Pulse performance in regionally relevant environments

Rohan Brill[1], Michael Moodie[2], Maurie Street[3], Ben O'Brien[3], Tom Price[4], Ben Morris[4], Barry Haskins[5] & Rachael Whitworth[5]

[1] Brill Ag, [2] Frontier Farming, [3] GOA, [4] FAR Australia, [5] AgGrow Agronomy

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Take home message

- Faba beans were the standout pulse crop across southern and central NSW pulse agronomy sites in 2021 and 2022, for grain yield and net nitrogen contributions to the soil
- Total N fixation of all pulses was measured using the ^{15}N natural abundance technique and ranged from 88 to 594 kg/ha with an average of 271 kg/ha
- N fixation was primarily driven by biomass production, with ~33 kg N/ha fixed per tonne of above ground biomass
- Total N fixation included a measure of nitrogen derived from the atmosphere (NDFA) in shoots which is then multiplied by established root factors for each pulse to determine above and below ground contributions
- The N balance provided by pulses (after subtracting grain N removal from total N fixed) ranged from 2 to 343 kg/ha, with an average across species of 146 kg N/ha
- Net N contributions were greatest after faba beans (average 194 kg N/ha) and lowest after lentils (43 kg N/ha).

Introduction

The GRDC funded 'NSW Pulse Agronomy Project' commenced in 2021 and has two major themes of research activity:

1. Assessment of the yield and nitrogen fixation of different pulse species in regionally relevant and often challenging environments. This work is conducted across the project area including sites at Barellan, Canowindra, Caragabal, Buraja, Ganmain, Gol Gol and Parkes.

2. Locally relevant research, addressing local limitations to pulse production. Research to date has included plant density, disease management, nutrition management, inoculation strategy, phenological development, and herbicide tolerance.

Trial results from 2021 are published on the GRDC website and a link to this information is provided in the 'further reading' section of this paper. Trial data from 2022 will be published in the same way in the first half of 2023. This paper provides an update of progress on point number 1 above, with a full set of data from 2021 available including grain yield, peak biomass, and nitrogen balance of pulse species. Data available from 2022 at this point includes peak biomass and grain yield but not nitrogen balance.

Materials and methods

Trials were conducted at seven sites across southern and central NSW in 2021 (Table 1). Sites were selected to be regionally relevant with challenges (both perceived and real) that may restrict the use and production of pulses in the rotation. The research is not designed to compare the performance

of pulses in a benign situation but is focused more on determining the performance of pulse species for yield and nitrogen fixation performance in the local environment where adapted species may thrive, but less adapted species may struggle. Each site had their own specific challenges (Table 1) including surface acidity (Barellan, Buraja, Canowindra); subsoil sodicity (Caragabal, Ganmain, Parkes), low rainfall (Gol Gol); waterlogging (Caragabal, Ganmain, Parkes) and calcareous subsoil (Gol Gol).

Table 1. Site description of seven pulse agronomy research sites from 2021

Site	Sowing Date	Rain Jan-Mar	Rain Apr-Nov	pH (Ca) 0-10 cm	Site description
Barellan	13 May	270 mm	435 mm	4.5	Acidic sandy loam soil with 3.3% Al.
Canowindra	3 May + 20 May[1]	290 mm	490 mm	4.8	Moderately acidic, well drained red loam soil
Caragabal	29 April + 18 May[1]	280 mm	480 mm	5.0	Slightly acidic loam (chromosol) with sub-soil sodicity
Buraja	7 May	180 mm	450 mm	4.6	Moderately acidic silty loam soil
Ganmain	28 April + 18 May[1]	220 mm	360 mm	5.3	Slightly acidic loam soil with sub-soil sodicity (15% Na in 30-60 cm)
Gol Gol	31 May	0 mm	115 mm	7.7	Alkaline calcarosol, sandy loam topsoil with clay increasing with depth
Parkes	31 May	290 mm	485 mm	5.7	Neutral pH, moderately heavy soil type with sub-soil sodicity

[1]Faba beans, vetch and lupins sown at earlier sowing date; field peas, lentils and chickpeas sown at later sowing dates.

