Wheat yields after perennial pastures under drought conditions

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Abstract

Perennial pasture phases may increase the sustainability of cropping rotations through their role in increasing out of season water use, reducing leakage to the water table, and improving ground cover over the summer months. The dominant perennial pasture species used is lucerne (*Medicago sativa*). The perennial grasses phalaris (*Phalaris aquatica*) and cocksfoot (*Dactylis glomerata*) are broadly adapted, particularly to the more acidic soils of the grainbelt, but have been studied less extensively in cropping rotations.

The effects of lucerne, phalaris, cocksfoot and mixtures of these species, on growth and yield of following wheat crops was studied in the field at Junee Reefs in southern NSW (AAR 530 mm). During three dry seasons (2001-3) wheat yields after a phalaris + cocksfoot mix were not different to wheat yields after a 12 month chemical fallow (3 t/ha). Wheat after lucerne suffered a yield penalty consistent with observations of haying off associated with greater early biomass production, in response to greater N availability after the legume pasture. Grain protein trended higher following the legume pastures. Overall grain size was small ranging from 25 to 32 mg, but grain screenings were not high (average 4%).

In seasons of below average growing season rainfall, wheat after perennial grass did better than wheat after lucerne through a more conservative early growth with lower N accumulation. Yields were still better than 2.3 t/ha for crops after all perennial pastures including lucerne, demonstrating that it is possible to obtain reasonable yields following perennial pastures, even in drought conditions.

Key Words

Phase farming, rotation, phalaris, cocksfoot, lucerne, nitrogen

Introduction

Perennial pasture phases are widely recommended across southern Australia to increase environmental sustainability of cropping rotations. Summer active perennial pastures are able to use water out of season, and hence, increase water use compared to annual pastures by 50 mm or more per year (Ward *et al*. 2001). This may directly reduce drainage to ground water and create a buffer of dry soil, which prevents leakage for up to 4 years upon return to annual pastures or crops (eg. Ridley *et al*. 2001, Ward *et al*. 2006). This may ameliorate or delay the onset of salinity.

The main perennial pasture species grown is lucerne (*Medicago sativa*), which has been extensively studied in cropping rotations (eg. Ridley *et al*. 2001, Ward *et al*. 2001, Ward *et al*. 2006). The perennial grasses phalaris (*Phalaris aquatica*) and cocksfoot (*Dactylis glomerata*) are broadly adapted to the cropping regions of south eastern Australia (Oram and Hoen 1967). However, phalaris and cocksfoot do not dry the soil as quickly, nor to the same extent as lucerne (Sandral *et al.* 2006). Whereas lucerne is able to fix substantial amounts of N (eg. Peoples *et al*. 1998), perennial grass pastures have been shown to promote high rates of N mineralisation (Ellis *et al*. 2003). Perennial pastures also contribute to system sustainability through greater ground cover over summer months, preventing or reducing erosion, and through the provision of greater quantities of high quality feed for livestock, allowing greater rotation flexibility.

Methods

The interactions between perennial pasture species and following crops were studied using a phased rotational experiment in the field at Junee Reefs in SE NSW. The site was a lightly stony red loam soil (red kandosol). Characteristics of the top 0.1 m of soil were: pH 6.0 (H_20), pH 5.2 ($CaCl_2$) and EC 0.11 dS m^{-1}, total N 1.06 g kg^{-1} and Colwell extractable P 11 mg kg^{-1}.

The site had grown unfertilised subterranean clover (*Trifolium subterraneum*)/annual grass pasture for 6 years. Grasses were removed with paraquat at 0.1 kg ai./ha in August 1998, and lime applied at 2.5 t/ha in April 1999. Five perennial pastures: lucerne (*Medicago sativa*); phalaris (*Phalaris aquatica*); cocksfoot (*Dactylis glomerata*); a phalaris + cocksfoot mixture (ph/co) and lucerne + phalaris + cocksfoot mixture (triple), several annual crops and a chemical fallow were established in a four-replicate design in May 1999. All pastures retained a volunteer subterranean clover component.

The trial was designed to have an advancing frontier of crops over the previous perennial pastures, allowing a 'first year out' crop to be grown in each of 3 different seasons. A sub-plot of each pasture was removed with herbicides and cropped to *Triticum aestivum* cv.Diamondbird in 2001, 2002 and 2003. Crops were supplied with 25 kg P/ha as single superphosphate at sowing, but no N fertiliser. Weeds were controlled using herbicides at recommended rates.

Biomass of the wheat was measured via quadrat cuts at the end of tillering (approximately DC30 using the Zadoks decimal code), mid-anthesis (DC65) and harvest (DC93). Grain was harvested from whole plots using a Wintersteiger plot harvester. Nitrogen concentration of the vegetative plant material and grain was determined as total N using a combustion analyser (ANCA SL, Europa Scientific, Crewe, UK) or by NIR spectroscopy.

