GOA Trial Site Report

Quantifying the legacy impacts of a range of alternate break crops on subsequent crop performance- Trundle 2022-2023

GRDC Investment code	**GOA2106-002RTX**
Project Name	Validation and extension of farming system sequences to maximize WUE in low rainfall sandy soils of Southwest NSW
Trial Code:	GPMA01023-2
Season/Year:	Winter 2023
Location:	Trundle
Trial Partners:	Chris Berry
Trial Establishment Date:	Winter 2022 (with various pulse species)

Keywords

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

Take home messages

- High biomass pulse crops can fix large amounts of N
- 25 – 75% of this N is exported in grain or hay- but it varies widely depending on crop type
- Theoretical N remaining following pulse crops is often not reflected in soil testing for nitrates, nor crop responses.
- Soil moisture can be affected by break crop option – late maturing crops effected soil moisture levels that reduced yields in the subsequent crop
- Soil borne disease levels can be impacted by break crop option, and maybe a consideration in disease effected paddocks and for minimising risk in the subsequent crop
- The legacy effect of pulses can have positive responses in subsequent crops, however similar results can also be achieved t with added fertiliser N in a non-pulse system

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 and sustainable 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 trial 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.

Location – approx. 9 km south of Trundle

Soil type – Chromosol

Crop chronology-	2022- Various pulse and break crops
	2023- Wheat
Growing conditions –	2022 Had good soil starting moisture and received above average rainfall throughout the growing season. Sowing of the pulse crops was significantly delayed to the 28/6/2022 due to the wet conditions. Lupins and lentils established poorly.
	2023 Starting soil moisture from the previous wet conditions of 2022 was moderate. In-crop rainfall was limited in 2023 however yields were relatively high most likely due to stored soil moisture.

Treatments – the base treatments that are referred to throughout the rest of this report relate to the break crop options sown in 2022 winter season. These broadly consisted of six pulse species each with three varieties of each apart from vetch, which consisted of one variety with brown manure, hay and grain treatments. One non-pulse break crop option in canola was tested, and it had three contrasting nitrogen application rate strategies applied to its management- N rate was determined based on yield potentials in decile 2,5 and 7 outlooks.

Wheat was also sown in this trial as a non-break crop option, this also had three N management strategies applied determined similarly to the canola. In both the wheat and canola options, N rates

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

were applied in 2022, and the subsequent crop in 2023 as detailed below. A summary of the break crop choice, variety and/or N management are listed in **Table 2** below.

Details of the base treatments, including species, variety and N rates applied are detailed in (**Table 2**).

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

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
2022	120	7	21	116	86	9	44	79	106	118	126	34	866
2023	77	26	78	28	5	26	23	16	6	19	126	80	510
LTA	48	46	44	37	39	39	37	37	34	48	50	46	505

Table 2. Break crop species and varieties tested in 2022 and N rates applied 2022 & 2023

Description	2022 N (kg/ha)	2023 N (kg/ha)	Total N (Kg/ha)
CANOLA-DEC-2	0	0	0
CANOLA-DEC-5	45	11	56
CANOLA-DEC-7	149	64	213
CHICKPEAS-CBA Captain			
CHICKPEAS-PBA Hatrick			
CHICKPEAS-PBA Seamer			
FABA BEANS-Ayla			
FABA BEANS-Nasma			
FABA BEANS-Samira			
FIELD PEAS-PBA Butler			
FIELD PEAS-PBA Whartons			
FIELD PEAS-Sturt			
LENTILS-GIA Leader			
LENTILS-PBA Hallmark			
LENTILS-PBA Kelpie XT			
LUPIN-BL-Luxor			
LUPIN-BL-Muringo			
LUPIN-NL-PBA Bateman			
VETCH-Grain			
VETCH-Hay			
VETCH-Manure			
WHEAT-DEC-2	0	0	0
WHEAT-DEC-5	45	32	77
WHEAT-DEC-7	149	76	225

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

Results

Summary of the 2022 pulse crop results

- Yield differences were greater between species than within species, with a difference of 3.5 t/ha from highest to lowest yielding species.
- Faba beans were the highest yielding species, with an average grain yield of 3.9 t/ha
- Field peas had an average yield of 1.6 t/ha, yielding less than faba beans but more than lentils and lupins.
- Chickpeas yielded 1.9 t/ha.
- Vetch, harvested for grain, yielded of 1.7 t/ha. Vetch yielded less than faba beans, but more than both lentils and chickpeas
- Faba beans grew over 12 t/ha of dry matter (DM). Biomass correlates closely with nitrogen (N) fixation so it is expected that N input will be greatest from faba beans. All other pulse species grew <10 t/ha DM (measured at 30–50 % podding).
- Wheat had very high yields and DM's (just lower than faba beans) while canola yielded less than 2 t/ha.

