Break crops can improve wheat production in the Mallee

Angela Clough[1] and Dave Monks[2]

[1] Victorian Department of Primary Industries, 402 Mair St, Ballarat, VIC, 3350. Email angela.clough@dpi.vic.gov.au
[2] Victorian Department of Primary Industries, Corner Eleventh St & Koorlong Ave, Irymple, VIC, 3498.

Abstract
Agriculture in the Mallee is primarily based on intensive cereal production using no-till farming. The region has a diverse range of soils which potentially could benefit from site-specific management. The inclusion of break crops in rotations on some soil types was proposed by local farmers as a means of increasing wheat productivity. The effects of various break crops on the next wheat crop were assessed in field experiments at Ouyen on three soil types (dune, slope and swale) within a paddock previously sown to wheat. Break crop treatments were canola, lupin, wheaten hay and chemical fallow. Continuous wheat was also included as a control treatment to represent this common practice in the district. Soil water and soil mineral nitrogen were measured to 100cm depth immediately prior to the second year's sowing. In the second year, wheat was sown over all the first year's treatments with nitrogen fertiliser applied at growth stage 31 only to the continuous wheat grown on slope and swale soils. Crop growth was assessed non-destructively during the season using a crop reflectance device. Grain yields from treatments in the second year differed for each soil type. On dune soils, continuous wheat produced significantly less grain than wheat after any break crop treatment (P=0.002). On slope soils, wheat grain yields were not significantly different regardless of prior treatment (P=0.155). On swale soils, grain yields were highest in the continuous wheat and significantly higher than in wheat after wheaten hay or canola with low inputs (P=0.024). Grain yield, grain protein, the effects of nitrogen fertiliser management and profitability are discussed.

Key Words
Dryland cropping, crop rotation, cropping sequence, no-till cropping

Introduction
Cropping practices have changed dramatically in the Mallee over a long period and especially over the last fifteen years since the advent of no-till practices. Farmers have adopted cropping systems focused largely on more intensive cereal production, centred on wheat with no-tillage and site-specific management (D'Emden et al. 2008). Site-specific management in the Mallee tends to be based on zoning paddocks by soil type and topography rather than yield mapping (Robertson et al. 2012). Farmer awareness of the variability of their soils within single paddocks provides an opportunity to improve wheat productivity by emphasising the diversity of their soils and aiming to reach the potential of each soil type. Mallee farmers recognised that wheat productivity might be improved by including a break crop option in their cereal rotations on some of their soil types. In general, break crops, including fallow, are known to lead to higher grain yields in following wheat crops (Kirkegaard et al. 2008). The aims of this field research were to assess whether wheat yields were affected on the major soil types in the Mallee after a series of break crop treatments and to assess if N fertiliser might have a similar effect to any of the break crops. A participatory action approach was taken with crop and site selection chosen by farmers from the Mallee and break crops managed with low and high inputs of seed and fertiliser. This paper reports on the effect of a single year of break crop on the following year's wheat crop on three soil types.

Methods
The field site was located in a cereal paddock at Ouyen on dune, slope and swale soil types (lat. 35.056 S, long. 142.331 E). Average long-term annual rainfall at Ouyen is 334mm and average long-term growing season rainfall (GSR April - October) is 214mm. Initial soil characteristics in the 0-10cm layer across all soil types were organic carbon 0.4 – 0.58%, pH(H_2O) 7.7 – 7.9 and phosphorus (Colwell P) 21 – 44 mg/kg. Soil water (0-100cm) prior to sowing was 134, 156 and 171 mm whilst mineral N (0-100cm) was 50, 76 and 103 kg/ha on the dune, slope and swale soils respectively.

The experiment was conducted on the same plots for two years. The trial on each soil type had the following treatments in the first year (2010): continuous wheat (cv. Yitpi) for grain and wheat for hay sown at 60kg/ha, lupin (cv. Mandelup) sown at low and high seeding rates (50 and 100kg/ha), canola (cv. Pioneer 43C80) sown at low and high seeding rates (1 and 3kg/ha), and chemical fallow. Canola, lupin, wheaten hay and chemical fallow are considered break crops within this paper. In 2011, all treatments were sown to wheat (cv. Yitpi) at a target density of 75 plants/m^2. All treatments were replicated three times (4.8m x 10m plots) within each soil type in a randomised complete block design. All sowings were completed by 5 May 2010 in the first year and by 28 April 2011 in the second year. There was no livestock on the site during or between seasons.

