A comparison of lucerne and chicory based intercrops and competition effects

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Abstract

Pasture-crop intercropping can be productive in the medium to high-rainfall zones of southern Australia although this practice often results in large yield reductions of either or both of the intercrop components. Here we describe competition effects of an intercrop sequence based around annual crops sown with established perennial pastures. The perennial species, lucerne and chicory, were established in a double skip row arrangement and maintained in a cropping sequence with wheat and lupin for three years (2006-08), and compared with annual crops grown either as monoculture or half monoculture arrangements. Lucerne in the intercrop had a consistent negative impact on productivity of both crops, reducing both dry matter (DM) and grain yields. Wheat grain yields were reduced by 32 to 44%, depending on the season. Chicory had a lesser impact on the overall crop performance with wheat yield reductions between 0 and 41%. Yield and quality traits measured post anthesis, showed that the number of grains, protein and grain weight were largely unaffected by intercropping, and in some cases were better than that of the monoculture treatments. Leaf area index (LAI) data collected in 2007 did not show significant differences that would account for the observed yield reductions. Soil moisture showed stronger competition for water by lucerne than chicory when grown in intercrop, which explained much of the affect intercropping had on reducing yields. The likely cause of the yield reductions seen in this study was a combination of the effect of spatial design and competition for water.

Introduction

Crop and pastures grown together (intercropping) provides an opportunity to address some environmental issues arising from the reliance on annual-based systems, such as waterlogging, rising watertables and salinity (Humphries *et al.* 2004). Intercropping can have component species grown together either with distinct row arrangements or, as often occurs with perennials, cereals are over-sown into existing stands. To date the mix of lucerne with cereals has been the focus of the recent intercrop work reported in Australia (Egan & Ransom 1996; Harris et al. 2008; Humphries et al. 2004). Many studies have shown intercropping can be a more productive practice compared with growing the components as monocultures, but intercropping, can cause competition for resources, resulting in a reduction in both crop and pasture yield (Harris et al. 2008; Humphries et al. 2004). Light is a potential source of competition in intercropping that could reduce early growth, leading to grain yield reductions (Egan & Ransom 1996; Harris *et al.* 2008). Soil moisture is also a potential source of competition, a water deficiency in October was reported to have reduced crop biomass resulting in grain yield reductions (Humphries et al. 2004). This study aims to identify the impact and timing of such competition between annual grain crops and perennial pasture components lucerne, (*Medicago sativa*) and chicory (*Cichorium intybus*) as the intercrop.

Materials and Methods

The experiment was undertaken in 2006-08 at Benayeo Victoria (lat. 36?50' long. 141?30'), 12km east of the South Australia -Victoria border. The soil type at the site was a duplex soil, sandy loam over clay, with depth of about 30cm from the surface to the clay layer. The long-term rainfall is 500mm, and annual rainfall in 2007 was 473.5mm (308mm April – October) and rainfall in 2008 was 433.5mm (331mm April – October). The experiment was a randomized block design with 4 replicates, with crop-pasture sequences started in 2006 with 6 intercrops (wheat-lucerne, lupin-lucerne, canola-lucerne, wheat-chicory, lupin-chicory, canola-chicory) and 5 monoculture crops of each of the component species (canola data is not reported in this paper). Half monoculture treatments were also sown on the same row arrangement as the intercrop treatments. The configuration of the intercrop was a double skip-row, with seeding rate maintained per row irrespective of intercrop, monoculture or half monoculture treatment. Grain and yield components were measured in December; 10 days after the pasture species were desiccated with diquat at 2L/ha. DM was measured at cereal first node (GS31), anthesis (GS65) and maturity (GS95) for all crops. LAI was measured during the growing season using a Licor. Soil moisture was monitored throughout the growing season using time domain reflectometry (TDR) to 35cm.

Results and Discussion

Grain yield

The monoculture wheat and lupin treatments generally produced higher grain yields (P<0.05) than the intercrop and the half monoculture treatments (Table 1). Yield differences between monoculture and half monoculture treatments indicate there was an effect of spatial design or seeding rate on the intercrop grain yield. However, the results from a seeding rate experiment in 2006 (results not shown) indicated the effect was likely from spatial design rather than seeding rate for wheat. Comparison of the yields of the half monoculture and intercrop treatments determines the effect of competition. The lower yields (P<0.05) of the lucerne intercrops and not of the chicory intercrops shows that lucerne is more competitive with the grain crop for resources during the growing season, and this is negatively impacting on crop grain yield.

