetch yielded the least at 1.2 t/ha (Figure 3).

Table 3. *Establishment, nodulation, final dry matter and yield of pulse species at Ogilvie in 2022.*

Variety	Establishment (p/m2)		Nodulation (0-8 score)		Dry matter (t/ha)		Yield (kg/ha)	
Amira	12.4	ab	2.7	c	11.0	d	2306	bc
CBA Captain	14.4	b	0.2	a	6.4	bc	1530	a
Genesis 090	13.0	ab	0.5	a	4.3	a	1279	a
PBA Butler	28.1	d	2.7	c	12.1	d	1269	a
PBA Highland XT	47.3	e	1.1	b	5.7	ab	1757	ab
PBA Jurien	22.4	c	3.3	d	12.0	d	2590	c
PBA Marne	10.6	a	4.3	e	11.1	d	2379	bc
Studenica	27.6	d	2.8	c	8.1	c	1180	a
Prob	<0.001		<0.001		<0.001		0.005	
LSD	3.6		0.4		1.9		748	

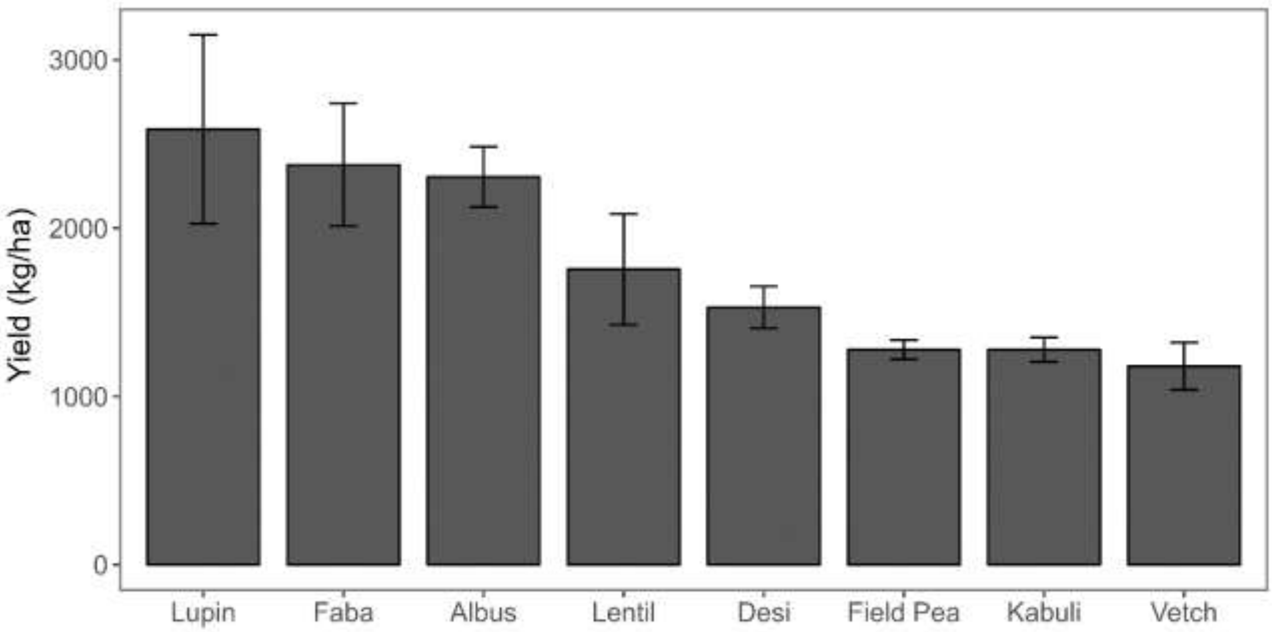

Figure 3*. Yield of various pulse species at Ogilvie in 2022.*

2023

Annual rainfall was 148 mm. Growing season rain ~131 mm, taken from patch point data (Figure 4), with this being a decile 1 season. The break of the season occurred in late May, although this was <10 mm. The crop was dry sown on 24 April germinating from marginal moisture (wet to around 7 cm in the furrow).

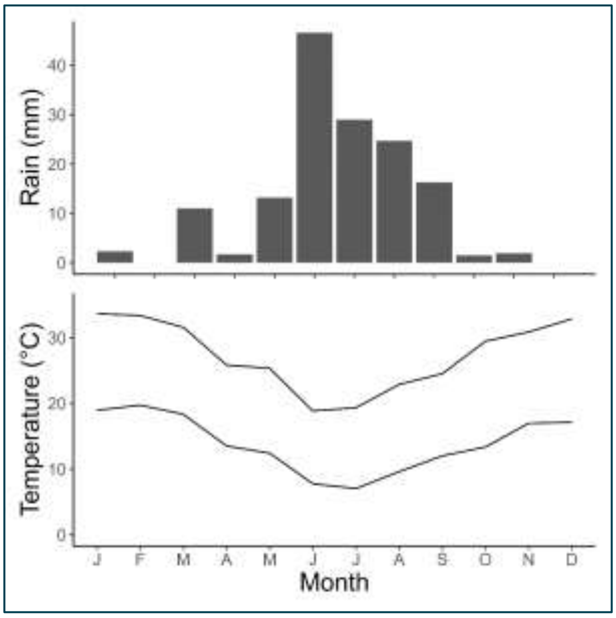

***Figure 4**. Rainfall and minimum and maximum temperatures at the trial site in 2022. Patch point data (-28.178688, 114.700047) 20/04/2022 to 31/9/2022.*

Yield

Wheat across the site averaged 1,334 kg/ha. There was not a statistically significant difference of the yield of wheat due to the pulse species that was grown before it (P = 0.273). Establishment was poor due to dry conditions around seeding (data not shown). This would have contributed to variability in the results reducing the likelihood of identifying statistically significant differences in responses to the previous crop species. Despite no significant differences of wheat yield there was quite a large difference in mean wheat yield obtained after the various pulse species. Wheat after field pea had the highest yield, of 1.57 t/ha, compared to wheat after kabuli chickpea of 1.18 t/ha (Figure 5).

There was a significant difference (P = 0.04) in the amount of green plant area covered by the wheat after various legume species, as measured by NDVI on 8 August, with more wheat green area after field pea, faba bean and vetch at this time (Figure 5).

Water use efficiency averaged 10.1 kg/mm. This was reasonable considering establishment was poor, which may have contributed to evaporation, and temperatures spiked above 31°C on 30 and 31 August, when the crop was flowering (Sadras 2020; Harries *et al.* 2022). The range in water use efficiency realised for wheat grown on different pulse residues was 12 kg/mm after field pea to 9 kg/mm after either chickpea species, this was not statistically significant.

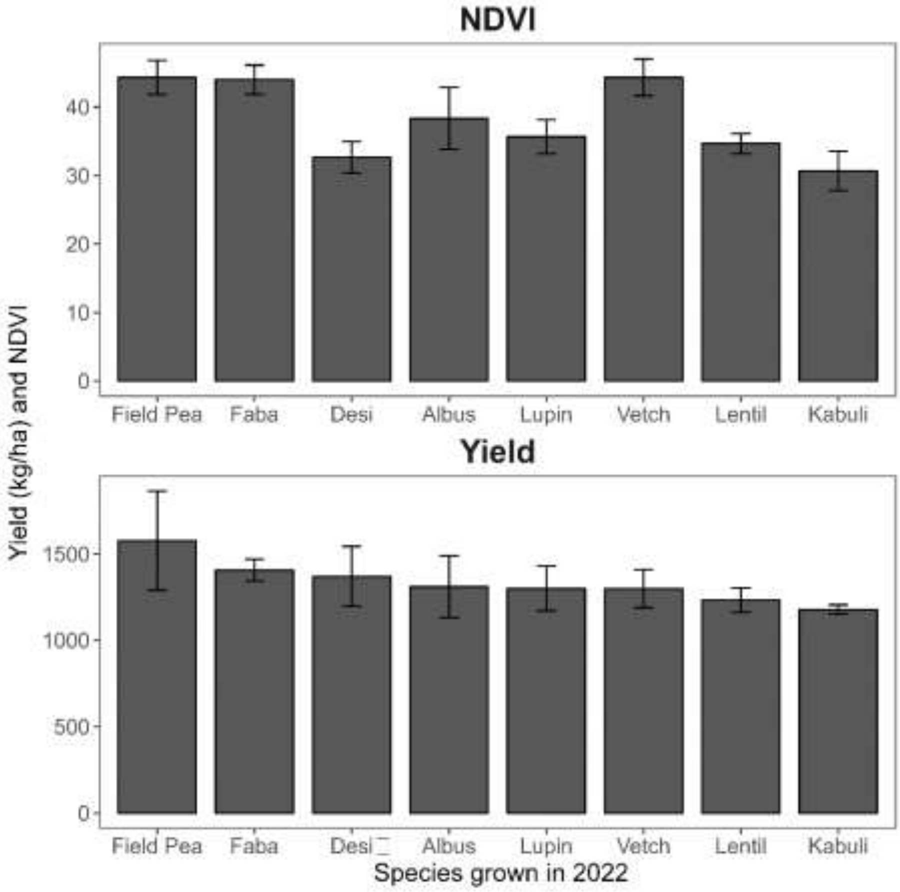

Figure 5. *Top panel: NDVI of wheat after various pulses (Aug 8). Bottom panel yield of wheat after various pulses.*

Grain quality

Mean protein was 12.1%. There was no significant difference in wheat protein based on pulse species grown in 2022, although it was close to significant ($P = 0.08$). Highest protein was obtained after narrow leaf lupin, at 12.7%, and lowest after desi and kabuli chickpea, at 11.4% (Figure 6).

