Pushing yield barriers in irrigated and dryland faba bean

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Keywords

faba bean, yield potential under dryland and irrigation

GRDC codes

FAR1906-003RTX, DJP2105-006RTX

Take home messages

- In 2020 and 2021, faba bean crops yielding over 7t/ha were produced under irrigation in northern Victoria and southern NSW on red brown duplex and grey clay soils (highest yield of 7.88t/ha)
- In 2021 in a dryland scenario in NE Victoria, faba beans achieved yields over 7t/ha.
- Faba bean crops yielding over 7t/ha had total in season water availability of 500mm or more either as growing season rainfall (GSR) alone or GSR plus irrigation.
- Excessive rainfall in October 2022 (in many cases 200mm for the month), reduced faba bean yields through a combination of transient water logging and increased disease pressure.
- Under irrigation, the yield penalty from low plant populations (15 plants/m^2 and below) was 'magnified' when targeting high yielding crops.
- Allowing 30 kg N fixed per tonne of faba bean dry matter measured at peak biomass (30% podding and considers roots contribution) and using 40 kg N removed per tonne of grain is a useful way of estimating net N contribution also known as N balance.
- Nitrogen applied at 6-8 leaf stage with trace elements (mix of Zn, Mn, Cu, S, B, and Mo) increased yield in faba bean by 0.53 t/ha in a dryland trial at Bundalong, Victoria, achieving the highest yield of 7.96 t/ha.

Pushing yield boundaries

The research results presented in this paper was generated between 2019-2022 at irrigated research sites at Kerang, Victoria (grey clay), Finley, NSW (red brown duplex) and in dryland scenarios at Bundalong and Dookie in Victoria (red/brown soils). The research is primarily based on the Optimising Irrigated Grains (OIG) project, which seeks to push productivity boundaries in six crops including faba beans. Supplementary data have been generated as part of the 'Southern Pulse Agronomy' project and both projects have been resourced by GRDC.

What makes a 7-tonne crop?

Growing season rainfall (GSR) and irrigation

In the majority of research conducted in the Optimising Irrigated Grains project, high yields of >7t/ha have been associated with growing season rainfall (GSR) and/or irrigation totalling ≥500mm. In 2021 with a mild spring and a GSR of 500mm near Bundalong, dryland plots yielded over 7t/ha. In 2022, even though GSR in excess of 500mm were recorded, yields did not reach 7t/ha due to waterlogging and disease pressure in part due to a total of 200mm of rainfall in October. Under irrigation many of the 7t/ha plus yields have been achieved with surface (flood) irrigation, however in 2021 at Finley, autumn irrigation caused winter waterlogging due to higher than average rainfall.

Increased importance of plant population under irrigation

Irrigated grain production for faba beans plateaus at around 25 – 30 plants/m^2 on red/brown soils with little to be gained above 30 plants/m^2. On grey clays the optimum plant population is slightly lower at 20-25 plants/m^2, however if this falls below 20 plants/m^2 under irrigation the yield loss can be significant. With higher yield potentials in irrigated cropping systems, small differences in plant populations have a potential 'magnifying' effect on grain yield, with reductions in population of 10-15 plants/m^2 resulting in significant losses of 1.0 - 1.5t/ha. Moving from 20 to 30 plants/m^2 under irrigation has increased yield by 0.5t/ha and whilst populations greater than 30 plants/m^2 were rarely higher yielding. The risk of poorer performance in higher populations has been very low in comparison to the risk when populations drop below the optimum. In dryland scenarios where typically yield potential is lower, reductions in grain yield associated with populations falling below the optimum have been far less significant.

