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Red Meat Targets: Grazing Management of Dual-Purpose Winter Wheat under Irrigation

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Abstract

Dual-purpose irrigated winter wheat offers a high quality forage source to fill the winter feed gap in southern Australia, without compromising grain yields. A trial compared set-stocking and rotational prime lamb grazing systems and three end-grazing forage residuals for animal performance and grain yield outcomes. Grazing of *Mackellar* wheat increased grain yields in comparison with not grazing. Set stocking to 520kg DM and rotational grazing to 940kg DM/ha at wheat stem elongation produced around 350 kg of lamb weight gain/ha, and 6.7 and 7.1 T/ha of grain respectively, and tended to outperform the other treatments for total income, returning $1870 and $1820/ha respectively. The rate of lamb weight gain declined in line with reductions in available forage, with a minimum offer of 1000 kg DM/ha required to maintain good growth rates. The trial developed practical management recommendations for the effective grazing of dual-purpose winter wheats.

Executive Summary

The Red Meat Targets RD&E Program (RMT) was a 5-year joint venture agreement between the Tasmanian Institute of Agricultural Research, the Department of Primary Industries and Water, Tasmania, and MLA. The RMT identified through a participatory planning process that options to fill the winter feed gap and improve continuity of red meat supply in Tasmania were needed. Extensive areas of Tasmania have been developed for cropping under centre pivot irrigation, and new dual-purpose wheat cultivars offer high quality winter forage for meat-producing lambs. While continuous grazing is more common under irrigation to maximise animal performance, producers are also using rotational grazing to better manage grazing pressure, reduce wastage and control feed intake. The aim of this 1-year project was to quantify lamb performance and grain yield of irrigated dual purpose wheat and evaluate set-stocked & rotational grazing systems and 2 end-grazing forage residuals.

The trial was carried out on irrigated *Mackellar* wheat in the northern Midlands of Tasmania. The grazing treatments comprised two grazing systems (set-stocked, 4 paddock rotation) and two post-grazing residuals (400, 800 kg DM /ha when the crop reached Zadoks Growth Stage 30) replicated 3 times in 0.2ha plots. Two extra set-stocked plots (0 kg DM/ha) were included to maximise forage harvest. Mixed-sex, second cross, 10 month old, Dorset/Suffolk lambs (37kg, 2.5 BCS, 50kg DM/hd) were put on plots when forage reached a mean 1850 kg DM/ha. Lambs were weighed weekly, BCS determined at the start and end of grazing, and faecal samples collected to monitor worm burdens. As plots were grazed down to the desired forage residuals before GS 30 was achieved, all animals were removed after weighing at the end of the fifth week of grazing. Plots were re-stocked 21 days later for a further 11 days until GS 30 was achieved. Crop measures included DM accumulation at harvest, grain yield, protein content, percentage screenings, and specific (test) weight.

End-grazing residual DM did not differ between grazing systems and were 520 ± 23 and 940 ± 29 kg DM/ha for the 400 and 800kg treatments respectively. The average daily forage growth rate during the grazing period was 38 kg DM/ha. Number of lamb grazing days did not vary between set-stocked and rotational management (Table A). The average rate of liveweight (LW) gain declined each week during the initial grazing in line with reductions in available forage. A minimum offer of 800 to 1000 kg DM/ha was required to maintain good rates of lamb LW gain. Lambs gained an average of 0.17 of a BCS during grazing and 195g/d LW. Rotationally grazing to a 400kg DM/ha residual resulted in higher end-grazing forage fibre and lower protein and DM digestibility levels, and required a greater amount of forage DM per kg LW produced than set stocking to a 400kg residual, or rotationally grazing to 800 kg DM/ha. This included feed consumption, leaf senescence and trampling losses. There was no difference in forage utilisation between set-stocking and rotational grazing. As the forage had excess potassium, blood concentrations were elevated after 28 days on feed, but magnesium concentrations were within the normal range, indicating loose mix supplementation with 1:1 magnesium oxide & coarse salt, provided *ad libitum* (about 20g/h/d) was effective. Drenching pre-grazing effectively controlled internal parasites, bloat was not observed, light footrot was controlled by foot-bathing (10% zinc sulphate solution), & no lamb deaths occurred.

Grain yields were lower ($P < 0.05$) for ungrazed areas (5.6 ± 0.38 T/ha) than for set stocked (6.58 ± 0.27 T/ha) or rotationally grazed areas (7.08 ± 0.31 T/ha). While harvested quadrat yields were in line with past results, mechanical harvester yields were lower than expected due to grain losses from wind damage prior to harvest. Total plant DM accumulation at harvest and the number of grain ears per m^2 were higher for rotationally grazed plots compared to set stocking to 400kg, but grain yields and quality parameters were unaffected by grazing treatments. While the separate economic returns for lamb and grain were not statistically different for the different grazing systems, when the returns for both grazing and grain are combined, the 400kg set stocking and 800kg rotationally

grazed treatments outperformed the other systems. There was no economic difference between set and rotational grazing when post-grazing residual was not taken into account.

Table A. Lamb performance and grain yield characteristics from grazed winter wheat.

	Set Stocked			Rotationally Grazed		SEM
Item	0	400	800	400	800	
Grazing Days (/ha)	1723	1595	1463	1712	1595	104.4
LW gain (g/h/d)	183[ab]	224[b]	207[ab]	168[a]	191[ab]	18.2
LW produced (kg/ha)	332	354	336	304	351	31.2
FCE (kg DM/kg LW)	10.4[ab]	8.2[a]	8.1[a]	10.3[b]	7.9[a]	0.69
Meat Income ($/ha)	670	713	677	614	707	62.8
Yield (T DM/ha) - hand harvested	6.22	6.71	6.68	7.08	7.08	0.462
Yield (T DM/ha) - machine harvested	4.65	5.04	4.27	4.58	4.86	0.372
Bulk density (kg/hL)	80.8	80.6	80.1	79.8	79.9	0.71
Crude protein (%)	10.85	10.8	11.7	11.2	12.0	0.43
100 grain wt (g DM)	3.97	3.89	3.75	3.86	3.79	0.082
Grain < 2.2mm (%)	8.4	9.7	11.4	11.3	11.3	0.92
Grain > 2.5mm (%)	68.8	66.6	65.2	63.9	61.7	2.28
Grain Income ($/ha)	1069	1159	983	1053	1117	85.6
Total Income – grazing & grain ($/ha)	1738[ab]	1872[a]	1659[b]	1667[b]	1824[ab]	57.4

Averages presented with different superscripts are statistically different ($P < 0.05$). SEM – standard error of the mean, FCE - feed conversion efficiency. Gross returns do not account for additional labour and fencing associated with rotational grazing.

Grazing increased grain yields over ungrazed areas, reduced lodging, and there were no clear advantages in rotational grazing over set stocking under the conditions of this trial. The greatest LW production per hectare, best feed efficiencies and financial returns were achieved when set stocking to a lower residual and when rotationally grazing to a greater residual. Lamb growth rates above 200g/d were achieved when FOO was above 1000 kg DM/ha. Lamb LW should be monitored more closely once feed on offer falls below 800 kg DM/ha. Advantages of rotational grazing may still apply within larger paddocks, to avoid patch-grazing and to ensure even forage utilisation over the area. This would not have been tested in the small experimental plots used. Greater grazing pressure and lower residual resulted in a more open crop canopy and encouraged weed competition. Effective chemical control of ryegrass post-grazing is important for maintaining grain yields.

Two extension events were held and the results of the trial presented to over 80 participants, and in articles in Tas Regions and The Advocate. This project will provide prime lamb producers with basic quantitative knowledge of animal, grain and economic performance levels from both rotational and continuous grazing systems and a summary of important practical considerations to assist them manage grazing and grain yields of winter cereals under irrigation. Future research could address; timing of the start of grazing relative to DM accumulation to maximise LW production; systems studies including management of cattle and rotations at commercial scales; the physiological drivers of feed intake control on these high quality feeds; and post-grazing management, including fertilisation to offset animal related nutrient removal.

Contents

1 Background

The development of profitable grazing management systems for improving supply of finished stock during winter has been identified through Tasmanian red meat industry consultation as a priority area for research (Red Meat RD&E Business Plan 2003-2008). The use of dual purpose wheat as a high quality forage can contribute to overcoming the feed-gap that occurs during winter in temperate Australia, and which limits overall carrying capacity of farms in this region. Extensive areas of Tasmania have been developed for cropping under centre pivot irrigation, with the pressure to maximise returns on this capital investment driving the increasing interest in the use of dual-purpose winter cereal crops. Winter wheat has a requirement for a period of cold temperatures (vernalisation) before progressing onto the reproductive stages of growth and the production of grain. This means that these varieties can be sown early and be maintained in a vegetative state and able to be grazed during winter months until the vernalisation requirement is satisfied without risk of grain yield reductions. While the potentially conflicting aims of maximising animal production and grain yields have been achieved successfully, past grain yield outcomes have been variable, ranging from a decrease due to grazing of almost 28% to an increase of 18%, and an average across 134 comparisons of a 4% reduction (Virgona et al., 2006). More research is indicated to enable producers to confidently implement these dual-purpose systems.

A Red Meat Targets internal review of Australian research work (mainly dryland based) and publications in the international scientific literature revealed that while it is well understood that grazing must cease before stem elongation (Zadoks growth stage 30), there is a lack of relevant information on the post-grazing residual required for optimising animal liveweight (LW) production while maximising subsequent grain yields. Beef research 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 et al., 2003). Further, as nutritive value of winter cereals is quite high throughout the growing season (Lovett and Matheson, 1974; Coblentz et al., 2000, 2002; Freebairn et al., 2002; Kelman and Dove, 2007), available feed on offer is likely to determine individual animal forage intake and hence will determine animal LWG performance. While continuous grazing is more common, Australian producers are also using rotational grazing of dual-purpose cereal crops to better manage grazing pressure, reduce wastage and control feed intake. Grazing pressure needs to be high enough to avoid patch grazing (Vergona et al., 2006), but not so high that the time required for plants to recover from grazing is extended.

