A comparison of land equivalent ratios and water use in lucerne and chicory based intercrops

Penny Roberts Craig[1], David Coventry[1] and Janelle Hocking Edwards[2]

[1] University of Adelaide, School of Agriculture, Food and Wine, South Australia
Email penny_roberts@bigpond.com
[2] SARDI Livestock and Farming Systems, Struan Research Centre, Naracoorte South Australia

Abstract

Intercropping often causes a reduction in yields of the component species; however the system can still be more productive than growing the individual components as monocultures, as the system is able to utilize more of the resources available. Lucerne and chicory when sown with wheat, lupins and canola produced crop dry matter (DM) and grain plus pasture DM with Land Equivalent Ratio (LER) values of greater than 1, in the favourable growing season of 2008. Chicory intercrops were often more productive than the lucerne intercrops in the drier seasons of 2006 and 2007. Wheat intercrops produced growing season and annual total DM LERs of greater than 1 in all three seasons (1.05 - 1.34), indicating greater resource use both within the crop growing season and the extended perennial pasture growing season. Time Domain Reflectometry measurements taken throughout the growing seasons of 2008 showed differences in the soil moisture profiles of the different species used in this trial, indicating differences in water capture and usage. Although the rainfall was below average in the three seasons of this experiment, the results showed the intercropping was able to increase water utilization efficiency, an important attribute in a region that is susceptible to waterlogging, rising water tables and dryland salinity.

Introduction

The medium to high rainfall zone of southern Australia has seen an increasing trend towards the inclusion of annual cropping into the traditional grazing system largely based on perennial pasture species. This farm practice change has the potential to lead to problems associated with lower water use of the annual-based systems including waterlogging, rising water tables and salinity (Humphries *et al.* 2004). Intercropping that incorporates perennials pastures into cropping systems may address some of these issues through increased resource use. Oversowing existing lucerne stands with cereals can be more productive than growing the components as monoculture stands (Humphries *et al.* 2004; Harris *et al.* 2008). Land Equivalent Ratio (LER) 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. This paper reports the LER and water use of pasture-crop intercrop combinations in a medium to high rainfall zone in southern Australia.

Materials and Methods

The experiment was undertaken during 2007 and 2008 at Benayeo Victoria (Lat. 36?50' Long. 141?30'). The soil type of the site was a duplex soil consisting of a sandy loam over clay, with a depth of about 30cm from soil surface to the clay layer. The experiment was a randomized block design with 4 replicates, with crop-pasture sequences started in 2006. The treatments established were 6 intercrops; wheat-lucerne, lupin-lucerne, canola-lucerne, wheat-chicory, lupin-chicory, canola-chicory; and 5 monoculture crops of each of the component species. The configuration of the intercrop was a double skip row.

Grain crops were harvested in December and DM harvests of the crops and pastures were taken during the growing season as well as 3 times post-harvest and the final measurements were taken 8-9days prior to the sowing in the following year.

Grain and forage yields were used to calculate LER following the method of Mead and Willey (1980). LERs were calculated in three ways. Firstly, the LER for growing season 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. Thirdly, the LER for economic traits of grain yield and pasture available for livestock grazing was calculated using crop grain yield and the annual total DM produced for the monoculture pasture treatments, and for the intercrops the amount of out of growing season DM as well as that available at crop maturity. Soil moisture within the growing season in 2008 was measured using Time Domain Reflectometry (TDR) to 35cm depth. Two reading were taken in the monocultures treatments, in-row and inter-row. Five reading were taken in the intercrops treatments two in the crop zone (in-row and inter-row), two in the pasture zone (in-row and inter-row), and one in the inter-row of the crop and pasture.

Results and Discussion

Land Equivalent Ratios

LERs greater than 1 were achieved for all productivity measures in all treatments in the more favourable season of 2008, with the exception of the canola-lucerne treatment (Table 1). Wheat-lucerne intercrops were able to utilize more resources to produce greater DM than the respective monocultures in all years, both within the growing season and on an annual basis. However, wheat-lucerne intercrops only achieved economic LERs greater than 1 in 2008 (Table 1).

There were differences in the DM LER values depending on the crop component of the intercrop. Wheat intercrops generally had LERs greater than 1 irrespective of season. In contrast, lupins only produced LERs greater than 1 in the more favourable season of 2008. LER also differed depending on the pasture component of the intercrop. For example, LERs for canola-chicory intercrops were always greater than 1, however the canola-lucerne intercrops only achieved LERs greater than 1 on an annual DM basis in 2008. Overall the chicory intercrops were more likely to produce DM and economic LERs greater than 1 than lucerne intercrop, even under less favorable growing seasons, such as 2007 (Table 1). The resources used within the growing season may have affected the amount of resources available to the intercrop pasture component in the out-of-growing season period. The difference between resource use of lucerne and chicory is likely to be a reflection of the difference in season growth of the two species. Lucerne competition within the growing season was higher compared to chicory (Roberts Craig et al, 2010), and the likely reason for the differences seen in LERs. This may also be why lucerne intercrops more often produced LERs less than 1 than the chicory intercrops (Table 1). This conclusion is supported where prolonged competition between two grain crop intercrop species resulted in LERs less than 1, indicating an inefficient system (Cendekdee and Fukai 1992).

