Opportunities for grazing crop/pasture intercrops

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Abstract
The effect on grain and biomass yields of wheat as a monoculture, and as a crop-pasture intercrop when grazed by sheep prior to wheat growth stage 30 was investigated. In addition, pasture biomass yields of the intercrops were analysed. Land Equivalent Ratio (LER) and gross margins were used as indicators of productivity of the intercropping system. Grazing reduced wheat grain yield by 34% for the chicory intercrop, 40% for the lucerne intercrop and 32% for the wheat monoculture. The yield components affected by grazing for all treatments were the number of grains/head and spikelets/head. Additionally, thousand grain weight (TGW) and screenings were affected in the wheat-lucerne intercrop.
Productivity of the intercropping systems based on LER, generally increased due to the additional value of the dry matter removed at grazing, although there was a reduction in grain yield. Gross margin economics based on the yield reductions from this one-year grazing study showed that grazing of monoculture crops and intercrops gave lower gross margin return than the comparable un-grazed treatments.

Key Words
Intercropping, companion cropping, grazing, chicory, lucerne

Introduction
Crop/pasture intercropping systems may give increased productivity and more flexibility with integration of crop and livestock enterprises, although generally the practice results in yield reductions of both components than if grown as monocultures (Humphries *et al.*2007). Thus where reductions in grain yields occur, intercropping maybe more suited to farming focused on livestock. There may be an opportunity to graze the intercrop early in the season to increase dry matter utilisation and the value of intercropping in a livestock system. Grazing of cereal crops is a practice increasingly being adopted in southern Australia (Kelman & Dove 2009), as it provides an opportunity to fill the winter feed gap of the livestock enterprise on mixed farming properties, and whilst grazing has been shown in some cases to reduce grain yields, the economic benefits can be greater compared to un-grazed treatments (Kirkegaard *et al.* 2008). Land Equivalent Ratio (LER; Mead and Willey 1980) is often used as a measure of the productivity of intercropping, and this measure can give an indication of the resource use of the intercrops.
There are no published studies on the effects of grazing wheat where the wheat is grown in a crop-pasture intercrop, so this experiment was conducted to identify the impact of early sheep grazing, prior to wheat growth stage 30 (GS 30; Zadoks *et al.* 1974), of crop-pasture intercrops on grain and biomass yields, and to assess the effect of grazing on the overall productivity of the intercrop system.

Methods
The experiment was conducted at Benayeo Victoria (36°50'S, 141°30'E), 12km east of the South Australia - Victoria border. The soil type at the site is 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 2008 was 433.5mm (331mm April – October). The experiment was a randomized block design with 4 replicates. Crop treatments were wheat, lucerne and chicory monoculture, and wheat-lucerne and wheat-chicory intercrops, and these were either grazed prior to wheat GS30 or non-grazed. Crop-pasture sequences were established in 2007. The monoculture wheat and intercrop wheat were re-sown 25 May 2008. For the intercrop plots the tynes were removed over the pasture rows to prevent pasture damage. The configuration of the intercrop was a double skip-row, with seeding rate maintained per row irrespective of whether intercrop or sole treatment.
The grazing trial was conducted on 2nd year pasture stands. Ten sheep were randomly selected from a flock that had been previously exposed to the feed types in the experiment to prevent selective grazing due to lack of familiarity with a feed type. Plots were grazed in August 2008 at a stocking rate of 100 sheep/ha (100 DSE/ha). Sheep were placed in three small fields that ensured that each plot was split in two halves, one which was grazed the other which remained un-grazed. Herbage samples were taken at the start, mid and conclusion of grazing. The samples were sorted into species, then dried and weighed.
Wheat grain yield and yield components were measured in December at harvest; this occurred 10 days after the pasture species were desiccated with diquat.

