GOA Trial Site Report

Quantifying the legacy impacts of a range of alternate break crops on subsequent crop performance- Canowindra 2021-2022

Project Name	Validation and extension of farming system sequences to maximize WUE in low rainfall sandy soils of Southwest NSW
GRDC Investment Code	GOA2106-002RTX
GOA Trial Code:	GPMA01022-2
Season/Year:	Winter 2022
Location:	Gindurra', Canowindra
Trial Partners:	Rob Atkinson, Viridis Ag
Trial Establishment Date:	Winter 2021 (with various pulse species)

Keywords

Pulses, chickpeas, faba beans, vetch, field peas, lupins, lentils, nitrogen, protein, PredictaB, soil moisture, Canowindra, GPMA010

Take home messages

- High biomass pulse crops can fix large amounts of N
- 25 – 65% this N is exported in grain or hay- but it varies on crop type (and is effectively nil in the case of vetch manure
- Theoretical N remaining following pulse crops is often not reflected in soil testing for nitrates
- Trial site was only slightly responsive to N, regardless of whether fertiliser or fixed by pulse crop options – The benefits of pulse fixed nitrogen are likely to provide more legacy benefit when they are gown in paddocks that are known to be low to very low in N
- Soil moisture at this site was relatively unaffected by break crop option- most likely due to wet conditions – In higher rainfall/eastern environments, summer fallow rainfall may be enough to overcome legacy moisture differences between pulse crops
- Soil borne disease levels can be impacted by break crop option, and maybe a consideration in paddocks with risk of damaging levels of disease and for minimising risk in the subsequent crop
- There was very limited legacy crop response to any of the various break crop options tested reinforcing the need for the alternate break crops to be profitable in their own right.

Background

The term "break crop" is often attached to crops other than wheat or other cereals. This probably stems from previous eras of farming that generally had little crop diversity and crop rotations were largely non-existent. To be adopted as part of a cropping system or rotation is not unreasonable to expect the crop needs to be profitable in the year of growing them. However, break crops have also been suggested to provide additional, ongoing benefits to the farming system such as disease or weeds breaks to minimise their impacts and in the case of pulse crops, they may build on soil N reserves compared to other non-leguminous crop options. This in turn may reduce the need or reliance of fertiliser N in subsequent crops which may offer some savings or increased crop performance. There could also be benefits in regards capture, usage or storage of soil water.

The GRDC Funded, NSW Pulse Project (BRA2105-001RTX)[1] specifically focused on the performance of pulse options as break crops. The project looked at range of common pulse crops and varieties and quantified their performances. The project however was not able to quantify the potential legacy benefits of the various options tested.

GRDC funding under this project GOA2106-002RTX however specifically set out to quantify some of the potential influence that several alternate break crops options would have on subsequent crop performance. It aims to focus on four key areas-

- Soil mineral N prior to sowing of subsequent crops
- Soil water prior to sowing of subsequent crops
- Soil borne disease
- Subsequent crop performance in terms of yields and grain quality

To achieve this, the trials undertaken in the Pulse project sites were continued to be managed, sampled and analysed for soil N, water and disease and the trial areas then sown to winter crop in the season following to quantify the impact on crop performance. This report details the findings of this work.

Site details

Location – Canowindra

Soil type – Chromosol

Crop chronology- 2021- Various pulse and break crops

2022- Canola

Growing conditions – 2021 Was a wet year, faba beans yielded very well, as did lupins. The mild conditions rainfall through November and December delayed chickpea harvest to January 2022.

[1] Development and extension to close the economic yield gap and maximise farming systems benefits from grain legume production in New South Wales

2022 The trial site started the season with high levels of stored soil water from rainfall prior. Well above average growing season rainfall was received at the site.

