Estimated value of legumes to crop sequences at research and commercial scale in Southern NSW

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Abstract

Diversifying a crop sequence to include a legume can be profitable and increase the resilience and sustainability of modern farming systems. Benefits can include increased soil nitrogen (N) availability and improved rotational and environmental outcomes. Large-seeded legumes sown into retained cereal residues in modern no-till crop sequences can emerge easily, facilitating stubble retention, reducing N tie-up and improving the conversion of carbon-rich cereal stubbles into stable soil organic matter. Yet despite compelling evidence of economic and environmental benefits of diverse cropping systems, adoption on commercial farms in Southern NSW remains low. We explore reasons for this by scaling up the results from three fully phased replicated small plot experiments (2014-23) to commercial farm scale. Results confirmed that including a legume into a 3- or 4-year cropping sequence can be as profitable as a "Baseline" canola-wheat-barley sequence favoured by growers. Systems incorporating a legume were less risky (higher profit:cost ratio) and required significantly less inorganic N-fertiliser (35 to 83 kg/ha/year) compared to Baseline systems. At the whole farm level, when the business is managed at a high level of efficiency, changing cropping systems to include legumes was effective and profitable for growers by reducing synthetic N required and reducing economic fluctuations. Additional on-farm pulse grain storage was important to increase the return on assets managed (1%) at farm scale. Our work indicates outcomes of experimental research on the value of diverse crops into cereal-based systems should be combined with a clear understanding of farm- and industry level constraints.

Keywords

Stubble retention, diversity, nitrogen, profit, legumes, canola, cereals, whole farm economics

Introduction

Australian farmers have been enthusiastic advocates of no-till or zero-till cropping systems, retaining stubble to enhance water capture and storage, improve "soil health" and increase crop yields. Over past decades, farmers and scientists have continued to examine a range of methods to flexibly manage stubble to improve profitability. These have included diversifying cropping systems, by changing crop sequences, varying N applications and herbicide options. The addition of a break crop such as canola or a pulse legume into the sequence has been shown to be profitable in plot experiments in NSW and effective at controlling weeds and diseases in stubble retained systems (Swan *et al*. 2023). However, while farmers have found that stubble retention provides many benefits, there has been little research on the effect that different farming systems have on whole farm economics. This paper reports results from three small-scale, fully-phased factorial field experiments between 2014-2023 that compared the effect of diversifying Baseline (canola-cereal) systems with Diverse systems involving legumes on crop yield, net margins and N management where crops were established using a single disc or a tine seeder. Information and results from three experiments are combined with commercial farm economic assumptions to predict whole farm economic outcomes. The results from the 1st field experiment (2014-18) were scaled up to a 5000ha whole farm where a "Diverse Mix" system that included a legume crop was compared to two "Baseline" systems with crops established using both disc and tine seeders. In Experiments 2 and 3, the information from the plot experiments (2018-2023) was incorporated into the whole farm models and scaled up to a 10,000ha farm using a disc seeder. At the 10,000ha scale, we compare two Diverse crop systems, a 4-year sequence of fababean-canola-wheat-barley with a 3-year sequence of fababean-canola-wheat. We explore the impact of farm-level adjustments such as additional storage, increasing efficiency, additional equipment and labour, and changes in the N requirement. Scaling up to farm level revealed key drivers necessary to improve whole farm profit in diverse, stubble retained farming systems.

Methods: *Experiment 1*

Field experiment

A fully phased 4-year replicated field experiment was established at the Temora Agricultural Innovation Centre in 2014 comparing three management systems (Baseline High-N, Baseline Low-N and Diverse Mix Low-N) for crop yield and net margins by seeder type in a paddock with medium plant populations of herbicide resistant annual ryegrass ARG. The Baseline Low-N and High-N systems incorporated a single break crop rotation of "canola-wheat-wheat". The Baseline High-N was managed aggressively which included expensive herbicides, more N early in the season and increased plant density for greater crop competition, whereas the Baseline Low-N was managed conservatively with cheaper herbicides, less crop competition, less early N. Both crop systems were compared to a "Diverse Mix, Low-N" double break crop sequence of "vetch (Hay/BM)-canola-wheat-barley" with expensive herbicides and crop competition from barley, sown on 300 mm row spacing with a Flexi-coil tine seeder or single disc seeder with Arrick's wheels.