Table 3. Dry matter production, yields, calculated nitrogen fixed and nitrogen balance, 2022. N balance calculated as starting soil N 2022 (assume all treatments the same level ~120 kg/ha) plus fertiliser N and N fixed by legumes minus N exported in grain

Species	Variety or treatment	Dry matter (t/ha)	Yield (t/ha)	Calculated N fix (kg/ha)	N Balance (kg/ha)
CHICKPEAS	*CBA Captain*	4.5	1.58	69	106
	PBA Hatrick	5.3	2.23	81	115
	PBA Seamer	6.3	1.85	95	121
FABA BEANS	*FBA Ayla*	9.6	3.65	379	299
	PBA Nasma	12.8	3.91	505	411
	PBA Samira	15.2	4.05	595	491
FIELD PEAS	*PBA Butler*	5.3	1.60	55	90
	PBA Wharton	5.7	1.39	57	85
	Sturt	6.3	1.82	66	88
LENTILS	*GIA Leader*	2.1	0.13	24	104
	PBA Hallmark	3.0	0.47	34	101
	PBA Kelpie XT	2.4	0.21	27	105
LUPIN (broad)	*Luxor*	0.0	0.23	0	78
	Muringo	0.0	0.70	0	64
LUPIN (narrow)	*PBA Bateman*	8.0	1.36	273	285
VETCH	*Grain*	6.9	2.09	207	187
	*Hay**	6.9*	6.9	58	146
	*Manure**	6.9		207	295
CANOLA	*Decile2-N*	7.3	1.16	0	60
	Decile5-N	9.2	1.37	0	100
	Decile7-N	9.7	1.63	0	194
WHEAT	*Decile2-N*	10.0	2.87	0	37

	Decile5-N	12.2	3.32	0	73
	Decile7-N	15.0	4.22	0	148
lsd	*lsd*	4.6	0.66	114	127

*vetch treatments were assessed for dry matter before management treatments were applied, and assumed to have the same dry matter production. Yield for vetch hay is the same as dry matter.

Contribution to residual nitrogen prior to planting of 2023 crop

For the pulse options tested in 2022 the amount of N fixed was calculated by measuring the peak biomass of the crop and determining the portion of the N that was derived from the atmosphere, i.e. that what is fixed by rhizobia. **Table 3** details the amount of N fixed by the respective pulse crop options. As can be seen the higher biomass of the faba beans resulted in very high levels of N fixed of over 500kg N/ha for the Samiras and Nasma.

Chickpeas, lentils and field peas fixed less than 100 kg/ha. The narrow leaf Bateman lupins fixed ~270 kg/ha, while both albus varieties had no biomass due to waterlogging.

However, of the total amount of N fixed by the respective crops some will be exported in the grain. If the grain removal is subtracted from the amount of N fixed that results in the final N balance. As can also be seen in **Table 3**. N content of the various grain crops also varied significantly which impacts on the final N balance. Lupins had nearly double the N concentration than chickpeas (data not shown).

The N balance of the non-pulse species is also shown. As a non-pulse they cannot fix any N and draw their requirements entirely from soil reserves or added fertiliser. As can be seen in the **Table 3** even under the higher N strategies the net N balance finished lower than most other options tested.

Figure 1 below illustrates the soil mineral N levels present just prior to sowing of the 2023 crop.

- Vetch, both hay and manure had the highest soil mineral N with over 130 kg/ha
- The lower N treatments (Decile 2 and 5) for wheat had the lowest soil mineral N (less than 91 kg/ha & 77 kg/ha, respectively)
- Nasma faba beans had an N balance after the pulse phase of ~350 kg/ha, however only 126 kg/ha was detected in soil testing, only 20-30 kg/ha more than the non-pulse crops.
- Bateman lupins, with a high predicted N fix (270 kg/ha) had residual N of ~100 kg/ha.

The residual N is generally higher following the pulse break crop options than the non-pulse options with low N rates applied. However it can be seen that there is very little correlation between the theoretical N balance and the tested soil levels. Soil N levels in wheat and canola that higher levels of nitrogen applied were not dissimilar to pulse break crops.