Mean seed weight was 37.7 g/1000 seed and not significantly affected by preceding pulse crop species ($P = 0.531$).

Mean screenings were 4.4% and were not significantly affected by preceding pulse crop ($P = 0.324$), but screenings were over 5% for wheat grown after faba bean, hence this would be a receival issue (Figure 6).

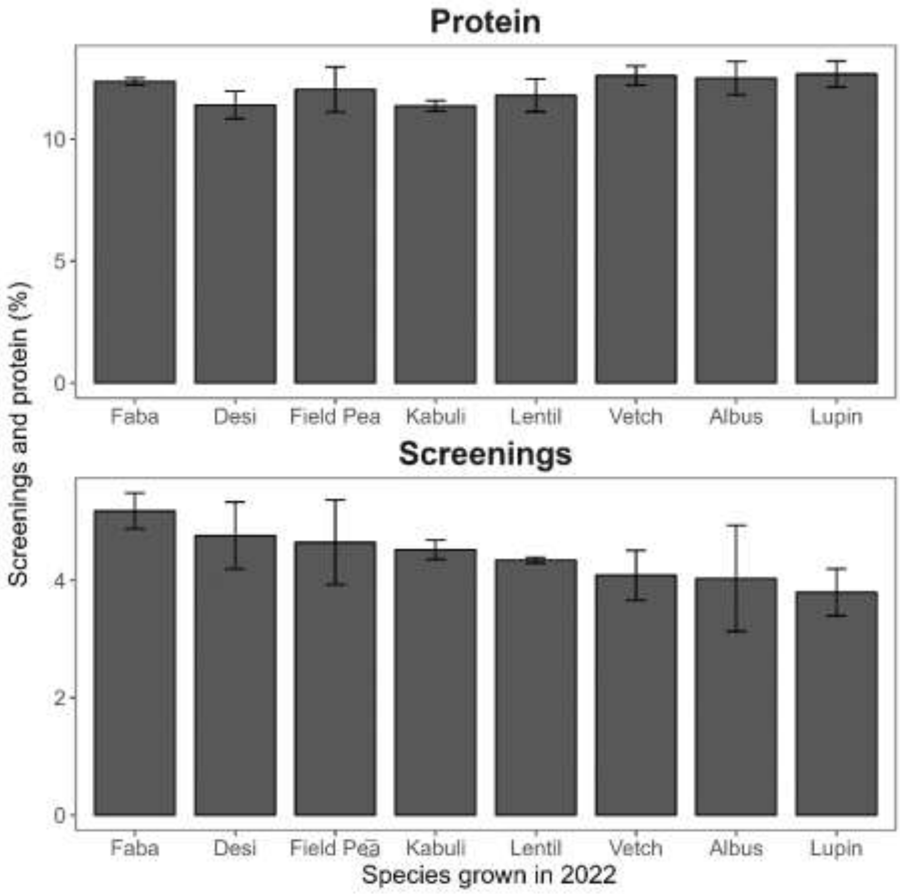

Figure 6. *Top panel: wheat protein after various pulse species. Bottom panel; wheat screenings after various pulse species*.

Conclusions

2022 results show that narrow leaf lupin is a very reliable choice of legume crop for this soil type at this location. Other species, that can attract higher grain prices, including faba beans and albus lupin also yielded well. However, it should be noted that these species do need a favourable season with early sowing time to yield well in this location and marketing of grain should be considered before sowing. Chickpea yields were disappointing and were likely impacted by less-than-ideal establishment.

The 2023 yield results showed no significant difference in wheat after the pulse species, although there was a lot of variability due to a very dry season. Given the difficult establishment period and lack of rain the mean wheat yield of ~1.3 t/ha was good.

The amount of nitrogen removed from the paddock in wheat grain in 2023 was similar to the amount of fertiliser nitrogen applied. Considering this, the trial will be sown to wheat again in 2024 to further investigate legacy effects of pulses. Rotational water use efficiency and nitrogen use efficiency and gross margin will be calculated after the 2024 season.

References

Angus, J, Bell, M, McBeath, T, Scanlan, C (2020) Nutrient-management challenges and opportunities in conservation agriculture. In 'Australian agriculture in 2020: from conservation to automation in the search for sustainability.' (Eds J Pratley, J Kirkegaard.) pp. 221-237. (Agronomy Australia and Charles Sturt University: Wagga Wagga NSW)

Harries, M, Anderson, G, Hüberli, D (2015) Crop sequences in Western Australia: what are they and are they sustainable? Findings of a four-year survey. *Crop and Pasture Science* **66**, 634-647. http://dx.doi.org/10.1071/CP14221

Harries, M, Flower, KC, Renton, M, Anderson, GC (2022) Water use efficiency in Western Australian cropping systems. *Crop and Pasture Science* -. http://dx.doi.org/https://doi.org/10.1071/CP21745

Harries, M, Flower, KC, Scanlan, CA (2021) Sustainability of nutrient management in grain production systems of south-west Australia. *Crop and Pasture Science* **72**, 197-212. http://dx.doi.org/10.1071/CP20403

Kirkegaard, JA, Peoples, MB, Angus, JF, Unkovich, MJ (2011) Diversity and evolution of rainfed farming systems in southern Australia. In 'Rainfed Farming Systems.' (Eds P Tow, I Cooper, I Partridge, C Birch.) pp. 715-754. (Springer: Dordrecht, The Netherlands)

Sadras, VO (2020) On water-use efficiency, boundary functions, and yield gaps: French and Schultz insight and legacy. *Crop science* **60**, 2187-2191. http://dx.doi.org/10.1002/csc2.20188

Acknowledgments

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Chapman Valley - Species x time of sowing trial

Stephanie Boyce, Martin Harries, Chris Shaw and Lea Obadia

Key Messages

- This is a multi-year trial assessing the impact and legacy effects of legumes, canola and barley on wheat.
- The 2023 Season was below Decile 1, with lower-than-average yields.
- Barley yielded 2.3 t/ha, wheat 2.1 t/ha, grain legumes ranged 0.7 to 1.9 t/ha and canola 1.2 t/ha.

Background

The Chapman Valley Species by Time of Sowing trial is a satellite site of the Western Australian Farming Systems Project, the project was established to Investigate strategies to increase profit across the rotation while managing weeds, diseases, soil fertility and risk. The three main outputs of the project are:

- Output 1; Sowing opportunities
    - A thorough analysis on the opportunities and risk of changing the timing of seeding.
- Output 2; Diversity/rotation
    - System break options that deliver improved profit and acceptable risk.
- Output 3; Nitrogen inputs and GHG emissions
    - Analysis of management options for maintaining profitability under low greenhouse gas (GHG) emission scenarios.

Objectives

The objective of the Chapman Valley Species x TOS trial is to test all the common species of crops grown in WA agist each other within the same trial. There are many studies of sowing time effects on each crop species in separate trials but none which directly compare between species. In 2024 plots will be sown to wheat and split into high and low nitrogen treatments, such that we can investigate legacy effects and interactions of legume crops and fertiliser nitrogen application rates.

This works towards provide answers to all the project's outputs.

The trial will assess the relative yield of different crop species, so growers can make more informed decisions on when to change species sown, relative to sowing opportunities. It will also assess the impact and legacy effects of legumes, which is important when assessing the impact of more diverse rotations and whether fertiliser N rates can be reduced by incorporating break crops.

