Interactions between plant density and grazing in cereals under dual-purpose management

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Abstract

Comparative analysis of cereal species has been used to identify traits associated with grain yield. This approach would also be helpful in examining dual-purpose systems that use crops for grazing and grain production in the same season, particularly in rain-fed environments where variable autumn rainfall affects establishment density from year to year. Three cereal cultivars, Urambie barley, Eurabbie oats and Mackellar wheat were sown at high (100 kg/ha) and low (50 kg/ha) rates in large field plots. Half of each cropping area was grazed before the start of stem elongation (40 dse/ha for 18 days) and half left ungrazed. Replicate samples of 0.5 m of row in each crop ? density ? grazing treatment were taken at regular intervals during the growing season to measure total above-ground biomass, leaf area index, tiller number and stem apex height. Grain yield was determined from hand cuts of 2.7 m^2 at maturity. At the start of grazing biomass on offer at high plant density was 2.0, 1.2 and 0.8 tDM/ha for barley, oats and wheat, respectively, with little difference between crops in proportional reduction at low plant density (31-34%). In each crop there was a significant reduction in stem apex height associated with both grazing and low plant density. The rate of re-establishment of leaf area was faster in barley than oats and wheat. A notable difference between the cereals was the maintenance of high tiller density in barley, particularly under grazing. There were significant crop ? density ? grazing treatment effects on grain yield, most notably the absence of a significant yield penalty in grazed, low density barley. Barley thus exhibited favourable traits for a cereal under grazing, namely fast early growth rate, rapid recovery of leaf area after grazing, maintenance of high tiller number and no grain yield reduction after grazing.

Key Words

Dual purpose cropping, wheat, barley, oats,

Introduction

Comparative analysis of cereal species has been an informative avenue for identification of traits for improving grain yield in rain-fed environments (L?pez-Casta?eda and Richards 1994). This approach would also be helpful in examining dual-purpose systems that use various cereal crops for grazing and grain production in the same season. An important factor that will influence this comparison is the effect that established plant density has on subsequent growth and development. Although this aspect has been studied with respect to effects on grain yield (e.g. Whaley *et al*. 2000), the added influence of grazing during vegetative growth has not been widely documented. Under dual-purpose use, variation in establishment density is important because of its potential effect on the amount of feed on offer at the start of grazing, and the likely interaction that plant density will have with crop species and grazing.

An experiment was conducted at Ginninderra Experiment Station (GES; 35? 12' S, 149? 4' E), near Canberra, in which two sowing rates were used to produce high and low establishment densities of representative cultivars of bread wheat, oats and barley. Vegetative traits and grain yield of each crop in grazed and ungrazed areas of high and low plant density were analysed to evaluate important crop ? density ? grazing interactions.

Methods

Cereal cultivars and experimental layout

Urambie is a dual-purpose barley cultivar bred by I&I NSW with good performance in southern NSW under grazing. Eurabbie is a dual purpose winter habit oat with good recovery after grazing. Mackellar is a standard long-season, dual-purpose wheat. Each cultivar was sown on 21 April 2009 in single strip plots (6 m x 100 m) at high (100 kg/ha) and low (50 kg/ha) sowing rates with 110 kg/ha Starter 15 fertiliser (15% N, 12% P, 12% S). At the start of grazing on 13 July, the crops were passed the double ridge stage of development but stem apices were less than 10mm above the crown. At this time, each plot was divided in half; one half was grazed by Merino wethers at 40 dse/ha for 18 days, and the other left ungrazed.

Biomass, leaf area development and tiller number

On 5 occasions (1 pre-grazing and 4 post-grazing), replicate lengths of 0.5 m of row were sampled in each crop ? density ? grazing treatment and individual plants were scored on the decimal growth stage system (Zadoks 1974) i.e. main stem leaf number and tiller number. Stem apex stage (vegetative or reproductive) was recorded and height above the crown was measured from 10 main stems per sample. Samples were separated into leaves and stems. In each sample the leaf area of 4 representative leaves was determined using a flat-bed scanner, and leaf dry weight was determined after oven drying at 70?C. Leaf mass per area (LMA) was calculated and total leaf area index (LAI) of the sample was determined from the LMA and the total leaf dry weight of the sample:

$$LAI = (DM_{leaf} / \text{ground area}) / LMA$$

Growth rates in the post-grazing period were calculated from differences in biomass values on 3 August and 6 October (64 days). Grain yield and grain yield components were determined from 5 random cuts of 0.54 m^2 in each crop ? grazing ? sowing density treatment combination.

Results

At high sowing density, oats had better establishment than wheat and barley (218, 180 and 146 plants/m^2, respectively) and relative to the high density sowing, establishment at the low sowing rate was reduced by 25% in oats, compared with 54%, 59% reductions in wheat and in barley.