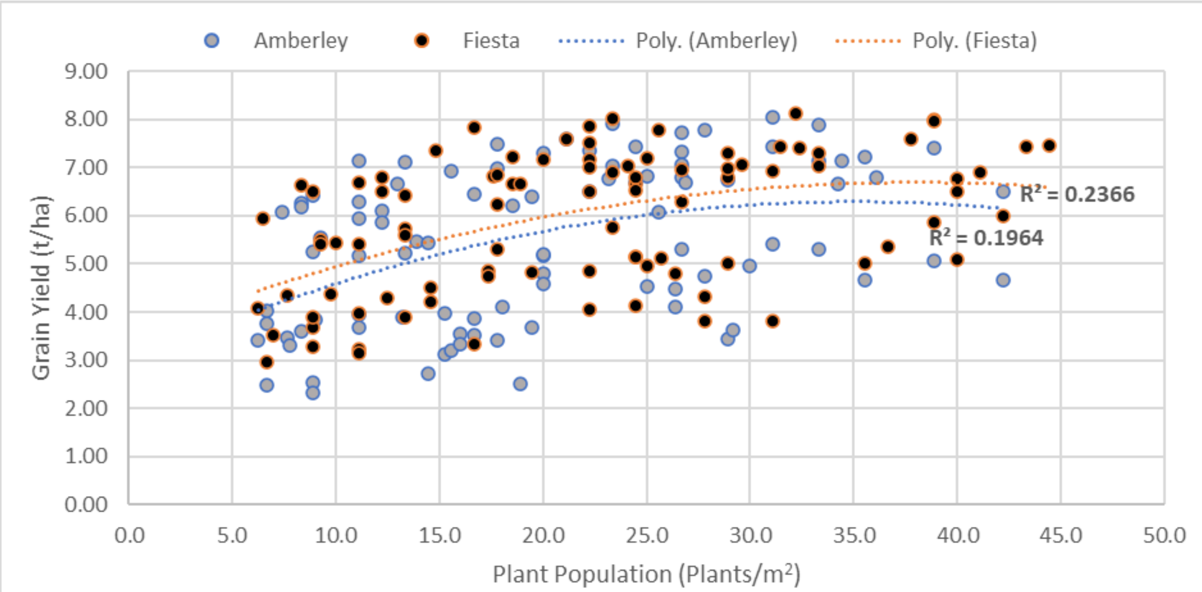

Figure 1. The influence of faba bean plant populations on grain yield (t/ha). Data points from 6 trials across two years (2020 & 2021) and two sites – Finley, NSW and Kerang, Victoria. (Poly. = Polynomial line applied to data)

Whilst slower sowing speeds are necessary for the higher seed rates, high seed rates are one of the most important factors influencing faba bean yield under irrigation in the OIG project. So, in summary, for irrigated crops there are greater negative consequences of populations that are too low (i.e. 10-15 plants/m^2) than too high (i.e. greater than x-x plants/m^2, Table 1).

Table 1. Grain yield (t/ha) of four seed rates grown under surface irrigation. Finley, NSW 2020 mean of two cultivars PBA Amberley & Fiesta (GSR 244mm plus 3 x 80mm surface irrigations – total 484mm)

Seed rate (mean Plant Population)	Grain Yield (t/ha)	
12 seeds/m2 (12 plant/m^2)	6.20	b
24 seeds/m2 (23 plants/m^2)	7.10	a
36 seeds/m2 (29 plants/m^2)	7.19	a
48 seeds/m2 (29 plants/m^2)	7.04	a
Mean	6.88	
P val	<0.001	
LSD P=0.05	0.35	

Where letters against treatments are different, treatments are significantly different (P<0.005)

Final harvest dry matter

Higher plant populations (20-30 plants/m^2) resulted in high dry matter by the early flowering stage and in general were associated with more stems per unit area at harvest. This early biomass is associated with pod formation higher up the stem compared to less dense crops, but pod number per stem is usually inversely related to the number of stems per unit area such that more stems per plant results in fewer pods per stem. Examining the yield components of 7t/ha crops has revealed that populations of approximately 20-30 plants/m^2 with 55 or more stems and 450 or more pods/m^2 resulted in 7t/ha or greater yield. While these parameters build yield potential of 7+t/ha, sufficient rainfall or irrigation is required to fulfill the potential as evident in table 2.

Table 2. Yield components of high yielding 7t/ha plus faba bean crop.