Whole Farm

The results from the field experiment (2014-18) were scaled up to a 5000ha whole farm economic analysis, using results from the Baseline High-N and Diverse Mix systems only, as they are more comparable to the results from Experiments 2 and 3 (below). For the whole farm analysis, the key assumptions are outlined in Table 1. No fallow sprays were included, land prices ($6175) are assumed constant over the four-year period and no capital appreciation accounted for. All operational, administrative, and plant and equipment expenses were included.

Methods: Experiment 2 and 3

Field experiment

The methods for the field experiment are described in Kirkegaard et al. (2024). In summary, 2 sites were established in 2017 in Southern NSW at Greenethorpe and Urana. At both sites, six-year fully phased, replicated field experiments were established in a randomised block design to compare the performance of the "Baseline" system of a canola-wheat-wheat (Experiment 2) or canola-wheat-barley (Experiment 3) sequence with two "Diverse" crop systems (Diverse Mixed, low-N: Vetch hay/BM-Canola-Wheat) or (Diverse Low Value, low-N: Faba bean-Canola-Wheat). Crops were timely sown in late April-early May and top-dressed with N in mid-July to target either a conservative "Low-N" or an optimistic "High-N" grain yield. The yield target was based on soil N at sowing with the quantity of N applied in mid-July based on predicted end of season rainfall to achieve either a decile 2 (Low-N) or decile 7 (High-N) grain yield.

Whole Farm

The information from the 6-year project (Experiments 2 and 3) were combined with whole farm economic data to compare a 3-year and 4-year crop sequence (faba bean-canola-wheat *cf* faba bean-canola-wheat-barley) on the return on assets managed (ROAM) at the whole farm level using a disc seeder across a 10,000ha enterprise. At the whole farm level, the modelled scenarios included all costs associated with managing a 10,000ha property such as deprecition and land value ($6,500/ha) over a ten-year period using ten decile years. Scenarios also included cost of additional on-farm pulse grain storage (7000 T/property), additional equipment (1 x class 10 header, 1x 18m disc seeder & box, 1 x 36m self-propelled boom sprayer) and 2.5 FTE additional labour to improve whole farm efficiency, plus reduced N requirements. In scenarios examining on-farm storage, the fababean price was a decile 3 (low-harvest price) compared to a decile 5 (stored price +$30 t). In the whole farm analysis, only a disc seeding system is used which may benefit the entire operation due to the timeliness of sowing.

Table 1: Key assumptions used to calculate the whole farm analysis in 2014-18 (from Experiment 1). A detailed list can be found at Swan T, et al. 2018 (GRDC Wagga Business Update, 2018)

Tractor 1	Tractor 2	Seeder	Row spacing	Seeder speed + fuel usage	Labour units
450hp	330hp	a. 18m flexi-coil at $290K*		a. 10 km/hr (69L/hr)	$115K x 1
1000hrs/yr	400 hrs/yr		300mm		$70K x 1
$428K*	$313K*	b. 18m disc at $370K*		b. 12km/hr (60L/hr)	$66K x 1.5

** Cost to purchase tractor or machinery in 2018*

Results

Experiment 1 (2014-18): Effect of diversity and N strategy

Over the 4 years in the experiment, the Diverse Mix Low-N system generated the highest profit with average earnings before interest and tax (EBIT) of $478 ha/year compared to $454 ha/year or $328 ha/year in the Baseline High-N and Baseline Low-N systems, respectively. When weeds were not effectively controlled in the Baseline Low-N system in the disc seeder system, EBIT was reduced by 45% (Table 3). However, at whole farm level, there were no differences in average annual EBIT between the Baseline High-N and Diverse Mix Low-N system at $447 ha/year (Tables 2 & 3).

