Influence of end-grazing forage residual and grazing management on lamb growth performance and crop yield from irrigated dual-purpose winter wheat

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Abstract. The effects of end-grazing forage residual and continuous v. rotational grazing systems on prime lamb performance, grain yield and quality were examined in an irrigated dual-purpose winter wheat (cv. Mackellar) crop in Tasmania. The design was a two end-grazing residual (400 and 800 kg/ha of dry matter (DM) at Zadoks Growth Stage 30, Low and High respectively, 0.2 ha plots) $\times$ two grazing system (continuously, or rotationally grazed in four subplots) factorial, replicated three times. Mixed-sex, second-cross lambs [37 kg liveweight (LW), 2.5 body condition score, 45 kg DM/head initial feed allowance] grazed for a total of 46 days before removal. Initial feed availability was 1875 kg DM/ha, with final residuals of 520 $\pm$ 57 and 940 $\pm$ 70 kg DM/ha for the Low and High treatments respectively. Particularly for the Low residual, in vitro digestibility and crude protein at stem elongation were reduced ($P < 0.05$) by rotational compared with continuous grazing. The weekly lamb growth rate (g/day) during the first 5 weeks of grazing was linearly related to average weekly available DM in kg/ha (GR = 0.35 $\pm$ 0.041 $\times$ DM – 194 $\pm$ 49.0, $P < 0.01$, $R^2 = 0.56$). Total LW produced (336 $\pm$ 11.7 kg/ha), and grain yield (6.9 $\pm$ 0.21 t/ha), protein (11.4%), screenings <2.2 mm (10.9%) and 100 grain weights (3.82 g DM) were not different between treatments. There were no advantages of rotational grazing compared with continuous grazing. Irrigated dual-purpose winter wheat can be continuously grazed by lambs up to a 500 kg DM/ha residual at stem elongation without compromising total LW produced, grain yields or grain quality.

Introduction

The use of dual-purpose wheat cultivars as a high-quality forage for meat-producing lambs can contribute to overcoming the winter feed-gap that occurs in temperate Australia, and which limits carrying capacity of farms in this region (Moore \textit{et al.} 2009). While the potentially conflicting aims of maximising animal production and grain yields have sometimes been achieved successfully for grazed cereal crops, past grain yield outcomes have been variable (Virgona \textit{et al.} 2006). Research with cattle in Argentina has shown that leaf area index of winter wheat at anthesis is affected by grazing pressure and positively correlated with grain yield (Arzadun \textit{et al.} 2003). It is also understood that, under dryland conditions, grazing must cease before plant stem elongation to avoid removing the emerging grain head (Virgona \textit{et al.} 2006); however, this grazing effect may be offset by providing irrigation to encourage post-grazing tillering (McMaster \textit{et al.} 1994). Further, as vegetative winter cereals have high nutritive value (Dove and McMullen 2009), available feed on offer is likely to determine individual animal forage intake and hence animal growth performance. Little is known about the effect of the amount of residual forage at stem elongation on animal and grain yield performance for irrigated, dual-purpose cereal grazing systems. While continuous grazing (CG) is more common under centre-pivot irrigation systems to maximise animal performance, producers are also using rotational grazing (RG) practices to better manage grazing pressure and reduce wastage. An additional objective of the study was to compare CG with a simple 4-paddock RG system.

The present paper reports an examination of the influence of end-grazing forage residuals under both continuous and rotational grazing management on lamb production and subsequent grain yields of dual-purpose winter wheat under irrigated conditions.

Materials and methods

\textit{Crop, animals and experimental procedures}

The experiment was carried out within a 14-ha Dermosol gradational red-brown clay-loam paddock under centre-pivot irrigation in the northern Midlands of Tasmania (41°37′S, 147°00′E). Dual-purpose winter wheat (\textit{Triticum aestivum} L. subsp. \textit{Aestivum} cv. \textit{Mackellar}) was sown at 120 kg/ha (0.18-m rows) on 13 March 2008 using triadimenol treated seed and 250 kg/ha NPK (9:14:17) basal fertiliser. During the week following sowing the paddock was irrigated (50 mm), and was sprayed on 16 April with herbicides (2-methyl-4-
chlorophenoxyacetic acid 1.5 L/ha; carfentrazone-ethyl, 50 g/ha). The experimental design was three replicates of a two end-grazing residual [400 and 800 kg/ha DM at Zadoks Growth Stage (GS) 30, Low and High, respectively] × two grazing system (CG or RG in four subplots) factorial. Plots (n = 12) were 0.2 ha (50 × 40 m), with RG plots divided into four subplots using netting fences. Clean water was provided ad libitum in troughs. Weather conditions at the site were recorded every 30 min (rainfall, temperature, wind speed; Watchdog 2700, Spectrum Technologies, IL, USA).