Table 1. Trial site rainfall[2] in 2021, 2022, 2023 and the long-term average (LTA).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2021	61	76	101	1	34	88	80	76	72	44	130	46	809
2022	107	23	35	106	50	23	42	102	89	133	205	31	946
LTA	60	54	47	43	44	50	52	50	47	58	55	56	616

Treatments – the base treatments that are referred to throughout the rest of this report relate to the break crop options sown in 2021 winter season. These broadly consisted of five pulse species with 2 varieties of each. One non legume break crop option in canola was tested, and it had two contrasting nitrogen application rate strategies applied to its management- a high and low. Wheat was also sown in this trial as a non-break crop option, this also had two N management strategies applied. One final non cropped option tested was a fallow treatment, under this treatment weeds were continuously excluded for all the 2021 winter season and subsequent fallow period leading up to sowing in 2022. In both the wheat and canola options, N rates were applied in 2021 as detailed below. For the fallow treatment no N was applied in 2021, but differing rates of N was applied in the subsequent crop year of 2022. Break crop choice, variety and/or N management are listed in **Table *2*** below.

Table 2. Break crop species and varieties tested in year 1 and N rates applied

Description	2021 N (kg/ha)	2022 N (kg/ha)	Total N (Kg/ha)
Canola - Trophy - High N	107	95	202
Canola - Trophy - Low N	0	0	0
Chickpea - Captain			
Chickpea - Hattrick			
Faba - Nasma			
Faba - Samira			
Fallow - High N	0	120	120
Fallow - Low N	0	0	0
Lentil - Hallmark			
Lentil - Kelpie			
Lupin (broad) - Murringo			
Lupin (narrow) - Bateman			
Vetch - Studenica - Brown manure			
Vetch - Studenica - Hay			
Wheat - Mustang - High N	107	115	222
Wheat - Mustang - Low N	40	0	0

[2] Gridded data from: Access Gridded Data | LongPaddock | Queensland Government

Results

Summary of the 2021 pulse crop results (for yield and dry matter results see **Table 3**

- Faba beans had the highest grain yield (average 5.1 and 5.8 for Nasma and Samira respectively) and produced remarkably high biomass (average 14.8 t/ha and 15.0 t/ha or Nasma and Samira respectively).
- The high biomass indicates a high amount of nitrogen fixed, and the beans also had remarkably high removal in the grain with an average removal of 229 kg N/ha.
- Faba beans outyielded both canola and wheat even with high N input.
- Murringo (albus) and PBA Bateman (narrow leaf) lupins produced remarkably high biomass (17.6 and 15.6 t/ha respectively) similar to faba beans, but grain yield was lower than faba beans.
- Grain yield followed a similar trend with high yield for Murringo (4.3 t/ha) and PBA Bateman (3.4 t/ha)
- The dry matter production from vetch was low however the vetch was cut at an earlier growth stage (before podding) to simulate hay cut timing.
- CBA Captain chickpeas had low biomass compared to faba beans at both sites, with moderate grain yield (2.2 t/ha).
- CBA Captain chickpeas yielded more than lentils.
- Lupins had the highest seed N content, removing 90% more N than chickpeas (lowest seed N content) per tonne of grain produced.

Table 3. Dry matter production, yields, calculated nitrogen fixed and nitrogen balance, 2021. N balance calculated as starting soil N 2021 (assume all treatments the same level ~157 kg/ha) plus fertiliser N and N fixed by legumes minus N exported in grain matter production, yields and calculated nitrogen fixed, 2021

Species -variety/treatment	Dry matter (t/ha)	Yield (t/ha)	Calculated N fix (kg/ha)	N Balance (kg/ha)
Chickpea - Captain	7.03	2.15	112	195
Chickpea - Hattrick	3.98	0.82	111	240
Faba bean - Nasma	14.76	5.12	324	271
Faba bean - Samira	15.01	5.80	345	272
Lentil - Hallmark XT	6.74	1.41	124	222
Lentil - Leader	6.81	1.60	135	223
Lupin (narrow) - Bateman	15.60	3.42	520	498
Lupin (broad) - Murringo	17.59	4.29	525	419
Vetch - Studenica - manure	5.56		154	311
Vetch - Studenica - hay	5.39		49	206
Canola - Trophy - High N	14.75	3.98	0	127
Canola - Trophy - Low N	12.46	3.83	0	24
Wheat - Flanker - High N	13.74	4.30	0	169
Wheat - Flanker - Low N	12.10	3.94	0	72
Fallow - High N			0	264
Fallow - Low N			0	157
Lsd	2.79	0.57		

