GOA Trial Site Report

Quantifying the legacy impacts of a range of alternate break crops on subsequent crop performance- Wellington 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:	GPMA01023-1
Season/Year:	Winter 2023
Location:	Comobella, Wellington
Trial Partners:	Angus Maurice
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
- 10 – 60% 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 – Comobella, approx. 27 km north of Wellington

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.

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.

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	116	17	103	150	66	14	78	122	95	172	98	19	1050
2023	73	32	26	42	7	44	34	19	7	38	98	50	470
LTA	66	53	52	42	41	47	47	45	44	56	59	56	608

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

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

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 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.

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	**20**	**0**	**20**
CANOLA-DEC-7	**100**	**7**	**107**
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	**0**	**0**	**0**
WHEAT-DEC-7	**60**	**21**	**81**

Results

Summary of the 2022 pulse crop results

- Yield differences were greater between species than within species, with a difference of 5 t/ha from highest to lowest yielding species.
- Faba beans were the highest yielding species, with an average grain yield of 5.9 t/ha
- Field peas had an average yield of 3.2 t/ha, yielding less than faba beans but more than lentils and lupins.
- Chickpeas yielded 1.1 t/ha.

- Vetch, harvested for grain, yielded of 2.1 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), while field peas also produced a similar result. 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 and canola were sown at both sites as a comparison, 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*	5.9	1.1	111	194
	PBA Hatrick	6.0	1.1	114	195
	PBA Seamer	6.5	1.0	122	206
FABA BEANS	*FBA Ayla*	15.0	5.8	509	381
	PBA Nasma	13.9	5.8	470	317
	PBA Samira	14.4	6.0	484	338
FIELD PEAS	*PBA Butler*	16.3	3.8	369	352
	PBA Wharton	12.9	3.3	293	290
	Sturt	10.3	2.5	233	256
LENTILS	*GIA Leader*	7.5	0.7	149	241
	PBA Hallmark	8.0	0.5	160	263
	PBA Kelpie XT	6.8	0.6	136	230
LUPIN (broad)	*Luxor*	5.7	2.1	168	186
	Muringo	8.3	2.7	245	224
LUPIN (narrow)	*PBA Bateman*	7.1	2.7	243	224
VETCH	*Grain*	7.6	1.7	241	281
	Hay	7.6		80	200
	Manure	7.6		241	361
CANOLA	*Decile2-N*	8.1	1.7	0	86
	Decile5-N	10.2	1.8	0	92
	Decile7-N	9.7	2.2	0	157
WHEAT	*Decile2-N*	13.5	4.8	0	27
	Decile5-N	13.6	4.6	0	29
	Decile7-N	13.9	4.7	0	87
lsd	*lsd*	2.5	0.6	55	59

*Hay yield

Break crop 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 480kg N/ha.

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 presented).

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 residual mineral N present just prior to sowing of the 2023 crop.

- Vetch, both hay and manure had the highest residual N with over 180 kg/ha
- The lower N treatments (Decile 2 and 5) for both wheat and canola had less than 120 kg/ha of residual nitrogen (though this is similar to the starting soil N) Despite the N balance being lower than zero- i.e. more N has been removed from the system in grain than has been added. This is assumed to have been supplied by mineralisation.
- Nasma faba beans had an N balance after the pulse phase of over 300 kg/ha, however only 126 kg/ha was detected in soil testing. Only 26 kg more than the lowest residual N measured in wheat followed by wheat with Decile 2 N.

The residual N is higher following the pulse break crop options than the non-pulse options with low N rates applied. Soil N levels in wheat and canola that higher levels of nitrogen applied were not dissimilar to pulse break crops.