Mixed-sex, 9-month old, second-cross lambs [liveweight (LW), 37.3 ± 2.09 kg; body condition score (BCS), 2.5 ± 0.23 on a 5-point scale; mean ± s.d., n = 99] grazing a tetraploid Italian ryegrass pasture were allocated to treatment groups (balanced for LW and BCS) and put in the treatment plots on 29 May 2008, after receiving a drench (Ivermectin, 10 mL/head, Genesis® with selenium, Ancare Australia, NSW, Australia) and booster vaccine (2 mL, Guardian 6 in 1®, Schering-Plough, NSW, Australia). Stacking rate (SR) was based on an initial allowance of 45 kg DM/head (42 heads/ha, 1875 kg DM). CG lambs had access to the entire plot area, with RG subplots grazed to the desired forage residual before removal of lambs to the next subplot. Lambs were weighed weekly without a curfew period off-feed and BCS was determined at the start and end of grazing. On the day before (10 randomly selected lambs) and after 28 days grazing (three lambs/plot), blood samples (10 mL, jugular) were collected for Ca, Mg, Na and K analysis. From the second week of grazing, lambs were supplemented with 1 : 1 magnesium oxide and coarse salt as a loose mix provided at ~20 g/lamb.day (Dove et al. 2007). Where the desired feed residual was achieved before GS 30, SR was reduced (4th or 5th week) to maintain residual levels. Due to the emergence of patch grazing, all animals were subsequently removed after an initial grazing period of 35 days, and plots were re-stocked after 3 weeks for a final 11 days to achieve the desired residuals at plant stem elongation. GS was monitored by dissection of 10 randomly selected plants per plot. The additional forage and LW production was recorded.

Prior to grazing and fortnightly during grazing, forage samples were collected (four bulked quadrat samples cut to ground level per plot, one per subplot) and processed (dried at 60°C to constant weight, ground 1 mm) for nutritional-quality analysis. Pre-grazing samples were also analysed for Mg, Ca, K and Na contents. A rising plate meter (315 mm², ≥60 recordings per plot, ≥20 per subplot) was used weekly and at stock rotations for determining forage DM yield. Meters were calibrated at each use by linear regressions of plate meter height against DM/ha measured from 10 to 12 quadrat cuts (0.25 m², to ground level, dried at 100°C for 24 h) taken across the range of forage mass present (Earle and McGowan 1979). Feed-use efficiency was calculated from estimated growth-corrected DM use (from the difference in DM yield at the start and end of a grazing period, assumed to include intake plus trampling losses), divided by the amount of LW produced.

On 30 August, the paddock was top-dressed with 64 kg N/ha as urea, and treated with fungicide on 24 September and 8 October (100 mL/ha, Tilt, Syngenta, NSW, Australia). Irrigation was applied on 24 October (70 mm, including 51 kg N/ha as urea), on 29 October (70 mm over 2 days) and on 24 November (48 mm over 3 days). DM accumulation in plots was measured at anthesis and harvest by bulking six 0.25 m² quadrats per CG plot and three per RG subplot. Exclusions (4 m²) were included in each plot to record ungrazed DM and grain production. Ungrazed plant DM yield was measured by using a minimum of three 0.25 m² quadrats cut to ground level from four exclosures across the site at the end of grazing, at anthesis, and again at harvest. Samples were dried at 60°C to a constant weight for determination of total DM and grain yields, harvest index (ratio of grain weight to total sample weight), average grain weight (3 × 100 grains), number of ears per square metre, and grains per ear. Samples were also taken for percentage screenings, specific (test) weight and N-content determination.

