Farming system profitability over time – exploring the impact of nitrogen strategy on profit in different farming systems

Mathew Dunn[1], John Kirkegaard[2], Tony Swan[2], Jeremy Whish[2], Xiaoxi Li[2], Russell Pumpa[1], Kelly Fiske[1]

[1] NSW Department of Primary Industries
[2] CSIRO Agriculture and Food

Key words

farming systems, crop sequences, nitrogen, legumes, gross margin

GRDC code

CFF00011, CSP2110-004RMX

Take home messages

- Compared to historical seasons, both higher rainfall and more seasonally variable rainfall occurred at the Wagga Wagga and Urana sites during the experimental period (2018–23).
- The non-legume, canola and cereal based crop sequences achieved higher gross margins under the high (decile 7) nitrogen (N) strategy, where N application rates exceeded N removal in grain. Any high N induced grain yield reductions (haying off) in the lower rainfall seasons were more than offset by grain yield increases in the higher rainfall seasons.
- In contrast, diverse (legume containing) crop sequences resulted in higher gross margins under the low (decile 2) N strategy. This effect was partially driven by the lack of grain yield response to the high N strategy (decile 7) in the canola crops directly following a legume (double break).
- At Wagga Wagga under the high N strategy (decile 7), where N application rates exceeded N removal in grain, consistently higher soil mineral N concentrations were found at sowing each season. This indicates minimal N losses between seasons and therefore may favour N banking approaches in this environment.

The Southern Farming Systems Project – background and description

Australian farmers have been enthusiastic adopters of crop benchmarking tools (such as the French and Schultz water use efficiency calculation or Yield Prophet®) to compare the performance of individual crops to their water-limited potential. However, in dryland farming systems, it is important to consider the efficiency of water use across crop sequences to account for the inevitable legacy effects (i.e., carry over effects on soil water, soil fertility, nutrition, weeds and disease).

To cover the wide range of soil and climate in southern NSW, experimental field sites were established at Wagga Wagga, Greenethorpe, Condobolin and Urana. A range of fully phased crop sequences were established in 2018 and compared with the common canola-wheat-barley baseline crop sequence (Table 1). These included more intensive cereal sequences (wheat and barley), a range of high-value (lentil, chickpea) and low-value (lupin, faba bean) legume options as well as grazing (Wagga Wagga & Greenethorpe only) and forage options. In addition, interactions of early sowing (March/early-April) and timely sowing (mid-April/mid-May) of wheat and canola options (grazed and un-grazed) and different nitrogen (N) management strategies based on either decile 2 or decile 7 rainfall outlooks were included. These treatments generated different water and N use patterns as well as weed, disease, residue loads and other legacies which were monitored across each crop sequence.

This article will focus exclusively on the Wagga Wagga and Urana sites to examine overall system profitability and dive deeper into the individual factors driving system performance. Results from other sites can be found in previous update papers (Farming systems profit and risk over time: exploring the N legacy impacts on profit in different farming systems).

Table 1. Selected systems common to both Wagga Wagga and Urana for comparison in this paper.

Treatment description	Crop sequence	Sowing time	Nitrogen strategy
Baseline	Barley – Canola – Wheat	Timely	Decile 2 & decile 7*
Intense baseline	Canola – Wheat	Timely	Decile 2 & decile 7
Diverse high value	Chickpea/Lentil** – Canola – Wheat	Timely	Decile 2 & decile 7
Diverse low value	Faba bean/Lupin*** – Canola – Wheat	Timely	Decile 2

* Only decile 2 at Urana, ** Lentil 2018–20, chickpea 2021-23, ***Faba bean at Urana and lupin at Wagga Wagga.

Seasonal conditions at the sites during the 2018–2023 seasons

At both sites a diverse range of seasons were experienced during the 6-year experimental period. The 2018 and 2019 seasons were dry with well below average rainfall. In contrast, 2021 and 2021 were particularly wet with well above average rainfall. While rainfall in 2020 and 2023 was close to, but still above average (Table 2).