Several trials were sown at each site, driven by local demand to fill knowledge gaps and nitrogen balance of key pulse species was measured at all sites. Nitrogen balance was determined by collecting biomass samples at peak biomass (i.e., 30-50% podding stage and before leaf drop) and analysed using the ^{15}N natural abundance technique (Unkovich *et al*., 2008) to determine what proportion of the Nitrogen in the biomass was Derived From the Atmosphere (NDFA). Once the quantity of NDFA in above ground biomass was calculated (peak biomass * N content of biomass * NDFA%), total nitrogen fixation (N fix) was calculated by multiplying by 1.5 for faba beans, field peas, lentils, lupins and vetch; and by 2.0 for chickpeas. These figures (1.5 and 2.0) are known as 'root factors' and are described by Swan *et al.* (2022). The root factor calculation is a rule of thumb to provide an allowance for below ground biomass so an improved estimate of total nitrogen fixed can be provided. Finally, the nitrogen balance is calculated by subtracting the nitrogen removed in grain.

Results 2021

Total nitrogen fixation (kg/ha): Total nitrogen fixation was highest in faba beans (405kg N/ha average) in four of the six sites where NDFA was measured (Table 2). Three of these sites, Caragabal, Ganmain and Parkes had sodic subsoils and experienced periods of waterlogging through the season, while the Barellan site experienced no waterlogging, but was moderately acidic soil (4.5 $CaCl_2$, 0-10 cm). Lupins had very high biomass and total nitrogen fixation on a red loam soil at Canowindra, while at Buraja, chickpeas continued growing later into the season and had the highest total nitrogen fixation. Lentils had the lowest total nitrogen fixation at all five sites where NDFA was measured (113kg N/ha average).

Nitrogen off-take (kg/ha): Nitrogen removal in grain was highest or equal highest for faba bean (211kg N/ha average) in five of the six sites where they were grown and NDFA measured (Table 2) and lowest in lentils (71kg N/ha) in all five sites where NDFA was tested. Average grain yields across sites ranged from 5.05t/ha for faba bean to 1.70t/ha for lentil while nitrogen removal per tonne ranged from 55 kg N/t for lupin to 34 kg N/t for chickpea. The contrast in nitrogen off-take results is therefore primarily explained by grain yield differences which varied on average by 3-fold with nitrogen removal per tonne varying 1.6-fold.

Nitrogen balance (kg/ha): Positive nitrogen balance numbers indicate a net contribution of nitrogen to the soil system from atmospherically derived nitrogen while negative numbers indicate a loss of nitrogen from the soil system. Despite large nitrogen off-take in faba bean they provided the largest

contribution of nitrogen to the soil (194 kg/ha average N balance) at Barellan (followed by field pea), Caragabal (followed by vetch), Ganmain (followed by field pea) and Parkes (followed by chickpea). Faba beans had a high harvest index at Buraja and removed 42 kg of nitrogen per tonne of grain resulting in a more modest nitrogen balance of 86kg N/ha.

Species and site insights: Lentils and chickpeas generally had lower N fixation but combined with lower yield and for chickpeas low N concentration in grain, they still had a positive N balance and a potentially higher value grain produced. Lentils had an average N balance of 43 kg/ha and chickpeas 165 kg/ha. Vetch and field peas generally had moderate N fixation and removal, but removal would be much higher if cut for hay. Vetch is widely used as a brown manure crop to supply N to the system, but other options such as beans and lupins may provide greater N fixation benefits for this role, although with different challenges such as very high seeding rates (faba beans) and rotational effects of diseases (e.g., sclerotinia in lupins).

N balance in lupins was variable, limited by waterlogging at Parkes, but very high at the Canowindra site which had few growth constraints. Where lupins had high biomass, N fixation was also high, but they had high grain N concentration, with close to 60 kg of N per tonne in albus lupins (Murringo(b) and Luxor(b)) and just above 50 kg of N per tonne in narrow leaf lupins (PBA Bateman(b)).

Table 2. Peak biomass (30-50% podding), total N fix (including below ground roots), grain yield, N removed in grain and overall nitrogen balance of pulse species at research sites in NSW for 2021.