In summary, there was a need to compare the impact of post-grazing residual, under both set-stocking and rotational winter wheat grazing systems, on forage utilisation, animal health and productivity and grain yields.

2 Project Objectives

The objectives of this project were to:

1. Quantify lamb performance on irrigated dual purpose wheat
2. Evaluate in agronomic, animal health and economic terms, set-stocked & rotational grazing systems and 2 end-grazing residuals for lamb performance
3. Quantify grain production from grazed, irrigated dual purpose wheat, and evaluate set-stocked & rotational grazing systems and 2 end-grazing residuals for grain production

4. Compare the agronomic, animal health and economic outcomes of these alternative grazing management strategies for grain and lamb production, and potential for cattle production, highlighting threats/opportunities for the grazing cereals
5. Monitor and evaluate the presence/significance of internal parasites under irrigation, including appropriate baseline data on burdens and applicable anthelmintic resistance data
6. On the basis of the trial results, draft guidelines for grazing cereals under irrigation systems.

3 Methodology

The project met the requirements of the UTAS Animal Research Ethics approval process prior to commencement.

3.1 Trial design

The treatments comprised two grazing systems (set stocked or rotationally-grazed) and two post-grazing residuals (400 and 800kg/ha DM when the crop reached Zadoks Growth Stage 30). Therefore, the experimental design was a 2 x 2 factorial, replicated three times, plus a replicated set stocked control area aimed at achieving maximum forage utilisation. Treatment allocation to plots was randomised.

3.2 Trial site

The trial was carried out at Stewart and Gordon McGee's property 'Stratheden' near Bishopsbourne in the northern Midlands of Tasmania (41^{o}.37'.16"S, 147^{o}.00'.23"E, 184 m elevation). The soil type was a Dermosol gradational red brown clay loam with the chemical and nutrient profile presented in Table 1. The trial area had previously been planted with poppies (*Papaver somniferum*).

Table 1 Soil characteristics at the trial site (0 to 20 cm depth, n = 5 samples).

	Mean	*SE*
pH (H_2O)	5.92	0.05
Bulk density (g/cm^3)	1.06	0.019
Nitrate N (mg/kg)	17.6	1.17
Phosphorus (mg/kg)	103	9.0
Potassium (mg/kg)	384	23.6
Sulphur (mg/kg)	18.1	1.01
Organic carbon (%)	3.9	0.15
Conductivity (dS/m)	0.10	0.003
Exch. Ca (meq/100g)	9.97	0.309
Exch. Mg (meq/100g)	2.22	0.131
Exch. Na (meq/100g)	0.11	0.004
Exch. K (meq/100g)	0.95	0.055

The trial site was fenced into 14 x 0.2 ha plots (as 2 rows of 7 plots with a central laneway), with the 6 rotationally-grazed plots further divided into 4 sub-plots using netting fences (Figure 1). Water was provided in troughs to each of the plots. Un-grazed exclosures (2.5 m^2) were included in each plot to record ungrazed forage and grain production. Forage growth rate during the grazing period was estimated from three 50 x 50 cm quadrats cut to ground level from 6 exclosures across the trial site.

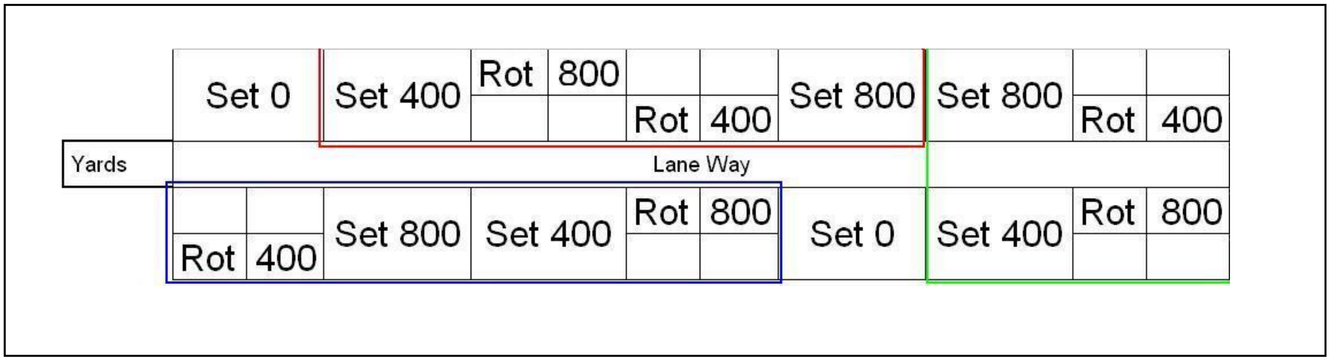

Figure 1. Trial site layout indicating treatment locations and the 3 replicates outlined in blue, red and green lines. (Set = set stocked, Rot = rotationally grazed, 0 = maximum utilisation, 400 = 400kg DM/ha residual, 800 = 800kg DM/ha residual.)

Weather conditions at the trial site were recorded daily (recording every 30 min of rainfall, temperature, humidity, and wind speed) from a weather station (Watchdog 2700, Spectrum Technologies Inc., IL, USA) located in the centre of the trial site.

3.3 Crop and animals

The dual-purpose winter wheat variety used was *Triticum aestivum* L. *subsp. Aestivum* cv. *Mackellar*, a longer season, awnless feed-wheat variety resistant to Barley Yellow Dwarf Virus (BYDV) and moderately resistant to stem, leaf and stripe rust. The crop was sown on 13 March 2008 (120 kg/ha, 17.5cm row spacing) using seed treated with triadimenol (Baytan®, Bayer Crop Science). The paddock was fertilised at sowing with 9:14:17 NPK (250 kg/ha) fertiliser and was irrigated (50mm in total) during the period 14 to 21 March to assist crop establishment. The crop was sprayed with MCPA (2-methyl-4-chlorophenoxyacetic acid, 1.5L/ha) and carfentrazone-ethyl (50g/ha Affinity®, Cropcare) herbicides on 16 April 2008.

After grazing, on 30 August, 140 kg/ha of urea was applied to the paddock followed by 2 applications of a fungicide (Tilt®, 100ml/ha, Syngenta) on 24 September and 8 October. Supplemental irrigation was applied on 24 October (70mm, with 110 kg urea/ha), on 29 October (70mm, over 2 days, no fertiliser), and again on 24 November (50mm over 3 days).

Mixed-sex, second cross Dorset/Suffolk lambs (n = 115) born on the property during August 2007 were used in the trial. These lambs were drenched with Ivermectin (Genesis® with selenium, 10ml/head) and then grazed on Feast ryegrass for 35 days prior to trial commencement. On the day prior to stocking the lambs were weighed (6 hr curfew), body condition score (BCS) recorded (2.5 ± 0.05 BCS, Russel et al., 1969) and allocated to treatment group. Treatment groups were balanced for LW and BCS. Blood samples (10ml, jugular) were also taken from 10 randomly selected lambs and analysed for calcium, magnesium, sodium, potassium and GSHPx (Glutathione Peroxidase - an indicator of selenium status).

On 29 May, the treatment lambs were weighed without curfew (37.3 ± 0.73 kg LW, mean ± S.D.), drenched again, a booster vaccine administered (Guardian 6 in 1®, 2ml), and the lambs placed in the appropriate treatment plots. Stocking rate (SR) allocations were based on the provision of 50kg DM/head (as at 24 May), producing an average SR of 41 head/ha and 45.4 kg DM/head at the commencement of grazing (1850 ± 288 kg DM, mean ± s.d.). SR was selected to ensure sufficient grazing pressure to avoid patch grazing effects.

Lambs were weighed without a curfew at the same time weekly and BCS determined at the commencement and completion of grazing. Faecal samples were collected per rectum from 3 individually-identified lambs per plot group (2 replicates of each treatment) at initiation of grazing (pre-drenching) and then on a fortnightly basis, and ova counts completed for *Strongylus* and *Nematodirus sp*.

In Week 2 of grazing, lambs were supplemented with 1:1 MgO & salt, provided *ad libitum* (about 20g/h/d) as a loose mix. In response to incidences of footrot (protease stable *Dichelobacter nodosus*), a foot-bath containing a zinc sulphate solution (10% as zinc sulphate heptahydrate) was used at each weighing from Week 3 of grazing. A blood sample was collected from 3 lambs randomly selected from each plot group after 28 days of grazing and analysed for Mg, Na and K. Of these, 10 samples were randomly selected and also analysed for Ca, GSHPx, Cu and Vitamin B12. A subjective dag score (1 to 5 where 0 = none, 1 = very light, 2 = light, 3 = heavy, 4 = very heavy) was recorded for all lambs at the end of the grazing period.

3.4 Grazing management

Set-stocked treatments had lambs grazing the entire plot area during the grazing periods; rotationally-grazed sub-plots were grazed to a residual similar to the desired treatment residual level and then the animals were removed to the next sub-plot. This occurred about every 6 to 7 days. As some plots were grazed down to the desired forage residuals before Growth Stage 30 was achieved, the SR in those plots (all 800 kg residual plots, 400 kg - 2 rotational and 1 set stocked plot) was reduced to 25 lambs/ha during the fourth or fifth weeks of grazing, to maintain the desired forage residual levels. However, due to the emergence of patch-grazing in those plots and LW loss in some lambs, all animals were removed from the trial site after weighing at the end of the fifth week of grazing, producing an initial grazing period of 35 days (to 3rd July). To achieve the desired post-grazing residuals when the plants reached Growth Stage 30, plots were re-stocked 21 days later (with trial and some additional lambs from the paddock surrounding the trial site) for a further 11 days. The additional forage production and utilisation, and animal production from this final grazing were recorded. Growth stage at the end of grazing was monitored by dissection of 10 randomly selected plants per plot (excepting the 400 kg rotational plots).

