Crop yield response to pasture legumes in a pasture-crop rotation

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Abstract

The performance of crop plants following a pasture phase in pasture-crop (P-C) rotations was measured at three sites in Victoria. Positive crop yield responses to strong pasture legumes were recorded under applications of no nitrogen (N) fertilisers other than the N fixed by the pasture legumes the year before.

At the Hamilton site where the crops were based mainly on N input from subterranean clover, canola produced 4.1 t/ha of grain and wheat averaged 6.0 t/ha. At the Gnarwarre site, highly significant ($P < 0.01$) differences in grain yields of wheat cv. Silverstar were indicated for six treatments. Grain yields following balansa clover reached 7.0 t/ha, contrasting with those from continuous crop (C/crop, 2.4 t/ha) or fallow/crop (F/crop, 2.0 t/ha) in which 50 kg N/ha was applied. The wheat crop following three other clovers (Persian clover, subterranean clover and red clover) each produced lower grain yields than that following balansa clover but significantly higher grain yields than that following the F/crop or C/crop. At the Streatham site, average grain yields of the same wheat variety harvested from each of these six treatments reached 5.2 t/ha, with significant ($P < 0.05$) differences between the clovers (as a group, except the red clover) and F/crop or C/crop.

Further analyses of data collected at the Gnarwarre site showed significant differences among the six treatments in most of the plant characters measured. Clover-based plants were taller, and produced more heads per unit area and larger seed sizes. The good combination of these yield components following balansa clover, subclover or Persian clover resulted in the higher grain yields of the wheat cv. Silverstar. The differences in grain yields recorded may reflect the different soil nutrient status, particularly the N fertility of these treatments. Further research into the beneficial functions and underlying mechanisms of strong pasture legumes is needed.

Key words

Wheat, canola, nitrogen fertiliser, grain yield, yield components, dry matter

Introduction

The use of pasture legumes containing subterranean clover grown in crop rotations has long been an integral part of the rotational cropping system in the cereal-livestock mixed farming industry of southern Australia. Pasture-crop (P-C) rotations are practised to maximise economic returns from livestock and/or crop production. Perceived advantages of these rotations include the restoration of soil fertility, particularly the built-up nitrogen (N) fertility from symbiotically fixed N by pasture legumes, disease break, selective control of weeds, reduced use of herbicides and associated reduced risks of herbicide resistances (1,2). N input from pasture legumes is particularly useful in the sense that no N fertilisers need to be applied when a crop is grown following a pasture phase. The availability of alternative annual pasture legumes provides more options to explore the potential of the existing long growing season in this cool-temperate, high-rainfall zone for high crop grain yields by using those promising pasture legumes effectively (3). This research was undertaken to investigate the crop response to preceding pasture legumes in terms of plant growth and grain production to provide information about the beneficial effects of P-C rotations. Results reported here are concerned exclusively with the wheat and canola crops in 2001.

Methods

The experiment was conducted at three sites in Victoria: Hamilton (37?49’S, 142?04’E, altitude 200 m), Gnarwarre (38?10’S, 144?15’E) and Streatham (37?41’S, 143?04’E). Annual rainfall and soil properties are shown in Table 1.

Table 1. Soil physical and chemical properties of three experimental sites (data from State Chemistry Laboratory, Werribee of Victoria, 1999)

Site	Average annual rainfall (mm)	Soil type *	pH ($_{CaCl2}$)	Total C (%)	Total N (%)	P-Olsen (mg/kg)	K-Skene (mg/kg)
Hamilton	690	Fine s.c.l.	4.7	5.4	0.44	23	160
Gnarwarre	600	Fine s.c.l.	5.7	3.3	0.30	35	807
Streatham	547	Light s.l.	4.9	2.8	0.23	34	300

* s-sandy, c-clay, l-loam.

Hamilton site

The 2001 crop trial was sown into a preceding subterranean clover monoculture in a paddock where a P-C rotation of 1 year’s pasture followed by 1 year’s crop has been running since 1997. In the pasture phase 2000, the four varieties of subclover each produced high yields of herbage dry matter, being 9.8, 7.0, 9.9 and 8.7 t/ha respectively for Leura, Enfield, Trikkala and a clover mixture (containing Enfield, Karridale, Larisa and Trikkala). Self-regenerated clover seedlings following the opening rains in mid-March 2001 were killed using 450g/L glyphosate plus 200g/L dimethylamine salt in early May, followed by an application of Fastac at 100 ml/ha to control red-legged earth mites. No N fertiliser was ever applied as the system relies on atmospheric N. For instance, 200-300 kg N/ha/yr had presumably been fixed by the clover as proposed by Peoples *et al*. (4). Fertiliser Blend50 (NPKS: 0-7-12-8) was top-dressed at 500 kg/ha over the paddock in mid-May to ensure adequate supply of P, K and other nutrients.