For more details see the 2021 Summary of field trial results (https://grdc.com.au/__data/assets/pdf_file/0042/577977/2021-Pulse-reports-book.pdf)

Break crop contribution to residual nitrogen prior to sowing the 2022

To calculate what contribution pulse would make to the soil N pool, first it must be determined what proportion of N in the crop is derived from the air (fixed by rhizobia) versus that taken up from the soil N reserves. This was achieved by laboratory analysis. Once known this proportion can be applied to the peak crop biomass to calculate the fixed N per hectare- this is termed “N-Fix”. Adding this amount to starting soil N levels but subtracting what N is removed in grain or hay results in a figure of the N Balance.

Table 3 details the N-Fix and the N balance calculated for each of the crop options tested. As can be seen the higher biomass of the lupins and to a lesser extent the faba beans resulted in very high levels of N fixed of up to ~520kg N/ha. However, when N removed in the grain is subtracted these numbers are reduced substantially.

The N balance of the non-pulse species is also shown. As a non-pulse they cannot fix any N and draw their requirements from soil reserves or added fertiliser. As can be seen in the **Table 3** even under the higher N strategies the net N budget theoretically should be lower following harvest.

Figure 1 below illustrates the soil mineral N as measured by soil sampling and analysis. Samira faba beans and vetch (hay) had soil nitrogen levels over 200 kg/ha, but not necessarily the highest N balance. Both lupin varieties had the highest N balance (>400kg/ha), but both had less than 200kg/ha of soil mineral N measured. Captain chickpeas had the lowest residual nitrogen with 119 kg/ha.

Low N wheat or canola had the lowest N balance yet had soil mineral N levels equal to or better than the chickpeas.

- The calculated nitrogen balance for lupins was over 400 kg/ha.