Site	Species	Cultivar	Peak biomass (t/ha)	N fix (kg/ha*)	Grain Yield (t/ha)	N removed (kg/ha)	N balance (kg/ha)
Barellan	*Chickpea*	*CBA Captain*(b)	5	148	2.2	72.1	76
	Faba beans	*PBA Samira*(b)	9.4	335	4.4	171	164
	Field Pea	*PBA Wharton*(b)	9.9	287	3.9	146	141
	Lentils	*PBA Hallmark XT*(b)	6.8	129	2.6	105	24
	Lupins	*Luxor*(b)	5.5	188	3	174	14
	Vetch	*Timok*(b)	9.3	240	3.5	162	78
Buraja	*Chickpea*	*CBA Captain*(b)	7.1	220	2.3	74	146
	Faba beans	*PBA Samira*(b)	6.7	209	2.9	123	86
	Vetch	*RM4*(b)	4.8	187	1	51	136
Canowindra	*Chickpea*	*CBA Captain*(b)	8.9	247	2.2	89	158
	Faba beans	*PBA Samira*(b)	15	395	5.8	230	165
	Lentils	*PBA Hallmark XT*(b)	6.7	124	1.4	58	66
	Lupins	*Murringo*(b)	17.6	525	4.3	263	262
	Lupins	*PBA Bateman*(b)	15.6	519	3.4	179	340
Caragabal	*Chickpea*	*CBA Captain*(b)	9.6	278	2.1	72	206
	Faba beans	*PBA Samira*(b)	17.4	594	5.7	251	343
	Field Pea	*PBA Taylor*(b)	7	278	3.4	134	144
	Lentils	*PBA Hallmark XT*(b)	7.2	133	1.7	71	62
	Lupins	*PBA Bateman*(b)	9.7	313	2.1	112	201
	Vetch	*Timok*(b)	11.1	345	1.6	92	253
Ganmain	*Chickpea*	*CBA Captain*(b)	5	164	Not harvested due to hail		
	Faba beans	*PBA Samira*(b)	12	347	5.2	211	136
	Field Pea	*PBA Wharton*(b)	8.3	294	2.7	104	190
	Lentils	*PBA Hallmark XT*(b)	5.5	93	2.1	91	2
	Vetch	*Timok*(b)	6.6	166	2.7	127	39
Gol Gol	*Chickpea*	*CBA Captain*(b)	1.7	*	0.6	*	*
	Faba beans	*PBA Samira*(b)	1.5	*	0.5	*	*
	Field Pea	*PBA Wharton*(b)	2.4	*	1	*	*
	Lentils	*PBA Hallmark XT*(b)	1.8	*	0.6	*	*
Parkes	*Chickpea*	*CBA Captain*(b)	9	328	2.6	89	239
	Faba beans	*PBA Samira*(b)	15.1	552	6.3	282	270
	Lentils	*PBA Hallmark XT*(b)	3.9	88	0.7	29	59
	Lupins	*Murringo*(b)	3	98	0.8	47	51
	Lupins	*PBA Bateman*(b)	7.9	318	2.6	132	186

Overall, there was a consistent increase in total nitrogen fixed with increases in above ground biomass for all crops, with on average, each tonne of above ground biomass (above ~1 t/ha)

resulting in 33 kg/ha total N fixation allowing for below ground N estimated by using root factors (Figure 1).