Statistical analyses

The data were analysed using linear mixed models using preceding treatments for the 3 previous years and adjacent treatments as fixed effects, and Year / Replicate / Plot as random effects. An auto-regressive model was fitted within plots to account for spatial effects. Data presented are estimated means from the fitted model, plus or minus the standard error of the difference (SED), for treatment effects over all 3 seasons combined. Individual seasons were analysed separately by taking a subset of the data based on ‘year’.

Results

Seasonal conditions

The local climate is warm temperate, with 530 mm long-term average annual rainfall (AAR), distributed approximately equally over the full 12 months and 330 mm average growing season rainfall (GSR) (Apr – Oct) (Table 1). Wetter than average conditions occurred in 1999, and 2000 was close to average rainfall, which was conducive to high yields and good pasture growth. There was below average rainfall in 2001, 2002 and 2003 with significant periods of water stress, particularly during spring, with resulting lower yield potential. In 2002 and 2003 there was almost no post-anthesis rainfall, with rain early in October followed by several weeks of hot, dry weather.

Table 1. Rainfall for the experimental site (source: BOM datadrill)

	Longterm	1999	2000	2001	2002	2003
Annual rainfall	530	720	520	410	368	363
Growing season rainfall	330	365	359	258	151	235

Wheat growth and N uptake

There was no significant difference in biomass production of wheat growing in the first season after perennial pastures (Figure 1a). Wheat after fallow was consistently the highest producing treatment. Plant N decreased after anthesis following pastures that contained lucerne (lucerne and triple mix) (Figure 1b). The large errors are due to the combination of three distinct seasons.

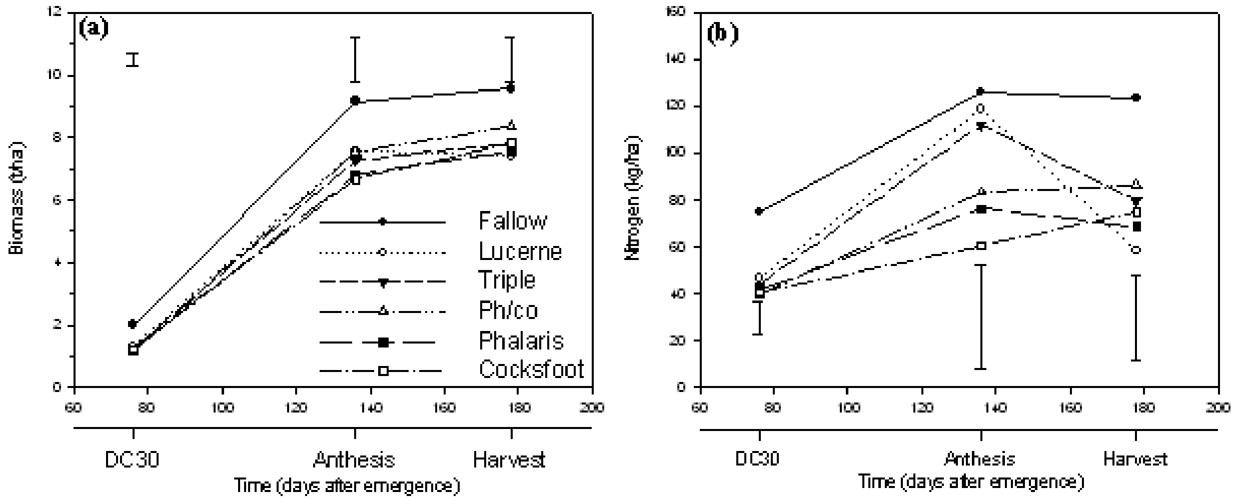

Figure 1. Wheat biomass and N accumulation over 3 seasons. (a) Above ground biomass (t/ha) (b) Amount of N in the above ground biomass (kg/ha). The bars represent plus or minus the SED.

The severity of the drought in 2002 (only 45 % of average GSR) led to restricted plant growth throughout the season, with a maximum 6.78 t/ha of biomass at anthesis, and 7.06 t/ha biomass at harvest. In contrast, 2001 and 2003 were both more moderate years early in the season allowing relatively high biomass and plant N accumulation by anthesis, before terminal drought occurred. In 2001 wheat following fallow had 9.94 t/ha DM at anthesis and lost biomass by harvest (7.85 t/ha DM). Plant N followed a similar pattern, declining from 150 kg N/ha at anthesis to 100 kg N/ha by harvest for wheat after fallow. Wheat after lucerne exhibited a similar response, whereas the wheat after the individual perennial grasses or perennial pasture mixtures lost neither biomass nor N. In 2003 there was no significant loss of biomass post-anthesis, but there was significant loss of plant N, particularly for wheat following pastures that contained lucerne, ie both lucerne alone and the triple mix.