Cultivar - location	System	Population (plants/m^2)	Harvest dry matter (t/ha)	Stems/m^2	Pods/m^2	Grain yield (t/ha)
PBA Amberley 2020 – Finley*	Irrigated	20	13.59	60	453	7.45
PBA Amberley 2021 - Finley	Irrigated	21	11.66	60	490	7.18
Fiesta VF 2020 – Finley	Irrigated	27	15.15	70	557	7.06
Fiesta VF 2021 – Finley	Irrigated	23	13.68	60	624	7.23
PBA Amberley 2020 – Finley**	Irrigated	32	9.05	61	351	5.17
PBA Samira 2021 – Bundalong GSR 504mm	Dryland	18	14.17	56	474	7.66
PBA Samira 2020 – Dookie GSR 341mm	Dryland	29	8.58	77	310	4.62
PBA Samira 2019 – Dookie GSR 254mm	Dryland	28	6.90	92	434	2.74

The two 2020 trials on PBA Amberley were identically managed except for irrigation. (**) received 150mm irrigation through an overhead lateral compared to 240mm surface irrigation (*)

Harvest index

In both dryland and irrigated trials, higher yielding crops with higher plant populations had higher harvest indices. However, it is generally higher dry matter at harvest that correlate strongly with 7t/ha + yields.

Soil amelioration

In another component of the OIG project, FAR Australia and the Irrigated Cropping Council (ICC) have been working in collaboration with NSW DPI on soil amelioration. At Finley under irrigation, a red/brown duplex soil was ameliorated with a number of soil ameliorants treatments following deep ripping in March 2020. The first crop sown after amelioration was faba beans. The trial was followed with canola in 2021 and durum wheat in 2022. In 2020, all amelioration treatments significantly increased the yield of faba beans (Table 3). In all cases, amelioration increased water use efficiency.

Table 3. Influence of soil amelioration and soil amendments on faba bean cv PBA Samira⁽ᵇ⁾ crop yield at Finley, NSW in 2020.

Treatment No	Treatment	Grain yield (t/ha)	
1	Nil (Control)	4.85	c
2	Deep rip (tillage control)	5.87	ab
3	Surface applied organic amendment (15t/ha)	5.51	b
4	Deep rip; Deep applied organic amendment	6.03	ab
5	Deep rip; Deep applied organic amendment; Deep applied gypsum	6.17	a
6	Deep applied gypsum	5.68	ab
	Mean	**5.65**	
	LSD	0.54	
	P val	0.002	

Notes: Organic amendment based on lucerne pellets applied at 15t/ha, gypsum applied at 5t/ha, deep ripping conducted to a depth of 35-40cm after 3 passes.

Where letters against treatments are different, treatments are significantly different (P<0.05, LSD 0.54)

Trial subject to 244mm GSR and 6 applications of 25mm of irrigation applied with a lateral overhead irrigator. Total water (GSR and irrigation) = 394mm.

Nitrogen fixation and removal

Faba beans can produce large quantities of dry matter and typically the dry matter of well nodulated legumes correlate with N fixation (Brill et al. 2022). Allowing for root factors Brill et al. (2022) found faba beans fix ~30kg N/t of dry matter. However, it should be noted that high grain yields also export a proportion of the fixed N from the paddock and that the N balance (N-fixed less N off-take in grain) is the most important consideration. Nitrogen off-take in a 7t/ha crop with ~40kg of N per tonne of grain, results in N off-take of 280 kg N/ha. In the work undertaken by Brill et al (2022) they found faba bean had an average N balance of 194kg N/ha across five sites with an N balance range of 86 to 343kg N/ha. In this research (Table 2 and 4) N balance ranged from 65 to 172 kg N/ha with a mean of 102 kg N/ha which is 94 kg N/ha less than the mean reported by Brill et al (2022). These results highlight nitrogen contributions can be variable and are dependent on the amount of dry matter produced and N off-take in grain.

Value of nitrogen and grain

The total value of nitrogen ($1.7/kg) and grain ($350/t) is provided in Table 4. The highest value ($/ha) site years for faba bean (i.e., >$2,600/ha total value) were equivalent to growing 3.7 to 4.0 t/ha of canola valued at $700/t. The nitrogen legacy from faba bean was enough to grow between 1.1 to 3.0 t/ha of canola assuming an efficiency of labile organic matter derived nitrogen of 70% (Peoples et al 2017) and 40 kg N/ha of shoot nitrogen required per tonne of canola grain production. At this efficiency only 57 kg of soil N is required per tonne of canola grain production, while for fertiliser nitrogen typically 80 kg of soil N/ha is required and assumes a soil N efficiency factor of 50%.