A rising plate meter (31.5 x 31.5 cm) was used for determining forage DM yield on a weekly basis and at stock rotations, with at least 60 recordings per plot, and 20 per rotational sub-division. Meter readings were calibrated at each use by linear regressions of meter height against DM/ha measured from 10 to 12 quadrat cuts (50 x 50cm, to ground level, dried at 100^{o}C for 24 hours) taken across the range of forage mass present (Earle and McGowan, 1979). Un-grazed plant DM accumulation was measured using a minimum of 3 x 0.25m^2 quadrats taken from 6 exclosures across the trial site at the end of grazing, at anthesis, and again at harvest.

Forage samples (bulked per plot) were collected prior to initial grazing for analysis of Mg, Ca, K and Na contents by a NATA accredited laboratory. Prior to initial stocking and then fortnightly during grazing, from 4 random quadrat samples bulked from within each plot (dried at 60^{o}C, ground 1 mm screen), measures were made of forage nutritive quality (DM, OM, NDF, ADF, N) and 48 hr *in vitro* digestibility (rumen fluid from 4 fistulated wethers fed a diet of 60% lucerne chaff and 40% concentrate pellet) in an Ankom Daisy II incubator (Ankom Technology, Macedon, New York, USA).

Average DM intake on a weekly basis was estimated from the difference in accumulated DM in each plot or subdivision using the rising plate method outlined above, corrected for forage growth recorded within the grazing exclosures, divided by the number of animals per plot for the period.

Feed conversion efficiency (feed: gain) was calculated from this estimated DM use divided by the amount of LW produced in the period.

3.5 Post-grazing and grain measures

Prior to and after grazing was completed, soil compaction was measured using a penetrometer at one location in each of the three 400kg set stocked plots and in the relevant ungrazed enclosures. Soil water profile was measured using a push tube at flowering in 3 replicates of the set and 2 replicates of the rotationally grazed 400 kg DM residual plots (0 to 5cm and 5 to 10cm, dried at 100^{o}C to constant weight).

Grain yields were measured on 30 January 2009 using a plot harvester (Kingaroy Engineering Works Pty, Ltd, Kingaroy, Queensland) cutting 1 to 2 harvester widths x 10m long from each plot. Percentage screenings, specific (test) weight and crude protein were determined using standard procedures. Measures of DM accumulation were taken at flowering and at grain harvest using 4 x 0.25 m^2 quadrats per set-stocked plot and 3 per rotationally grazed subplot. Length and weight of these quadrat plant samples were recorded before being dried at 60^{o}C to constant weight to calculate total DM yields, grain yields, harvest index (ratio of grain yield to total plant DM yield). From these hand harvested samples, average grain weight (300 grains) and number of ears per square meter and grains per ear were also determined.

3.6 Economic analysis

To estimate gross income from the LW produced, LW was valued at $4.20/kg dressed (48% dressing used), based on commercial values for similar lambs sold at the time from the wheat crop outside the trial site. Skin values were set at $8/skin, also based on current prices for skins in Tasmania, and this was added to LW income on a per head basis at the initial SR applied. The addition of skin values was done for comparison purposes with a local grazing trial run in 2007. Grain was valued at $230/T on the basis of current market values for similar red feed wheat.

To compare grazing systems on the basis of additional fencing and labour for lamb paddock movements within the rotational system, a 100ha area was used for calculations. This was considered to be divided into 4 sub-paddocks using a temporary electric fence (mains energiser, 3 x 1.6mm wires, 10m post spacing, 5 additional strainer posts and 4 gate posts) and a single moveable water trough and associated poly-pipe and fittings. Using materials costs relevant to the trial infrastructure this was calculated to cost $4000. Erection of the fence was estimated to take 20hr of labour valued at $30/h, and livestock and water trough movements to take 1 hr of labour valued at $30/hr for 2 grazing events within each subdivision. Total additional costs for a 100ha area under a rotational system in comparison to set-stocking for the same period were therefore $4850.

3.7 Extension

A progress report was provided to interested producers and this included a trial site inspection which occurred on 30 July 2008. The purpose and method of the trial was highlighted, and an overview provided of the animal performance results to date. A site walk was conducted allowing producers to see the targeted grazing residuals, the livestock in some plots and the stage of plant development.

A final overview of the trial results, including the grain production and final economic analysis, was presented at a Grains Research and Development Corporation Research Update Day in Hadspen on 24 July 2009. Trial results have also been promoted in rural press articles. A 4 to 8 page decision support brochure for producers was also to be prepared and a scientific paper for presentation to the Australian Society of Animal Production in 2010.

3.8 Statistical analysis

All statistical analyses were carried out using the SAS/STAT software (Version 9.1, 2002-2003, SAS Institute Inc., Cary, NC, USA). Analysis of variance was performed using least squares regression (PROC GLM of SAS) to fit a general linear model containing the fixed effects of management type (set stocked or rotationally grazed) and residual forage level within management type (0, 400 and 800 kg DM/ha). Least Squares means are presented as appropriate and differences between means were tested using protected t-tests. Penetrometer measurements for grazed and un-grazed areas were compared using 2 sample t-tests at each depth. DM and grain yields for the un-grazed exclosures were compared against the set-stocked and rotational systems using a model including management system only. Significance was declared at $P < 0.05$ and trends discussed at $P < 0.10$.

4 Results and Discussion

4.1 Results

4.1.1 Weather conditions

Weather conditions during the grazing period are presented in Figure 2. A total of 74mm fell in 3 rainfall events during the main grazing period, with mean minimum and maximum temperatures during that period of 4.5 ± 3.18 and 12.5 ± 1.62°C respectively. Average daily humidity was 84% and wind speed was 7.5 ± 6.87 km/hr, with daily average wind gusts of 30.8 ± 17.58 km/hr. There was one rainfall event during the final grazing period totalling 16.1mm, with mean minimum and maximum temperatures during that period of 0.4 ± 2.33 and 10.1 ± 1.20°C respectively. Average daily humidity and wind speed in that period were 83% and 3.3 ± 4.33 km/hr respectively, with daily average wind gusts of 18.4 ± 11.50 km/hr.

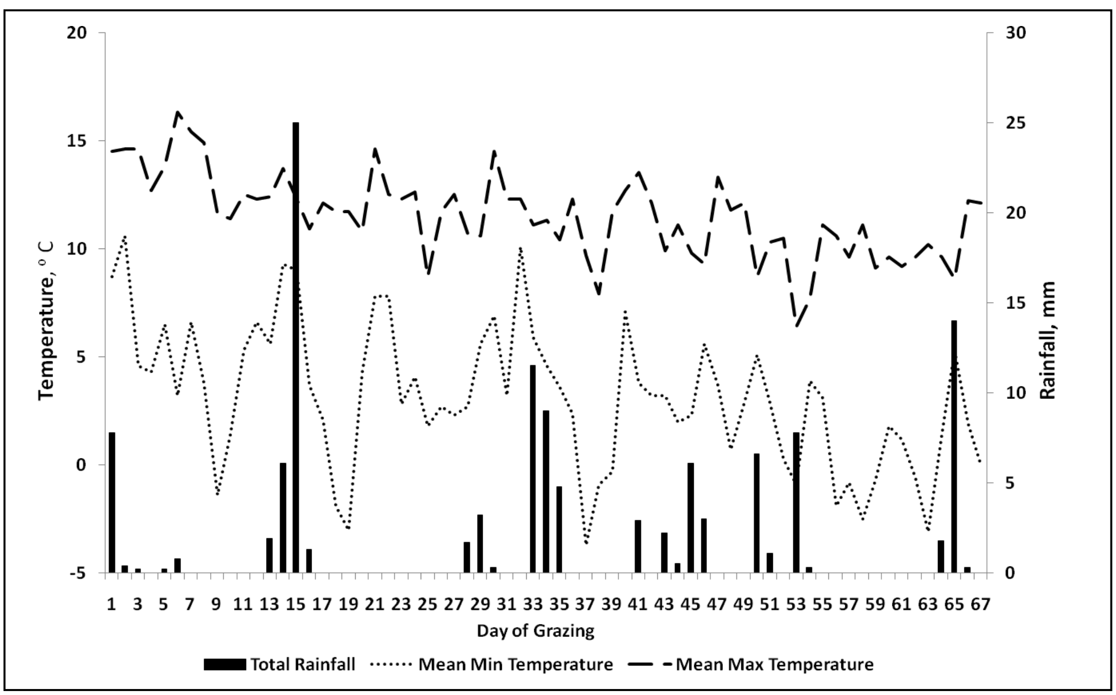

Figure 2. Weather conditions during grazing

Total crop growing season rainfall was 464 mm and total applied irrigation 240 mm. Air temperatures in the post-grazing period are shown in Figure 3, with several frosts experienced in October, and 5 days with maximum temperatures over 30°C in January 2009. Wind gusts of up to 60km/hr were experienced on 22nd January, 8 days prior to mechanical harvest, causing some grain losses.