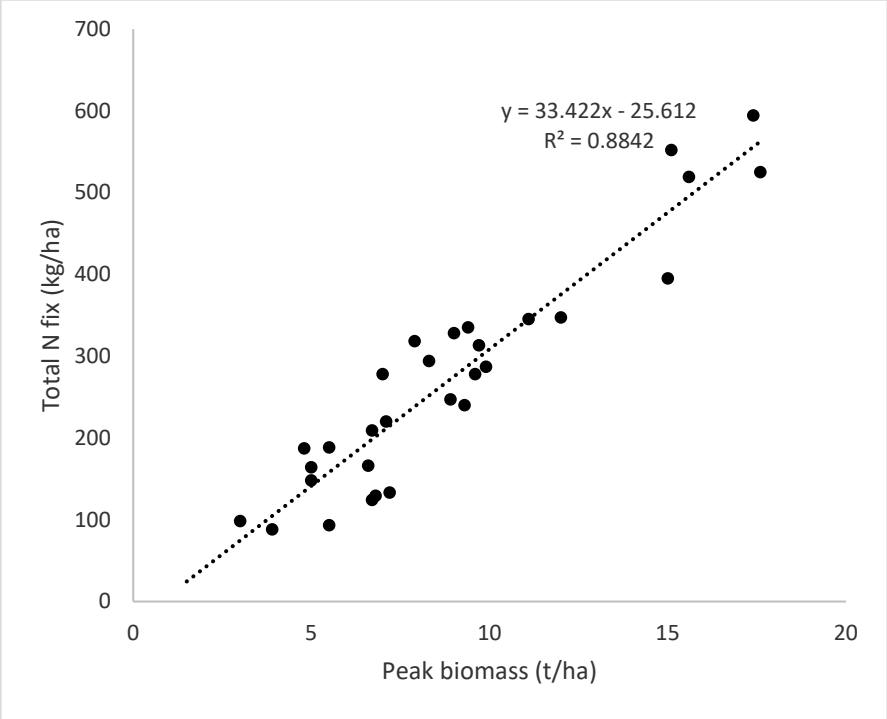

Figure 1. Relationship between peak biomass (above ground, measured at 30-50% podding) and total N fixation in 2021. Crops included = chickpeas, faba beans, lentils, lupins, field peas and vetch.

Results 2022

Research conducted in 2022 had similar themes to 2021, with locally driven research combined with evaluation of key pulse species for nitrogen balance. With the very wet season, five of the sites provided data on full peak biomass and grain yield, with N fixation and grain N samples yet to be processed. The Southern NSW site around Coreen/Buraja was sown successfully but was severely impacted by waterlogging and not harvested. The Caragabal site was not sown at all and in its place, a second site was sown at Ganmain in late July, simulating sowing with a spreader with and without incorporation (data not yet available). The main Ganmain site was sown on a more favourable soil type than was initially planned due to very wet conditions at sowing. As a result of the need to shift sites and the loss of planned sites, the data is skewed toward relatively well drained soils, but even these sites were impacted by waterlogging in the very wet 2022 season (Table 3).

Table 3. Site description of five pulse agronomy research sites from 2022.

Site	Sowing Date	Rainfall Jan-Mar	Rainfall Apr-Nov	pH (CaCl2) 0-10 cm	Site description
Barellan	*6-May*	255 mm	536 mm	5.2	Slightly acidic sandy clay loam
Ganmain	*9-May*	184 mm	555 mm	5.7	Sandy clay loam with minimal constraints
Trundle	*28-Jun*	154 mm	712 mm	5	Slightly acidic sandy clay loam
Wellington	23-May	287 mm	815 mm	5	Slightly acidic clay loam soil
Wentworth	*12-May*	25 mm	381 mm	8	Alkaline sandy soil, part of Mallee Dune/Swale system

Overall and like 2021 results, faba beans generally grew very high quantities of biomass (12.7t/ha average across sites) but didn't always have the highest biomass at individual sites (Table 4). Vetch had the most biomass on the sandy soil at Wentworth (7.8t/ha), lupins grew the most biomass at Barellan (16.5t/ha) and field peas grew the most biomass at Wellington (14.8t/ha). Except for

Wentworth, faba bean biomass was always >12 t/ha. It is expected that N fixation analysis will show high amounts of N fixation by beans again in 2022. Average vetch biomass (8.9t/ha) was about average of all species (8.8t/ha), generally not getting to very high levels but also consistent throughout.

Lupins had relatively high biomass on the drier Wentworth and well drained Barellan sites, but biomass was lower at the wetter Trundle and Wellington sites. Lentil biomass was relatively low overall (5.2t/ha) and was very low at the wet Trundle site.

Table 4. Peak biomass (30-50% podding) of pulse species at five pulse agronomy research sites in 2022.