Key observations within the trial we will be focusing on are the legacy effects of nitrogen and water, to assess Nitrogen Use Efficiency (NUE) and Water Use Efficiency (WUE) on the different crop types and rotations.

Methods

The trial was sown on Brady Green's property 60 km to the north/east of Geraldton, in the Shire of Chapman Valley. The soil is a red loam typical of the valley floors in the region. Time of sowing (TOS) 1 occurred on 24 May and TOS 2 14 June (3 weeks apart). Plots were 20 m long by 2.0 m wide, with varieties grouped into species blocks for ease of management (Figure 2).

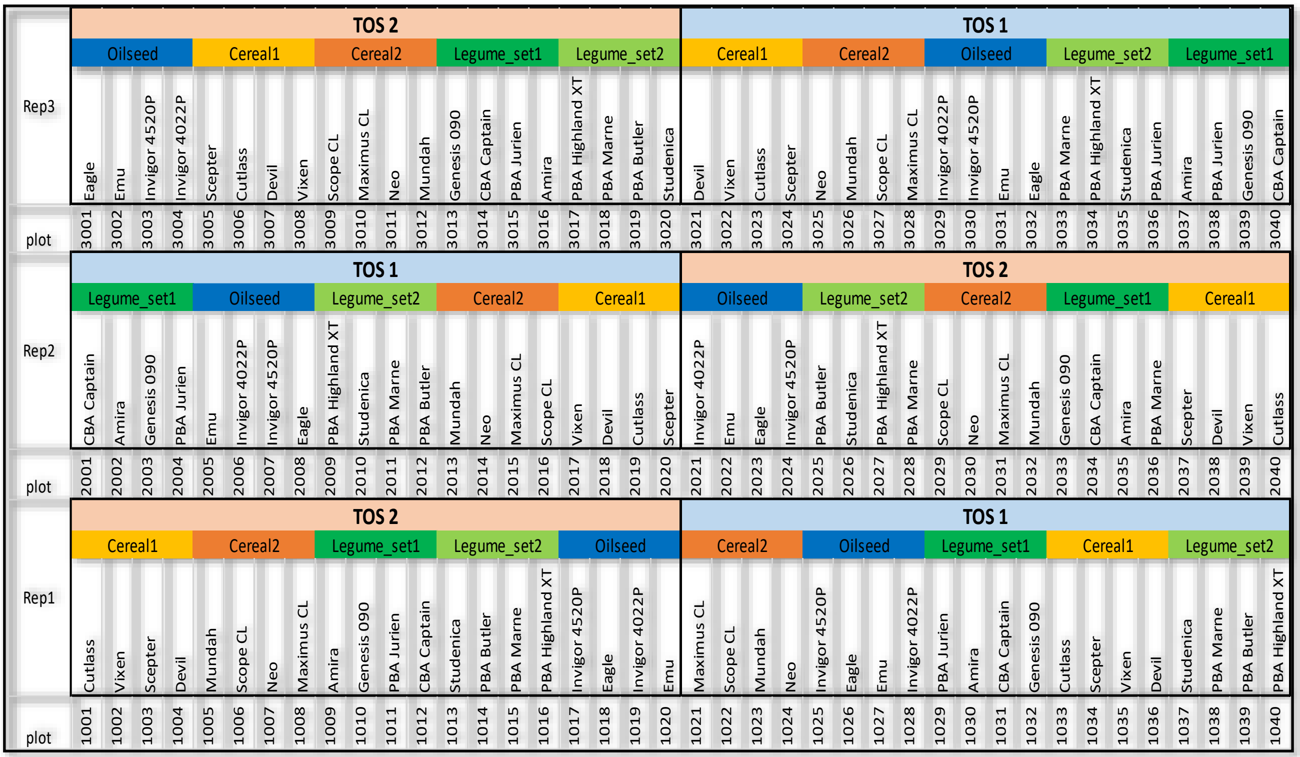

***Figure 2:** Chapman Valley Species by TOS Trial layout 2023.*

For cereals (wheat or barley) and oilseeds (canola), 4 varieties were selected to provide a range of maturity types. For the two legume sets a range of legume species were selected, which also provide a wide range of maturity types (Table 1). This resulted in 40 treatments (20 varieties/species x 2 TOS), by three replicates.(Table 1).

***Table 17:** Chapman Valley treatment details. Including species, variety, targeted seeding densities and variety details.*

Crop type	Variety	Variety Details
Cereal1	Cutlass (APW)	Mid-slow maturity (2015). Later season Wheat
Cereal1	Vixen (AH)	Quick maturity (2018). Highest yielding variety in this Agzone.
Cereal1	Scepter (AH)	Quick-mid maturity (2015). Remains the yield benchmark in WA
Cereal1	Devil (AH)	Quick-mid maturity (2018).
Cereal2	Mundah	Very early Spring. Feed Barley.
Cereal2	Scope CL	Medium Spring. Malting Variety.
Cereal2	Neo	Neo is the newest IMI variety, Mid-Spring maturity (2023).
Cereal2	Maximus CL	Early Spring (2018). Malting Variety.
Legume_set1	Amira	Albus Lupin. Early Flowering, Anthracnose resistant variety
Legume_set1	Genesis 090	Kabuli Chickpea. Longer reproductive duration (Compared to desi)

Crop type	Variety	Variety Details
Legume_set1	PBA Jurien	Narrow Leafed Lupin (2016). High yielding sweet lupin, resistant to Anthracnose.
Legume_set1	CBA Captain	Desi Chickpea. Most productive and adapted (compared to Kabuli)
Legume_set2	Studenica	Vetch, common type for grazing, hay or grain
Legume_set2	PBA Butler	Field Pea, high yielding semi-leafless
Legume_set2	PBA Marne	Faba Bean, early flowering, adapted for shorter seasons than other varieties
Legume_set2	PBA Highland	Lentil, medium size red with group B herbicide tolerance
Oilseed	Invigor 4520P (TF)	Early-Mid Maturity (4.5).
Oilseed	Eagle (TF)	Mid-Maturity (5).
Oilseed	Invigor 4022P (TF)	Early-Mid Maturity (4).
Oilseed	Emu (TF)	Early Maturity (3).

Agronomic management included application of fertiliser and pesticides. For cereals Agstar extra was applied at sowing at a rate of 100 kg/ha plus an additional 60 kg/ha of urea for legumes, 80 kg/ha of AGNP, and for canola 100 kg/ha agstar extra plus 75 kg/ha of urea. 60L/ha of MAXamFLO post emergent was applied to the wheat, barley and canola. Herbicides and fungicides were applied such that weeds or diseases did not impact the trial.

Measurements included pre-seeding soil sampling, plant establishment counts, regular Normalised Difference Vegetation Index (NDVI) readings, regular BBCH phenology scores, drone flights, root nodulation scoring, foliar harvest cuts, grain yield, grain quality, and end of year soil moisture to 1.5 m. Yield results reported were analysed using hand harvested yields.

Statistical analysis was conducted using Asreml-R R version 4.3.1. Linear mixed models were fitted to assess interactions between variety and time of sowing, crop type and time of sowing and crop type, variety and time of sowing, for the variables yield establishment and biomass.

Location

The trial was sown on Brandon Green’s property 60kms to the North/East of Geraldton, in the Shire of Chapman Valley.

Table 18: *Chapman Valley (CV) Trial location.*

Site	Latitude (dd)	Longitude (dd)	Nearest town
CV	-28.445032	114.948336	Nabawa, Chapman Valley

Results

Pre-seeding soil analysis

Soil chemical analysis was taken prior to seeding (March), in 10 cm increments to a depth of 30 cm (Table 3). Ammonium nitrogen, phosphorus and pH levels were adequate/reasonable at the site.

Table 19: *Pre-Seeding Soil Chemical Analysis.*

Depth cm	Ammonium Nitrogen mg/kg	Nitrate Nitrogen mg/kg	Phosphorus Colwell mg/kg	Sulphur mg/kg	Organic Carbon %	Conductivity dS/m	pH Level (H_2O)
0-10	7	7	34	7.9	1.25	0.185	8
10-20	3	3	44	2.6	0.86	0.067	7.4
20-30	3	1	24	1.4	0.46	0.048	7.6

Meteorological

The site received 198 mm of yearly rainfall and 172 mm of growing season rainfall, which put the site below decile 1 for the 2023 season (Figure 3).