Analytical procedures
Blood plasma was analysed for Ca and Mg using colourimetric analysis at 650 and 570 nm, respectively (Thermo Electron Oy, Vantaa, Finland). Na and K were measured with ion-selective electrodes (Konelab™ Micro Volume, Thermo Electron Oy). The extent (48 h) of in vitro DM digestibility (IVDMD) was determined in a Daisy II incubator (Ankom Technology Corporation, Fairport, NY, USA) using rumen fluid from four fistulated wethers fed to maintenance requirements a 60% lucerne chaff and 40% concentrate pellet diet [11.2 MJ metabolisable energy (ME)/kg DM, 17.7% CP, 31.2% neutral detergent fibre (NDF)]. Feed samples (2 g) were combusted at 600°C for 2 h to determine organic matter content. NDF contents (ash corrected) were determined with an Ankom® Fibre Analyser (Ankom Technology Corporation, Fairport, NY, USA) based on the method of Van Soest et al. (1991). N content was estimated using a Kjeldahl block digestion procedure (AOAC 1990).

Statistical analyses
Analysis of variance was performed using least-squares regression (PROC GLM of SAS) to fit a general linear model containing the fixed effects of grazing system, forage residual, and their interaction. Grazing treatments were compared with ungrazed exclosure measurements using one-way analysis of variance. Least-squares means are presented, and differences among means were analysed using a protected (P < 0.05) F-test by means of t-tests. The Tukey–Kramer adjustment for multiple-comparison procedures was used. Significance was declared at P < 0.05 and trends discussed at P < 0.10.
mmol/L) and Ca (2.8 ± 0.05 mmol/L) concentrations after 28 days of grazing were also not different. Ungrazed forage accumulation was 4450 ± 947 kg DM/ha (mean ± s.d.), producing an average daily forage growth rate during the grazing period of 38.0 ± 4.42 kg DM/ha. End-grazing forage nutritive quality, animal performance during grazing and grain yields and quality are presented in Table 1. Available forage at the start of the final grazing period was lower (P < 0.01) in the CG (650 ± 260 kg DM/ha) than RG plots (1170 ± 227 kg DM/ha). Final residuals were 520 ± 57 and 940 ± 70 kg DM/ha for the Low and High treatments, respectively. Average GS at the end of grazing was 29.8 ± 0.28 for the CG plots and 30.3 ± 0.31 for the RG plots (P = 0.05).

The average SR in the first grazing period (37.9 ± 1.11 heads/ha) or across both grazing periods (33.8 ± 1.06 heads/ha) did not vary between treatments. The weekly rate of LW gain (g/day) during the first 5 weeks of grazing was linearly related (P < 0.01) to available DM in kg/ha (LW gain = 0.35 ± 0.041 · average weekly DM – 194 ± 49.0, R² = 0.56). Rate of LW gain for the period was greater (P = 0.05) for the CG (216 ± 11.9 g/day)

Table 1. Feed quality, lamb performance and grain-yield characteristics of irrigated dual-purpose winter wheat grazed to two forage residual amounts (Low and High) under continuous or rotational grazing systems