Table 4. Estimated nitrogen fixation, nitrogen removal in grain (N offtake), nitrogen balance (net N contribution) and value of nitrogen balance and grain yield take. Assumptions include: 30 kg nitrogen fixed per tonne of peak dry matter, 40 kg N/t nitrogen in faba bean grain. Dry matter and grain yield is used from table 2, prices assumptions include $1.70/kg for nitrogen and $350/t for faba bean on-farm.

Cultivar - location	System	N fixed (kg N/ha)	N removal (kg N/ha)	N balance (kg N/ha)	N value ($/ha)	Grain Value ($/ha)	Total value ($/ha)
PBA Amberley⏀ 2020 – Finley*	Irrigated	408	298	110	$186	$2,608	$2,794
PBA Amberley⏀ 2021 - Finley	Irrigated	350	287	63	$106	$2,513	$2,619
Fiesta VF 2020 – Finley	Irrigated	455	282	172	$293	$2,471	$2,764
Fiesta VF 2021 – Finley	Irrigated	410	289	121	$206	$2,531	$2,737
PBA Amberley⏀ 2020 – Finley**	Irrigated	272	207	65	$110	$1,810	$1,919
PBA Samira⏀2021 – Bundalong GSR 504mm	Dryland	425	306	119	$202	$2,681	$2,883
PBA Samira⏀2020 – Dookie GSR 341mm	Dryland	257	185	73	$123	$1,617	$1,740
PBA Samira⏀2019 – Dookie GSR 254mm	Dryland	207	110	97	$166	$959	$1,125

Nutrition

At Bundalong, Samira⏀ produced exceptional yields in 2021 with the nutrition trial set up in a commercial paddock averaging 7.7 t/ha under dryland conditions. The trial examined different lime applications pre sowing and different post sowing nutrition treatments (Table 5). Although the application of lime (top dressed and incorporated by sowing) did not increase yield, a number of the post sowing treatments significantly increased yield relative to the limed and non-limed controls (Figure 3).

Table 5. Nutrition treatments, products and nutrient contents, and application rates and timings at Bundalong, Victoria cv PBA Samira⚐. *STT = Spraygro® Smartrace Triple, Boly = Spraygro® Boly, Combi 7 = Rapisol® Combi 7 pH site - 5.3*

Treatment no	**Treatment**	**Pre-Sowing (20 April)**		**6-8 leaf (28 June)**		**Early flowering (29 Aug)**	
		Product	Rate	Product	Rate	Product	Rate
1.	**Untreated + lime Control**	Lime	1 t/ha				
2.	**Micronutrients (standard) +lime**	Lime	1 t/ha	STT Boly	2.5L/ha 2L/ha	STT Boly	2.5L/ha 2L/ha
3.	**Micronutrients (standard) + N+ lime**	Lime	1 t/ha	STT Boly Nitrogen	2.5L/ha 2L/ha 50kg N/ha	STT Boly Nitrogen	2.5L/ha 2L/ha 50kg N/ha
4.	**100N split + lime**	Lime	1 t/ha	Nitrogen	50kg N/ha	Nitrogen	50kg N/ha
5.	**100N early + lime**	Lime	1 t/ha	Nitrogen	100kg N/ha		
6.	**100N late + lime**	Lime	1 t/ha			Nitrogen	100kg N/ha
7.	**Untreated**						
8.	**Micronutrients (standard)**			STT Boly Nitrogen	2.5L/ha 2L/ha 50kg N/ha	STT Boly Nitrogen	2.5L/ha 2L/ha 50kg N/ha
9.	**Micronutrients (regional)**	Lime	1 t/ha	Rapisol 321	1kg/ha	Rapisol 321	1kg/ha
10.	**Micronutrients (regional)**	Lime	1 t/ha	Rapisol 321 Combi 7	1kg/ha 1.5kg/ha	Rapisol 321 Combi 7	1kg/ha 1.5kg/ha