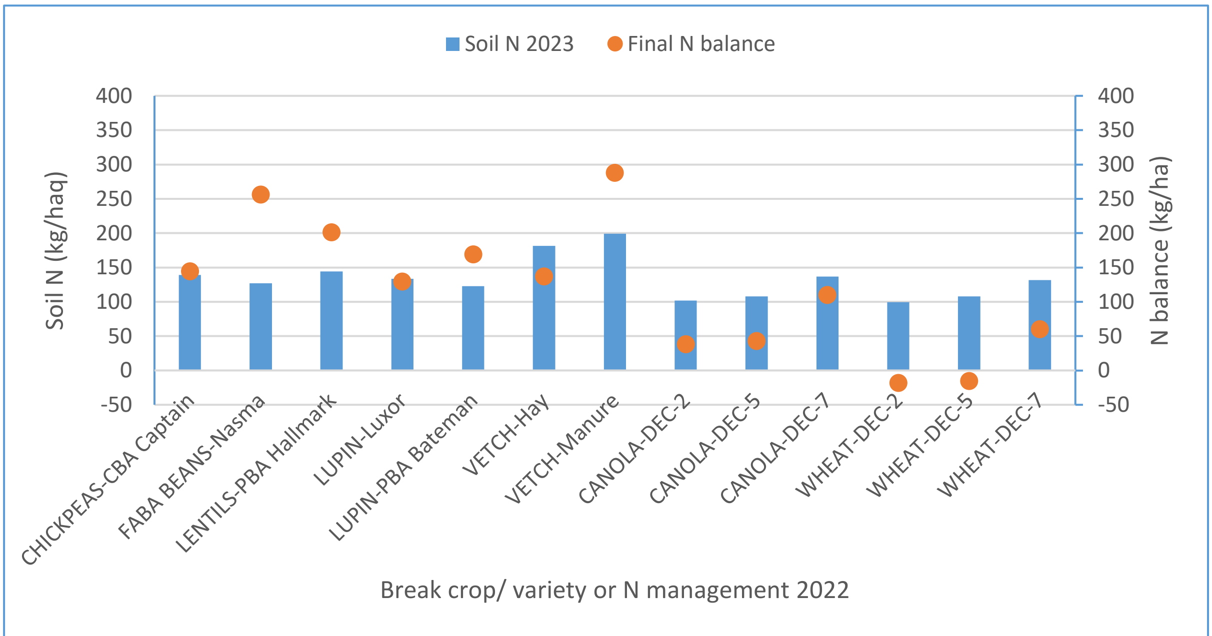

Figure 1. N balance following the sequence crops planted in 2022 and 2023 and soil N as tested prior to sowing the 2023 winter crop. Note that selected canola and wheat treatments had additional nitrogen fertiliser in the 2022 and 2023 winter crop (see treatment list). N balance calculated as

starting (2022) soil N (~120 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.

Wheat, vetch and chickpeas resulted in the highest level of crown rot inoculum detected. Canola, faba, field pea, lentils and lupins all resulted in low levels detected. Chickpeas and wheat resulted in the highest levels of RLN (*neglectus)*. Sclerotinia was highest following Lentils, slightly lower under Vetch and canola. Faba field pea, lupins and wheat reduced levels to low-risk categories.

Table 4. Results from PredictaB testing conducted prior to sowing the 2023 wheat crop

		Fusarium Crown Rot	Root lesion nematode	Sclerotinia stem rot	Ascochyta blight of chickpeas	Phytophthora root rot
		F. pseudograminearum (test 1)	Pratylenchus neglectus	Sclerotinia sclerotiorum/ S. minor	Phoma rabiei	Phytophthora megasperma clade
Species	Variety	pgDNA/g Sample*	nematodes /g soil	kDNA copies/g Sample*	kDNA copies/g Sample*	kDNA copies/g Sample
CANOLA	Trophy	37.21	0.87	970.32	0.00	0.00
CHICKPEAS	CBA Captain	252.96	1.84	191.15	0.05	0.00
FABA BEANS	PBA Nasma	25.37	0.10	91.35	0.00	0.00
FIELD PEAS	PBA Wharton	39.83	0.05	788.67	0.00	1.51
LENTILS	PBA Hallmark	42.67	0.32	1452.91	0.00	4.12
LUPIN	Luxor	160.98	0.41	189.67	0.00	6.85
LUPIN	PBA Bateman	19.46	0.86	287.47	0.00	0.00
VETCH	Hay	343.45	0.39	1125.72	0.00	0.00
VETCH	Manure	253.31	0.60	1233.39	0.00	0.00
WHEAT	Spitfire	408.92	1.39	96.74	0.00	0.00

Impact on soil water as prior to sowing of the 2023 crop

Soil water was assessed prior to sowing the 2023 crop gravimetrically.