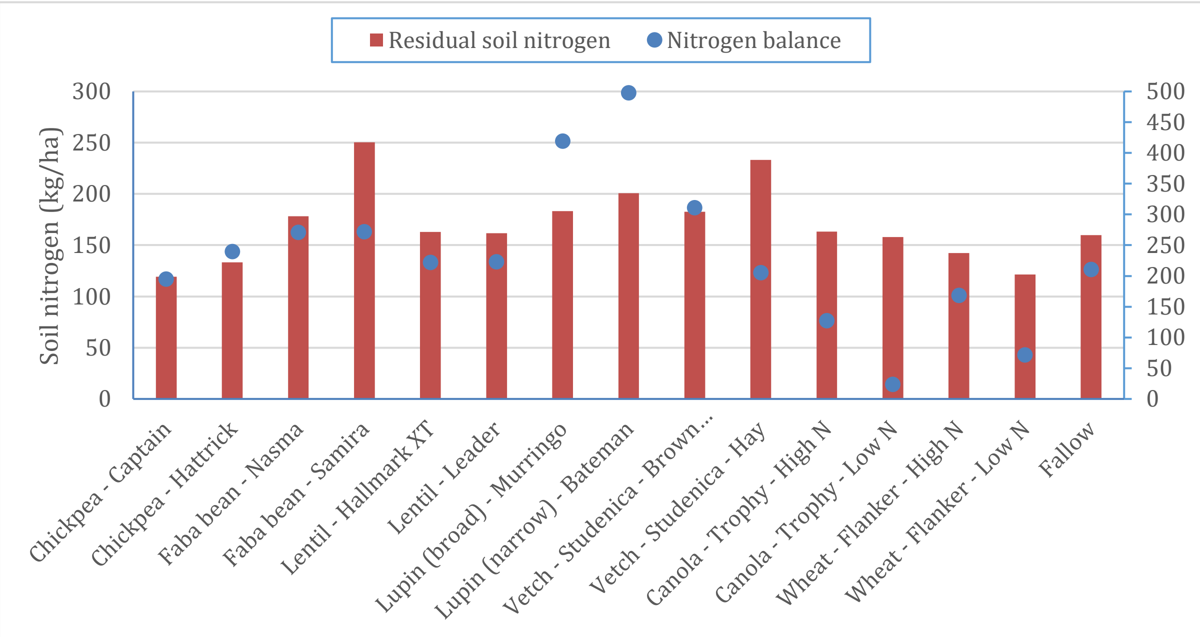

Figure 1. N balance following the crops planted in 2021 and soil N (0-60 cm) as tested prior to sowing the 2022 winter crops. Note that selected canola and wheat treatments had additional N added in the 2021 winter crop (see treatment list). N balance calculated as starting (2021) soil N (~157 kg/ha) plus fertiliser N and n fixed by legumes minus N exported in grain.

Impact on soil borne disease as tested by PredictaB testing prior to sowing of the 2022 crop

Trial treatments were sampled prior to sowing of the 2022 crop and analysed by PredictaB for a range of soil borne diseases.

The results are detailed in Table 4 below. Crown rot was highest following wheat and second highest following canola. Most other options tested showed significant reduction in the disease with nothing detected under the faba beans. Root lesion nematodes (*neglectus)* was highest following wheat and canola as well, lowest following faba bean and lupins. Lentils, lupin and chickpeas resulted in the largest increase in sclerotinia, more than 50 times higher than following canola. Ascochyta blight was highest following chickpeas but very low under all other options tested.

Table 4. PredictaB results, tested following the 2021 pulse trial and prior to sowing the 2022 winter crop

		Fusarium Crown Rot	Root lesion nematode	Sclerotinia stem rot	Ascochyta blight of chickpeas
		Fusarium pseudograminearum (test 1)	Pratylenchus neglectus	Sclerotinia sclerotiorum/ S. minor	Phoma rabiei
Species	**Variety**	pgDNA/g Sample*	nematodes/g soil	kDNA copies/g Sample*	kDNA copies/g Sample*
Canola	Trophy	2.86	0.84	1.63	0.00
Chickpea	Captain	0.68	0.28	562.99	6.60
Faba beans	Samira	0.00	0.00	0.00	0.01
Fallow	-	0.22	0.00	0.00	0.02
Lentils	Leader	1.31	0.12	230.03	0.22
Lupin	Bateman	0.61	0.06	111.11	0.00
Lupin	Murringo	0.44	0.00	9.60	0.04
Vetch	Studenica	0.17	0.25	0.01	0.00
Wheat	Flanker	5.59	0.81	0.25	0.02

Impact on soil water as prior to sowing of the 2022 crop

Soil moisture was assessed in early autumn following the pulse trial of 2021 using an EM38. Relative differences between the treatments are shown in Figure 2.

- Lentils, vetch (hay) had the highest relative stored soil moisture following the pulse trial.
- Faba beans had the lowest relative stored soil moisture.