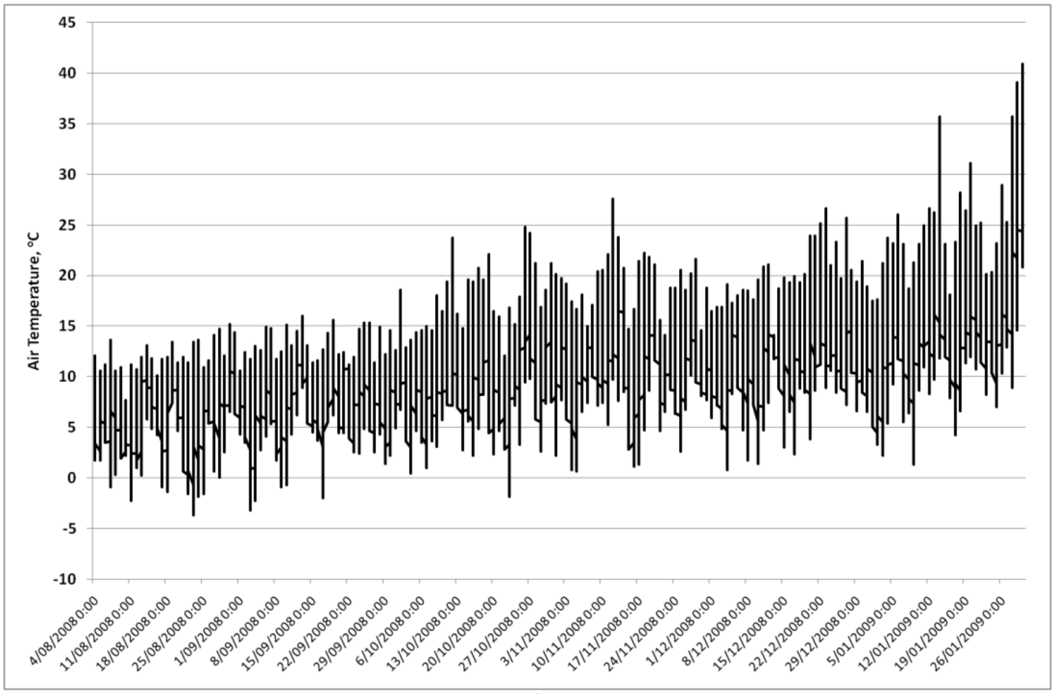

Figure 3. Post-grazing air temperatures (°C) to grain harvest.

4.1.2 Forage and soil

Recorded DM availability at the start of grazing was 1850 ± 288 kg DM (mean ± s.d.) and was not different across treatments (Figure 4). There were no ($P > 0.23$) plot differences in pre-grazing forage mineral contents across the trial site (Table 2). The post-grazing residuals at the end of the first grazing period were 540, 690 and 940 kg/ha for the 0, 400 and 800 kg residual levels respectively. There was no difference in residual DM between the set and rotationally-grazed 400 (610 vs. 770kg, respectively; $P = 0.29$) and 800kg (840 vs. 1040kg, respectively; $P = 0.18$) residual treatments.

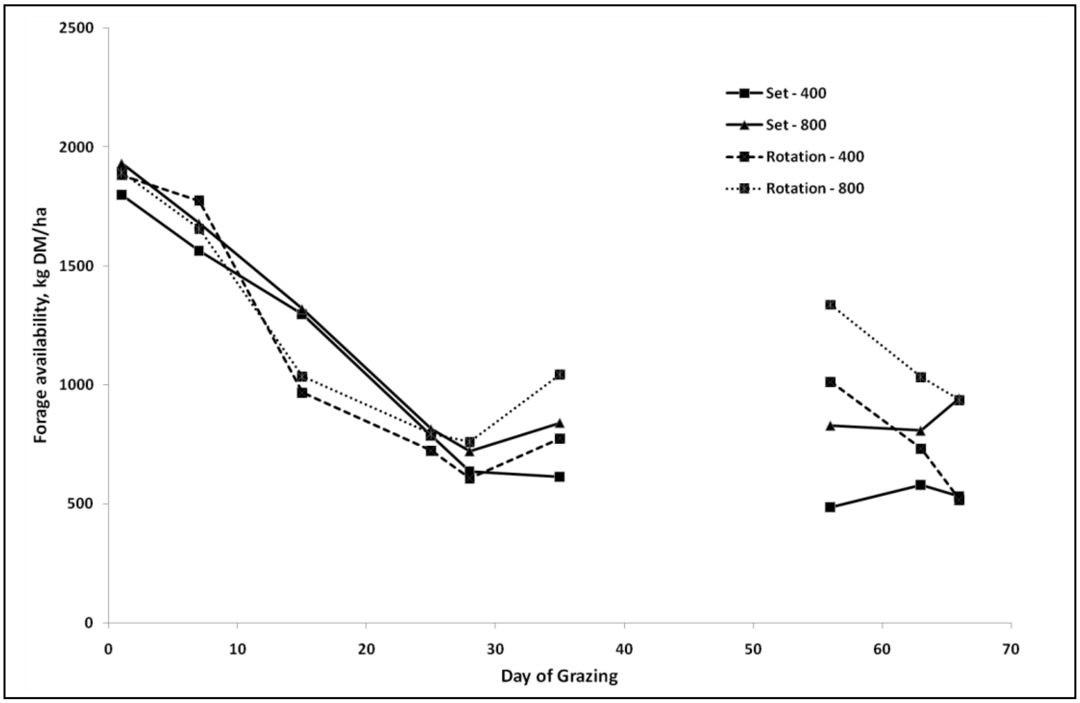

Figure 4 – Forage availability (kg DM/ha) of dual purpose winter wheat grazed by prime lambs. (SE of the LS means were 190, 126, 107, 94, 111, 100, 200 and 69 kg DM/ha for starting, end weeks 1, 2 ,3, 4, and 5 of initial grazing period, and for the start and end of the second grazing period respectively).

Table 2. Mineral content in pre-grazed dual purpose winter wheat.

Mineral component	Content in forage (g/kg DM)	Recommended allowances[1]
Potassium	55.9 ± 2.89	5.0
Phosphorus	3.9 ± 0.21	1.84
Calcium	2.5 ± 0.16	2.6
Magnesium	1.7 ± 0.10	0.9
Sodium	< 0.1	0.7

Mean ± S.D. presented
[1] – Anon. (2007) for growing lambs

The available DM at the start of the final grazing period tended ($P = 0.10$) to be lower in the set-stocked than the rotational plots for both 400 (490 vs. 1010 kg/ha, respectively) and 800kg residual treatments (830 vs. 1340 kg/ha, respectively). However, end-grazing residual DM amounts for these rotational and set-stocked treatments were not different ($P > 0.87$), being 410 ± 210, 520 ± 23 and 940 ± 29 kg DM/ha for the 0, 400 and 800 kg residual plots respectively. The 400 kg treatment end residual was less than ($P < 0.001$) the 800 kg treatment residual. To compare calibrated rising plate and quadrat cut methods, 4 quadrats were cut and bulked in each of the 14 plots at the end of grazing. The average of the differences between the rising plate estimates and the quadrat cut estimates was 87 ± 29.8 kg DM/ha (range of -69 to 282 kg), with cuts providing the higher estimate.

Average Zadoks cereal growth stage at the end of grazing was 29.7 ± 0.14 for the set-stocked plots and 30.3 ± 0.23 for the rotationally grazed 800kg plots ($P = 0.04$). There were no significant differences between the 0, 400 and 800 kg DM/ha set stocked treatments.

Nutritive quality analyses are presented in Figure 5. Grazing management had no (P > 0.05) effect on NDF content during the grazing period, although rotational grazing resulted in higher (P < 0.05) final NDF and ADF contents (44.9 and 26.2% of DM respectively) than set stocking (41.1 and 23.9% DM respectively) when grazed to the 400 kg residual.

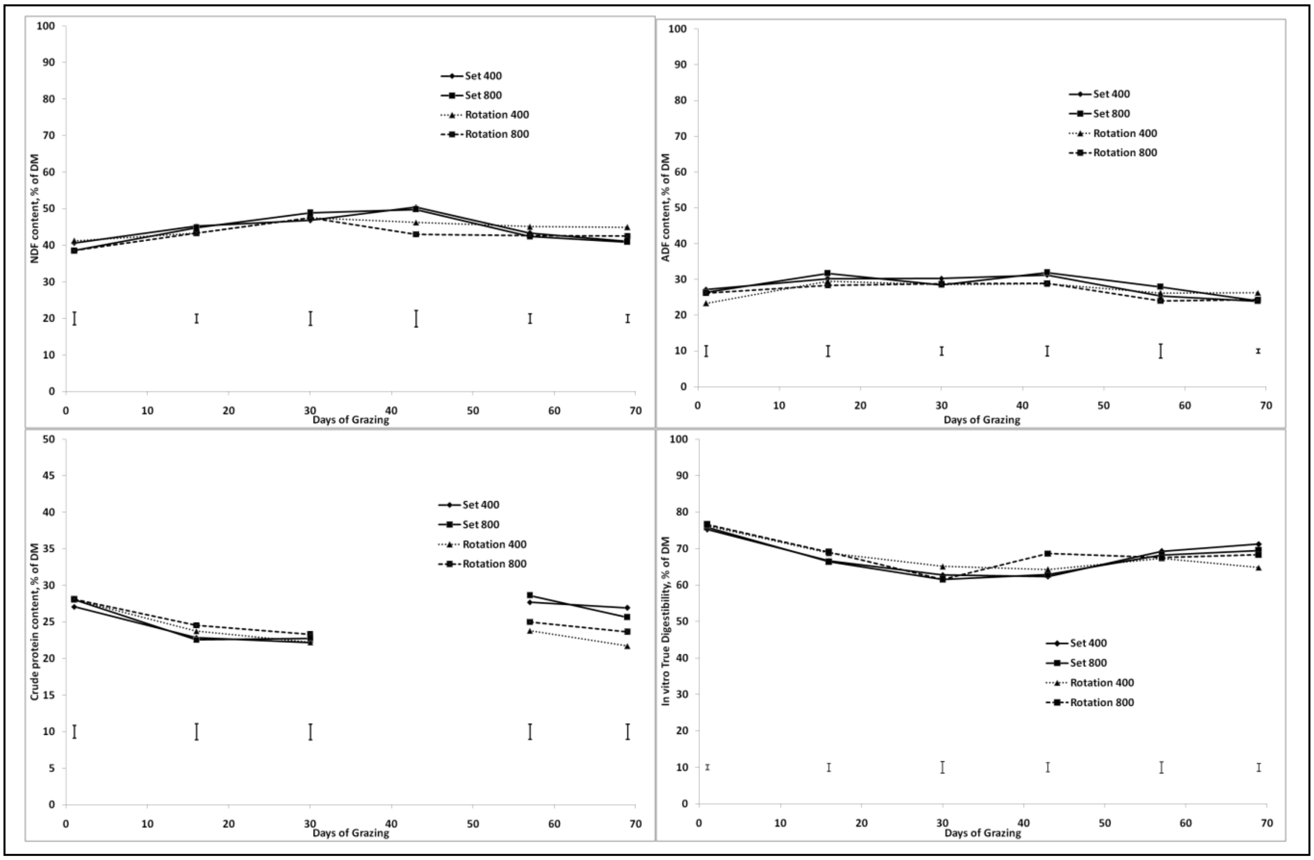

Figure 5. The NDF, ADF, crude protein and *in vitro* true DM digestibility (% of DM) of winter wheat grazed to 400 or 800 kg DM/ha using set stocked or rotational grazing practices (LS Means presented with SEM).