Table 2: Income, expenses and earnings before income and tax (EBIT) averaged across the whole farm for each system by opener type ($/ha) and cost of production ($/t) at 5000 ha (experiment 1, 2014-18).

Cropping System	Opener	Gross Income ($/ha)	Enterprise expenses ($/ha)	Cost of production ($/t)	Total fuel costs ($/ha)	Average EBIT ($/ha)
Baseline High N	Tine	$1,004	$427	$176	$23	$457
Diverse Mix	Tine	$971	$398	$155	$19	$457
Baseline High N	Disc	$982	$424	$177	$25	$437
Diverse Mix	Disc	$959	$399	$152	$21	$443

Table 3: Average gross margins and average total costs ($/ha/yr) and the profit:cost ratio for three fully phased experiments over 4 years (experiment 1) or 6 years (experiments 2 and 3). The average quantity and cost of fertiliser nitrogen applied per system and the ratio of fertiliser cost to the total gross margin or total cost (%). In experiment 1, all results were the combined values from crops sown with a disc and tine seeder.

Exp't	Location Soil Type Rainfall	System by Nitrogen	Average Annual GM ($/ha/year)#	Average Annual Total Costs ($/ha/yr)	Profit:Cost ratio (ROI)#	Average N fertiliser applied (kgN/ha/yr)	Average Cost of fertiliser N ($/ha/yr)	Average fertiliser N cost *cf* GM (%/ha/yr)	Average fertiliser N cost *cf* TC (%/ha/yr)
1	**Temora**	Baseline (High N)	454	547	0.83	100	111	24%	20%
	Red Chromosol	Baseline (Low N)	328 (233 *cf* 422)	475	0.78 (0.69 *cf* 0.88)	98	107	33%	23%
	Medium rainfall	Diverse Mix (Low N)	484	487	0.98	65	72	15%	15%
2	**Greenethorpe**	Baseline (High N)	1076	949	1.13	119	217	21%	29%
	Red Kandosol	Baseline (Low N)	1069	877	1.22	77	149	15%	14%
	High rainfall	Diverse Mix (Low N)	812	844	0.96	41	118	13%	28%
		Diverse LV (Low N)	1150	881	1.31	36	73	8%	7%
3	**Urana**	Baseline (Low N)	812	793	1.02	72	160	17%	17%
	Brown Vertosol	Diverse Mix (Low N)	606	708	0.86	34	76	13%	9%
	Low rainfall	Diverse LV (Low N)	987	746	1.32	29	66	6%	7%

\# Values in brackets indicate the gross margin and the ROI in the disc and tine systems

The cost of production was lowest (13% lower) in the Diverse Mix Low-N system at the 5000ha farm scale with 18% reduction in fuel costs (Table 2), and depreciation was always lower. There was no significant difference in average EBIT between the Diverse Mix Low-N and Baseline High-N systems when crops were established with either a disc or a tine seeder. At the whole farm scale, there was no significant difference in ROAM between the Diverse Mix Low-N and Baseline High-N systems (average of 6.5% - data not shown). However, significantly less N fertiliser was required in the Diverse Mix Low-N system compared to Baseline High-N system (65 kgN/ha/yr *cf* 100 kgN/ha/yr). This reduced the cost of synthetic fertiliser N in the Diverse Mix system GM by 9% (Table 3). The economic instability in the 4-year average Diverse Mix system was significantly reduced compared Baseline High-N system with lower volatility in ROAM (coefficient of variation of 15% *cf* of 24% - data not shown), and a higher Profit:Cost ratio of 0.98 *cf* 0.83 (Table 3).