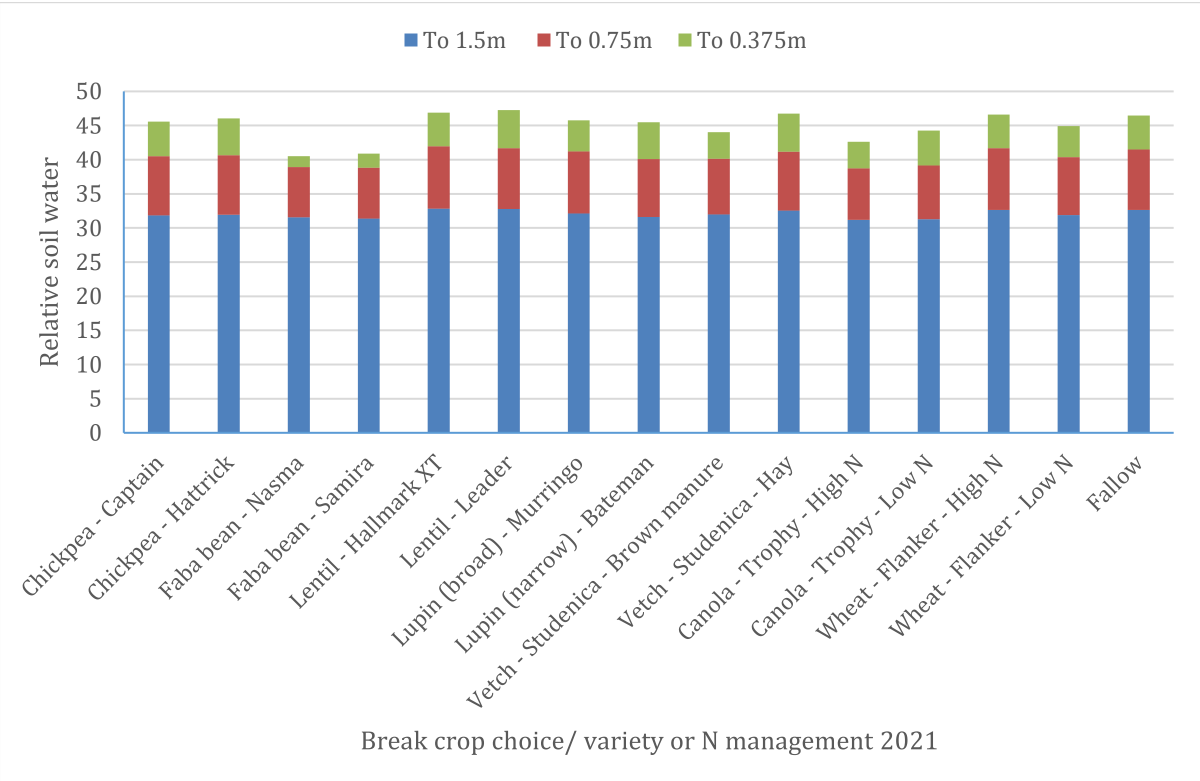

Figure 2. Relative soil water differences following the pulse trial of 2021, as assessed on the 3/3/2022.

Summary of 2022 canola performance

The canola following the break crop phase was very high yielding with all treatments achieving over 3.21 t/ha. The highest yields were 3.7t/ha and 3.65 t/ha following Hatrick chickpeas and Leader lentils respectively. These were amongst the lowest yielding break crops in 2021. Canola following canola with no added nitrogen fertiliser (3.2 t/ha) had the lowest yield and was not different to canola on canola where nitrogen was added (3.4 t/ha). The addition of nitrogen fertiliser to canola following wheat did not improve yields and adding additional N fertiliser to fallow treatments slightly reduced yields. Canola grown over the top of lupins (both albus and narrow leaf) did not perform better than other pulse crops, despite having a very high calculated N fix.