- Chickpeas had the lowest soil moisture (~20%), they were also the last to be harvested, almost a month after most other species, so assuming further consumption of soil water and short fallow periods to rechange than the other options tested.
- Vetch hay had a lower soil moisture than vetch manure. Both were terminated at the same time (4/11/2022), the ground cover in the manure plot may have contributed to the higher moisture status.
- Pulses did not necessarily have higher levels of residual soil moisture than wheat or canola

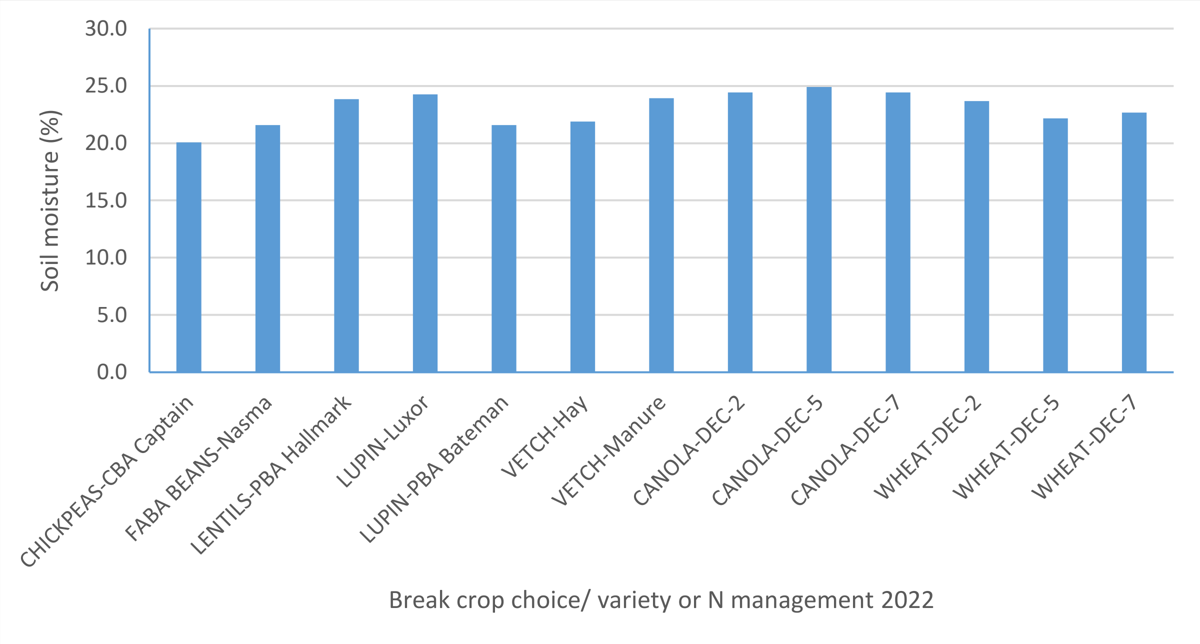

Figure 2. Gravimetric soil moisture content to 60cm (measured oven drying) prior to sowing of the 2023 crop

<u>Summary of 2023 wheat performance (first year after break crop options)</u>

The average yield of the wheat at the site was 3.1 t/ha. The yields following the various break crop options is illustrated in Figure 3 below. Wheat following Sturt field peas had the highest yields (3.6 t/ha) while following chickpeas (regardless of variety had the lowest yields (2.2-2.4 t/ha). Adding nitrogen in 2022 and 2023 to the wheat/wheat and canola/wheat rotations did not improve yields compared to the low N strategy (that had no added nitrogen).

The average protein at the site was very low at 10.8%, the highest protein of 12.4 and 12.1% was where wheat followed chickpeas and wheat following manured vetch respectively. Lowest proteins were found in the wheat/wheat and canola/wheat rotations, where all treatments were below 9.5%.