Table 2. Rainfall at the Wagga Wagga and Urana experimental sites from 2018 to 2023, the longer team average rainfall and the decile for each season (in brackets). Rainfall data sourced from on-site weather stations. Long-term average (LTA) data sourced from SILO gridded data.

Site	2018	2019	2020	2021	2022	2023	LTA
Wagga Wagga	403 (3)	320 (2)	557 (8)	757 (10)	886 (10)	559 (6)	526
Urana	276 (1)	222 (1)	488 (6)	564 (9)	968 (10)	552 (8)	449

To better understand how the seasons experienced during the experimental period (2018 to 2023) compared to historical seasons, 6-year moving frequency distributions (histograms) were created. These histograms compare all consecutive 6-year periods between 1960 and 2023 by plotting the average annual rainfall (Figure 1A & 1C) and annual rainfall standard deviation (Figure 1B & 1D) of each 6-year period as a distribution.

During the experimental period (2018–23), both higher rainfall and more seasonally variable rainfall was received at the Wagga Wagga and Urana sites. Specifically, Wagga Wagga and Urana received an average of 41 and 54 mm higher annual rainfall respectively than the long-term average (Figure 1A & 1C). The annual rainfall standard deviation, which measures how variable the annual rainfall was compared to the average for each 6-year period, was higher by 20 mm at Wagga Wagga and 106 mm Urana.