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Table 1 Crop grain, crop and pasture dry matter yields expressed as Growing Season, Annual and Economic LER

	LER Growing Season			LER Annual			LER Economic Basis		
Treatment	2006	2007	2008	2006	2007	2008	2006	2007	2008
Wheat Lucerne	1.11	1.05	1.09	1.05	1.12	1.22	0.80	0.89	1.32
Wheat Chicory	0.90	1.27	1.19	0.90	1.34	1.34	0.94	0.99	1.58
Lupins Lucerne	0.94	0.64	1.53	0.99	0.71	1.66	0.40	0.88	1.56

Lupins Chicory	0.92	0.96	1.18	0.96	1.01	1.25	0.34	1.05	1.32
Canola Lucerne		0.92	0.95		0.99	1.01		0.95	1.28
Canola Chicory		1.06	1.09		1.08	1.27		1.03	1.18

Resource competition

There were differences in water use between the lucerne and chicory when intercropped with wheat and lupins (Table 2). Whilst the differences are not always significant, the water use of the chicory monoculture tended to be lower than the water use of the wheat intercrops and their respective monocultures. Soil moisture under chicory was higher than that of the wheat-chicory intercrop (Table 2).There was no significant difference between the moisture readings under the monoculture lucerne and the wheat-lucerne intercrop (Table 2). This indicates increased competition for water between lucerne and wheat during the growing season leading to a reduction in the efficiency of the intercrop. The lower use of water by chicory during the growing season is likely to encourage a greater capture of water by the associated grain crop. This difference in water use between lucerne and chicory when grown in intercrop has enabled the chicory intercrops to more often produce LERs greater than 1 then lucerne intercrops. In addition to differences in resource use of the pasture components, there are differences in water use of the intercrops depending on the grain component of the intercrop.

Soil moisture under the monoculture lupin was significantly lower than both the monoculture pasture species; however there were no significant differences between the monoculture lupins and pasture species and the lupin intercrops (Table 2). Unlike the wheat intercrops which were able to access greater amounts of water during the growing season, the lupin intercrops do not appear to have this capacity. The lower soil moisture of the lupin intercrop is likely to have enabled greater access to this resource by the pasture component out of the growing season.

The soil moisture results support the conclusions from the LER results in that the difference in the use of water between the components affects the overall productivity of the intercrops.

Table 2. Volumetric water content (%) of wheat and lupin intercrops and monocultures in 2008 at 35cm depth

?	Date of Measurement					
Treatment and Site	28/07/2008	23/09/2008	29/09/2008	20/10/2008	24/11/2008	8/12/2008
Wheat Chicory						
Mono Interrow Wheat	14.33 *ab*	18.60	11.33 *abc*	6.23 *abc*	4.90 *b*	5.47 *ab*
Mono Inrow Wheat	13.40 *ab*	19.47	10.83 *abc*	5.60 *c*	4.47 *b*	6.17 *ab*
Mono Interrow Chicory	15.97 *ab*	19.27	15.80 *ab*	10.70 *ab*	8.80 *ab*	9.37 *ab*

Mono Inrow Chicory	18.87 *a*	21.70	16.70 *a*	11.67 *a*	10.33 *a*	10.87 *a*
Inter Interrow Wheat	11.60 *b*	15.63	7.37 *c*	4.20 *c*	3.33 *c*	3.73 *b*
Inter Inrow Wheat	11.97 *b*	16.20	7.63 *c*	4.53 *c*	4.03 *b*	4.60 *b*
Inter Interrow Wheat Chicory	11.53 *b*	15.53	7.90 *bc*	3.87 *c*	3.90 *b*	3.80 *b*
Inter Inrow Chicory	12.10 *b*	16.33	7.97 *bc*	4.37 *c*	3.90 *b*	4.33 *b*
Inter Interrow Chicory	11.73 *b*	15.00	7.70 *c*	4.63 *bc*	3.70 *b*	4.63 *b*
l.s.d (P<0.05)	6.702	n.s.	8.096	5.497	5.122	5.76
Wheat Lucerne						
Mono Interrow Wheat	14.33	18.60	11.33	6.23	4.90	5.47
Mono Inrow Wheat	13.40	19.47	10.83	5.60	4.47	6.17
Mono Interrow Lucerne	14.83	19.13	17.00	9.63	6.40	7.17
Mono Inrow Lucerne	15.53	19.17	16.73	10.87	7.20	7.60
Inter Interrow Wheat	17.00	21.43	16.47	10.00	7.83	8.83
Inter Inrow Wheat	16.20	20.97	17.70	8.47	7.03	8.63
Inter Interrow Wheat Lucerne	17.00	21.20	16.80	8.87	6.87	7.80
Inter Inrow Lucerne	15.67	20.70	15.43	8.10	6.20	7.60
Inter Interrow Lucerne	13.60	19.67	13.47	7.80	5.67	6.03
l.s.d (P<0.05)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lupins Chicory						