In 2011, N fertiliser management of the continuous wheat was based on starting soil N and were fertilised to estimated yield potential according to accepted district practice (whilst higher N rates may have been theoretically plausible, they are not commonly practised due to the high risk associated in this low rainfall environment). Wheat following break crops were not fertilised with N after sowing (Table 1). Nitrogen fertiliser applied to the continuous wheat treatments enabled the evaluation of whether the effects of break crops on following wheat could be matched by applying N fertiliser to continuous wheat, or if there was another yield-limiting factor that was managed through the use of a break crop (e.g. disease or water availability).

In both years prior to sowing, soil was sampled to a depth of 100cm to measure soil water and soil nitrogen. A *Greenseeker®* canopy reflectance meter was used in September 2011 to assess wheat growth non-destructively as Normalized Difference Vegetation Index (NDVI). Harvest occurred in November in both years with a grain sample retained from each plot for grain protein analysis.

Table 1. Management of nitrogen fertiliser on different soil types applied to wheat at sowing and in-season (GS31) during 2010 and 2011 at Ouyen, north-western Victoria. No nitrogen was applied after sowing in 2010.

Treatment in 2010	MAP kg/ha at sowing 2010*	Treatment in 2010	MAP kg/ha at sowing 2011*	Urea (kg/ha) at GS31 in 2011		
				Dune	Slope	Swale
Chemical fallow	0	Wheat after a break crop in 2010	50	0	0	0
Canola - low input	25					
Canola - high input	50					
Lupin - low input	25					
Lupin - high input	50					
Wheaten hay	50					
Continuous wheat	50	Continuous wheat	50	0	87	76

* MAP is the fertiliser mono-ammonium phosphate

Results

Residual effects from the first year

Annual rainfall at Ouyen was above average during this experiment (558mm in 2010 and 487mm in 2011). The growing season rainfall was 272mm in 2010 and 167mm in 2011. Rainfall was very high during the summer between seasons (381mm). Prior to sowing in 2011, soil water (0-100cm) was 128mm on the dune, 183mm on the slope and 238mm on the swale and soil mineral N (0-100cm) was 77kg/ha on the dune, 54kg/ha on the slope and 147kg/ha on the swale. There was no significant difference in soil water or mineral N between any treatments within any soil type prior to sowing in 2011. The break crops yielded between 0.5 and 1.5 t/ha.

Wheat in the second year

All wheat crops had visual symptoms of yellow leaf spot (*Pyrenophora tritici-repentis*) early in the season. The disease appeared to be uniform across each experiment. There was no difference in crop reflectance for any of the wheat treatments in September, including continuous wheat, on the dune or slope soils (data not shown). Continuous wheat grown on the swale soils produced significantly higher NDVI values than any other wheat treatment. The greener canopy of the continuous wheat on the swale soils is likely due to the additional 76 kg N/ha applied to that treatment at GS31.

In 2011, grain yield ranged from 864 to 2245 kg/ha (Table 2). On dune soils, wheat after any break crop produced significantly more grain than continuous wheat (P=0.002). Grain yields on slope soils were not significantly different regardless of prior treatment (P=0.16). On swale soils, grain yields for continuous wheat were significantly higher than wheat after wheaten hay or canola with low inputs (P=0.02). Protein levels (< 10.5%) were below the minimum for premium white wheat (APW) classification in all treatments on all soil types (Table 2). All treatments in each experiment met the receival standard for wheat test weight (≥ 74 kg/hl) with no significant difference between treatments; averages ranged from 80 to 82 kg/hl.

Table 2. Grain yields (kg/ha) and protein content for wheat grown at Ouyen in 2011. Treatments can only be compared within the same soil type. Treatments within the same soil type and with the same letters are not significantly different.

		Soil type									
Treatment in 2010	**Treatment in 2011**	**Dune**		**Slope** (kg grain/ha)	**Swale**		**Dune**	**Slope** (% protein)		**Swale**	
Chemical fallow	Wheat	1688	c	1747	2161	c	7.6	7.1	a	7.7	a
Canola – low input	Wheat	*	*	1567	1749	a	*	7.4	ab	8.0	ab
Canola – high input	Wheat	1536	bc	1500	2080	abc	7.1	7.2	a	7.7	a
Lupin – low input	Wheat	1511	bc	2103	2169	c	7.7	7.6	ab	8.4	bc
Lupin – high input	Wheat	1648	bc	2142	2245	bc	7.9	7.9	b	8.7	c
Wheaten hay	Wheat	1329	b	1634	1834	ab	7.7	7.4	ab	8.5	bc
Continuous wheat	Continuous wheat	864	a	1856	2235	c	7.7	9.1	c	8.2	abc
		P=0.002		P=0.16	P=0.02		P=0.56	P<0.001		P=0.01	

* Data excluded due to poor crop emergence in 2010.