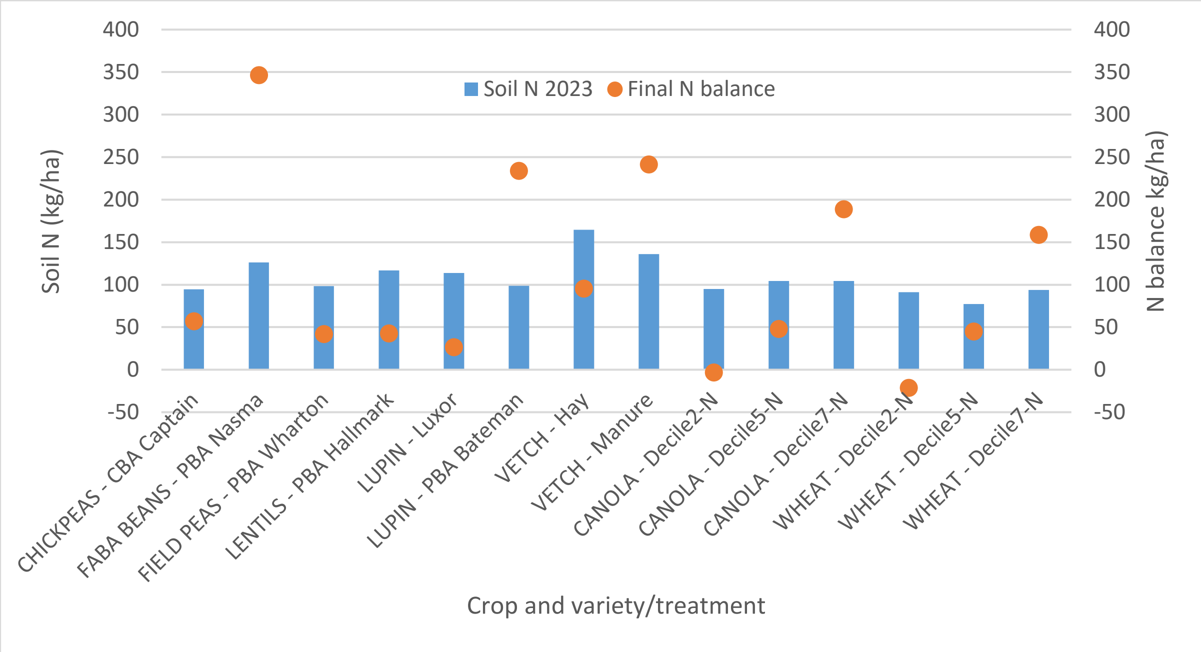

Figure 1. N balance following the sequence crops planted in 2022 and 2023 and soil N as tested prior to sowing the 2023 winter crop. Note that selected canola and wheat treatments had additional nitrogen fertiliser in the 2022 and 2023 winter crop (see treatment list). N balance calculated as starting (2022) soil N (~85 kg/ha) plus fertiliser N and n fixed by legumes – N exported in grain in all 2 years.

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

The trial site was sampled and analysed by PredictaB testing at sowing time in 2022.The result of this testing is presented in **Table 4** below. NB- Not all break crop varieties were tested due to cost. Ascochyta blight of chickpeas (Phoma rabiei) was not detected (data not shown), even though susceptible lines of chickpeas were grown and seasonal conditions were very conducive for disease. . Phytophthora root rot was not detected in lupin plots, possibly due to very low plant numbers, but this also suggests that the lupins failure to establish or death soon after planting was not because of disease more so simply waterlogging.

Table 4. Results from PredictaB testing conducted prior to sowing the 2022 wheat crop

		Fusarium Crown Rot	Root lesion nematode	Sclerotinia stem rot	Phytophthora root rot
		F. pseudograminearum (test 1)	Pratylenchus neglectus	Sclerotinia sclerotiorum/ S. minor	Phytophthora megasperma clade
Species	Variety	pgDNA/g Sample*	nematodes /g soil	kDNA copies/g Sample*	kDNA copies/g Sample
CANOLA	Trophy	152.59	1.26	0.00	0.00
CHICKPEAS	CBA Captain	4.42	2.60	0.13	0.00
FABA BEANS	PBA Nasma	9.50	0.22	0.27	0.00
FIELD PEAS	PBA Wharton	1.04	0.61	0.24	9.89
LENTILS	PBA Hallmark	2.99	0.08	0.59	0.94
LUPIN	Luxor	35.72	0.29	0.00	0.00
LUPIN	PBA Bateman	2.65	0.07	0.00	0.00
VETCH	Hay	4.37	1.37	0.15	0.00
VETCH	Manure	62.77	1.18	0.46	0.00
WHEAT	Spitfire	196.02	2.07	0.94	0.00

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

Soil water was assessed prior to sowing the 2023 crop gravimetrically (0-60cm).