A split-plot design with two replicates was used, with the four clover varieties as the main plots and six varieties of two crops the subplots. They were wheat cvs. Brennan, Kellalac and Silverstar; and canola cvs. Charlton, Mystic and Surpass 400. Each subplot measured 2.85 m by 85 m. Wheat was machine-sown at 110 kg/ha (3.5 cm deep) and canola at 6 kg/ha (1.5 cm deep) on 20 May 2001, with a row spacing of 15 cm. Edges along the fence were sown with a buffering line (cv. Silverstar) by a cone seeder (1.50 m wide, row spacing 15 cm). The following day Dual Gold (S-metolachlor) at 210 ml/ha was sprayed to control toadrush (*Juncus bufonius* L.). On 6 June and 25 July, Meta was broadcasted over the paddock to control snails and on 10 September, a general fungicide Tilt 250EC at 500 ml/ha was sprayed. Because of the varying growth periods and maturity, the crops were harvested at different dates, starting with Mystic in early December 2001 and ending with Brennan and Kellalac in mid-January 2002. Three 1-m^2 quadrat cuts per plot were taken to determine grain yields per unit area.

A sub-sample of grain was prepared for chemical analysis of wheat protein content (%) and canola oil content (%).

Gnarwarre and Streatham sites

At both sites the 2001 crop trial was based on a preceding pasture phase of a P-C rotation for which six treatments have been imposed since 1998. They include 4 pasture legumes (ie. subterranean clover cv. Leura, balansa cv. Bolta, Persian clover cv. Nitro plus and red clover cv. Astred) and two conventional practices, continuous crop (C/crop) and fallow/crop (F/crop). The F/crop means chemical fallow in the pasture phase and N input through fertiliser application in the crop phase.

The field layout was the same at the two sites. A randomised complete block design was used with four replicates. Each replicate was a rectangular plot measuring 9 m by 4.5 m with 2 m spaces between blocks and 1 m spaces between plots. For those plots with pasture treatments, no N fertiliser was applied, while each C/crop or F/crop plot was fertilised with 109 kg urea/ha (equivalent to 50 kg N/ha) at crop sowing.

Wheat cv. Silverstar was direct drilled at a rate of 110 kg/ha to a depth of 3-4 cm using a cone seeder, on 15 and 25 May, respectively, at Streatham and Gnarwarre. Fertiliser Blend50 (NPKS: 0-13-0-8) was incorporated into the soil at a rate of 200 kg/ha. S-metolachlor was sprayed at 210 ml/ha to control toadrush on 29 May at the Gnarwarre site. The crop was harvested on 5 and 18 December 2001 respectively at Gnarwarre and Streatham, with two 1-m^2 quadrat cuts taken from each plot for determination of grain yields. A sub-sample was then collected at the Gnarwarre site to examine major yield components and yield-associated characters.

Statistical analysis

Data were analysed on a plot mean basis. The general treatment structure with randomised blocking of Genstat 5.4 was used for ANOVA of grain yields and other characters. When *F*-test indicates significant differences between treatments, multiple comparisons were made; least significant difference (*lsd*) was calculated at $P = 0.05$.

Results and discussion

Hamilton site

Throughout the season, both wheat and canola crops performed well. There were no significant ($P > 0.05$) differences among the main effects of subclover varieties, but highly significant ($P < 0.01$) differences were observed between the two crops and among the three wheat varieties (Fig. 1). Canola produced 4.1 t/ha of grains and wheat averaged 6.0 t/ha. Within wheat, Kellalac produced the highest grain yield (6.6 t/ha) followed by Silverstar (6.3 t/ha).

Although Silverstar produced grains with apparently higher protein content (12.9%) than Brennan (12.5%) and Kellalac (11.2%), no significant ($P > 0.05$) differences were detected between them. However, highly significant ($P < 0.01$) differences were recorded in oil content of the three canola varieties: 45.1% for Charlton and 44.7% for Surpass 400, both are significantly higher than 40.8% for Mystic.

It is noted that the grain yields were achieved under application of no N fertilisers. This result suggests that at least sufficient amounts of soil N were made available for the wheat and canola crops to maintain normal plant growth and achieve high crop production. Based on the assumption proposed by Peoples *et al*. (4), we estimate that the preceding subclover symbiotically fixed about 250 kg N/ha into the soil during the 2000 pasture phase.