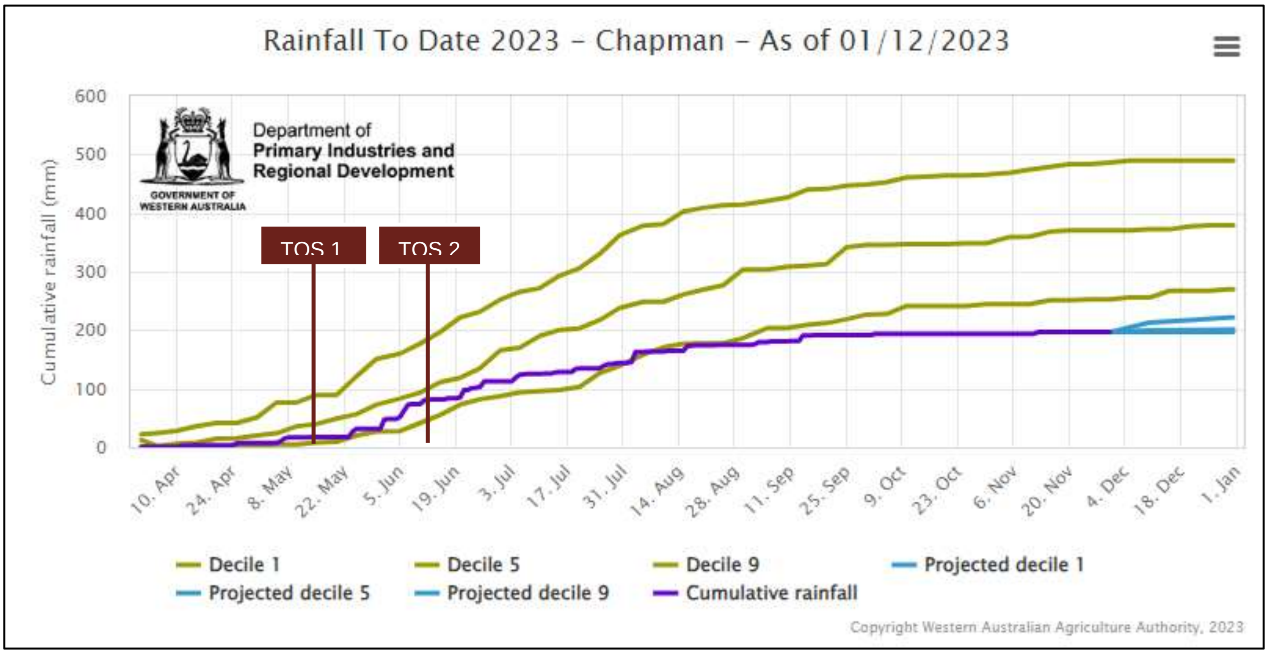

Figure 3: *CV rainfall to date.*

Monthly minimum and maximum temperature were measured using an onsite weather station, rainfall from Bureau of Meteorology Naraling weather station, 13 km away (BOM site 008274). Annual rainfall was well below the sites long term average rainfall of 364 mm.

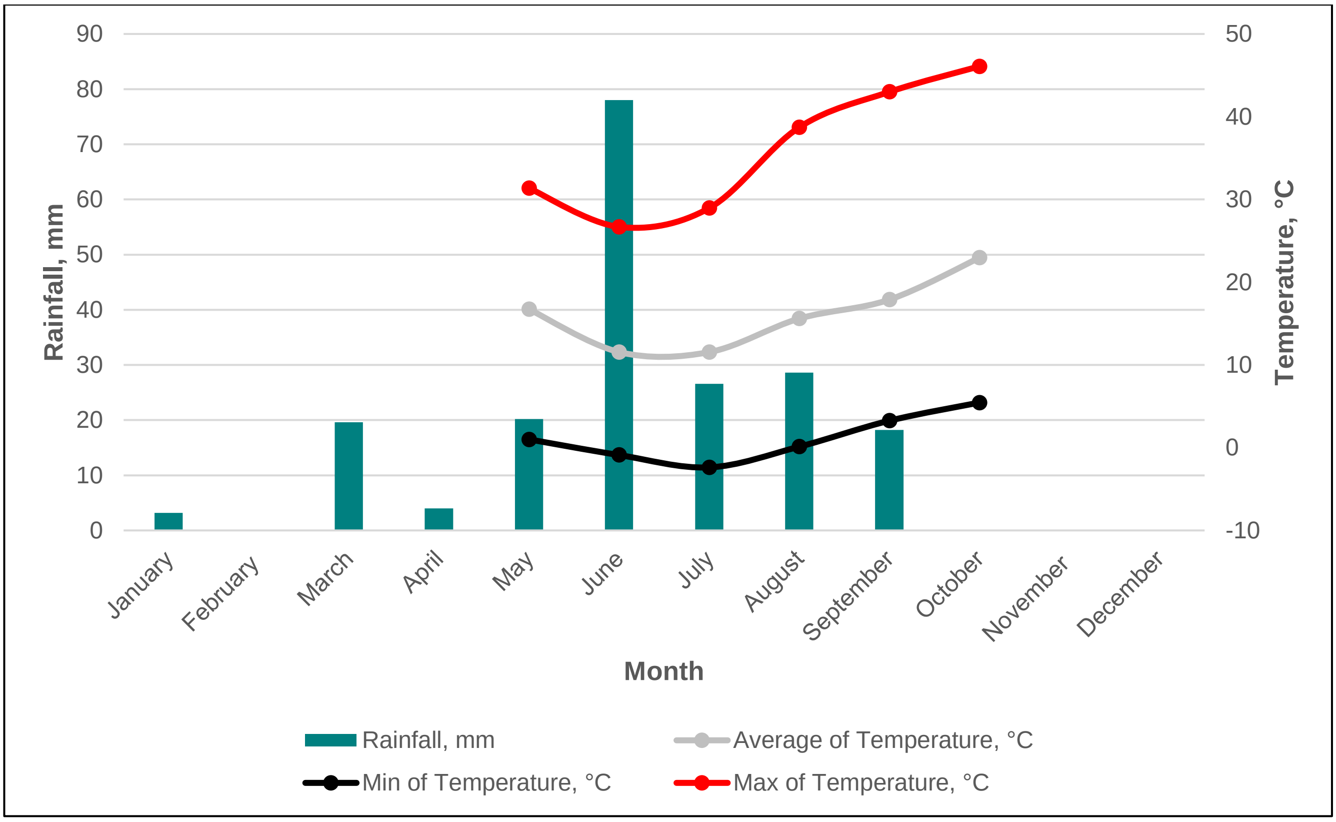

Figure 4: *CV site rainfall, min/max/average temperature.*

There was limited moisture at seeding, with a total of 38 mm of rainfall falling in 2023 before seeding and 9 mm falling just after TOS 1 (May 24). Fortunately, TOS 2 (June 14) was sown into reasonable soil moisture, with 26 mm falling the week prior to seeding. Resulting in better establishment rates at TOS 2, compared to TOS 1.

Plant establishment

Due to unfavourable conditions at seeding most species established below the target density (Table 1, Figure 6). Achieved densities of legume1, legume2 and oilseeds were close to target densities, with the exception of lentils and for cereal sets achieved density was well below the target. This was likely due to the dry conditions at sowing.

As expected, given the large difference in target density of the varieties/species, there was a significant difference in establishment between varieties/species and crop types (P = 0.001). Overall mean plant density from TOS 2 (70 ppm^2) was greater (P = 0.023) than TOS 1 (64 ppm^2). For all crop types, plant density was greater at TOS 2 hence there was no significant interaction effect of crop type and sowing time (Figure 5). Similarly, TOS 2 (June 14) establishment was better for most varieties/species compared to TOS 1 (May 24), except for Neo barley, Amira lupin, and Marne faba bean, which established better from TOS 1 (Figure 6). However, there was no significant interaction between variety/species and TOS, hence no evidence to suggest any variety responded to TOS differently (P = 0.192).