Crude protein concentrations at the end of the grazing period were lower (P < 0.01) for the rotationally grazed plots (21.7 ± 0.92% of DM) than the set-stocked plots (26.9 ± 0.92% of DM) when grazed to 400kg. There were no treatment differences of *in vitro* true DM digestibility at the start of grazing (76.0 ± 0.28%) or after 4 weeks of grazing (62.8 ± 0.80%). DM digestibility at the end of grazing was lower (P < 0.05) for the rotationally grazed plots when grazed to a 400 kg residual (64.8%) compared to the 800 kg residual (68.3%) or the set stocked plots (71.2% and 69.5% for 400 and 800 kg residuals respectively, SEM ± 1.06%).

Ungrazed forage accumulation calculated from exclosure quadrat cuts 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. The 800kg set–stocked treatment had greater estimated growth-corrected DM use during the main grazing period than the rotationally grazed treatment (490 vs. 390 DM/plot, respectively, SEM ± 29 kg; P = 0.05). These effects were offset during the final grazing period such that there was no difference in forage utilisation between set-stocked and rotationally grazed management types across both periods (400kg - 570 vs. 620 kg DM/plot; 800kg – 540 vs. 550 kg DM/plot; SEM ± 36.4 kg). This forage use data includes consumption, senescence and trampling losses. Trampling losses could not be measured accurately under the wet conditions during the trial.

The effect of grazing on soil penetration resistance is presented in Figure 6. Compared to the ungrazed areas, grazing tended to increase the soil's mechanical resistance to penetration at 15mm (314 ± 29.3 vs. 768 ± 216 Kpa; P = 0.10), at 30mm (475 ± 67.7 vs. 1155 ± 285 Kpa; P = 0.08) and numerically at 45 mm (591 ± 85.1 vs. 1113 ± 278 Kpa; P =0.147). Soil water profile measured at anthesis (crop flowering) showed no differences between grazed plots or ungrazed exclosures (22.5 ± 0.28 % DM, P = 0.95) or for samples collected at 0 to 5 cm and 5 to 10 cm (P = 0.55). Extensive pugging was not observed, although areas without forage cover did develop in corners of some plots, near supplement containers, and around the watering troughs.

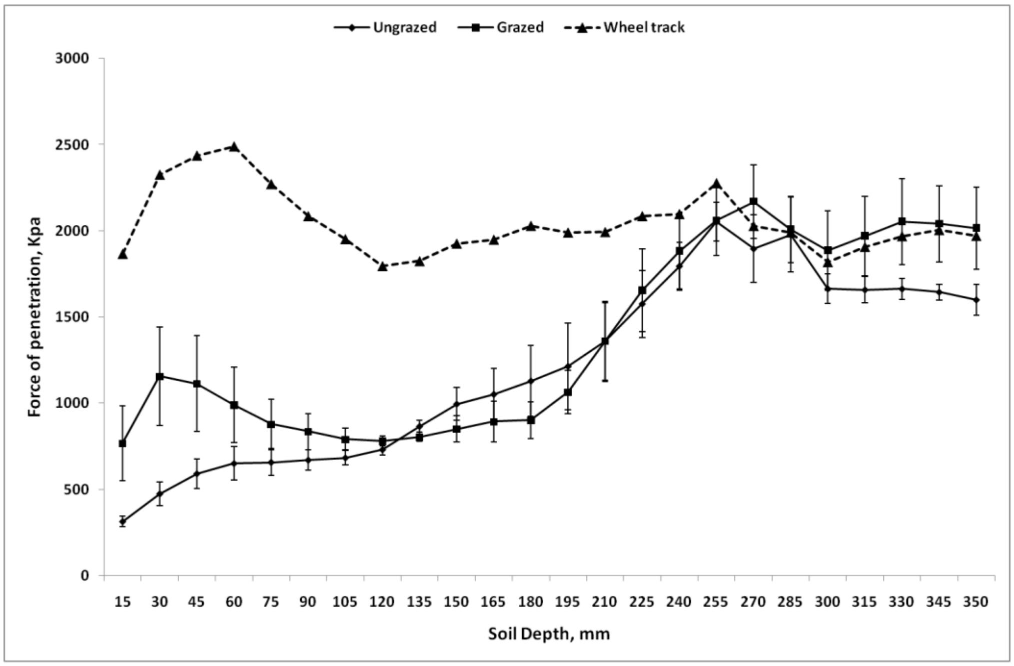

Figure 6 – Measure of the compaction effect of grazing on set-stocked plots grazed to 400 kg DM/ha compared with ungrazed exclosures and vehicular wheel tracks in the laneway around the trial site.

There were slight differences in anthesis date across the trial but these did not relate to grazing treatment effects. Ungrazed exclosures reached anthesis approximately 9 to 11 days earlier than grazed plots. Measures of DM accumulation taken at anthesis also showed no effect (P >0.10) of grazing management or end grazing residual on plant heights (94.5 ± 1.83 cm), plant DM percentage (34.5 ± 1.11%) or total DM accumulation (1184 ± 77 g/m^2). Further, there were no differences between the set stocked and rotationally grazed plots compared to ungrazed areas in terms of plant heights (P = 0.24), or DM percentage (P = 0.19) at anthesis. However, total DM accumulation was greater (P <0.01) in the ungrazed exclosures (1538 ± 58.9 g/m^2) than in the set stocked (1228 ± 31.7 g/m^2) or rotationally grazed (1125 ± 48.1 g/m^2) plots.

Crop disease control was good throughout the season with only a trace of stripe rust (*Puccinia striiformis*) being recorded, and there was some minor army worm damage observed prior to harvest.

4.1.3 Animal growth performance

The average SR in the first grazing period (38.2 head/ha) did not vary with management (P = 0.32) or residual level (P = 0.86), despite adjusting for initial DM availability in each plot and the SR adjustments in weeks 4 and 5 of grazing (Table 3). SR in the second period was higher for the rotationally grazed than set-stocked plots (29.2 vs. 16.3 head/ha, respectively; $P = 0.02$), but was not different over both periods (35.2 ± 1.57 vs. 33.9 ± 1.39 head/ha, respectively; $P = 0.56$). As expected, the number of lamb grazing days followed a similar pattern; the total number over the two periods did not vary between set-stocked and rotational management ($P > 0.40$).

LW and BCS at the commencement of grazing were 37.3 ± 0.73 kg and 2.5 ± 0.05, respectively and did not vary ($P > 0.10$) across plot groups (Figure 7). The average rate of LW gain each week declined through to Week 5, with the average rate of LW gain for the set stocked 400 kg treatment being higher ($P = 0.05$) than the average LW gain for the 400 kg rotationally grazed treatment.

LW change was linearly related to available forage as time on feed increased (Figure 8). Grazfeed predictions of lamb growth rate using the prevailing weather conditions, measured nutritive quality analyses and lamb characteristics produced expected daily rates of LW gain for 1800, 1000, 800 and 400 kg DM/ha of 245, 225, 209 and 158 g respectively. Lambs gained an average of 0.17 of a BCS over the period, and this was unaffected by treatments.

Starting LW and BCS for the second grazing period was 46.2 ± 0.40 kg and 3.0 ± 0.04 respectively. Total LW per hectare produced in both grazing periods was not different ($P > 0.29$) between set-stocked and rotational treatments. Rotationally grazing for the desired 400kg DM/ha residual required a greater amount of forage DM per kg LW produced (10.3 kg DM/kg LW) than set stocking for a 400kg residual (8.2 kg DM/kg LW, $P = 0.05$) or rotationally grazing for an 800 kg DM/ha residual (7.9 kg DM/kg LW, $P = 0.03$).

Table 3. Lamb grazing and growth performance on winter wheat grazed under set stocked or rotational grazing systems to 3 forage residual amounts.

	Set Stocked			Rotationally Grazed		SEM*
Item	0	400	800	400	800	
Stocking rate, hd/ha						
Period 1	40.0	39.5	38.3	38.1	35.9	2.28
Period 2	25.7[bc]	15.6[ab]	7.7[a]	30.9[c]	27.6[bc]	4.96
Overall	36.7	33.9	31.1	36.4	33.9	2.22
Grazing Days /ha						
Period 1	1440	1423	1378	1371	1292	82.1
Period 2	283[b]	172[ab]	85[a]	340[b]	303[b]	54.6
Overall	1723	1595	1463	1712	1595	104.4
LW gain, g/h/d						
Period 1	183[ab]	224[b]	207[ab]	168[a]	191[ab]	18.2
LW produced						
Period 1, kg/ha	256	314	312	237	278	33.7
Period 2, kg/ha	76	40	23	68	73	16.6
Overall	332	354	336	304	351	31.2
Overall FCE						
Kg DM/ kg LW	10.4[ab]	8.2[a]	8.1[a]	10.3[b]	7.9[a]	0.69

* SEM for 400 and 800kg DM residuals. Different superscripts indicate difference at $P < 0.05$.