Table 1. Wheat and lupin grain yields (t/ha) and the percent reduction of the monoculture (mono) treatment in 2007-08

Treatment	2007	%	2008	%	Treatment	2007	%	2008	%
Mono Wheat	3.33 *a*		4.28 *a*		Mono Lupins	1.97 *a*		2.05 *a*	
Wheat-Lucerne	1.87 *b*	44	2.93 *b*	32	Lupins Lucerne	0.52 c	74	0.57 *c*	72
Wheat-Chicory	1.95 *b*	41	4.39 *a*	0	Lupins Chicory	1.02 *b*	48	1.12 *b*	45
Half Mono Wheat	2.19 *b*	34	4.31 *a*	0	Half Mono Lupins	1.75 *b*	11	1.42 *b*	31
l.s.d (P<0.05)	0.705	?	0.944	?	l.s.d (P<0.05)	0.321	?	0.534	?

Note: Means within each treatment column followed by a different letter are significantly different (P<0.05).

Dry matter

The DM was higher (P<0.05) for wheat and lupin monoculture treatments compared with the intercrop treatments in 2007 (Table 2). In the more favourable season of 2008, competition affecting DM production occurred later in the growing season than 2007. Differences in the DM production of the half monoculture and intercrop treatments were only significant when lucerne was the intercrop. This supports the conclusions from the grain yield results that lucerne is more competitive than chicory.

Table 2. Dry matter (kg/ha) production of wheat and lupins prior to maturity

Treatment?	First Node (GS31)	Anthesis (GS65)	First Node (GS31)	Anthesis (GS65)

	2/09/2007	25/10/2007	10/09/2008	6/11/2008
Monoculture Wheat	3980 *a*	12509 *a*	5680 *bc*	13769 *a*
Wheat Lucerne	1730 *b*	9944 *b*	4444 *c*	7771 *b*
Wheat Chicory	1870 *b*	10635 *ab*	6446 *ab*	12626 *a*
Half Monoculture Wheat	1900 *b*	10322 *b*	7063 *a*	11574 *a*
l.s.d (P<0.05)	516.9	2055.2	1338.3	3367.0
Monoculture Lupins	933 *a*	8165 *a*	1155	8330 *a*
Lupins Lucerne	245 *b*	1887 *c*	955	3934 *b*
Lupins Chicory	369 *b*	4306 *b*	824	6416 *ab*
Half Monoculture Lupins	414 *b*	4462 *b*	998	8548 *a*
l.s.d (P<0.05)	367.9	2383.6	n.s.	4204.9

Note: Means within each treatment column followed by a different letter are significantly different (P<0.05).

Grain Traits

Intercropping either had no effect or in some cases improved the grain quality (Table 3). Protein was lower in 2008 for the intercrops; this could be a result of competition for N or water during this post anthesis period. Overall, the results showed competition that impacted on intercrop crop performance occurred prior to wheat anthesis and grain filling, as post anthesis competition did not negatively affects grain traits including grains per head, protein, grain weight (TGW) and grain size.

Table 3. Wheat screenings, TGW, grain protein and grains per head in 2007 and 2008

?	Screenings (%)		TGW		Grain Protein (%)		Grains per head	
Treatment	2007	2008	2007	2008	2007	2008	2007	2008
Monoculture Wheat	2.6	4.2 *a*	38.1 *b*	29.4 *b*	14.38	14.88 *a*	27.8	25.5
Wheat Lucerne	3.4	2.0 *c*	41.1 *a*	35.9 *a*	17.41	10.27 *c*	39.3	33.9

Wheat Chicory	3.2	2.2 *c*	41.5 *a*	34.5 *a*	13.80	12.97 *b*	43.1	31.4
Half Monoculture Wheat	3.2	3.2 b	39.8 *ab*	31.8 *b*	14.74	15.38 *a*	39.9	33.6
l.s.d (P<0.05)	n.s.	0.67	2.66	2.33	n.s.	0.974	n.s.	n.s.

Note: Means within each treatment column followed by a different letter are significantly different (P<0.05).

Light

LAI in July was low for all treatments and generally there were no significant differences (Table 4). The wheat-lucerne intercrop and both lupin intercrops had higher LAI than the half monocultures in September; however they were not significantly different from the monoculture treatment (Table 4). Wheat plant height was reduced in the wheat-lucerne intercrop in September compared to the other treatments but was only lower than the half monoculture treatment in December (Table 4). The LAI, plant height and dry matter at first node, indicates there may have been some competition for light between intercropped wheat and lucerne in 2008. However, the overall results did not show strong trends for early light competition and dry matter reductions as indicated in previous studies that over-sowed into an existing pasture stand(Egan & Ransom 1996; Harris *et al*. 2008). The lack of competition for light observed in the present study could be due to the double skip row arrangement used which allowed greater access to this resource by both intercrop species.