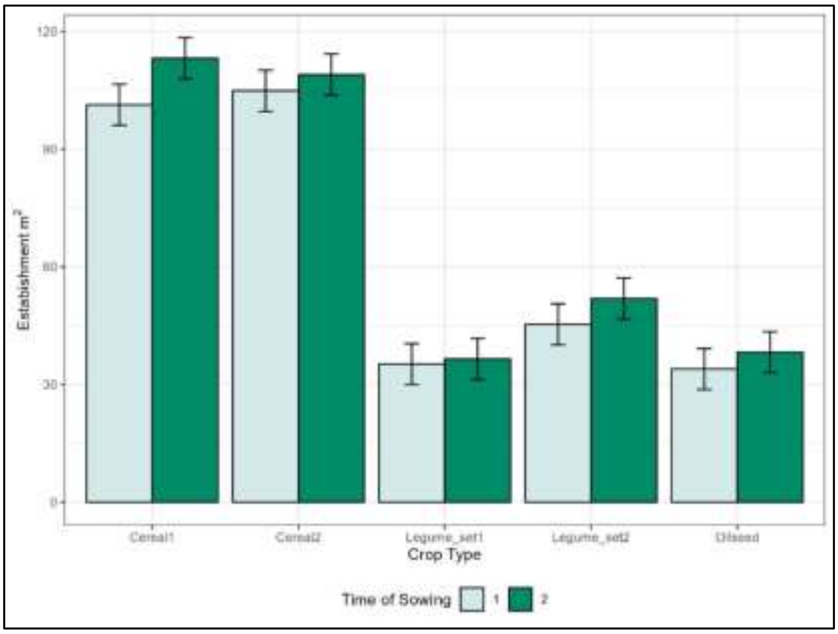

Figure 5: *Crop type average - plant establishment counts m2.*

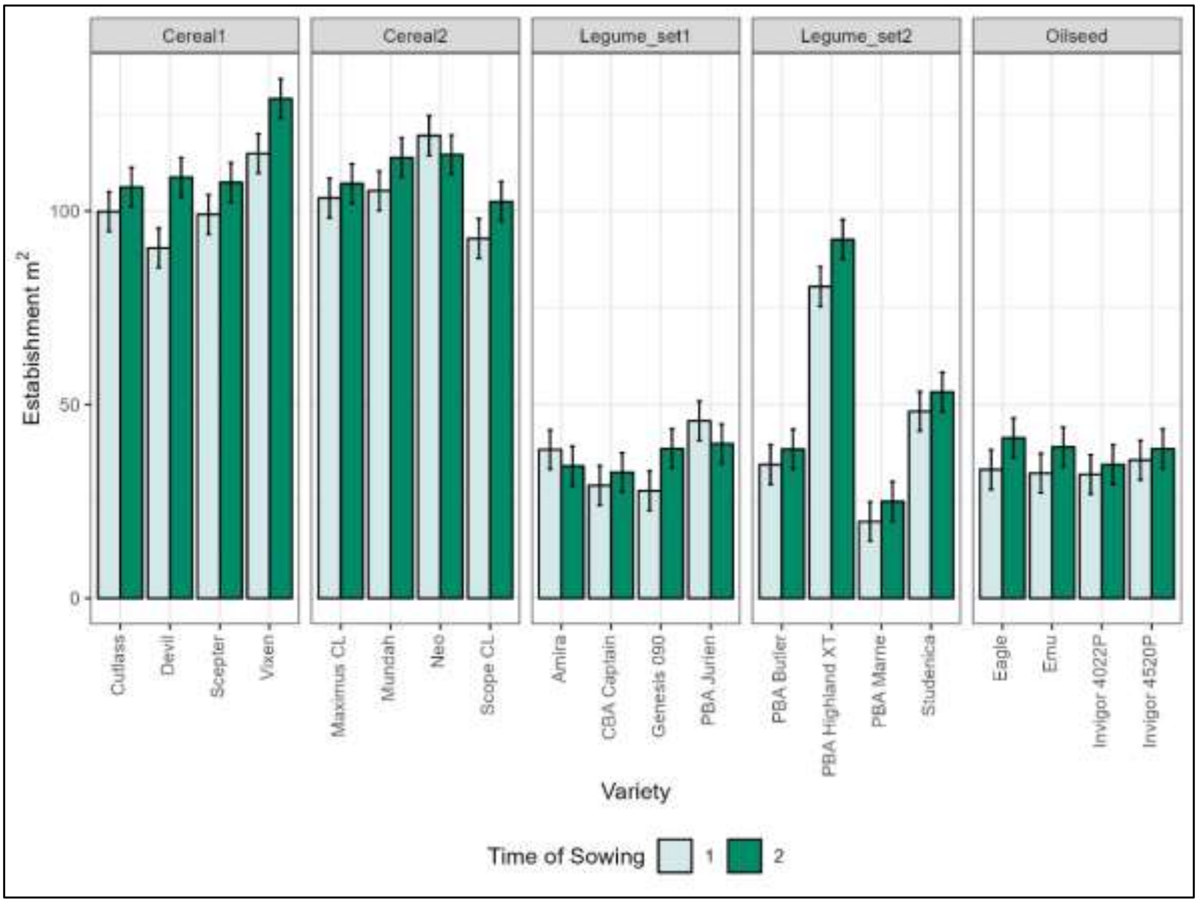

Figure 6: *Variety average - plant establishment counts (p/m²).*

Crop development

From July, fortnightly NDVI readings and BBCH Phenology scores were taken. Crop development and flowering durations were constrained and accelerated by numerous seasonal conditions.

Average days to flowering in order of species was as follows: canola 77 days, legume1 78 days, legume2 80 days, wheat 93 days and barley 97 days. There was more variation in phenology between the legume species than the cereals or canola, despite the selection of cereal and canola varieties with a wide range of season lengths. Nuseed's Emu TF Canola in TOS 2 was the first treatment to flower. It would be expected that flowering would occur in TOS 1 first, but TOS 1 of the canola was grazed by kangaroos.

Legume set2 (containing field pea, lentil, vetch and faba bean) matured the earliest with an average of 131 days to senescence, followed by wheat and barley maturing with an average of 139 and 136 days to senescence respectively, canola averaged 141 days and legume set1 (containing desi chickpeas, kabui chickpeas, narrow leafed lupins and albus lupins) averaged 155 days to senescence. Hence there was a large difference in days to senescence despite the season being very dry, with little spring rain.

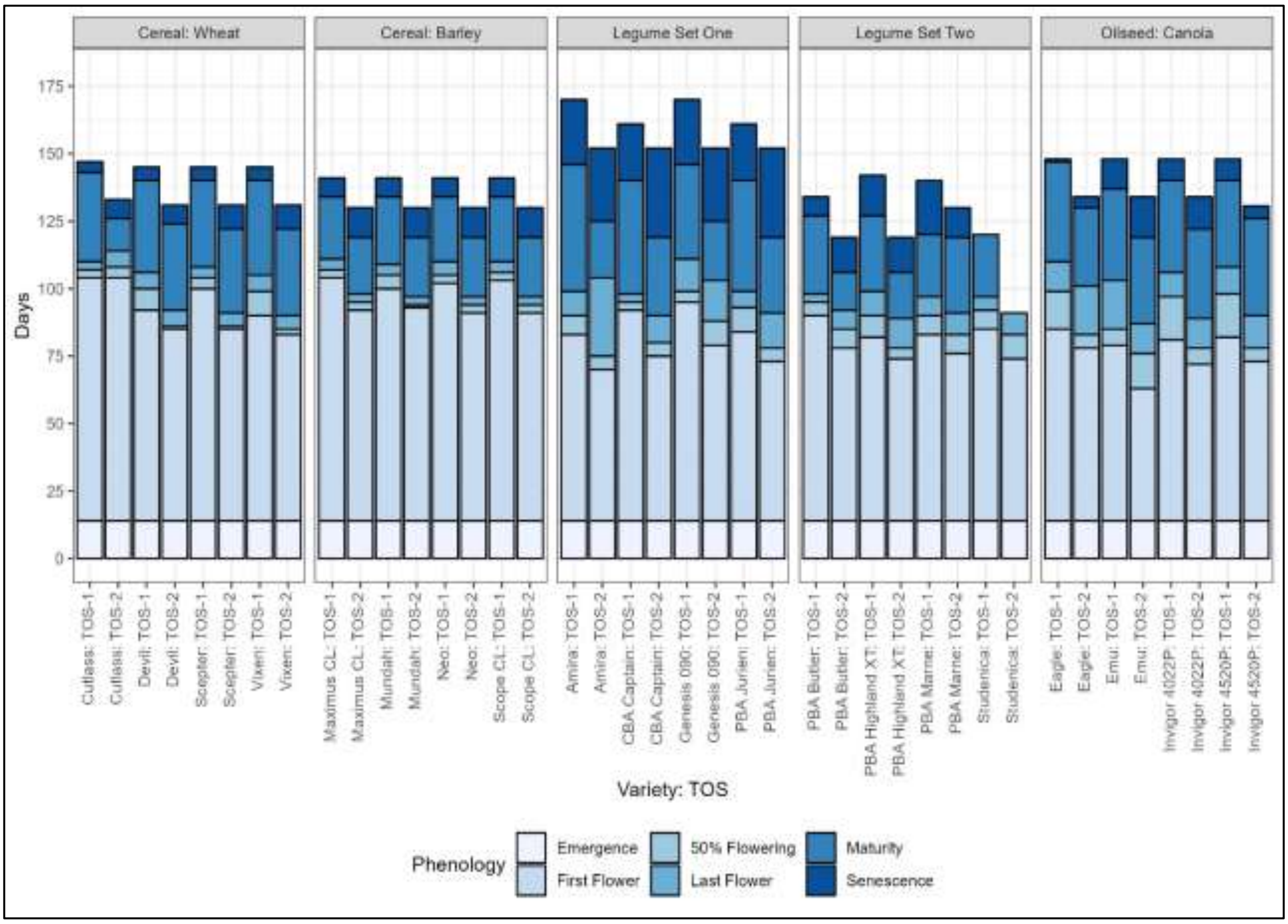

Figure 7: *Phenology.*

Normalised Difference Vegetation Index (NDVI)