- Wheat had the highest soil moisture (>15%), while the Bateman lupins had the lowest soil moisture (13%). All other pulse species ranged from 12-13%.
- Very high rainfall from September to October 2022 and above average rainfall in the 22/23 is likely to have mitigated any legacy moisture effects.

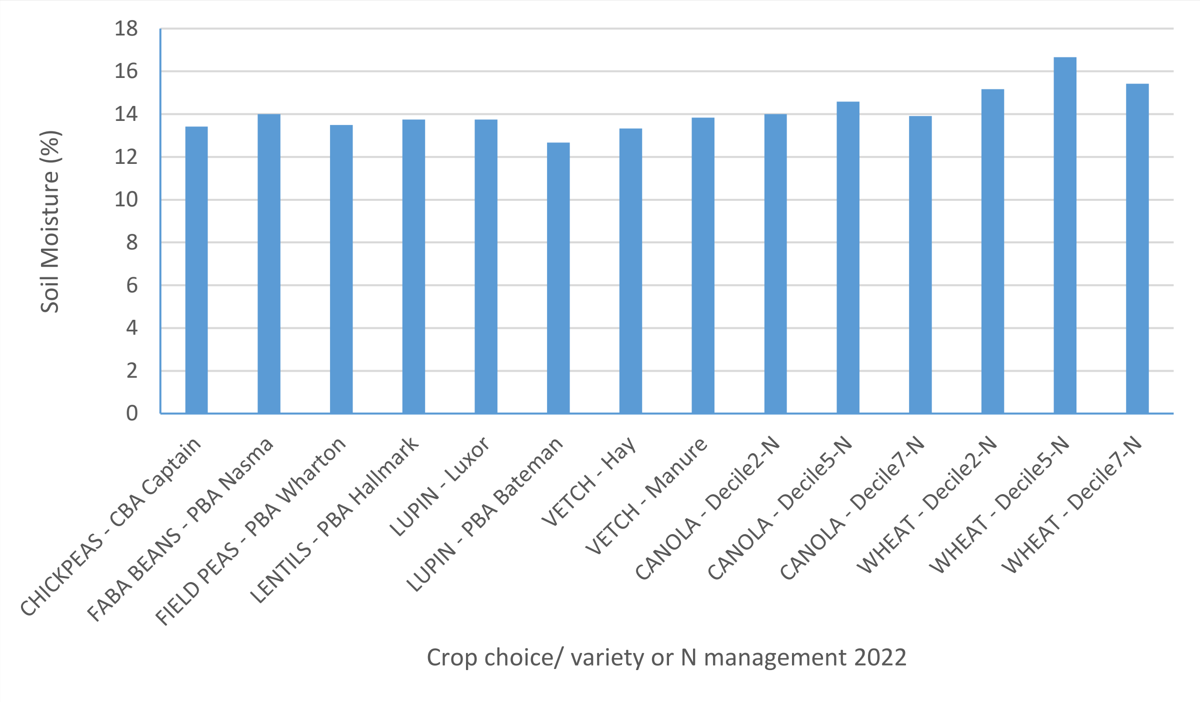

Figure 2. Gravimetric soil moisture content to 60cm (measured oven drying) prior to sowing of the 2023 crop

Summary of 2023 wheat performance (first year after break crop options)

The average yield of the wheat at the site was 2.6 t/ha. The yields following the various break crop options is illustrated in Figure 3 below. Wheat following wheat, canola or faba beans had the highest yields (2.9 – 3.0 t/ha), regardless of the nitrogen strategy. Wheat following lupins had the lowest yields (2-2.2 t/ha).

Kelpie lentils, Captain chickpeas and Sturt Field peas all had low yields (2.3, 2.3 and 2.2 respectively).

The average protein at the site was 12%, the highest protein of 12.9% was where wheat followed vetch manure. The decile 2 nitrogen input wheat following wheat and canola treatments had protein levels of 11.2 and 11.4% respectively, lower than the Decile 7 wheat following wheat and canola treatments (12.2 and 12.7% respectively).