<table>
<thead>
<tr>
<th>Parameter</th>
<th>End-grazing residual</th>
<th>s.e.m.</th>
<th>P-value</th>
<th>R</th>
<th>M</th>
<th>R × M</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Continuous</td>
<td>Rotational</td>
<td>High</td>
<td>Continuous</td>
<td>Rotational</td>
</tr>
<tr>
<td>Crude protein – end grazing (% DM)</td>
<td>26.9</td>
<td>21.7</td>
<td>25.6</td>
<td>23.7</td>
<td>1.02</td>
<td>n.s.</td>
</tr>
<tr>
<td>NDF – end grazing (% DM)</td>
<td>41.1</td>
<td>44.9</td>
<td>40.9</td>
<td>42.5</td>
<td>1.08</td>
<td>n.s.</td>
</tr>
<tr>
<td>IVDMD – end grazing (%)</td>
<td>71.2</td>
<td>64.8</td>
<td>69.5</td>
<td>68.3</td>
<td>1.12</td>
<td>n.s.</td>
</tr>
<tr>
<td>Total grazing days (/ha)</td>
<td>1595</td>
<td>1712</td>
<td>1463</td>
<td>1595</td>
<td>99</td>
<td>n.s.</td>
</tr>
<tr>
<td>LW gain, period 1 (g/head.day)</td>
<td>224</td>
<td>168</td>
<td>207</td>
<td>191</td>
<td>15.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>Total LW produced (kg/ha)</td>
<td>354</td>
<td>304</td>
<td>336</td>
<td>351</td>
<td>23.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>Feed-use efficiency (kg DM/kg LW gain)</td>
<td>8.1</td>
<td>10.3</td>
<td>8.1</td>
<td>7.9</td>
<td>0.66</td>
<td>* n.s.</td>
</tr>
<tr>
<td>Total DM at anthesis (t/ha)</td>
<td>12.41</td>
<td>10.79</td>
<td>12.76</td>
<td>11.71</td>
<td>0.803</td>
<td>n.s. n.s.</td>
</tr>
<tr>
<td>Total DM at harvest (t/ha)</td>
<td>13.59</td>
<td>15.51</td>
<td>14.82</td>
<td>15.95</td>
<td>0.525</td>
<td>n.s. n.s.</td>
</tr>
<tr>
<td>Grain yield (t DM/ha)</td>
<td>6.72</td>
<td>7.08</td>
<td>6.68</td>
<td>7.08</td>
<td>0.481</td>
<td>n.s. n.s.</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>10.8</td>
<td>11.2</td>
<td>11.7</td>
<td>12.0</td>
<td>0.45</td>
<td>n.s. n.s.</td>
</tr>
<tr>
<td>100 grain weights (g DM)</td>
<td>3.89</td>
<td>3.86</td>
<td>3.75</td>
<td>3.79</td>
<td>0.084</td>
<td>n.s. n.s.</td>
</tr>
<tr>
<td>Bulk density (kg/L)</td>
<td>80.6</td>
<td>79.8</td>
<td>80.1</td>
<td>79.9</td>
<td>0.75</td>
<td>n.s. n.s.</td>
</tr>
<tr>
<td>Ears/m²</td>
<td>388</td>
<td>470</td>
<td>468</td>
<td>478</td>
<td>18.8</td>
<td>** **</td>
</tr>
<tr>
<td>Grains/ear</td>
<td>44.7</td>
<td>39.5</td>
<td>38.1</td>
<td>40.1</td>
<td>2.12</td>
<td>n.s. n.s.</td>
</tr>
</tbody>
</table>
compared with the RG treatment (179 ± 10.1 g/day). Lambs gained 0.16 ± 0.02 of a BCS over the period, and this was unaffected by treatment. Starting LW and BCS for the second grazing period were 46.3 ± 0.42 kg and 3.0 ± 0.04 respectively. There were no differences between treatments in total LW produced per hectare (336 ± 11.7 kg/ha).

The harvest indices (46.1 ± 1.35%), grain screenings <2.2 mm (10.9 ± 0.42%) or >2.5 mm (64 ± 1.15%), or bulk density (80.1 ± 0.33 kg DM/L) were not different between treatments. Ungrazed exclosures produced greater total DM yield at anthesis (15.4 ± 0.59 t/ha, P < 0.001), and progressed to anthesis ~10 days earlier, than grazed areas. Ungrazed areas also had greater total DM yield at harvest (16.8 ± 0.45 t/ha) than CG plots (P < 0.01), but lower grain yields (5.60 ± 0.40 t/ha, P = 0.04) than RG areas, overall producing a lower harvest index (33.2 ± 2.34%, P < 0.01) compared with the grazed areas. Density of ears was greater (P = 0.03) for the ungrazed (521 ± 24.0 m²) than CG areas, but grains per ear were fewer (28.3 ± 2.19 per ear, P < 0.01) than the grazed areas.

Two additional CG plots were also measured that were aimed at investigating grain-yield effects after maximising forage utilisation by maintaining SR after residuals fell below 400 kg DM/ha at GS 30. These plots had a final residual of ~400 kg DM/ha at GS 30. Animal and crop production results did not differ from the CG Low residual treatment (data not shown).