Across the 3 seasons, wheat after fallow consistently had the highest N concentration throughout the season (Table 2). However, at DC30 this was only significantly higher than wheat after ph/co or cocksfoot alone. There were no significant differences in stem number at anthesis. Shoot N concentration of wheat after fallow at anthesis did not differ from wheat after lucerne or triple perennial pastures but was higher than after the perennial grasses. This result may reflect enhanced N nutrition of crops following the leguminous pastures and fallow. At maturity, the wheat after lucerne had low N concentration in the straw but high N concentration in the grain. This treatment lost large amounts of N overall.

Table 2. Tiller number and shoot N concentration of wheat growing in the first season after pasture removal, combined analysis for three seasons. Significantly different treatments denoted by different letters.

Anthesis	Nitrogen concentration (%)

	Stems/m^2		DC30		Anthesis		Straw		Grain	
Fallow	426		4.06	a	1.54	a	0.62	a	2.82	a
Lucerne	399		3.63	ab	1.36	ab	0.30	b	2.01	b
Triple	398		3.59	ab	1.31	ab	0.44	ab	1.99	b
Ph/co	407		3.50	b	1.03	bc	0.54	ab	1.67	b
Phalaris	355		3.58	ab	0.96	bc	0.47	ab	1.66	b
Cocksfoot	362		3.46	b	0.84	c	0.61	a	1.64	b
SED	36	ns	0.26	?	0.21	?	0.15	?	0.26	?

There was more N removed in the grain following fallow (83.6 kg/ha) than following the perennials (range 55.9 to 59.6 kg N/ha). This reflects both the high N content of the grain and the relatively high yield. There was more N in the total biomass at harvest (grain plus straw) following fallow (123.6 kg/ha) than after the perennials, which ranged from 58.5 for lucerne to 86.2 kg/ha for ph/co, although these did not differ significantly from each other.

Grain yield and quality

The most productive treatment in terms of biomass, grain produced, and grain quality was fallow. Despite the lack of difference in biomass production between wheat grown after different perennial pastures, the highest grain yield followed the perennial grass mix ph/co, but this was not significantly different from the yield of wheat following fallow (Table 3). Grain yields were almost all above 2 t/ha for all treatments in each season. The lowest individual grain yield was 1.70 t/ha in 2001 for wheat following lucerne.

Table 3. Grain yield and quality parameters, combined analysis for three seasons. Significantly different treatments denoted by different letters.

?	Grain t/ha		Protein %		Screenings %	Grain size (mg)		Harvest Index	
Fallow	3.32	a	16.0	a	3.4	26.5	b	0.37	a
Lucerne	2.37	cd	11.5	b	5.3	28.9	ab	0.32	b
Triple	2.74	bc	11.5	b	6.7	25.7	b	0.37	a

Ph/co	2.98	ab	9.6	b	4.0		30.2	ab	0.37	a
Phalaris	2.61	bc	9.6	b	4.4		30.3	ab	0.36	ab
Cocksfoot	2.74	bc	9.5	b	3.1		32.4	a	0.37	a
?	?	?	?	?	?	?	?	?	?	?
SED	0.25	?	2.1	?	2.5	ns	3.2	?	0.024	?

There were no significant differences in grain screenings, although there was a trend toward higher screenings following the treatments containing lucerne. This was strongly influenced by the 2003 season in which wheat following triple (17%) and lucerne (11%) had very high ($P<0.05$) levels of screenings.

Wheat after fallow had the highest grain protein. Although there was a trend for higher protein following the pastures containing lucerne, this was not significant. Grain size did not correlate well to screenings level or grain protein, but all grain was small, ranging from 25 to 32 mg. There was low harvest index following lucerne (0.32) but the other perennial and fallow treatments did not differ from each other (0.37).

Discussion

Across three difficult growing seasons wheat yield following perennial pastures was surprisingly high. Under the drier than average conditions experienced, the fallow could reasonably be expected to be the highest yielding option due to additional stored soil moisture. However, the extra plant available soil mineral N after fallow may have promoted excess pre-anthesis biomass growth, which exhausted soil water reserves, leading to a reduction in biomass and N post-anthesis. This was most apparent in 2001. Yield of wheat after the perennial grass mix ph/co was not significantly different to wheat yield after fallow. This was most likely due to more moderate early growth of wheat after the grass pasture. Wheat following lucerne had low yields, high protein, high screenings (particularly in 2003) and small grain size after excess pre-anthesis growth and high N content at anthesis. This is consistent with haying-off (van Herwaarden *et al*. 1998), although previous examples have not shown such large losses of crop N.

There was a clear disadvantage for wheat following lucerne. However, perennial grass pastures provided good prospects of reasonable wheat yields in following seasons through lower N availability and a more conservative growth pattern. These results have demonstrated that under difficult seasonal conditions, acceptable yields can still be achieved for wheat following perennial pastures. These pastures offer significant environmental sustainability benefits (eg. water use, erosion control) and this research has shown clear yield benefits for following crops. The most significant risk to farmers, of reduced yields following perennial pastures in dry years, can be ameliorated through the use of perennial grass pastures.

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