NDVI readings were taken using a handheld Trimble Greenseeker. TOS 1 vegetation greenness peaked around August 3 with TOS 2 vegetation greenness peaking approximately 2 weeks later, on August 17 (Figure 8). Following peak vegetation greenness, NDVI readings reduced for oilseed (canola) and to a lesser degree both sets of legumes. This was due to flowering, with readings of green area increasing after flowering.

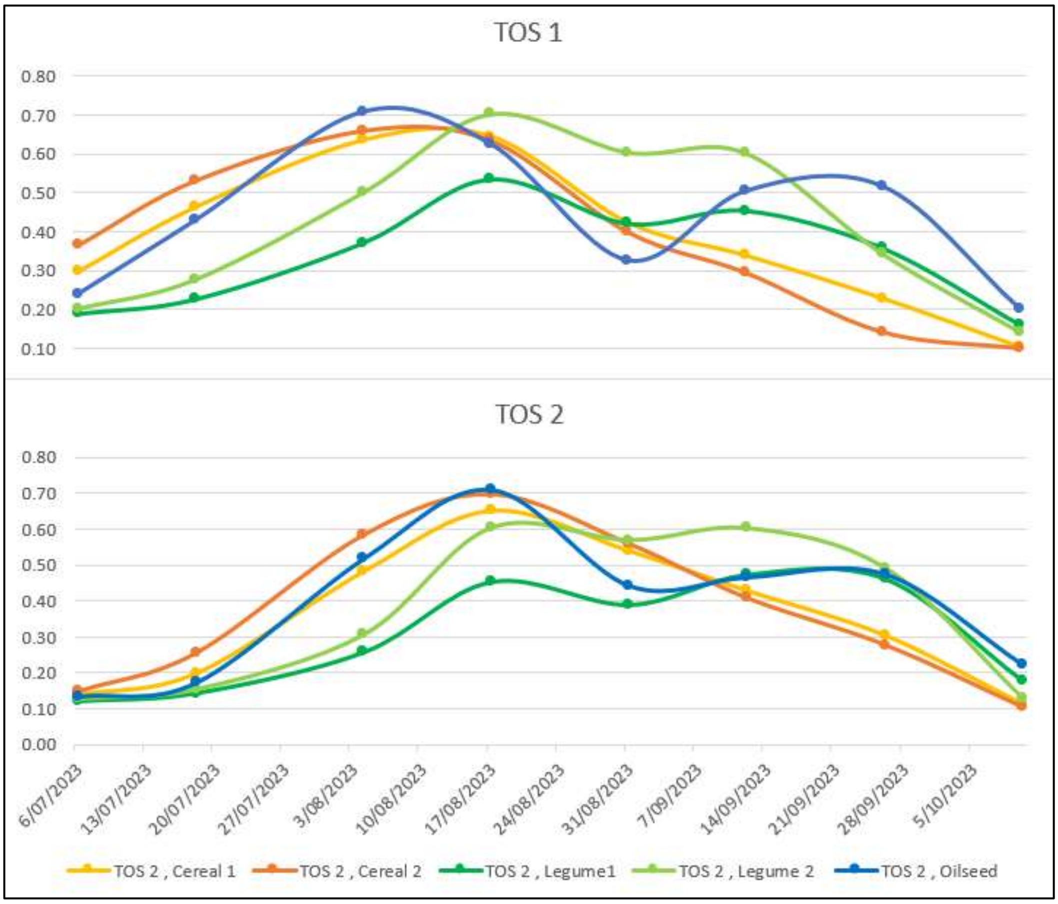

Figure 8: 2023 NDVI readings.

Root Nodulation

12 weeks after sowing, root nodulation scoring was conducted on all the legume plots. This involved digging up plants, bringing them back to the lab, washing roots and scoring/assessing them using a 0-8 scoring scale (Figure 9).

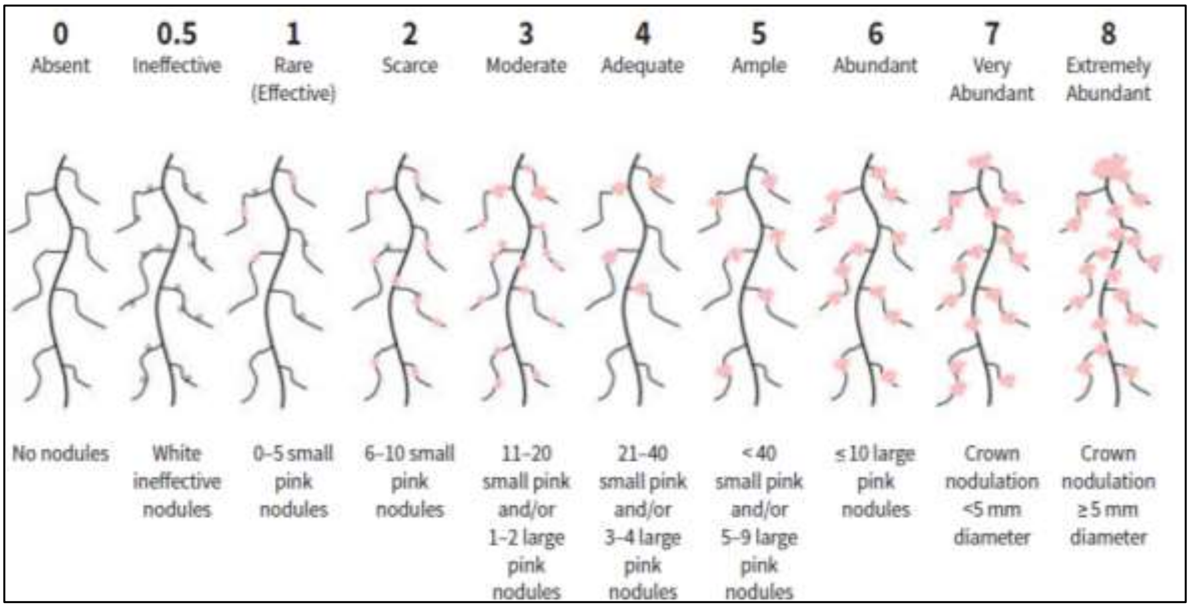

Figure 9: *Nodulation rating scale. Howieson, J.G. and Dilworth, M.J. (Eds.). 2016. Working with Rhizobia. Australian Centre for International Agricultural Research: Canberra.*

For most species legumes nodulated better from TOS 2, as the conditions at seeding were more favourable for inoculum survival. Marne faba bean received the highest average root nodulation score, followed by field pea, vetch, lentil, albus lupin, narrow leafed lupin, desi chickpea and lastly kabui chickpea (Figure 10). Lupin root nodulation was lower than anticipated and both the kabuli chickpea and the desi chickpea did not nodulate in TOS 1, despite being inoculated.