Table 4. LAI measurements in 2007 and plant height measurements in 2008 for wheat and lupins

?		LAI		Plant height (cm)	
Treatment	12/07/2007	28/07/2007	19/09/2007	5/09/2008	11/12/2008
Monoculture Wheat	0.01	0.53	4.38 *a*	53 *a*	85 *b*
Half Monoculture Wheat	0.01	0.58	2.40 *b*	54 *a*	91 *a*
Wheat Lucerne	0.02	0.89	3.89 *a*	48 *b*	85 *b*
Wheat Chicory	0.02	0.75	2.84 *b*	55 *a*	86 *ab*
l.s.d (P<0.05)	n.s.	n.s.	0.892	2.3	5.2
Monoculture Lupins	0.01	0.89 *a*	3.74 *ab*	18	69 *a*
Half Monoculture Lupins	0.01	0.02 *b*	2.93 *b*	21	68 *a*
Lupins Lucerne	0.01	0.44 *ab*	4.07 *a*	22	65 *ab*

Lupins Chicory	0.02	0.59 *ab*	4.03 *a*	18	60 *b*
l.s.d (P<0.05)	n.s.	0.842	0.600	n.s.	6.6

Note: Means within each treatment column followed by a different letter are significantly different (P<0.05).

Water

Soil moisture under the wheat intercrops and the monoculture components indicated differences in soil water use between the pasture species (Figure 1). Monoculture chicory had higher soil moisture readings throughout the growing season, compared with the wheat-chicory intercrop. The monoculture lucerne and the wheat-lucerne intercrop had similar moisture readings (Figure 1). This suggests that there is likely to be stronger competition for water resources between the wheat and lucerne grown as an intercrop compared with wheat intercropped with chicory. Competition for the water resource was the likely source of competition affecting intercrop performance (Roberts Craig *et al.* 2010); it therefore appears to be the reason for the higher lucerne intercrop dry matter and grain yield reductions found in this trial.

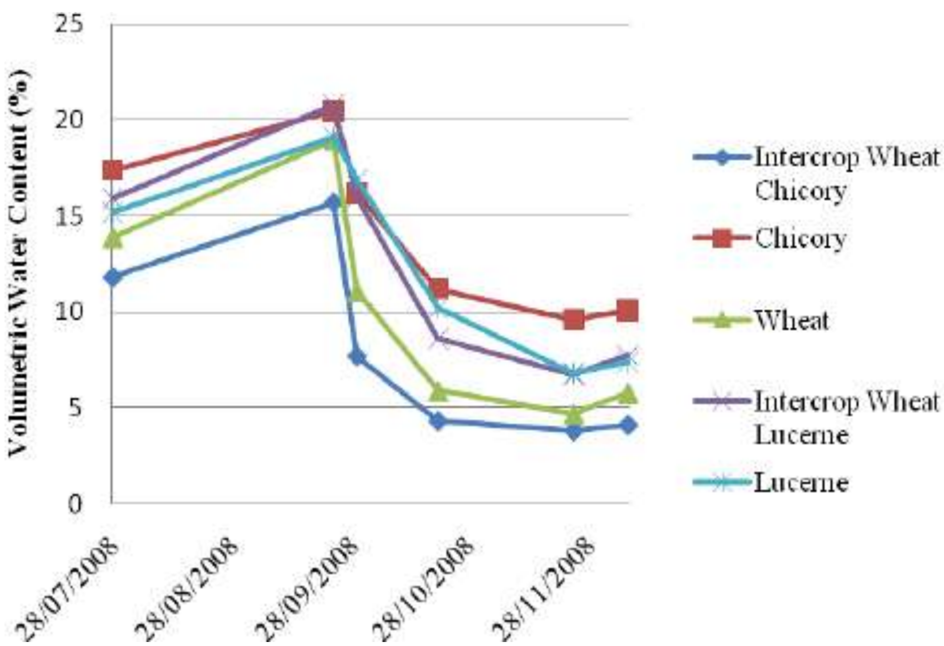

Figure 1. Volumetric Water Content (%) of wheat intercrops and monoculture, 2008, 35cm depth

Conclusions

Intercropping with both chicory and lucerne resulted in a yield reduction of the grain crop component. This yield reduction results from both an effect of changing spatial design and competition for resources between the intercrop components during the crop growing season. Timing of this competition varied between seasons, however in both years the greatest impact on the crop performance occurred prior to wheat anthesis and grain fill. Chicory and lucerne differed in their competitiveness with the associated grain crop with the lucerne providing greater competition than chicory. Intercrop competition for water was the likely cause for the reductions in grain yields.

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