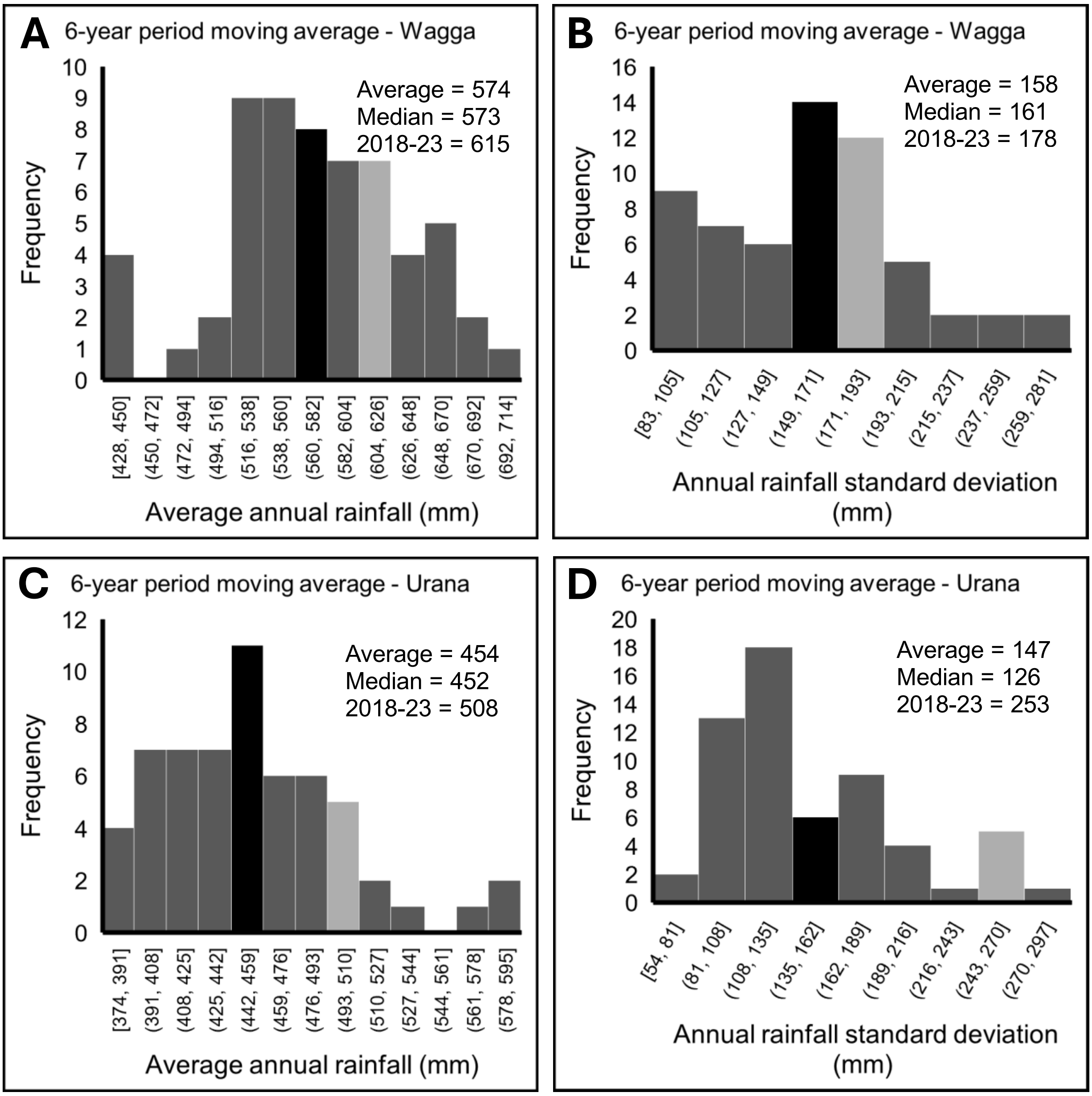

Figure 1. Frequency distribution (histogram) of the 6-year period moving average for average annual rainfall (A & C) and annual rainfall standard deviation (B & D) for both Wagga Wagga and Urana sites. Black bar = average containing grouping, light grey bar = 2018–23 containing grouping. Rainfall data from 1960 to 2023 included. Rainfall data sourced from BOM stations 072150 (Wagga Wagga Airport) and 074110 (Urana Post Office).

Nitrogen strategies, their implementation and resulting N application/removal rates

The N management strategies compared across some systems were based on either a conservative seasonal rainfall outlook (decile 2), or a more optimistic (decile 7) seasonal rainfall outlook. For each non-legume crop in each year, soil mineral N and soil water was measured pre-sowing, then at topdress time (June/July) a yield potential estimate was made based on the starting soil water, soil mineral N level and seasonal conditions up to that time. N was then applied as urea assuming either a decile 2 or a decile 7 finish to the season. Using this approach, the legacy benefits of carry-over N from either legumes or unused fertiliser N would be accounted for in the pre-sowing tests and less N applied accordingly. This approach (compared to set N rates) better reflects farmer practice in a farming systems context.

The N management strategies described above resulted in a wide range of N application rates across the variable seasons. At both Wagga Wagga and Urana, average N application rates for non-legume, decile 2 nitrogen strategy treatments matched or exceeded N removal rates (Table 3). While at both sites, average N application rates under the higher (decile 7) nitrogen strategies were well above N removal rates (Table 3).

At both Wagga Wagga and Urana sites, average N application rates were lower in the diverse (legume containing) sequences than the non-legume sequences (Table 3). This is due to both the legume crop in these sequences not having any urea applied to them as well as a decrease in the amount of N applied to the non-legume crops in these sequences. These legume N legacy effects are further explored in previous update papers (Farming systems profit and risk over time: exploring the N legacy impacts on profit in different farming systems).

The names of these strategies (decile 2 & 7) are somewhat misleading as there's a common expectation that a decile 2 N strategy should result in N application rates below N removal rates. However, this was not observed in these field experiments. A more accurate description in this case might be that the decile 2 N strategy is a close to neutral N balance strategy (where N supply matches N removal in grain), while the decile 7 N strategy is positive N balance strategy (N supply exceeds N removal in grain).

Table 3. Average annual N application, N removal in grain and the resulting partial nitrogen balance for a range of selected timely sown, grain only systems at Wagga Wagga and Urana. Average applied N values for systems that contain legume crops do not include fixed N (nitrogen derived from the atmosphere).