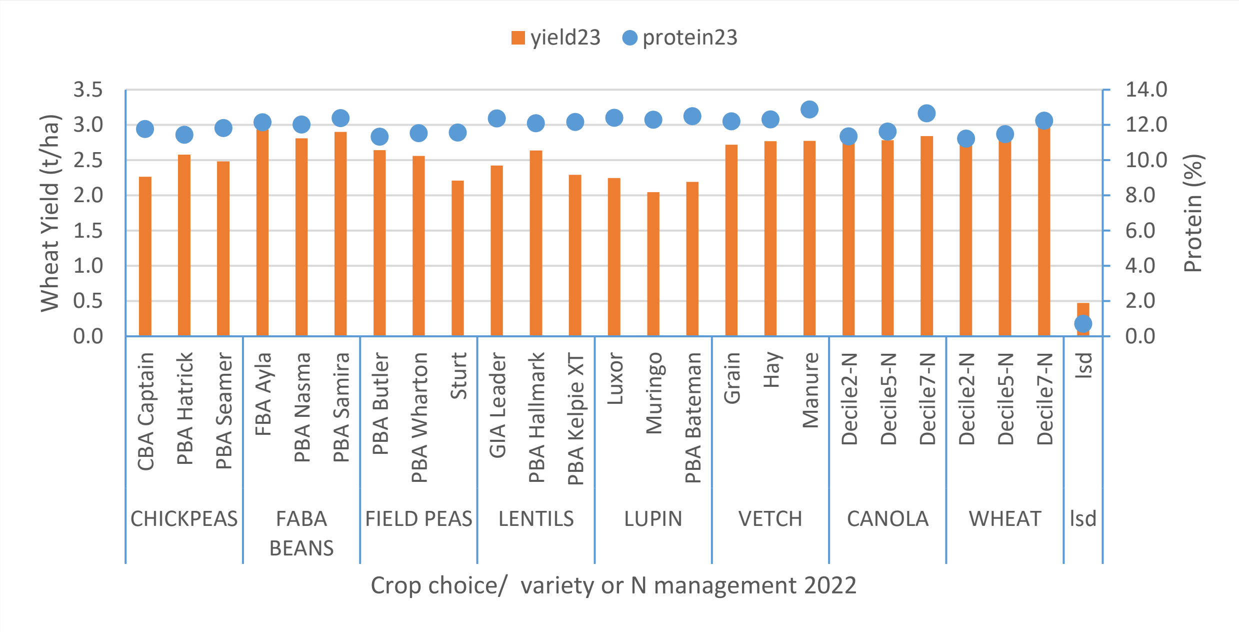

Figure 3. 2023 wheat yields and grain protein following various break crop treatments

Discussion

Calculated N fix (portion of nitrogen fixed from the atmosphere) and subsequent N balances were high for higher biomass pulses such as the faba beans, lupins, and chickpeas. However, this N was not able to be detected to the expected levels with soil testing. It is reasonable to expect that that much of the fixed and remaining N was tied up in organic matter or crop resides.

The site was marginally N responsive. Wheat following non pulse break options with the varying N strategies saw increasing protein with increasing N, but yield responses were not as prominent or not significant.

There were clear increases in the wheat yields following the various pulse crop options however the lack of N response discussed above may suggest the response may be due to other factors more than N.

There is a possible correlation with stored soil moisture and subsequent yields. Lupins generally had low wheat yields and the lupins were essentially long fallows as they largely failed to establish or persist. For example, Bateman lupins had the lowest soil moisture and one of the lowest wheat yields. Lentils were a similar circumstance. However, the hay vetch had all the tops of the plants removed from the site to reflect hay cutting and baling and as such had both water used during the growing season up till termination and a fallow period with literally nil ground cover, yet wheat yields were moderate. Faba beans had some of the highest biomass and hence crop residues and was some of the highest yielding wheat.

It is surmised however that the impact on soil water may be more an outcome of crop maturity as it is ground cover. Faba beans finish early and have high levels of crop residue. Chickpeas and lentils and vetch grain all matured later but with varying levels of crop residues. Unfortunately, no conclusion can be drawn from the information that is available.

Wheat following vetch also had some of the highest yields and protein levels at this site, although the manure treatment was not different to the hay and grain treatments where some of the N was exported.

There were differences in legacy disease profile of the various treatments, the most relevant of those measured for the 2023 wheat crop would be crown rot. The wheat in 2021 had predictably the highest levels of crown rot however wheat still performed well in this wheat, wheat scenario suggesting that disease was not a massive influence.

Conclusions

The legacy nitrogen following a pulse crop had a limited impact on subsequent wheat yields, however most of the pulses had a positive impact on protein. These effects however were only comparable to where nitrogen fertiliser was applied.

In western environments the stubble legacy (or lack of) may influence the amount of moisture stored in the subsequent summer fallow, and impact subsequent yields but the relative maturity of the various alternate crop options may have a significant effect as well.

Despite very high levels of N fixation and theoretical additions to the N balance soil testing did not accurately reflect this prior to sowing of the next crop. Crop performance did not reflect the significant theoretical increase in soil N either. Crop performance also better matched the N levels detected with soil testing than theoretical calculations of N balance.

This does leave the question of how we unlock or access the fixed N by pulse crops. If this could be better achieved it would clearly improve the value of pulses in the cropping systems promote their wider adoption.

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