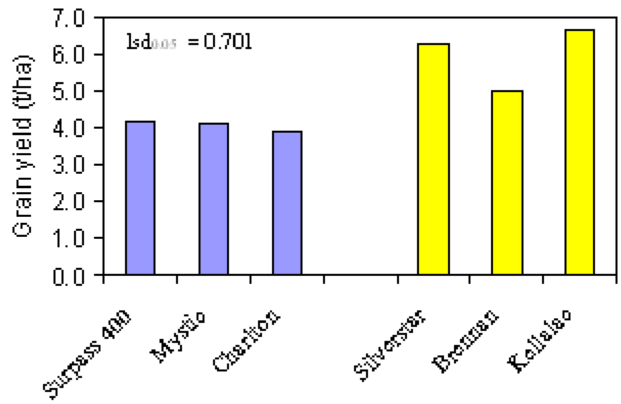

Figure 1. Grain yields (t/ha) of three canola and three wheat varieties harvested under applications of no N fertiliser at Hamilton, South western Victoria 2001.

Gnarwarre and Streatham sites

Significant ($P < 0.01$) differences in grain yields of wheat cv. Silverstar were indicated for the six treatments at the Gnarwarre site (Table 2). Grain yields following balansa clover (cv. Bolta) reached 7.0 t/ha, contrasting with low yields from the F/crop (2.0 t/ha) or C/crop (2.4 t/ha). The wheat crop following other three clovers each produced less than that following the balansa clover, but significantly higher grain yields than that from the F/crop or C/crop.

Table 2. Grain yield (t/ha) of wheat harvested following either of 4 clovers, C/crop or F/crop at Streatham and Gnarwarre in 2001
For each site values followed by the same letter(s) denote non-significant differences at *P* = 0.05.

Sites	Balansa clover	C/crop	F/crop	Subclover	Persian clover	Red clover
Gnarwarre	7.03a	2.35c	2.03c	5.99b	5.39b	5.19b
Streatham	6.42a	5.18b	5.34b	6.63a	6.72a	6.13ab

At the Streatham site, all the treatments resulted in grain yields of over 5.2 t/ha. There were significant differences between any clover (except red clover) and C/crop or F/crop, however no significant differences existed between the four clovers.

Results also showed significant differences among the six treatments in all the plant characters measured except number of grains per head (Table 3). For most of these characters, the four clovers each produced higher values than the F/crop or C/crop. Clover-based plants were taller, and produced more heads per unit area and larger seed sizes. The good combinations of these yield components resulted in the higher grain yields of wheat following balansa clover, subclover or Persian clover. This further suggests that such strong clovers as balansa, Persian and subterranean have a greater capability to improve plant performance of a subsequent crop without any application of N fertilisers, in comparison with the two conventional cultural practices, F/crop or C/crop. The differences in grain yields recorded in the same wheat cv. Silverstar may reflect the different soil nutrient status, particularly the N fertility of these treatments. Further research into the beneficial functions and underlying mechanisms of strong pasture legumes is needed.

Table 3. Comparisons of major yield components of wheat cv. Silverstar following 6 different treatments at Gnarwarre 2001
***** *P* < 0.001, ** *P* < 0.01, * *P* < 0.05, *n.s.*- not significant: *P* > 0.05.**

Treatments	Plant height (cm)	No. heads /m^2	No. grains /head	1000-grain weight (g)	Grain weight (g) /head
Subclover	88.7a	540a	54.2	37.4a	2.03a
Persian clover	88.9a	493b	41.4	31.5c	1.30b
F/crop	73.8b	280d	41.0	34.4b	1.41ab
C/crop	61.0c	293d	37.8	27.3d	1.03b
Balansa clover	86.3a	467c	51.4	38.0a	1.95ab
Red clover	87.0a	460c	53.0	34.3b	1.82ab
F-test	**	***	*n.s.*	***	*
lsd (*P* = 0.05)	8.0	19.2	19.4	0.52	0.68

Conclusions

A subsequent crop can benefit from a strong pasture legume grown in rotation with crops in the high rainfall zone of southern Australia. At Hamilton, both wheat and canola crops following a subclover pasture phase produced high grain yields without N fertilisers. At Streatham and Gnarwarre, clover-based wheat cv. Silverstar produced high grain yields in contrast with low grain yields from two conventional practices, F/crop or C/crop. The results provide more information about the beneficial effects of P-C rotations for high crop production in this region.

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