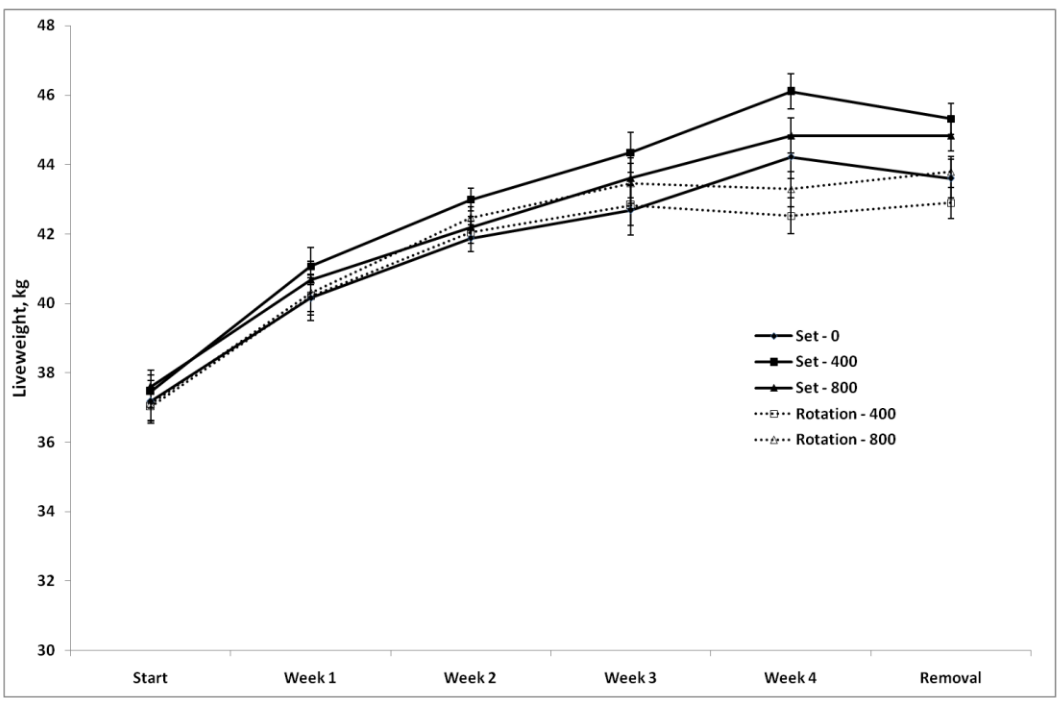

Figure 7 – Liveweight (kg) changes during the first grazing period of dual purpose winter wheat by lambs

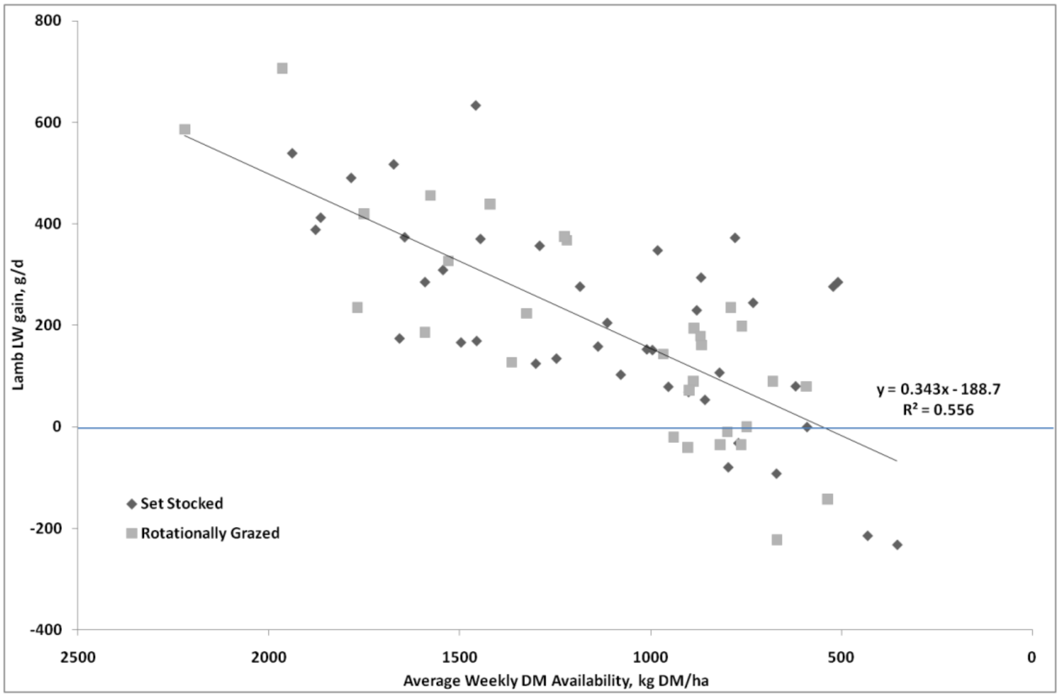

Figure 8 – The rate of change of LW of second cross lambs was linearly related to the availability of winter wheat forage across the main grazing period.

4.1.4 Animal health

Faecal egg counts (FEC) at the start of grazing indicated a low level *Strongylid sp.* infection (6 of 34 individuals recorded ova present, mean 10 ova/gram, mode 180 ova/gram), with only 1 lamb having a *Nematodirus sp.* infection (60 ova/gram). After 1 month of grazing, these incidences had fallen to 4 of 34 individuals recording *Strongylid sp.* ova present (3 x 30 and 1 x 60 ova/gram) and no sampled lambs recording *Nematodirus sp.* infections. The faecal sample (n = 19) collected before the second grazing showed 1 lamb with a low level *Strongylid sp.* infection (30 ova/gram) and none recording *Nematodirus sp.* infections.

Faecal material appeared to be well formed with little evidence of scours during the initial grazing period. There was no difference in dag scores at the end of grazing between set-stocked and rotationally grazed plots (P = 0.86), with only 2 lambs recording scores of either light or very light dag out of the 54 lambs monitored.

Blood characteristics recorded after 28 days grazing revealed that potassium concentrations were elevated above normal concentrations (Table 4) but were not affected by treatment.

At weighing 1 week after grazing commenced, 1 lamb in an 800kg DM residual set-stocked plot was limping and at the next weighing this lamb and one in a 0kg residual set-stocked plot showed signs of lameness. A veterinary inspection was undertaken next day and tissue-scraping cultures indicated moderate levels of protease stable *Dichelobacter nodosus*. All lambs were foot-bathed using a zinc sulphate solution at the next weighing on 19 June and again the following week. After 1 month of grazing, visual observations indicated 2 of the 400kg residual rotation plots (n =3 affected lambs and n = 1 lamb), one of the 800kg rotation plots (n = 1), one of the 400kg set stocked plots (n = 3) and one of the 800kg set-stocked plots (n = 2) contained lambs with signs of lameness. At destocking after 5 weeks of grazing only 1 lamb (from a 400kg set-stocked plot) showed symptoms of footrot.

No signs of footrot were observed in the final grazing to residuals. Bloat was not observed and no lamb deaths occurred during the trial period.

Table 4. Blood characteristics of lambs pre-grazing and after 28 days grazing winter wheat.

	Blood parameter						
	Mg mmol/L	Na mmol/L	K mmol/l	Ca mmol/l	GSHPx U/gHb	Cu µmol/L	B12 pmol/L
Low normal	0.82	139	3.9	2.4	50	9	400
High normal	1.23	152	5.4	3.2	550	25	5000
Pre-grazing	0.91	140	4.5	2.5	111	NA	NA
SE	0.010	0.4	0.11	0.03	12.2		
After 28 days	1.17	143	8.7	2.8	154	19.8	1060
SE	0.023	0.9	0.82	0.05	9.1	0.59	206

NA – not analysed

4.1.5 Grain and DM production at harvest

The hand harvested plant DM accumulation and grain characteristics from the quadrat samples are shown in Table 5. Total DM yield at maturity was lower (P<0.05) for the set stocked 0 and 400kg residual treatments than the other 400 or 800 kg DM/ha rotational grazing treatments. A similar effect was observed for the number of grain ears per m^2, however grains per ear and grain yields were not different (P>0.10). Grain yields measured using the plot harvester as well as percentage screenings; specific (test) weight; and crude protein are presented in Table 6. Grazing treatment had no effect on grain yield for either hand or machine harvests. The difference in grain yield between harvest methods was largely due to the hand harvest being conducted prior to severe wind damage. Quadrat measurements (2/plot) prior to machine harvest showed losses were relatively uniform across the trial area and in the order of 1.4 T/ha.

Table 5. DM and grain characteristics at hand harvest following grazing on winter wheat.

	Set Stocked			Rotationally Grazed		SEM
Item	0	400	800	400	800	
Plant DM content (%)	88.1	88.3	88.4	88.8	88.8	0.93
Total DM yield (T/ha)	13.23[a]	13.59[a]	14.82[ab]	15.51[b]	15.94[b]	0.514
Grain yield (g/m^2)	622	671	668	708	708	46.2
Harvest Index	47.0	49.5	45.1	45.6	44.3	2.68
Avg. plant height (cm)	87.5	88.3	90.0	86.3	87.1	2.96
Grain ears /m^2	381[a]	387[a]	468[b]	470[b]	478[b]	23.9
Grains per ear	41.7	44.7	38.1	39.5	40.1	2.22

Different superscripts indicate differences at P < 0.05.

Yield components varied between treatments with a significantly higher number of ears/m^2 produced under rotational grazing and the less intensive set stocking compared with set stocking to the 0 or 400 kg residual treatments. There were no significant differences in harvest indices or plant heights at harvest between treatments. There were no treatment differences in bulk density, crude protein, or 100 grain weight measurements.

Table 6. DM and grain characteristics at harvest following grazing on winter wheat.