System	Crop sequence	N strategy (decile)	Average applied N (kg N/ha/year)	Average N removal in grain (kg N/ha/year)	Partial nitrogen balance
		Wagga Wagga			
Int. Baseline	Canola – Wheat	2	115	92	0.80
		7	162	106	0.65
Baseline	Barley – Canola – Wheat	2	108	102	0.94
		7	159	118	0.74
Diverse HV	Lentil/Chickpea – Canola – Wheat	2	65	–	–
		7	103	–	–
Diverse LV	Lupin – Canola – Wheat	2	61	–	–
		Urana			
Int. Baseline	Canola – Wheat	2	78	80	1.02
		7	137	103	0.75
Diverse HV	Lentil/Chickpea – Canola – Wheat	2	36	–	–
		7	77	–	–
Diverse LV	Faba bean – Canola – Wheat	2	29	–	–

System economic performance

A summary of economic results for selected timely-sown, grain-only systems at Wagga Wagga and Urana are provided in Tables 4 and 5. Table 4 presents the system average gross margin results, while Table 5 breaks down the system gross margin results by crop type.

At both Wagga Wagga and Urana, the higher N strategy (decile 7) for both non-legume systems (Int. Baseline & Baseline) resulted in higher average annual gross margins compared to the lower N strategy (decile 2) (Table 4). This outcome is not unexpected considering the above average rainfall during the experimental period (2018–23). However, the results differed for the diverse high value (HV, legume containing) system at both Wagga Wagga and Urana where the lower N strategy (decile 2) led to higher average annual gross margins (Table 4). This effect is in part a result of the reduced canola gross margin under the higher N strategy (decile 7) (by $210 and $222/ha/year at Wagga Wagga and Urana respectively), although this is partially offset by the higher wheat gross margins (by $76 and $136/ha/year at Wagga Wagga and Urana respectively). Even during the seasons of higher-than-average rainfall, implementing a higher N strategy (decile 7) in the canola crop directly following a legume did not on average lead to an increase in grain yield at Wagga Wagga or Urana. This resulted in a poor return on the extra N investment.

Average annual gross margins for each crop type varied across both cropping sequences and N strategies. The highest average annual canola gross margin occurred at both sites in the diverse HV (legume containing) crop sequence under the decile 2 nitrogen strategy (Table 5). This was not the case for wheat, with the average annual wheat gross margin responding positively the higher N strategies (decile 7) under all crop sequences (Table 5). At Wagga Wagga there was no significant difference between annual wheat gross margins under any of the crop sequences, however at Urana both diverse crop sequence (HV & LV) resulted in higher (by $53/ha/year on average, although not statistically significant at P<0.05) average annual wheat gross margins compared to both non-legume (Int. Baseline and Baseline) crop sequence at the lower N strategy (decile 2) (Table 5).

Table 4. Average annual gross margin (2018–23) for a range of selected timely sown, grain only systems at Wagga Wagga and Urana under two different nitrogen strategies (decile 2 & decile 7)

System	Crop sequence	Average annual gross margin ($/ha/year)	
		Decile 2 N strategy	Decile 7 N strategy
Wagga Wagga			
Int. Baseline	Canola – Wheat	750	794
Baseline	Barley – Canola – Wheat	884	921
Diverse HV	Lentil/Chickpea – Canola – Wheat	752	730
Diverse LV	Lupin – Canola – Wheat	790	–
	l.s.d. (P=0.05)	100	95
Urana			
Int. Baseline	Canola – Wheat	679	843
Baseline	Barley – Canola – Wheat	812	–
Diverse HV	Lentil/Chickpea – Canola – Wheat	991	885
Diverse LV	Faba bean – Canola – Wheat	987	–
	l.s.d. (P=0.05)	136	103

Table 5. Average annual gross margin (2018–23) broken up by crop type for a range of selected timely sown, grain only systems at Wagga Wagga and Urana.