Profitability

Farmers indicated that a sequence was considered sufficiently profitable if it was at least 20% higher than the profitability of the continuous wheat and unacceptable if at least 20% lower (Table 3). Cumulative profitability over the two seasons was based on costs of inputs, grain selling prices and grain yields achieved in the experiments. Costs of insecticides and herbicides were excluded as use of chemicals varies widely between businesses.

Table 3. Cumulative profitability for seven treatments at Ouyen in 2010 and 2011. Treatments were only compared within the same soil type. Treatments marked with grey were at least 20% higher, black were at least 20% lower and all other treatments were within 20% of the profitability of continuous wheat.

		Soil type		
Treatment in 2010	**Treatment in 2011**	**Dune**	**Slope** ($ return/ha)	**Swale**
Chemical fallow	Wheat	178	189	268
Canola – low input	Wheat	*	388	491
Canola – high input	Wheat	430	521	547
Lupin – low input	Wheat	395	565	411
Lupin – high input	Wheat	330	414	350
Wheaten hay	Wheat	602	672	720
Continuous wheat	Continuous wheat	209	428	624

Note: Input costs were seed, seed dressing, fertiliser, inoculant, end-point royalties, harvest and haymaking (i.e. mowing, raking, baling). Cost of seed was sourced from a retailer in the Mallee. Other costs and grain selling price (five year average) for lupin and canola were from Rural Solutions SA (2010). Wheaten hay was estimated at $100/t and wheat at ASW grade at $190/t. * Excluded from analysis due to poor crop emergence in 2010.

Discussion

Wheat production

Grain yields on the dune soils met the expectation that wheat would benefit from break crops by producing higher grain yields than continuous wheat (Table 2). However, the cause of the benefit of the break crops was not able to be identified from these experiments. Higher grain yields were not due to higher residual soil water as there was no difference between treatments prior to sowing. The lack of difference in residual soil mineral N may be related to the high summer rains received. High

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summer rains may have resulted in elevated levels of N mineralisation that could have masked other N inputs. A possible reason for wheat after break crops yielding more than continuous wheat may be that the summer rains could have flushed soil mineral N below the 100cm sampling depth but the mineral N may nevertheless have been accessible to the crop late in the year. This explanation is supported by results for crop reflectance measured in September 2011, which showed no differences between treatments at that time. Yellow leaf spot, root rot (*Rhizoctonia solani*) and root lesion nematodes (*Pratylenchus* spp.) were known to occur on the dune soils. The break crops may have reduced the pressure from these diseases in the following wheat despite there being no visual differences in the presence of disease between treatments during the season. Leaf and root diseases do not need to display visible symptoms for yield losses to occur (Cooke, 2006).

As with the dune soils just discussed, break crops on slope and swale soils provided no benefit to the next crop through higher residual soil mineral N or residual soil water as measured prior to sowing in 2011. However, as on dune soils, there was a benefit to the following wheat crop from the break crops. These benefits were shown by the grain yield on the slope soils and grain protein on swale soils being equal to the results achieved in the continuous wheat with additional N applied at GS31 (Table 2). Thus, there was a benefit to the following wheat crop of including most break crop treatments however applying N fertiliser during the season had a similar effect on wheat yield. Further, in terms of grain protein, applying N to wheat on slope soils at GS31 benefited the wheat more than including a break crop in the sequence.

Profitability

This analysis, showed that fallow prior to wheat was a consistently poor economic option on all soil types. Poor profitability with a winter fallow supported the trend away from fallowing in the Mallee and gives further incentive for growers to crop rather than fallow. The effects of the other break crop options differed between soil types. Growing break crops on dune or slope soils was generally a more profitable sequence than growing continuous wheat (Table 3). A notable exception was lupin with high inputs on slope soils as plants were yellowed, small and yields on that site were restricted by high soil pH limiting crop growth (White and Robson 1989). On swale soils, there was no economic advantage of including any of the break crops. However, including wheaten hay and canola with high inputs was equivalent to continuous wheat and therefore may have a place in cereal-based systems on the heavier soils. These experiments were conducted in a period of above average rainfall. Further crop sequences experiments in drier years would be beneficial.

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