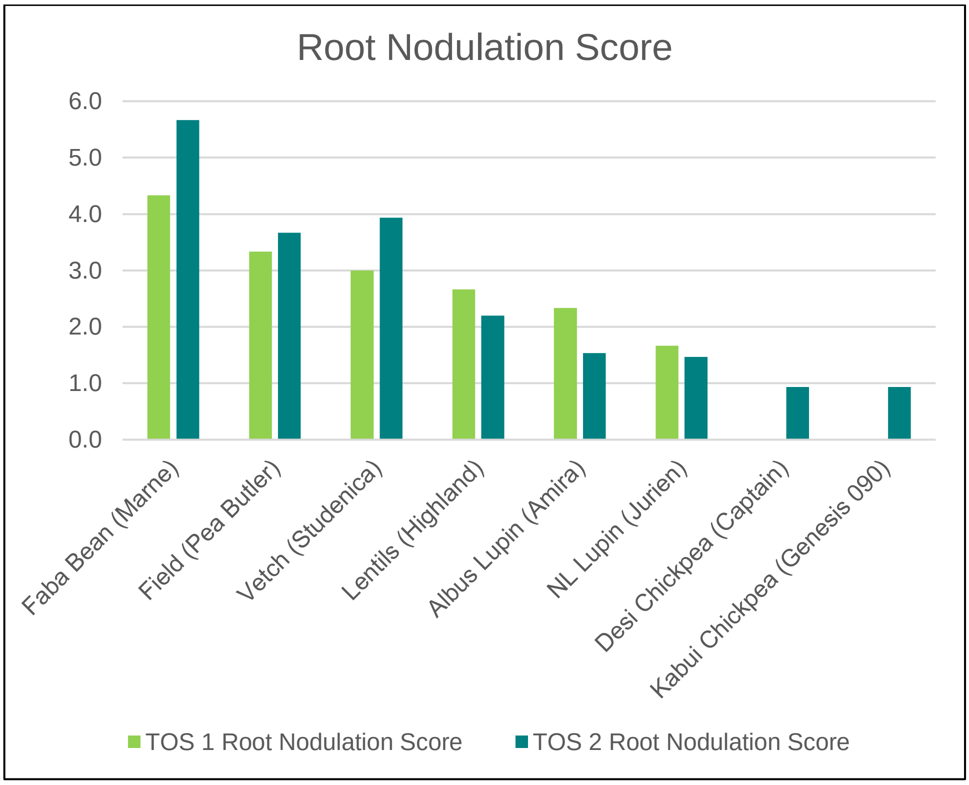

Figure 10: *Root nodulation scoring.*

Harvest cuts

Harvest cuts were conducted on all plots at maturity, but prior to senescence. This was therefore at different dates dependant on variety/species/TOS. Butler field pea had the highest accumulated foliage biomass and Highland lentils the least.

Overall biomass from TOS 1 was 4337 kg/ha and for TOS 2 3825 kg/ha with no significant difference (P = 0.138). There were differences between crop types (P < 0.001) (Figure 12). Despite legume set one not having a response to TOS (Figure 12), there was no significant difference in crop type response to TOS (P = 0.662). Within crop types there were significant difference in the response of varieties/species (P < 0.001), i.e., in legume set 2 chickpea biomass was lower at TOS 1 (as per establishment, Figure 6), compared to TOS 2, while for lupin it was greater (Figure 11).

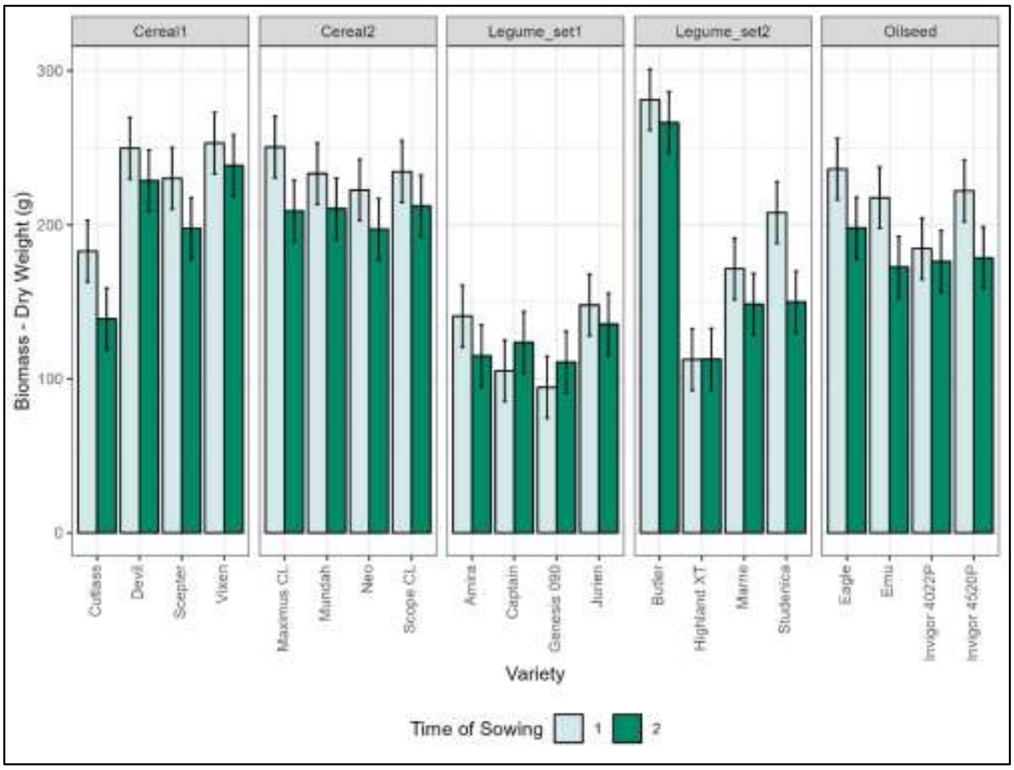

Figure 11: *Plant biomass (g) at maturity.*

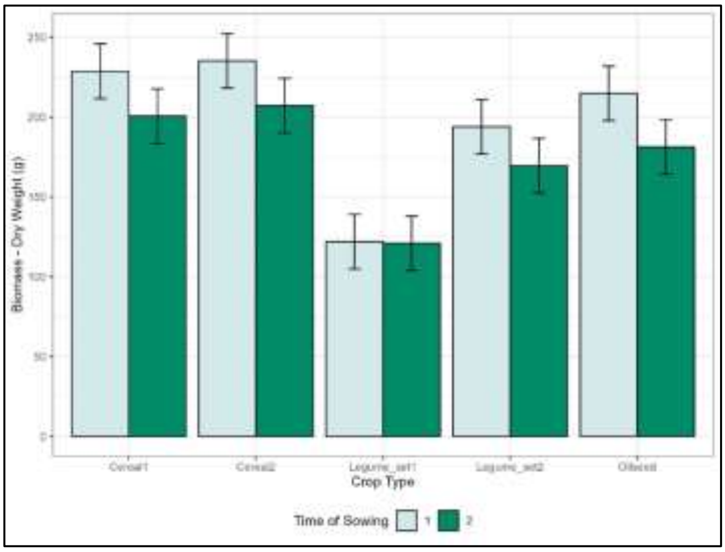

Figure 12: *Average biomass - Crop type.*

Yield

Overall yield was 1.8 t/ha from TOS 1 and 1.4 t/ha from TOS 2; note these are hand harvested yields, so may be slightly greater than expected for machine harvest. There were obvious differences in yield based on crop type, interestingly barley yielded more than wheat and legume set 2 more than legume set 1 (Figure 13).

Cereal set 2, barley, had the greatest average yields from TOS 1 at 2.6 t/ha. Legume set 1 TOS 1 had the lowest average yields at around 0.9 t/ha (Figure 13). The highest yielding treatment was Maximus CL barley in TOS 1 and the lowest yielding treatment Genesis 090 Kabuli Chickpea in TOS 1 (Figure 14).

There were different reposes of crop type and varieties/species within crop type to time of sowing. Hence significant differences between Variety/TOS and Crop Type/TOS (P < 0.001), meaning time of sowing needs to be considered when comparing crop type and or variety (Figure 14).

For the wheat the sorter season varieties yielded more, vixen the most and had lower yield reductions due to later sowing than the longer season varieties, such as cutlass. For barley the early spring variety Maximus yielded the most from TOS 1 however, unlike the wheat there was less difference between varieties of barley at TOS 2. For the legumes the TOS response was not as great as for the cereals or canola. Unlike cereals or canola yields at TOS 1, legume yields were not always greater than TOS 2. For canola there was no difference in yield of varieties for TOS 1 but a larger reduction in yield of longer season varieties from TOS 2.

Overall minimal summer rainfall, a late break, below average growing season rainfall and high temperatures restricted yields within the trial and throughout the district. Despite this the trial showed responses to sowing time that differ for species and varieties.

