Using broadleaf crops to improve wheat grain yield and on farm profitability

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Abstract
Broadleaf species are included in cropping systems to improve soil nitrogen (N) fertility, manage difficult weeds and reduce cereal disease incidence in crop rotations. A 4-year crop sequence experiment was conducted at Wagga Wagga to quantify the yield benefit of break crops (canola, field pea, lupin, vetch and high density legume pasture) to wheat crops in subsequent years. Results showed that grain yield increased significantly for the first wheat crop following any break crop that was brown manured. The benefit of break crops diminished in the 2nd and 3rd wheat crops although the grain yields tended to be higher under brown manured treatment. The yield benefits to subsequent wheat crops derived from legumes were compromised when harvested for grain or cut for hay. Overall, the N benefit from legumes was greater than, or equivalent to, fertiliser N (75 kg N/ha) for at least two wheat crops after break crops. Averaged across 4 years, the rotation with canola had the highest gross margin (average $500/year), and treatments that were brown manured were the lowest (average $259 - $289/year) due to income loss in year 1. The brown manured treatments, however, offer opportunities to manage herbicide resistant weeds and reduce the risk of diseases and provide significant N benefits.

Key words
Crop sequence, financial benefit, gross margin

Introduction
Including break crops into rotations with cereals can influence the nitrogen (N) dynamics of cropping systems (Peoples et al. 2001) and assist in the management of weeds and reduce disease incidence in crop rotations (Kirkegaard et al. 2008). However, the high input costs for canola and fluctuating grain prices of pulses give farmers an impression that broadleaf crops are high risk and not as profitable as cereals (Seymour et al. 2012). Indeed, some of the management options, such as brown manuring, will result in no income for a year. The question is whether the subsequent yield benefits obtained after break crops is sufficient to offset any reduction of income resulting from their inclusion in a cropping sequence. A 4-year crop sequence experiment was conducted at Wagga Wagga in 2011-2014, focusing on the rotational benefits of break crops for subsequent cereal crops. Gross margin analysis was also conducted to assess the potential beneficial impacts of break crop on the longer-term financial performance of grain cropping.

Materials and methods
There were 3 sets of treatments phased across years with a single break crop and double break crops, followed by two wheat crops in subsequent years, with a range of combinations of crop sequences contrasted with continuous cereals as a control (Table 1). The break crops used were canola, lupins, field peas, vetch, high density legume (HDL) pastures. Break crops, including canola, were used once over 4 years for the single break crop treatments, and twice in double breaks, i.e. one year with canola and one year with pulses or HDL pastures over 4 years. Wheat was used in the continuous cereal control treatment and was grown with and without N fertiliser (25 kg N/ha at sowing and 50 kg N/ha top-dressed). Field pea was brown manured at peak biomass or harvested for grain at maturity, vetch and HDL pastures were cut for hay or brown manured at peak biomass, while lupin and canola were harvested for grain only.

Gross margin analysis was conducted as per Farm budgets and costs from NSW Department of Primary Industries (Anonymous 2014). The input prices and output prices for all crops were 5-year average from 2009-2013 with urea at $652/t, single superphosphate at $387/t, wheat at $225/t, canola at $452/t, pea at $271/t and lupin at $310/t. The calculation of gross margin for vetch hay was adopted from the high density legume (Hay) budget, but used herbage dry matter yield from the site in corresponding years.

Table 1 Outline of treatments at the Graham Centre site, Wagga Wagga, NSW

	2011	2012	2013	2014
Single break	**Break crops**	Wheat	Wheat	Wheat
	Wheat+N	**Break crops**	Wheat	Wheat
Double breaks	Canola+N	**Break crops**	Wheat	Wheat
	Break crops	Canola	Wheat	Wheat
Control	Wheat+N	Wheat+N	*Wheat+N*	*Wheat+N*
	Wheat+N	Wheat-N	*Wheat-N*	*Wheat-N*

Results and discussion

Impact of break crops on wheat grain yield

The choice of break crop species and end-use both impacted on the grain yield of subsequent cereal crops. For example, the brown manured HDL pasture treatment increased grain yield significantly for the 1st wheat crop compared to the hay cut treatment (3.6 vs 3.0 t/ha, Table 2), although no difference were found between the brown manured and hay cut treatments in the 2nd and 3rd wheat crops. This is consistent to the result from Evans et al. (2003) who found that yields following clover forage conservation crops or green manures exceeded those after pea grown for grain by at least 0.4 t/ha for the 1st wheat crop. The significant increase in grain yield for the 1st crop was most likely due to extra input of N from above-ground biomass under the brown manured treatment combined with a longer period of fallow for N mineralisation and potential recharge of soil water reserves to occur. Nevertheless, the presumed N benefit derived from pasture legumes appeared to last at least 2-3 years as comparable grain yields were achieved to the continuous wheat treatment receiving 75 kg N/ha fertiliser.

When field pea was used as a break crop in year 1, the brown manured treatment increased grain yield at P = 0.055 for wheat, but not canola compared to the pea grain harvested treatment (Table 2). The grain yields of the 2nd and 3rd wheat crops after pea under either brown manured or grain harvested treatment were comparable to the continuous wheat with N fertiliser applied. There were no significant difference in grain yields between brown manured and hay cut treatments under vetch crop (Table 2).