At the commencement of grazing, high density barley had 2.0 t DM/ha compared with 0.8 t DM/ha of wheat and 1.2 tDM/ha of oats. The percent reduction in biomass of the low density relative to the high density treatment was similar between crops (31-35%). In the ungrazed treatments, the difference in biomass between low and high density treatment was reduced in barley by the 9 September sampling and in oats by the 6 October sampling. In wheat the low density biomass was still 46% lower than the high density biomass at the 6 October sampling.

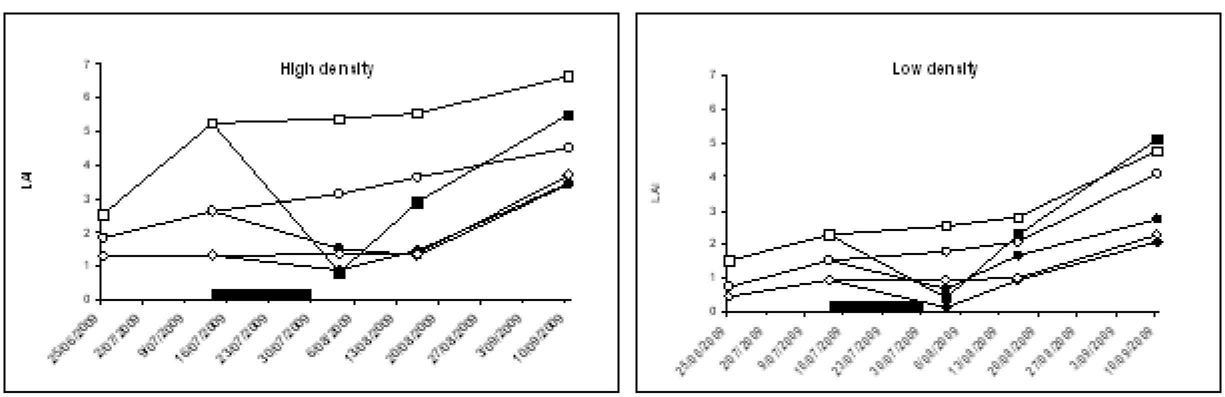

Figure 1: Leaf area index (LAI) of barley (squares), oats (circles) and wheat (diamonds) in ungrazed (unfilled) and grazed (filled) treatments at high and low plant densities. The black bar shows the period of grazing.

In the ungrazed, high density crops, LAI of barley increased from 5.2 in late July to 6.6 in early September (mid stem elongation stage). The corresponding increase in oats was from 2.6 to 4.5 and in wheat from 1.3 to 3.7. The rank order of LAI was the same at the lower plant density, with reductions of 28%, 37% and 9% relative to LAI under high density at the final sampling, for barley, wheat and oats, respectively. In the grazed crops, the initial recovery of leaf area was more rapid in barley than oats and wheat. At the final sampling, LAI of ungrazed crops was 83%, 76% and 94% of grazed crops at high density for barley, wheat and oats, respectively. At low density the corresponding values were 101%, 92% and 67%

Grazing was started when stem apices of all crops were less than 10mm above the crown. When apex height was measured on 9 September (6 weeks after the end of grazing) the apices in the grazed treatments of all crops were significantly ($P < 0.001$) lower than those in the ungrazed treatment and were also significantly lower ($P < 0.001$) at low compared with high plant density in each crop (Fig. 2).

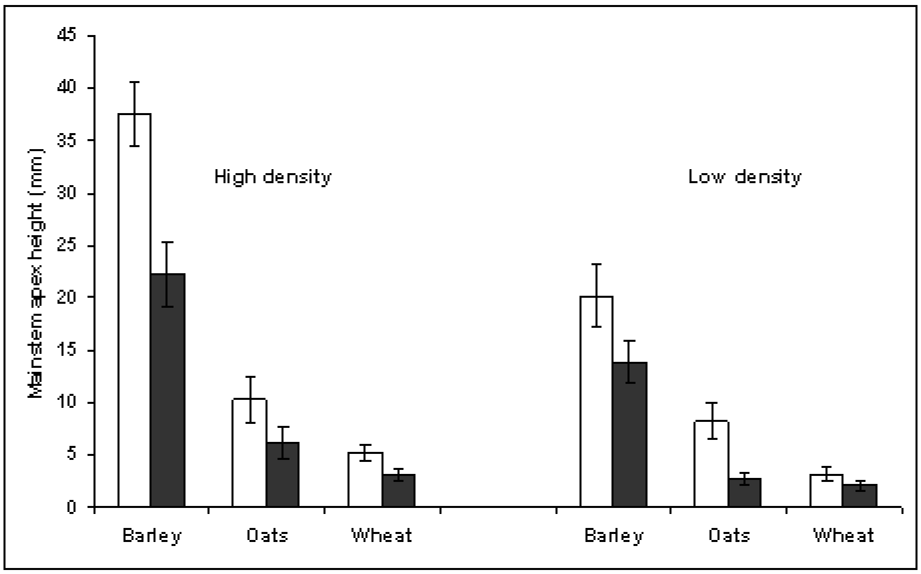

Figure 2: Average (? 2 SD; n = 10) stem apex height of barley, oats and wheat in ungrazed (unfilled bars) and grazed (filled bars) treatments at high and low plant population density, measured on 9 September (6 weeks after grazing)