	Set Stocked			Rotationally Grazed		SEM
Item	0	400	800	400	800	
Grain yield (T DM/ha)	4.65	5.04	4.27	4.58	4.86	0.372
Bulk density (kg/hL)	80.8	80.6	80.1	79.8	79.9	0.710
Crude protein (%)	10.85	10.83	11.67	11.19	11.97	0.430
100 grain wt (g DM)	3.97	3.89	3.75	3.86	3.79	0.082
Grain < 2.2mm (%)	8.4	9.7	11.4	11.3	11.3	0.92
Grain > 2.5mm (%)	68.8	66.6	65.2	63.9	61.7	2.28
Harvest height (cm)	82.5	83.3	85.0	81.3	82.1	2.96

Examining the effects at harvest of grazing management in comparison to ungrazed areas, ungrazed exclosures had greater DM yield (16.8 ± 0.46 T/ha) than both rotationally grazed (15.7 ± 0.37 T/ha, P = 0.09) or set-stocked plots (14.0 ± 0.32 T/ha, P = 0.003). However, grain yields were lower for ungrazed areas (560 ± 38 g/m^2) than for set stocked (658 ± 27 g/m^2, P = 0.05) or rotationally grazed areas (708 ± 31 g/m^2, P= 0.01) which were not different (P = 0.24). Thus ungrazed areas had a lower harvest index (33.2%) than the grazed areas (46.1%, P < 0.01). Plant heights at harvest were not different between grazed and ungrazed areas (P >0.10). The number of ears /m^2 was greater (P ≤ 0.05) for the ungrazed (521/m^2) and rotationally grazed plots (473/m^2) than for the set-stocked plots (416/m^2). In comparison, the number of grains per ear was lower (P ≤ 0.05) for the ungrazed (28.3 ± 2.14 per ear) than the rotationally grazed (39.8 ± 1.75 per ear) or the set-stocked plots (41.5 ± 1.51 per ear), which were not different (P= 0.47). There was also slightly more lodging (up to 15%) in ungrazed plots, but little lodging occurred in grazed plots.

4.1.6 Economics

The estimated gross income for LW produced in the first grazing period was numerically greater for the set-stocked compared to the rotationally grazed plots ($593 vs. $519/ha). However, total income per hectare for LW produced by set-stocking and rotational grazing over both periods were not different ($687 ± 39.2 vs. $660 ± 44.4, respectively; P = 0.67) and this increased to $1020 ± 48.6 and $987 ± 55.1 if a skin value is included (Table 7). Income from grain was also not different across treatments, although when meat and grain income were combined set stocking to the 400kg residual treatment produced higher incomes than rotationally grazing to the same residual or set stocking to the 800kg residual treatment. When the costs of fencing and labour for livestock and water point movement were accounted for in a hypothetical 100ha paddock a similar pattern in returns is observed whereby set-stocking to a lower residual was shown to be more profitable. Examining only the grazing management treatments, without including end grazing residual, revealed that there was no difference between set stocking and rotationally grazing in terms of gross income or returns after accounting for the additional capital and management expenditure.

Table 7. Lamb and gross returns and 100ha total income comparison.

	Set Stocked			Rotationally Grazed		SEM
Item	0	400	800	400	800	
Meat Income ($/ha)	670	713	677	614	707	62.8
Meat + Skin ($/ha)	990	1047	1023	934	1041	77.9
Grain Income ($/ha)	1069	1159	983	1053	1117	85.6
Total Gross Income	1738[ab]	1872[a]	1659[b]	1667[b]	1824[ab]	57.4
TGI incl. skin ($/ha)	2058[ab]	2205[a]	2006[b]	1987[b]	2158[ab]	57.8
100ha return ($K)	173.8[ab]	187.2[a]	165.9[b]	161.8[b]	177.6[ab]	5.73
100ha return incl.	205.8[ab]	220.5[a]	200.6[b]	193.9[b]	210.9[ab]	5.78

skins ($K)

Different superscripts indicate differences at $P \leq 0.05$.

4.1.7 Extension

The field day had an attendance of 27, with both croppers and red meat producers in attendance. Producers came from the Cressy, Bishopsbourne, Deloraine, Hagley, Scottsdale, Waterhouse and Ringarooma areas. Links were made to recent Southern Farming Systems work, and also to Grain and Graze workshops recently conducted in the state. The "Food for Thought" publication on grazing winter crops was also available on the day. Informal feedback was very positive, and a survey of attendees confirmed that 80% thought that the information presented was of value to their businesses and all of these indicated that they would use it in their farming operations.

The GRDC Update day was well attended with 55 participants presented with the full grazing and grain results from the trial. The audience engaged well with the material and raised questions included the relationship between forage heights and DM accumulation, and the comparison between set and rotational grazing outcomes and its application to large scale paddock situations. The decision support document and scientific paper are at a draft stage of preparation.

Information from the trial has been featured in a number of rural press articles and RMT presentations, and will form an important component of a planned series of RMT summary sessions.

4.2 Discussion

4.2.1 Lamb performance

Total LW production per hectare ranged from 300 to 350kg per hectare over the 46 days of grazing. Given the average annual LW production for beef enterprises in the state is in the order of 300-400kg, to achieve these production levels over a 6 week period indicates the potential of these irrigated dual purpose cropping systems.

The trial lamb growth rates ranged from about 170 g/h/d for the low residual rotational treatment and up to 225 g/h/d for the low residual set stocked treatment, with an average of 195 g/h/d. Grazfeed (V5.02) calculations for this type of growing lamb under the prevailing weather conditions predicted a LW gain of 257 g/d at 1800 kg DM/ha, decreasing down to 225 g/d at 1000 kg DM/ha and 158 g/d at 400 kg DM/ha. Our recorded weight gains were consistent with these predicted results. Dove et al. (2007) grazed 37 kg crossbred lambs at 35/ha on winter wheat (cv. *Wedgetail*, unrestricted intakes) supplemented with Mg, Ca and Na, and reported LW gains of 283 g/d over a 28-day period, compared to 184 g/d for un-supplemented lambs. *Wedgetail* is a facultative winter wheat and with its more rapid growth rate produces higher amounts of DM. In our study average LW gain in the first 3 weeks of grazing was 293 g/d, comparable to these results.

While wet conditions towards the end of the main grazing period may have contributed to the decline in LW gain in weeks 4 and 5, the availability of forage DM is likely to be the major driver of this reduced performance. While SR were initially set to avoid patch grazing, a lower SR may have been more appropriate in hindsight. Past studies on dryland winter wheats have set SR on the basis of providing 40 to 60 kg DM/head. The amount of forage (1850 kg) present at the start of grazing, if consumed at 1.83 kg/hd.day^{-1} (plus 25% wastage), with a daily forage growth rate of 38 kg DM/ha, was predicted to carry a SR of 36 head/ha for 24 days to an 800 kg residual, or for 33 days to a 400 kg DM/ha residual, under the conditions actually experienced during this trial (Grazfeed, 5.01). A preliminary SR trial at 'Pisa' in the northern Midlands during 2007 grazed 10 to 50 lambs/ha under similar conditions and reported that a SR of 20/ha maintained forage amounts around 1500 kg DM/ha, whereas 30 and 40/ ha reduced forage weights from around 1750 kg/ha to 500 kg/ha in about 56 and 42 days respectively. Selection of SR is driven by the accumulation of forage at the start of grazing, the desired rate of lamb growth, desired grain yield outcomes, and the rate of forage growth expected during the grazing period. The SR selected did result in relatively even grazing patterns, except where SR was reduced early in response to LW losses experienced, and these did exhibit some signs of patch grazing due to an increased ability for selective grazing. It was a limitation of the trial that the SR was such that plots had to be destocked prior to reaching Zadoks GS 30, as this obscures the interpretation of the grazing treatment effects. From these observations, a SR of 30 to 35/ha would provide both even grazing pressure and the opportunity to maximise LW production per hectare. This is in agreement with results from the ‘Pisa’ trial in 2007.

We observed a strong linear relationship between lamb growth performance and feed availability over time, a factor that can be manipulated with grazing management. More rapid rotation of lambs grazing to 400kg residual may have reduced some of the losses of LW that were seen in some individual lambs and contributed to a greater overall rate of LW gain for that treatment. This highlights the importance of management to the success of the rotation system when grazing to lower residual levels.

We successfully achieved the growth stage 30 target at the end of grazing, however the final forage residuals (520 and 940 kg DM/ha for the 400 and 800 kg residuals respectively) were slightly higher than desired. Despite this, a divergence between the high and low residual levels was achieved and is thought sufficient to demonstrate any grain yield differences that might result from variations in post-grazing residual. The calibrated rising plate meter was accurate to within ± 100 kg DM/ha so these residuals are likely to be close to what could be measured practically. There are two main factors linked to grazing management and post grazing residuals that will have a large influence on lamb performance. These are feed availability and nutritive quality.

Looking initially at feed availability, the amount of forage (1850 kg) present at the start of grazing, 77 days after sowing, was higher than previously reported (about 1000kg) for wheat in Tasmania (Free Food for Thought, Roadshow Workshop Notes, Grain and Graze, 2008). This likely reflects higher sowing and fertiliser application rates and responses to irrigation. Comparable biomasses were observed in the grazing trial at ‘Pisa’ in 2007, and the forage growth rate of 38kg DM/day over the grazing period was also consistent with previous reports. Given the demonstrated relationship between forage availability and lamb growth, a greater accumulation of forage at the commencement of grazing should result in the maintenance of higher rates of LW gain at the stocking rates examined. Defoliation (cutting) reduces overall DM production relative to un-cut crops, as a result of the cessation of root growth and nutrient uptake for 1 to 2 weeks, with later cutting having the least effect on forage production (Davidson et al., 1990). This indicates that the strategy of extending the grazing period by earlier grazing may not produce as much LW as delaying grazing until superior DM accumulation is achieved (Dann et al., 1983). This also has the advantage of decreasing the risk of nitrate poisoning. Freebairn et al. (2002) suggest accumulating 2500 to 4000 kg DM/ha before introducing livestock to dryland winter wheat, with good crop growth rates achieved when crops are maintained between 1500 to 4000 kg/ha. Early-sown, late maturing types without high vernalisation requirements may require early grazing before tillering to slow head emergence and to assist later regrowth. The question of whether more lamb production is achieved by early or delayed grazing is worthy of further investigation.