Table 2 Crop yield (t/ha) for different crops under different crop management at the Graham Centre site at Wagga Wagga, NSW

2011	2012	2013&2014	Crop	Grain (t/ha)			
Year 1	Year 2	Years 3&4	Management	Year 1	Year 2	Year 3	Year4
Pea	Wheat	Wheat	Grain	2.5	3.5	3.5	3.5
		Wheat	BM		3.7	4.2	3.5
			Significance		*P*= 0.055	*n.s.*	
	Canola	Wheat	Grain	2.5	2.0	3.7	3.5
		Wheat	BM		2.3	3.7	3.4
			Significance		*n.s.*	*n.s.*	
Vetch	Wheat	Wheat	Hay cut		3.4	3.6	3.5
		Wheat	BM		3.7	3.8	3.6
			Significance		*n.s.*	*n.s.*	
Pasture	Wheat	Wheat	Hay cut		3.0	3.4	3.4
		Wheat	BM		3.6	3.7	3.3
			Significance		*P*= 0.01	*n.s.*	
	Canola	Wheat	Hay cut		1.8	3.7	3.4
		Wheat	BM		2.3	3.7	3.4
			Significance		*P*< 0.05	*n.s.*	
Lupin	Wheat	Wheat	Grain	2.0	3.4	3.6	3.5
	Canola	Wheat	Grain		2.1	3.9	3.4
			Significance		*N.A.*	*P*< 0.05	
Wheat+N	Wheat+N	Wheat+N	Grain	5.2	3.5	3.6	3.4
	Wheat-N	Wheat-N	Grain		2.4	3.1	3.4
			Significance		*P*< 0.05	*P*< 0.05	

n.s., not significant; N.A., not applicable

When lupin was grown, the rotation with lupin-canola-wheat was more productive (and profitable) than rotation with lupin-wheat-wheat (Table 2). For the continuous cereal treatment, grain yields were significantly higher on the fertilised treatments compared with non-fertilised treatment in the 2nd and 3rd years, but not in the 4th year (Table 2).

Gross margin analysis

Rotations with single break crop. Averaged across two phases, the rotation including canola as a single break crop (canola-wheat-wheat or wheat-canola-wheat) had the highest average gross margin ($500/year) across 3 years (Table 3). Cutting for hay significant improved financial return for the rotation with vetch ($425/year) or pastures ($409/year) as a break crop compared to brown manured option, which was comparable to the continuous wheat option with 75 N/ha fertiliser applied. When break crops were brown manured, the gross margin was the lowest ($259 vs $289/year) due to loss of income in the 1st year. The gross margin was intermediate when pulses were harvested for grains ($360-$376/year). The profit/cost ratio was similar for all options (~2:1) except for the sequence with canola as a break crop where the ratio was 2.4 (Table 3). Results indicated that the additional yield benefits derived from the brown matured treatments could not offset the cost of establishment and loss of income. Nevertheless, the brown manure option could offer opportunities to reduce subsequent herbicide costs if it assisted in the control of herbicide resistant weeds (Robertson *et al*. 2010).

Rotations with double break crops. In general, double break crop strategies improved gross margin for all crop end-uses; particularly for the brown manured treatments. The gross margin increased nearly $100/year when canola was used as a break crop in combination with brown manured HDL pastures and field pea compared to rotations with a single break crop (Table 3). Cutting pasture for hay with one canola crop as a double break had the highest gross margin ($465/year), which was similar to continuous cereals with N fertiliser input. Double break crops also offer more opportunities to reduce disease incidence and to control difficult weeds (Lemerle *et al*. 1996).

Table 3 Gross margin analysis under different crop rotation sequence at the Graham Centre site

Crop Management	Treatment	Income	Variable cost	Gross margin	Profit/cost ratio
		Single break			
BManure	Pea	$585	$296	$289	2.0
	Vetch	$553	$295	$259	1.9
	Pasture	$562	$287	$275	2.0
Hay	Vetch	$825	$400	$425	2.1
	Pasture	$811	$402	$409	2.0
Grain	Pea	$714	$354	$360	2.0
	Lupin	$716	$339	$376	2.1
	Canola	$859	$359	$500	2.4
		Double break			
BManure	Pasture	$674	$311	$363	2.2
BManure	Pea	$674	$317	$357	2.1
Hay	Pasture	$863	$398	$465	2.2
Grain	Lupin	$780	$351	$430	2.2
Grain	Pea	$772	$361	$411	2.1
		Continuous cereals			
Grain	+N	$878	$412	$467	2.1
Grain	-N	$663	$333	$330	2.0

Conclusions

The apparent N benefits obtained from legume break crops were comparable to applications of 75 kg N/ha of N fertiliser. The wheat yield benefits derived from brown manured treatments were greater than the same legume treatments harvested for grain or cut for hay. This, however, did not translate to an improved economic benefit over grain harvest or hay cut treatments as the wheat yield increase for brown manuring was insufficient to offset the total loss of income in year 1. The brown manured option could, however, offer opportunities to reduce future herbicide control costs if the paddock contained herbicide resistant weeds. Therefore, the potential benefits from break crops should be fully evaluated by considering opportunistic costs of management of weeds and diseases in addition to any benefits obtained of improved N fertility.

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