		Peak Biomass (t/ha)				
Species	**Cultivar**	**Wentworth[2]**	**Barellan**	**Ganmain**	**Trundle**	**Wellington**
Chickpea	*CBA Captain*ⓑ	3.8	12.4	9.7	4.2	5.5
Faba bean	*PBA Samira*ⓑ	3.8	13.0	17.8	16.3	12.4
Field pea	*PBA Butler*ⓑ	4.8	11.3	8.7	5.6	14.8
Lentils	*PBA Hallmark*ⓑ	3.7	7.7	7.5	1.0	6.2
Lupins	*Luxor*ⓑ	5.2	15.0	*[1]	*	6.1
Lupins	*PBA Bateman*ⓑ	6.0	16.5	*[1]	9.7	8.1
Vetch	*Timok*ⓑ	7.8	10.7	12.2	7.0	6.8

[1]Lupins not sown at Ganmain due to rabbit and hare issues
[2]Wentworth sampling was done early to beat rising river flood water that would restrict site access. Further growth was likely on most species after sampling was conducted.

Faba beans had the highest grain yield at three of the five sites (4.5t/ha average, Table 5). Chickpeas had the highest yield at Wentworth (4.1t/ha) and Luxorⓑ albus lupins had the highest yield at Barellan (5.0t/ha). Grain yield above 4 t/ha was achieved at each site, but there was often high variability with chickpeas yielding 34% of albus lupins at Barellan; chickpeas yielding 5.3% of faba beans at Ganmain; Albus lupins yielding 4.9% of faba beans at Trundle and Lentils yielding 8.3% of faba beans at Wellington.

Grain nitrogen analysis will be completed on each species in 2023 and will be subtracted from total N fixation to determine the nitrogen balance of each species at each site.

Table 5. Grain yield of pulse species at five pulse agronomy research sites in 2022.

		Grain Yield (t/ha)				
Species	**Cultivar**	**Wentworth**	**Barellan**	**Ganmain**	**Trundle**	**Wellington**
Chickpea	*CBA Captain*ⓑ	4.1	1.7	0.3	1.2	1.1
Faba bean	*PBA Samira*ⓑ	2.4	4.5	5.6	4.1	6.0
Field pea	*PBA Butler*ⓑ	2.7	2.2	2.9	1.6	3.7
Lentils	*PBA Hallmark*ⓑ	2.7	2.4	1.1	0.4	0.5
Lupins	*Luxor*ⓑ	4.0	5.0	*	0.2	2.1
Lupins	*PBA Bateman*ⓑ	3.6	3.8	*	0.7	2.7
Vetch	*Timok*ⓑ	3.3	4.5	2.4	2.2	1.7

Discussion and conclusion

The above average rainfall in 2021 and 2022 have led to some very high grain yields being achieved across the project region, most consistently with faba beans. Other pulses such as lupins, lentils and chickpeas had more variable yield responses. Field peas and vetch (for grain) performed consistently across sites and seasons, only occasionally being the best performer but also rarely being the poorest performer. In addition to their excellent yield performance, faba beans had an average net benefit of 194 kg/ha nitrogen after accounting for N removal as grain in 2021. The total value of the faba bean crop (in simple terms) = grain yield * grain price + N benefit * N price. It is likely that at high N cost but even modest faba bean prices, they would still compete with most other crops in a

gross margin comparison. For example, at an on-farm price of $360/tonne, with a grain yield of 4 t/ha and a nitrogen value of $2 per kg of N, gross income = $1820/ha. This is roughly equivalent to the gross income of a 5 t/ha APW wheat crop, but with the added benefit of the break crop components such as weed control and disease break. In reality, pulses should not compete with cereals and oilseeds for cropping area but should complement their production as part of a system.

This project will continue for the next two years to generate more data on pulse production on regionally relevant soil types across species and seasons. It is highly likely that seasons will return to a more normal or even drier pattern, so different results will be expected.

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Further reading

NSW Pulse Agronomy Development and Extension Project – 2021 summary of field trial results. https://grdc.com.au/resources-and-publications/all-publications/publications/2022/nsw-pulse-agronomy-development-and-extension-project

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Contact details

Rohan Brill
Brill Ag
Ganmain, New South Wales
Ph: 0488 250 489
Email: rohan@brillag.com.au

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