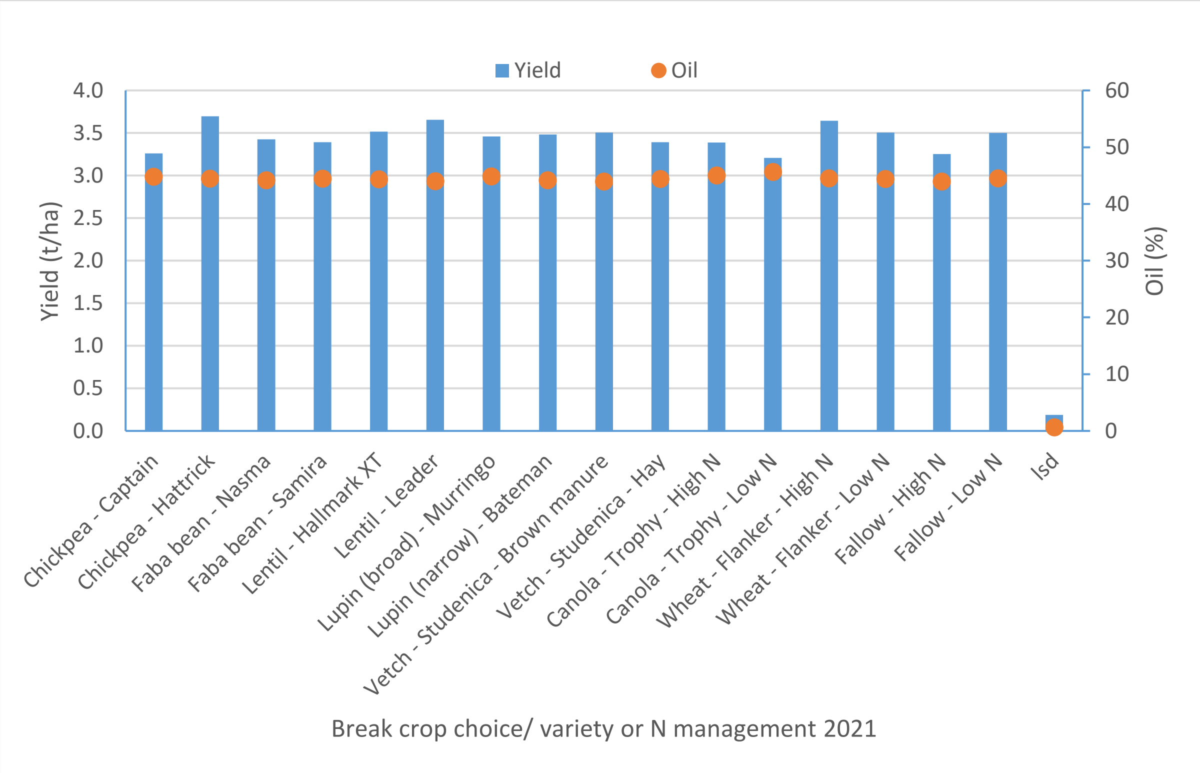

Figure 3. Canola yields (t/ha) in 2022 following crops planted in 2021

Discussion

The canola yields following the pulse trial of 2021 were very high, with an average of well over 3t/ha. Where nitrogen was added to non-pulse in 2021 (wheat, canola and fallow) there limited yield response. Again in 2022 added N only led to limited yield improvements. This would tend to suggest that nitrogen across the site was not a limiting factor for canola production in 2022.

Higher levels of nitrogen were identified in soil testing prior to 2022 sowing for some treatments. However, this was not necessarily well matched to the calculated N balance at this time, in the case of lupins, the soil testing detected less than half of the nitrogen that was calculated to have been added to the system. Treatments with high soil nitrogen did not necessarily correspond to increased yields in the subsequent canola crop.

There were considerable differences in legacy disease profile of the various treatments. The paddock had a history of wheat in 2020 and canola in 2019 and predictably the highest levels of root lesion nematodes and crown rot was detected where wheat was sown in 2021. The pulses in this trial all reduced the incidences of these diseases with none being detected where the faba beans were grown. There were differences in pulse effects on the legacy of other diseases which should be considered, particularly if double cropping is a consideration. Elevated levels of Sclerotinia were detected following chickpeas, lupins and lentils, suggesting that following these crops with canola might require a higher level of disease management. Chickpeas left behind higher levels of Ascochyta blight than other species demonstrating part of the reason that double cropping chickpeas is not recommended practice.

Differences were detected in legacy soil moisture, with faba beans having the lowest moisture. However, due to the wet conditions in the fallow period following the moisture testing and the subsequent winter crop, moisture differences did not appear to influence subsequent crop yields. In and eastern higher rainfall environment legacy soil moisture may be less of a consideration in choice of pulse crop than other factors.

Conclusion

The high biomass of the pulses in this trial was able to fix substantial amounts of N however this was not reflected in soil testing or crop performances in the following year. The site was most likely not limited by soil N which explains the lack of yield response in 2022. However, despite some increases in measured soil N the improvements did not remotely reflect the levels of N left by the pulses.

The lack of response in 2022 emphasises the need for pulse crops to be profitable, particularly if grown in non-N responsive situations. In this case the exceptional yields of the 2021 crops were likely to be very profitable and the lack of ongoing legacy benefits, not important.

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