Experiment 2 and 3 (2018-2023): Effect of diversity and N strategy

In a cropping system where herbicide resistant ARG was not a major constraint, and when the crop sequence was reduced to 3 years, the Diverse LV Low-N system of fababean-canola-wheat was more profitable than the Baseline Low-N system at both the Urana and Greenethorpe, and more profitable than the Baseline High-N system at Greenethorpe (Table 3). The Diverse LV system was less risky (higher profit:cost ratio) than either the Baseline Low or High-N systems (Table 3). A major benefit of the Diverse LV system was the reduction in synthetic fertiliser required (43 to 83 kgN/ha/yr). This reduced the cost of fertiliser N as a proportion of the gross margin from 16% to 7% (Table 3). The Diverse Mix Low-N system was not as profitable in this 3-year sequence compared to the 4-year sequence in 2014-18 as herbicide weeds were not a major problem, and the lower return from the vetch (hay/BM) year was not sufficiently offset in the following canola and wheat crops.

At the whole farm scale, the highest predicted increase in ROAM of 1.02% occurred between scenario 1 and 2 with the addition of a 7000 T, on-farm grain storage unit. However, scenario 2 is under resourced with machinery and timeliness of operations which results in the enterprise not able to sow, spray or harvest a pulse grain crop efficiently with significant losses occurring. When sufficient resources were factored into the whole farm economics to manage the 4-year sequence at optimal efficiency, the ROAM increased by only 0.61% *cf* scenario 1. In comparison, by removing the barley crop from the sequence (reducing the crop sequence from 4 to 3 years), adding 7000 T grain storage and resourcing the enterprise for optimal efficiency, this resulted in a 0.91% increase in ROAM compared to 4-year managed optimally (Table 4). The 3-year sequence requires less fertiliser N and has a higher ROAM, but possible long-term broadleaf disease issues such as an increase in sclerotinia and nematodes have not been factored into the scenario. The volatility in the pulse grain price is a major constraint at the whole farm level. J Francis (pers. comm. 2024) estimated that it was economical to add on-farm storage for lentils, faba bean and chickpea, but not lupin. In the past 13 years, the mean grain price and standard deviation for lentil, faba bean and chickpea has been $703 t (stdev271), $497 t (stdev197) and $827 t (stdev339) (SAGIT 2011-24).

Table 4: The predicted return on assets managed, the average 3- or 4-year gross margin and the average individual crop GM from four scenarios over a ten-year period across a 10,000ha enterprise. The scenarios included a 4-year crop sequence (Faba bean-canola-wheat-barley), the 4-year sequence plus additional 7000T grain storage, increased equipment and labour or a 3-year crop sequence (faba bean-canola-wheat) plus additional storage and resourcing.

				Average 10-year gross margin for each crop			
Scenario		**ROAM**	**Average 3 or 4-yr GM ($/ha/yr)**	**Faba bean GM ($/ha/yr)**	**Canola GM ($/ha/yr)**	**Wheat GM ($/ha/yr)**	**Barley GM ($/ha/yr)**
1	Base Model (F-C-W-B rotation) June 2023	5.69%	$979	$160	$1,313	$1,326	$1,117
2	Scenario 1 + higher faba price on-farm storage	6.71%	$1,064	$499	$1,313	$1,326	$1,117
3	Scenario 2 + resourcing to execute on time	6.30%	$1,109	$680	$1,313	$1,326	$1,117
4	Scenario 3 – Barley (3-year rotation F-C-W)	6.60%	$1,137	$680	$1,313	$1,412	NA

Conclusion

In summary, the Diverse Low Value system that include a pulse crop in either a 3-or 4-year sequence matched or improved the profitability and reduced the volatility compared to the Baseline systems at the small plot and whole farm scale. The Diverse Mix systems where pulse crops can be brown manured or cut for hay are more profitable where there may be weed issues or specific constraints compared to a Diverse system with a pulse grain crop. The combination of experimental and whole farm data indicates the agronomic value of including a legume (faba bean) in farming systems in southern NSW, and that issues of storage, marketing and logistics are essential to increase the Return on Assets Managed (ROAM) to ensure that profitability and sustainability of farming enterprises in southern NSW.

References

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