Discussion

Given the high nutritional quality of dual-purpose winter wheat recorded in this and in other studies (Cobeltz et al. 2002; Freebairn et al. 2002; Kelman and Dove 2007), it is not surprising that a linear relationship existed between available forage and lamb LW gain. However, there were no significant differences in total lamb LW produced per hectare between end-grazing residuals ranging from 500 to 950 kg DM/ha at GS 30. The regression indicated that a feed on offer of 550 kg DM/ha was needed to maintain lamb LW, and that lambs should be monitored more closely once available feed falls below 800 kg DM/ha, as was found by Lippke et al. (2000) with steers grazing irrigated wheat pastures. At lower residuals, a greater proportion of feed intake is used for maintenance and grazing energy expenditure. RG to a 500 kg DM residual tended to produce the least LW per ha and this was influenced by reductions in feed CP content, digestibility and use efficiency at low residuals for that system. CG allows greater expression of dietary selectivity, in terms of an individual animal’s ability to maintain their consumption of plant parts that are of relatively greater nutritive quality, and this likely contributed to the greater animal performance at lower residuals when compared with RG. The nutritive analysis indicated feed quality was similar for residuals >500 kg DM/ha, with no differences in animal performance observed between CG or RG treatments at the 900 kg/ha residuals. Rates of LW gain in the first 35 days were less than has been previously reported for similar lambs grazing winter wheat (Dove et al. 2007). With hindsight, this may relate to the selection of a greater SR than was appropriate for the growing conditions, in light of greater rates of LW gain recorded earlier in the grazing period while forage availability was greater, as well as cold weather experienced during the trial. It was a limitation of the trial that plots had to be destocked before reaching GS 30. From these observations, a SR of 30–35/ha should provide both even grazing pressure and the opportunity to maximise LW production per hectare. Winter wheats contain excess K and marginal Mg (Horn et al. 1995), with high rumen K reducing Mg absorption (Freer et al. 2007).

Blood analyses of circulating Mg after 28 days of grazing were in the normal range (Freer et al. 2007), confirming that supplementation with 1:1 MgO:salt (Dove et al. 2007) was effective in correcting any Mg deficiency. The total LW production of 300–350 kg/ha from a total of 46 days of grazing highlights the potential of these irrigated dual-purpose winter cereal systems.

Quadrat cut grain yields were lower than previously observed for cv. Mackellar in Tasmania (Dean et al. 2009), with damage to the developing grain embryo occurring due to frosts in late October. This was particularly evident in ungrazed areas, which had reached anthesis ~10 days earlier, resulting in a decrease in the number of grains per ear compared with grazed areas. CG and lower end-grazing residuals produced a reduced density of ears compared with RG and greater residuals respectively; however, grain yields were not significantly affected. Grazing has a variable impact on grain yields, relating to the seasonal growing conditions experienced (crop development relative to frost incidence, disease, crop lodging and water availability) and the removal of plant growing points (Dann et al. 1983; Virgona et al. 2006). In this trial, grazing was managed to avoid growing-point removal, little lodging or disease occurred (data not shown), and while grazing reduced the density of ears, frost damage reducing the number of grains/ear was less evident. Plant DM production at anthesis and harvest was greater for ungrazed areas; however, an end-grazing residual of 940 kg DM/ha did not result in greater DM production than for the 520 kg DM/ha residual. Regrowth following grazing, and so leaf area index at anthesis, is affected by the grazing pressure applied (Davidson et al. 1990). As a result of reduced transpiration, under dryland conditions grazed crops use less water during and soon after grazing, and this water may be subsequently used at a greater efficiency during grain filling (38 kg/ha.mm, Virgona et al. 2006). In the present study, grain yields and quality were unaffected by grazing management or end-grazing residual, suggesting that a greater reduction in leaf area at GS 30 does not compromise grain production where irrigation is available.

In conclusion, irrigated dual-purpose winter wheat provides a high-quality forage source, producing lamb growth rates consistent with forage availability. From our results, there does not appear to be any advantage in implementing a rotational system compared with continuous grazing. Dual-purpose irrigated winter wheat can be continuously grazed to a 500 kg DM/ha residual at stem elongation to produce in excess of 300 kg lamb weight gain per hectare, without compromising subsequent grain yield or quality.

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