The effect of grazing and cropping treatment and the interaction on grain yield, grain components, and DM production was analysed using analysis of variance (GenStat 11, release 11.1, VSN International Ltd, Hertfordshire, UK).
Land Equivalent Ratio (LER) was calculated in two ways. Firstly, the LER for growing season dry matter (DM) production was calculated using the DM production of both the crop and pasture when wheat reached anthesis. Secondly, the LER for annual total DM was calculated using DM of each of the crops when the wheat crop reached anthesis. The cumulative total of DM produced was used for the monoculture pastures, and the out of growing season dry matter in addition to the dry matter cut taken at crop maturity was used for the intercrops.
Gross margin expenses were calculated using actual farm benchmarking data. Pasture dry matter, and pasture quality at the time of grazing were used in GrazFeed (V4.2.1.) to simulate livestock weight gain, wool growth and pasture grazing days. Meat prices were adjusted to reflect seasonality in livestock prices (2008/09 over-the-hooks prices for 20-22kg carcase weight lambs). Wheat prices for 2008 were used to calculate grain income.

Results and Discussion

Grain yields
Grain yields for the grazed treatments were significantly lower ($P<0.05$) than un-grazed treatments (Table 1). There was no significant interaction between treatment and grazing for grain yield, and also grain yield components or grain quality (Table 1). Grazing of wheat intercrops and monoculture wheat resulted in grain yield reductions of between 32% and 40%. Previous cereal grazing studies have reported large variations in the effect of grazing on grain yields, with changes ranging from -27.9 to 29.4% (Virgona *et al.* 2006). The results from this present study are at the most severe range of grain yield reductions reported.

Grain yield components and grain quality
The large difference in yield between grazed and un-grazed treatments is likely due to a reduction in the number of grains/head, as a result of less spikelets/head (Table 1). This assertion is consistent with previous wheat-grazing studies which reported that the reduction in yield components was due to stress, particularly water, during critical phases of development. A reduction in yield components was associated with a delay in tiller development, resulting in grain fill of the grazed crop occurring during a period of greater moisture stress than in the un-grazed crop (Dann *et al.* 1983). These results indicate that additional stress in the current study is likely due to seasonal conditions, grazing conditions, and competition in the intercrops, which causes a reduction in the yield components (grains/head and spikelets/head).

Grain weight was reduced and screenings were higher in the grazed wheat-lucerne intercrop, compared with the monoculture wheat and wheat-chicory intercrop treatments (Table 1). This indicates there was greater competition for resources in the grazed wheat-lucerne intercrop, which continued late into the wheat growing season. Similarly, lower TGW was reported as the main cause of grain yield reductions in a study that simulated grazing through clipping (Dann 1968).

Table 1 Wheat grain yields (t/ha), grains per head, spikelets per head, TGW and screenings (%) for grazed and un-grazed monoculture and intercrop treatments

Treatment	Grain Yield (t/ha)	Grains/head	Spikelets/head	TGW(g)	Screenings (%)
Grazed					
Monoculture wheat	3.1	25	11	34.9	2.6
Wheat-lucerne	1.48	23	11	30.5	4.2
Wheat-chicory	1.76	20	10	38.7	1.4
Un-grazed					
Monoculture wheat	4.59	32	13	34.4	2.3
Wheat-lucerne	2.48	29	12	34.5	2.2
Wheat-chicory	2.65	24	11	39.3	1.1
l.s.d. ($P<0.05$) Treatment	0.542	3.4	0.9	3.23	0.87
l.s.d. ($P<0.05$) Grazing	0.442	2.7	0.8	2.63	0.71

Crop Dry Matter Production

There was no significant interaction between crop treatment and grazing in cumulative wheat dry matter production measured at wheat anthesis, which included dry matter removed by grazing (Table 2). Cumulative dry matter production was higher ($P<0.05$) in the monoculture wheat than the intercrops (Table 2). It is likely this reduction in dry matter, due to grazing, would mean less assimilates are available during the grain fill period, and consequently cause grain yields to be reduced. This assertion is supported by previous wheat grazing studies where reductions in dry matter production at anthesis, due to grazing, gave subsequent reductions in grain yield, highlighting the importance of pre-ear emergence photosynthesis and relocation of assimilates (Dann *et al.* 1983).

Pasture Dry Matter Production

There was no significant interaction between treatment and grazing for annual total production. There was no significant difference of grazing or treatment on annual dry matter production (Table 2).