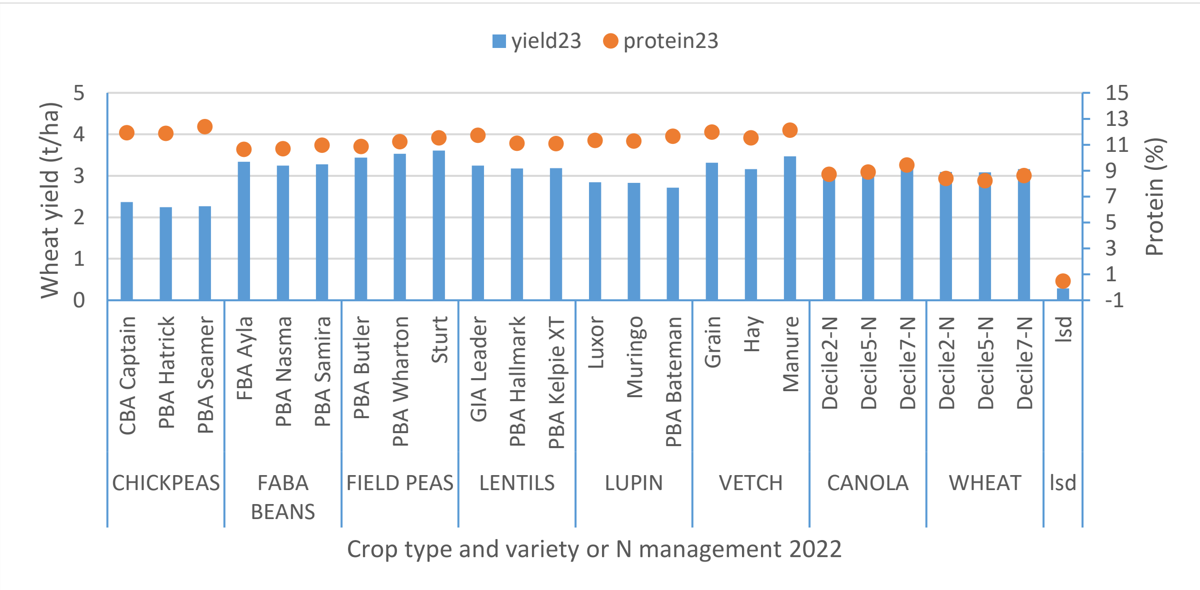

Figure 3. 2023 wheat yields and grain protein following various break crop treatments

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 could be described as N responsive, however this most demonstrated in protein levels than yields (approaching yield limit?). Wherever wheat followed a pulse, protein levels were higher than where wheat followed either wheat or canola. Both wheat and canola were top-dressed with N in crop, but limited rainfall in the winter of 2023 may have limited crop access to this nitrogen.

There was possibly a stronger correlation with stored soil moisture and subsequent yields. The milder conditions in the spring and early summer of 2022 allowed chickpeas to flower longer than usual and were not harvested till after the middle of January 2023. This extended growth period appears to have reduced the available soil moisture and yields of the subsequent wheat. The wheat following chickpeas had some of the highest protein levels, but lowest yields, leading to increased concentrations of protein.

It is possible that this site reached its water limited yield potential, and this restricted yield benefits from additional nitrogen from pulse/fertiliser sources?

Wheat following vetch also had some of the highest yields and protein levels at this site, and the manure treatment had higher yields and protein levels than where the dry matter was exported in the hay treatments.

There were considerable differences in legacy disease profile of the various treatments. The paddock had a history of wheat in 2021 and canola in 2020 and predictably the highest levels of root lesion nematodes and crown rot was detected where wheat was sown in 2022. Crown rot levels were still high following vetch, Luxor lupin and captain chickpea treatment. The remaining pulses all reduced crown rot levels considerably however none eliminated it. There were differences in pulse effects on the legacy of other diseases which should be considered, particularly if double cropping is a consideration. Apart from wheat and faba beans, elevated levels of Sclerotinia were detected following all crops, suggesting that a subsequent crop of canola might require a higher level of disease management. Lupins left behind higher levels of Phytophthora than other species suggesting that double cropping lupin should be approached with caution.

Conclusions

The legacy nitrogen following a pulse crop had a limited impact on subsequent wheat yields, however had a positive impact on protein.

The timing of crop senescence had more of an impact on legacy soil moisture than crop biomass. The later maturing chickpeas had much less stored soil moisture for the subsequent wheat crop that the high biomass faba beans and this appeared to have penalised the wheat crop following.

Soil testing prior to sowing gave a better indication of the available N than calculated N balances. 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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