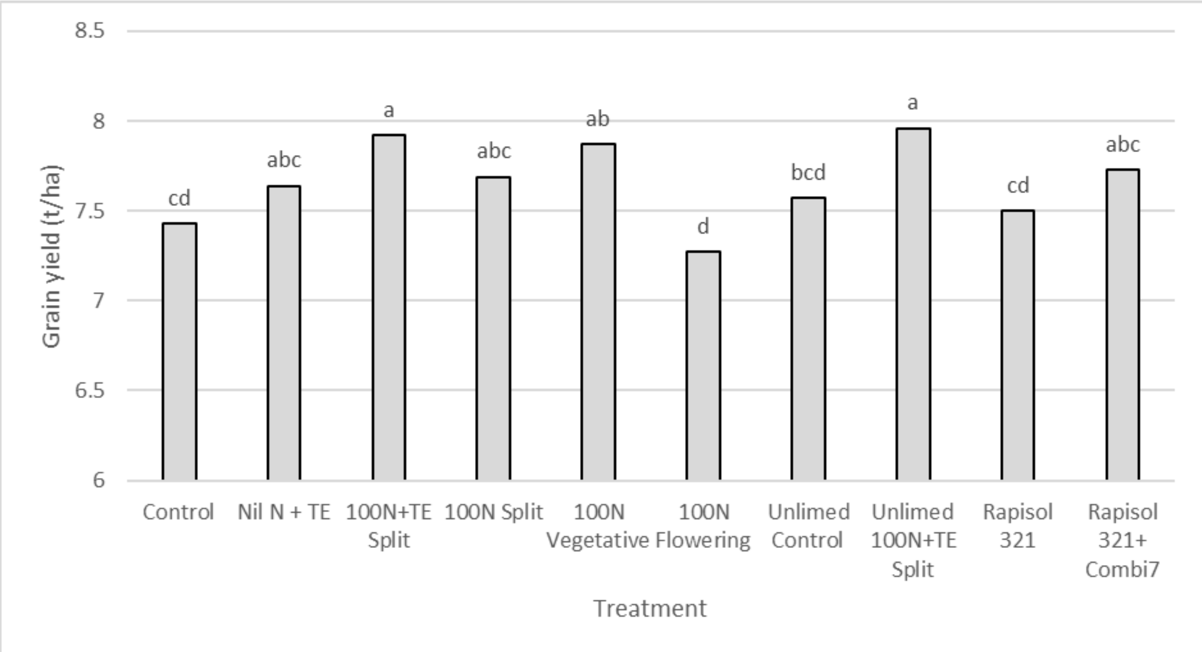

Figure 2. Influence of different nutrition treatments on faba bean yield at Bundalong, Victoria. P=0.005, LSD=0.34t/ha. Notes: N = Nitrogen, TE = Trace elements, Rapisol® 321 = Mn + Cu + Zn, Rapisol® Combi 7 = Fe + Cu + Zn + Mg + Mo + B + Mn. Split = different timings at 6-8 leaf and early flowering.

The application of additional nitrogen at the vegetative stage produced significantly higher yields compared to the control treatments (Figure 2). However, when N was split or applied at flowering there was no increase in grain yield. The application of trace elements didn't influence yield, although highest yields were observed when trace elements and nitrogen were applied together or nitrogen by itself at the 6 to 8 leaf stage (e.g., end of June).

Disease risk

Do bigger crop canopies under irrigation show much greater yield responses to disease management? Initial results generated in 2020 and 2021 at Finley using the more disease resistant cultivar PBA Amberley⟑ revealed little additional yield response to higher fungicide input based on more-expensive chemistry under irrigation at Finley. In 2022, excessive rainfall in the spring at the same site, resulted in significant reductions in yield with positive results in terms of yield, disease control and profit with greater fungicide input (data still being analysed at the time of publication).

While irrigation increased the canopy size at Finley in 2021, the conditions for disease were not as conducive for disease as those in the longer growing season of the southern Victorian HRZ near Geelong, despite similar yields (6 to 7t/ha).

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. FAR Australia would also like to acknowledge the support of Southern Growers from whom we leased land and water on their Finley Irrigation Complex, our 2022 host farmers Adam Inchbold, and Denis Tomlinson

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Date published

February 2023

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