Table 2 Wheat cumulative dry matter production (kg/ha) measured at anthesis and includes that removed at grazing and annual pasture production (kg/ha)

	Wheat DM (kg/ha)		Pasture DM (kg/ha)	
Treatment	Grazed	Un-grazed	Grazed	Un-grazed
Monoculture wheat	11199	12848		
Wheat-lucerne	5242	7623	6524	7336
Wheat-chicory	6654	5299	7698	6535
Monoculture lucerne			8347	
Monoculture chicory			8688	
l.s.d. ($P<0.05$) Treatment	1729.9		n.s.	
l.s.d. ($P<0.05$) Grazing	1412.5		n.s.	

Land Equivalent Ratio (LER)

While grazing had a significant impact on the performance of the grain component of the intercrop, overall the productivity of the intercropping system was not compromised by grazing. Wheat-lucerne and wheat-chicory intercrops over-yielded (LER >1) under both grazing treatments (Table 3).

Table 3 Growing season and annual total LERs, based on DM production, for grazed and un-grazed treatments

Treatment	LER Growing Season	LER Annual Total
Grazed		
Wheat-lucerne	0.97	1.25
Wheat-chicory	1.26	1.48
Un-grazed		
Wheat-lucerne	1.42	1.47
Wheat-chicory	1.33	1.16

Gross Margins

Grazed monoculture crop and intercrops had lower gross margins per hectare compared to un-grazed treatments (Figure 1). Of the grazed treatments, the wheat-chicory intercrop had the highest return. The un-grazed wheat-chicory intercrop had a gross margin comparable to monoculture wheat and lucerne, and was higher than both monoculture chicory and the wheat-lucerne intercrop.

In contrast to results from previous studies that have shown grazing of cereal crops improves the economic return of spring grown crops (Kelman & Dove 2007), this one-year study showed that grazing of monoculture crops and intercrops resulted in a lower gross margin than the comparable un-grazed treatments. This was due to lower than expected crop dry matter at the time of crop grazing, which, in part, be attributed to a heavy annual ryegrass (*Lolium rigidum*) infestation at this site, in this one season.

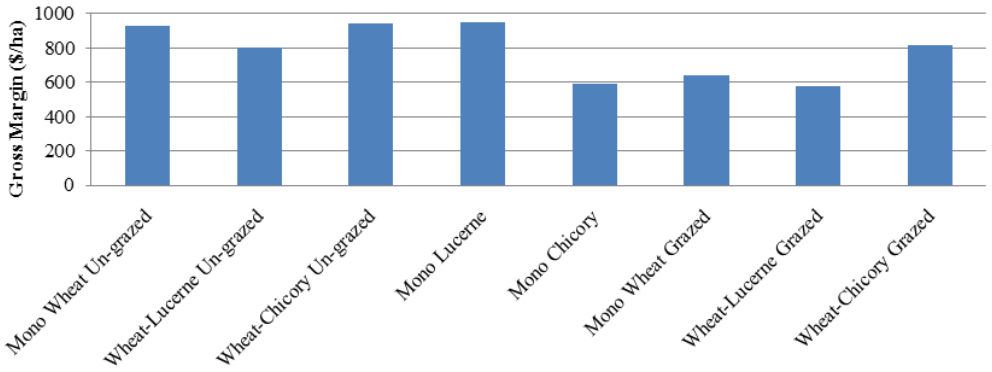

Figure 1 Gross margins ($/ha) for Site 2 in 2008, grazed and un-grazed treatments

Conclusion

This study showed that grazing of intercrops impacts negatively on wheat grain yield. The yield components affected by grazing for all crop treatments were the number of grains/head and spikelets/head. Additionally, TGW and screenings were affected in the wheat-lucerne intercrop.

Overall, LER results show that, despite the yield reductions from grazing, the grazed intercrop systems over-yielded. However, in this season, grazing of monoculture crops and intercrops resulted in a lower gross margin than the comparable un-grazed treatments.

Previous studies of cereal crop grazing have shown that, given appropriate timing and duration of grazing, yield penalties can be avoided. There is no other information available on the effect grazing has on the grain yields of wheat-pasture intercrops, so it is unknown if the result from this study is an accurate reflection of the impact of grazing. As such, further investigation is required in this area before conclusions can be drawn regarding the practice of early season grazing of intercrops.

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