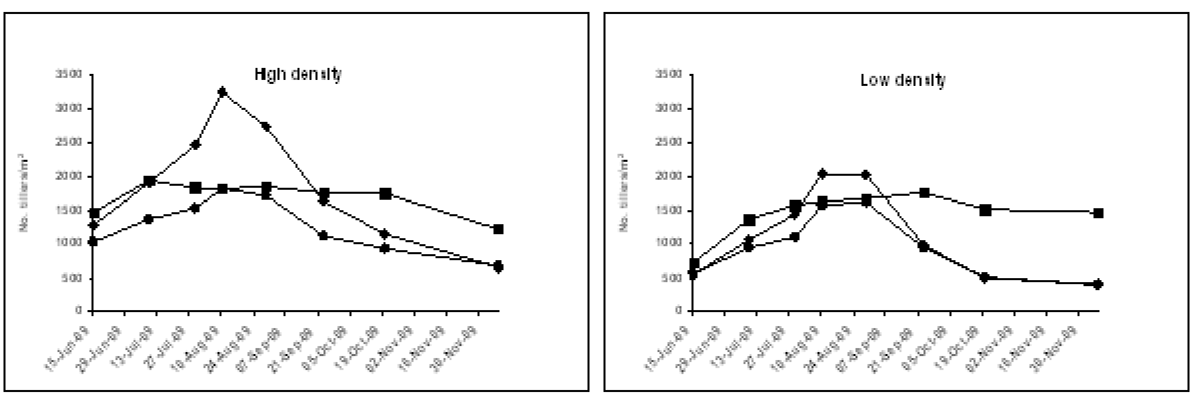

Figure 3: Number of tillers/m^2 in barley (squares), oats (circles) and wheat (diamonds) in the grazed treatment at high and low plant population density.

There was a marked difference between the species in the pattern of tillering in both grazed and ungrazed crops. In wheat and oats tiller number peaked in late August to early September, reaching 3000 tillers/m^2 in wheat and 1800 tiller/m^2 in oats at high plant density (Fig. 3, for the grazed crops). Thereafter, tiller number declined in both species to between 400-600 tiller/m^2 at grain harvest. In barley, tiller populations of 1500-2000 tillers/m^2 were developed by late July, followed by a lesser decline by grain harvest (1200-1400 tillers/m^2).

In the grazed crops of barley and oats, growth rates were similar between plant density treatments, averaging 24 g/m^2/day and 9 g/m^2/day, respectively. In wheat the growth rate in the high density treatment was 12 g/m^2/day, compared with 5 g/m^2/day in the low density treatment. Growth rates of the grazed crops at both high and low densities were very similar to those of the ungrazed crops.

Grain yield

Analysis of variance found a significant crop ? grazing ? density interaction for crop yield. This interaction could be attributed to the fact that while significant grain yield reductions were associated with low plant population densities in oats and wheat in both grazed and ungrazed treatments, grain yield of barley was not significantly reduced in the grazed crop (Table 1). Averaged over density and grazing treatments, grain yield of barley (696 g/m^2) was significantly higher than wheat (315 g/m^2) and oats (411 g/m^2). An important factor that contributed to this difference was rainfall around the time of flowering. Over time during which barley reached 50% anthesis (? 2 weeks around 1 October), there were 19 days on which rain was recorded (total of 99mm), compared with 5 days of rain (total 23mm) during which anthesis occurred in oats (30 October) and wheat (6 November). The yield components most closely correlated with grain yield were the number of heads/m^2 (r = 0.92) and kernel weight (r = 0.88). There was a negative correlation between grain yield and the number of kernels/head (r = -0.66), influenced largely by the small size of the heads in barley. The correlation of grain yield with the number of kernels/m^2 was 0.83.

Table 1: Grain yield (g/m^2) of barley, oats and wheat in ungrazed and grazed treatments at low and high plant densities.

Crop	Ungrazed		Grazed	
	High density	Low density	High density	Low density
Barley	764.7	595.3	709.3	713.6
Oats	475.0	411.8	426.0	331.7
Wheat	277.0	228.0	366.3	286.7
l.s.d., c ? g ? d		15.0		

Conclusion

Urambie barley exhibited favourable traits for a cereal under grazing. Pre-grazing biomass production of barley was greater than oats and wheat, as was its faster compensation for low plant density. There was also a more rapid re-establishment of leaf area after grazing. Although reproductive initiation occurred earlier in barley than in the other cereals, this did not appear to be disadvantageous, particularly under grazing, where the general response of grazed crops was a reduction in the height of the apex. A notable difference between the cereals was the maintenance of high tiller density of barley, which was also more evident in the grazed compared with the ungrazed crop. Although rainfall around the time of anthesis favoured grain yield development of barley more than wheat and oats, the most important element of the crop ? grazing ? density interaction was the absence of a grain yield penalty in barley at low plant density under grazing.

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