System	Crop sequence	N strategy (decile)	Average annual gross margin ($/ha/year)		
			Canola	Wheat	Barley/Legume
Wagga Wagga					
Int. Baseline	Canola – Wheat	2	769	730	–
		7	789	799	–
Baseline	Barley – Canola – Wheat	2	821	746	1084
		7	785	872	1106
Diverse HV	Lentil/Chickpea – Canola – Wheat	2	934	748	575
		7	724	824	642
Diverse LV	Lupin – Canola – Wheat	2	796	776	797
		7	–	–	–
	l.s.d. (P=0.05)		122	141	–
Urana					
Int. Baseline	Canola – Wheat	2	469	888	–
		7	645	1042	–
Baseline	Barley – Canola – Wheat	2	471	881	1085
		7	–	–	–
Diverse HV	Lentil/Chickpea – Canola – Wheat	2	910	936	1127
		7	688	1072	895
Diverse LV	Faba bean – Canola – Wheat	2	728	939	1293
		7	–	–	–
	l.s.d. (P=0.05)		197	129	–

Soil mineral N under higher nitrogen strategies

It is commonly assumed that if fertiliser derived N is not used by the crop in the year of application, it is lost and the return is limited. However, if the N isn't lost to the environment and remains in the soil, the unused fraction may contribute in maintaining soil fertility in continuous cropping systems. One method of examining the movement and potential loss of soil mineral N between seasons under higher N application strategies in these field experiments is to compare the additional N applied (decile 2 vs decile 7) in our systems with the soil mineral N (decile 2 vs decile 7) observed at sowing in the subsequent season.

A similar and relatively high proportion (66% and 69%) of the extra applied N (decile 2 vs decile 7) in both non-legume systems at Wagga Wagga was found as extra soil mineral N (decile 2 vs decile 7) at sowing in the following season (Table 6). This indicates that at this site, in the seasons that were experienced, unused fertiliser N appears to remain for following seasons without significant losses. At Urana the proportion of extra applied N (decile 2 vs decile 7) that was found as extra soil mineral N (decile 2 vs decile 7) at sowing in the following season was lower than Wagga Wagga at only 48% (Table 6). This is perhaps an indication of greater N loss from the system, which would not be unexpected at the Urana site (grey vertosol) given its higher soil pH and more frequent exposure to periods of water logging compared to the red acidic loam of the Wagga Wagga site.

Table 6. Average applied N in preceding season (2018,19, 20, 21, 22), average soil mineral N (0–110 cm at Wagga Wagga, 0–170 cm at Urana) at sowing (2019, 20, 21, 22, 23) and the ratio of extra mineral N to extra applied N in the higher N strategy (decile 7) compared to the lower N strategy (decile 2) for a range of selected timely sown, grain only systems at Wagga Wagga and Urana.

System	Crop sequence	N strategy (decile)	Average Applied N in preceding season (kg N/ha/year)	Average soil mineral N at sowing (kg N/ha)	Ratio of extra mineral N to extra applied N
Wagga Wagga					
Int. Baseline	Canola – Wheat	2	107	75	
		7	160	110	
		Difference (7 minus 2)	53	35	0.66
Baseline	Barley – Canola – Wheat	2	61	72	
		7	106	103	
		Difference (7 minus 2)	45	31	0.69
Urana					
Int. Baseline	Canola – Wheat	2	62	69	
		7	131	102	
		Difference (7 minus 2)	69	33	0.48

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial co-operation and the support of the GRDC and NSW DPI, the author would like to thank them for their continued support. The authors would like to especially thank Warakirri Cropping "Karoola Park" and Rod and Nick Kershaw "Iandra Pastoral" for their support and co-operation in hosting the Urana and Greenethorpe field experimental sites. The authors would also like to acknowledge the contributions of Graeme Sandral for his role as site leader during the first two and a half seasons of the project. We also thank Chris Baker (Baker Ag Advantage), Tim Condon (Delta Agribusiness), Greg Condon (Grassroots Agronomy), Heidi Gooden (Delta Agribusiness), Peter Watts (Elders), Rod and Nick Kershaw (Iandra), John Stevenson (Warakirri Cropping) and John Francis (Agrista) for the many useful discussions in their role on the project advisory committee.

Contact details

Mathew Dunn
NSW Department of Primary Industries, Wagga Wagga
Ph: 0447 164 776
Email: mathew.dunn@dpi.nsw.gov.au

Date published

August 2024

® Registered Trademark