Mono Interrow Lupins	12.00 *b*	15.03 *b*	7.20 *bc*	3.40 *c*	4.53 *b*	6.10
Mono Inrow Lupins	11.97 *b*	15.40 *b*	5.90 *c*	4.90 *b*	4.67 *b*	5.90
Mono Interrow Chicory	15.97 *ab*	19.27 *ab*	15.80 *a*	10.70 *ab*	8.80 *ab*	9.37
Mono Inrow Chicory	18.87 *a*	21.70 *a*	16.70 *a*	11.67 *a*	10.33 *a*	10.87
Inter Interrow Lupins	15.93 *ab*	20.63 *ab*	15.03 *a*	8.97 *abc*	7.13 *ab*	7.53
Inter Inrow Lupins	15.80 *ab*	20.67 *ab*	15.40 *abc*	9.57 *ab*	8.67 *ab*	8.13
Inter Interrow Lupins Chicory	14.43 *ab*	19.20 *ab*	13.23 *abc*	9.80 *ab*	7.80 *ab*	8.27
Inter Inrow Chicory	17.83 *ab*	21.43 *ab*	14.67 *ab*	9.77 *ab*	8.77 *ab*	8.53
Inter Interrow Chicory	15.13 *ab*	22.23 *a*	11.73 *abc*	8.33 *abc*	7.40 *ab*	7.77
l.s.d (P<0.05)	6.096	6.112	7.707	6.102	5.437	n.s.
Lupins Lucerne						
Mono Interrow Lupins	12.00	15.03	7.20 *b*	3.40 *c*	4.53	6.1
Mono Inrow Lupins	11.97	15.40	5.90 *b*	4.90 *bc*	4.67	5.90
Mono Interrow Lucerne	14.83	19.13	17.00 *a*	9.63 *ab*	6.40	7.17
Mono Inrow Lucerne	15.53	19.17	16.73 *a*	10.87 *a*	7.20	7.60
Inter Interrow Lupins	11.10	13.83	7.70 *b*	4.50 *cb*	4.70	4.23
Inter Inrow Lupins	14.30	17.53	10.43 *ab*	6.50 *abc*	4.90	6.67
Inter Interrow Lupins Lucerne	14.10	17.40	10.67 *ab*	6.70 *abc*	5.37	5.70
Inter Inrow Lucerne	12.73	16.53	10.53 *ab*	5.93 *abc*	4.57	5.63

Inter Interrow Lucerne	12.83	17.00	10.43 *ab*	6.73 *abc*	4.37	5.73
l.s.d (P<0.05)	n.s.	n.s.	7.486	5.373	n.s.	n.s.

Note: Dark grey shading highlights high moisture, light grey, low moisture. Mono=Monoculture Inter=Intercrop. Means within each treatment column followed by a different letter are significantly different (P<0.05).

Conclusion

The LER values based on economic and productivity traits indicate that chicory intercrops are more productive (LERs greater than 1) than lucerne intercrops. This was due to the greater competition for water resources between the lucerne and the grain component of the intercrop during the growing season.

Furthermore, this study shows that even in seasons receiving average rainfall, intercropping lucerne and chicory with a range of crops is more productive than growing the component species as monocultures.

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References

Cendekdee U, Fukai S (1992) Cassava/legume intercroppping with contrasting cassava cultivars. 1. Competition between component crops under three intercropping conditions. *Field Crops Research* **29**, 113-133.

Harris RH, Crawford MC, Bellotti WD, Peoples MB, Norng S (2008) Companion crop performance in relation to annual biomass production, resource supply, and subsoil drying. *Australian Journal of Agricultural Research* **59**, 1-12.

Humphries AW, Latta RA, Auricht GC, Bellotti WD (2004) Over-cropping lucerne with wheat: effect of lucerne winter activity on total plant production and water use of the mixture, and wheat yield and quality. *Australian Journal of Agricultural Research*, 839-848.