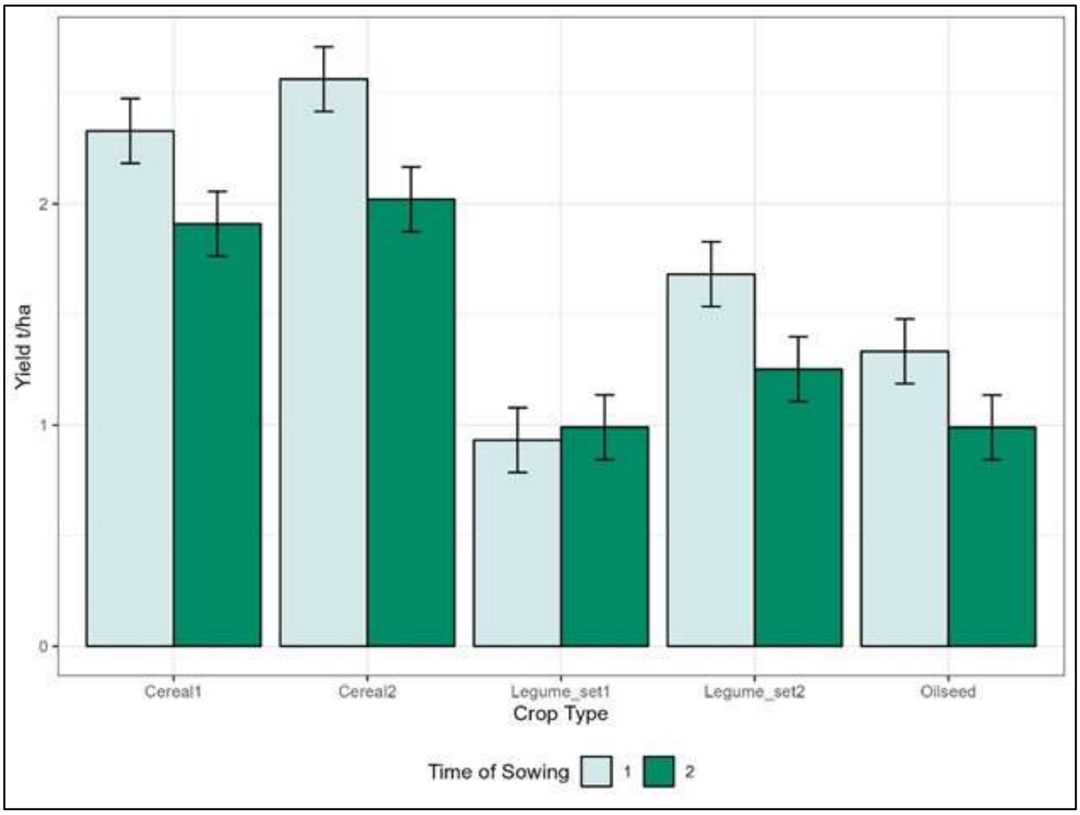

Figure 13: *Site crop types yield t/ha.*

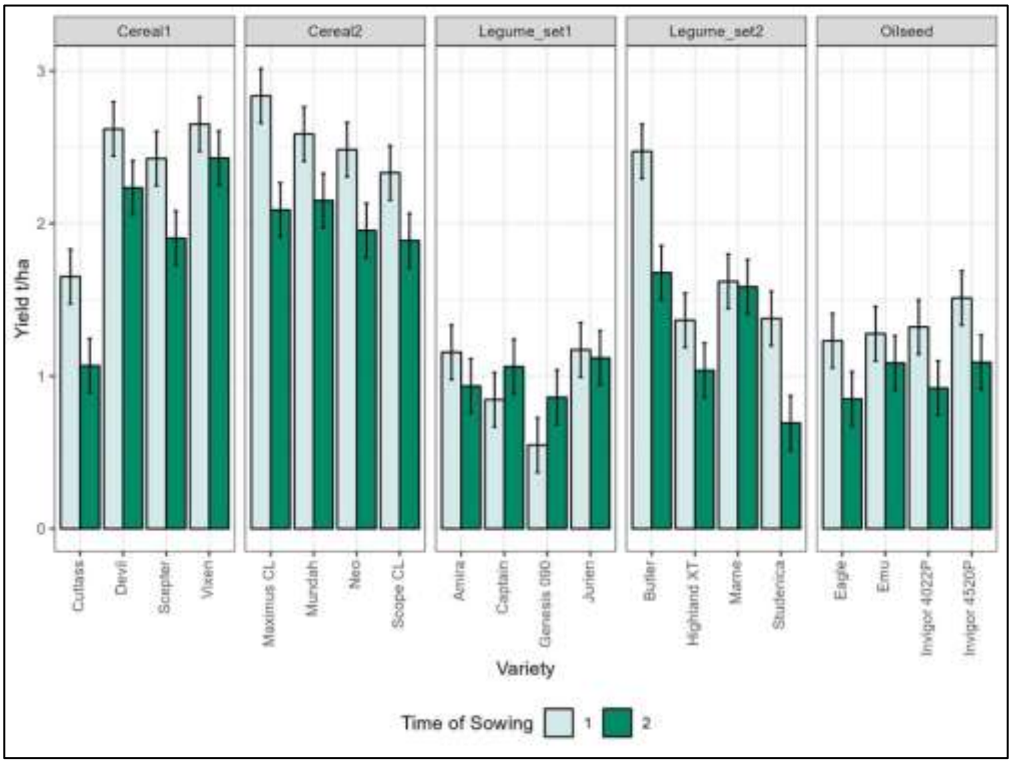

Figure 14: *Variety yield t/ha.*

Note Studenica vetch was removed from trial prior to seed set to avoid any contamination with future lupin crops.

Grain quality

Mean protein for the site was 16.6%. The lowest protein levels were obtained from the barley plots with an average of 8.9% for TOS 1 and 10.6% for TOS 2. The highest protein levels were seen in Legume Set 1, with 25.0% for TOS 1 and 24.7% for TOS 2 (Table 4).

Mean 100 seed weight for each of the species was 3.5g for the wheat, 4.9g for the barley, 21.2g for legume set 1, 16.7g for legume set 2 and 0.3g for the oilseeds. There was no significant difference between the TOS for each species, however there was a significant difference between the crop types.

Average canola seed oil content for TOS 1 was 41.4% and for TOS 2 was 39.4%.

Table 20: *Average protein levels for all species and TOS.*

Average of Protein (%)	TOS 1	TOS 2
Cutlass	10.4	12.3
Devil	9.4	10.9
Scepter	9.3	10.7
Vixen	9.4	10.6
Maximus CL	9.0	10.5
Mundah	8.9	10.2
Neo	8.5	10.9
Scope CL	9.1	10.9
CBA Captain	20.1	19.8
Amira	32.9	32.1
Genesis 090	19.3	19.7
PBA Jurien	27.6	27.1
PBA Butler	22.0	22.7
PBA Marne	27.6	27.6
Eagle	20.9	22.6
Emu	21.6	22.1
Invigor 4022P	20.4	22.1
Invigor 4520P	22.3	22.9

Soil moisture - post harvest

Soil moisture was measured to a depth of 1.5 m after harvest. Gravimetric soil water content differed between crop types (Table 5), greatest in fallow areas between plots and lowest in wheat plots at all depths in the profile. Previous studies have reported canola to use more soil water than other crop species, however, due to the small plant size and modest canola yields canola did not utilise more soil moisture compared to wheat. Both legume sets had similar gravimetric soil contents at depth (100–150 cm) to the fallow plots, indicating that at least some legume species roots did not reach this depth in this experiment.

Table 5: *Post harvest gravimetric soil water contents.*

Post harvest gravimetric soil content (%)	Cereal1	Cereal2	Fallow	Legume_set 1	Legume_set 2	Oilseed
0-10	5.3	5.9	7.0	5.6	5.6	5.7
10-30	8.3	9.0	11.7	8.5	9.1	9.0
30-50	10.0	10.1	14.8	10.2	10.8	10.3
50-100	12.2	12.5	17.1	13.5	14.8	12.1
100 -150	13.2	12.3	18.4	16.0	17.5	13.6
Mean	9.8	10.0	13.8	10.7	11.5	10.1

Conclusion

Minimal summer rainfall, a late break, below average growing season rainfall and high temperatures resulted in lower-than-average yields for the trial and the district. Given the seasonal conditions yields from TOS 1 cereals and canola were impressive. The trial showed responses to sowing time for both growth and yield that differ for species and varieties.

The poor 2023 season may impact the results in the 2024 trial, due to the low nodulation scoring, limited nitrogen fixation and mineralisation.

In 2024 all plots and bare areas between plots, that were managed as clean fallow, will be over-sown with wheat to measure the legacy effects of each crop species x TOS combination on wheat. In 2024 the plots will be split into 10 m lengths, of high or low nitrogen treatments.

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