Rotational grazing may reduce wastage and control intake levels, as may strip grazing and limiting grazing periods (Freebairn et al., 2002). Continuous grazing allows selective grazing of the best available feed and so produces higher performance for individual animals. Rotational grazing to 400 kg produced a numerically higher SR and number of grazing days per hectare, but produced a lower average rate of LW gain and numerically lower total LW produced per hectare than set stocking to the same residual. The rotational treatments recorded a greater decline in Feed on Offer (FOO) after 14 days of grazing compared to set stocked plots, and the 400kg residual treatment also recorded a lower dietary quality by the end of grazing (higher fibre, lower CP and in vitro true DM digestibility). Combined with the LW losses of some individuals, this could also explain the lower conversion of forage to LW than the equivalent set-stocked treatment. At lower residuals a greater proportion of feed intake is used for maintenance and grazing energy expenditure. Despite this, rotational grazing to a higher residual level produced almost identical LW performance and feed efficiencies to the set stocking treatments. Rotationally grazing to 800 kg produced a similar performance as set-stocking to a lower residual, indicating that a set-stocked grazing method to a lower final grazing residual can potentially maintain individual animal performance, due to selective grazing of the best available feed, and maintain feed conversion.

In summary, a set stocking system in situations where plant growth rates offset a significant proportion of intake requirements (related to SR) and the capacity for selective grazing is maintained may enable lower grazing residuals to be reached without compromising LW performance. Rotational grazing to a lower residual implies a higher relative SR, hence a reduced ability to select a higher quality diet, and an associated decline in available feed quality. Our data would indicate that for a SR of around 40 head/ha a forage availability of 1100 kg DM/ha would produce an average LW gain of 200 g/d and that a minimum of 550 kg/ha is needed to maintain lamb LW. The linear decline in growth rate with feed availability indicated that lamb growth rates were maintained at high levels when FOO was above 1000 kg DM/ha and it is recommended that lamb LW is monitored more closely once feed on offer falls below 800 kg DM/ha. In support, Lippke et al. (2000) grazed steers on irrigated wheat pastures and found that herbage mass below about 850kg/ha dramatically reduced LW gains below the 1.44kg/d reported when herbage availability was not limiting. Final FOO at each residual treatment level was not different between set and rotationally grazed plots, and there was no difference between management systems in terms of total kg of LW produced per hectare.

Turning to nutritive value of dual purpose grazing wheat, the quality of grazing cereals is very high (Coblentz et al., 2000; 2002) and often greater than that of native or improved pastures available at the same time. Current wheat and oat forage cultivars have DM digestibilities of over 90% (Kelman and Dove, 2007) and Freebairn et al. (2002) reported that in the vegetative stage winter wheats in NSW have crude protein concentrations of 20-25%, digestibility of 70-75% and energy levels of 10.5-11.2MJ/kg (all DM basis). *Mackellar* in Tasmania has been reported to contain 12.8 MJ ME per kg DM, 30.1% CP, 41.3% NDF and digestibility over 80% (Grain and Graze). Nutritive data from our trial was similar to that previously reported. Plant growth stage is closely related to the rumen degradation characteristics of winter cereals (Coblentz et al., 2000; 2002) and so is a useful predictor of digestion and hence animal performance on these forages. Rumen degradation rates of DM and fibre are rapid during the vegetative stage (>0.086/h). With the exception of the rotationally grazed 400 kg/ha plots, nutritive quality was not affected by grazing to lower residuals. While CP levels are still greater than requirements for this class of animal, the increase in fibre content and reduction in digestibility may have contributed to the reduced performance of this treatment. Given the high nutritional quality of these dual-purpose winter wheats, it is to be expected that LW gain is linearly related to forage availability, as was demonstrated in this study.

A forage quality factor that is suspected of being responsible for poor animal performance is mineral content. Winter wheats have been reported as containing excessive potassium, adequate calcium (although possibly inadequate for growing cattle), marginal magnesium and being deficient in sodium (Horn et al., 2005). In ruminant diets high protein (rumen ammonium) and K also reduce Mg absorption in the rumen, which is the primary site of absorption in adult animals (Anon., 2007). Magnesium is used in the body for enzymatic metabolism of carbohydrates, lipids and proteins and it also plays a role in nerve impulse transmission, hence the muscular spasms seen in cases of deficiency (Anon, 2007). Acid topsoils and soils high in K may also contribute to the development of hypomagnesaemic tetany by reducing plant Mg absorption.

Hypomagnesaemic tetany may be seen when plant Mg is below 1g/kg DM (closer to 2 for lactating cattle), Na is below 1.5g/kg and K is above 30g/kg DM (Anon., 2007). Potassium concentrations in the pre-grazed forage in this trial were about 10 times greater than recommended allowances (Anon., 2007) for this class of sheep, and in contrast sodium levels were much lower than recommended. The standard formula (Anon, 2007) for determining if there may be a potential Mg deficiency problem is (% K x 256) divided by (% Ca x 499 + % Mg x 823). If this ratio is greater than 2.2 then precautions against Mg deficiency is indicated. Our pre-grazing forage was 5.59% K, 0.25% Ca and 0.17% MG producing a ratio of 5.41, and suggesting MG deficiency could be a significant problem. In another local Tasmanian trial first cut Mackeller wheat had a ratio of 2.19 (3.21%K, 0.57% Ca and 0.11%Mg, G. Dean, pers, comm.). It is common practise to ensure sufficient potassium levels for grain production occur by adding potassium to the basal fertiliser and this is likely to exacerbate high K effects. While blood K concentrations were elevated by grazing winter wheat as previously observed (Dove, 2007), normal blood concentrations of Mg and Na were measured, and indicating that supplementation using MgO and salt was effective. Use of magnesium and sodium supplements is therefore recommended. Other measured blood characteristics appeared to be normal.

The faecal ova counts recorded are unlikely to be at a level affecting production and there was no scouring or bloat observed, with the lambs being adapted to high quality ryegrass forage prior to wheat grazing, and this confirms that an adaptation period specifically for wheat was not required under those conditions. Footrot may an important issue when grazing at high SR in wet conditions and could potentially impact on lamb performance. A suitable footrot management strategy should be in place prior to grazing irrigated winter wheat.

The estimated financial income from meat production by grazing winter wheat in this study revealed no differences between set or rotational grazing systems, although rotationally grazing to the lower residual or set stocking to higher residuals produced numerically lower gross incomes than the set stocked 400kg residual treatment. Gross income ranged from $614 to $713/ha, and given the subsequent benefit to grain yields in comparison to the ungrazed exclosures, the addition of grazing to a crop rotation offers significant financial benefits for little additional cost. Even after accounting for the additional capital and labour costs of rotational grazing, the 100ha comparison indicated no statistically significant differences between set and rotational grazing. Set stocking to 400kg residual and rotationally grazing to an 800kg residual had the highest returns of the systems tested.

4.2.2 Grain performance

Grain yields were lower for ungrazed areas (5.60 ± 0.38 T/ha) than for set stocked (6.58 ± 0.27 T/ha) or rotationally grazed plots (7.08 ± 0.31 T/ha). These quadrat cut yields are in line with previously recorded yields for *Mackellar* in Tasmania, but are not as great as has been previously recorded in Tasmania for that variety (G. Dean, pers. comm.). Damage to developing grains occurred due to a frost occurring on 23rd October, and the reduction in grains/ear resulted in a lower overall grain yield across the trial. Grazing delays crop development (Dann et al., 1983) and Vergona et al. (2006) found a delay in anthesis of 1 day for every 4 to 5 days grazing of wheat by sheep. Our own data shows a 9 to 11 day delay in anthesis with grazing, which is in line with these results.

Dual purpose cereal grain yields are affected by species (e.g. Lovett and Matheson, 1974), cultivar growth habit, soil moisture and fertility, time of grazing, and stocking rate (Kelman and Dove, 2007).

Seasonal conditions of rainfall and temperature have a large influence on the findings of varietal investigations, impacting significantly on the ability of a crop to produce grain following grazing. For example, *Mackellar* wheat has performed well in a Tasmanian evaluation but poorly compared to other lines at Bairnsdale in Victoria. Evaluations should be conducted at a variety of sites over a number of seasons using grazing animals to provide the most reliable indications of potential red meat and grain production.

Lower yields were recorded for the machine harvesting, a result of the loss of grain due to strong wind gusts just prior to harvest, and some minor army worm damage. Regrowth following grazing, and so leaf area index at anthesis, is affected by the grazing pressure applied (Davidson et al., 1990). Rotational grazing resulted in higher total plant DM production at maturity, and final grain ear density than more intensive set stocking. However, there was no effect of grazing management or end grazing residual on grain yields, despite lower density of ears when set stocking to a lower residual. These reductions were offset to some extent by numerical increases in grain weight and size, with rotational grazing resulting in numerically greater hand harvested grain yields.

Grazed crops use less water during and soon after grazing as a result of reduced transpiration from reduced leaf area, and this water may subsequently be used during grain filling at higher use efficiency (38kg/ha.mm, Vergona et al., 2006). While grazing did produce a slight increase in surface soil resistance to penetration, indicating a compaction effect, there was no difference in soil moisture content at anthesis between grazed and ungrazed areas, indicating this was not likely to be a factor determining grain yields. Further, irrigation of the site in October and November had the potential to remove any soil moisture effects of grazing that are likely to impact negatively on grain yield. Paddocks for winter wheat grazing should not be prone to water-logging as this will reduce forage production (Freebairn et al., 2002) and produce degradation of soil structure e.g. ‘pugging’. Despite the rainfall events during grazing, significant pugging did not occur, however this outcome may be different when grazing cattle under similar conditions.

There is high variability in the reported effects of grazing on crop yields (Dann et al., 1983) ranging from a decrease of almost 28% to an increase of 18%, and an average across 134 comparisons of a 4% reduction (Virgona et al., 2006). Most of this variability is likely related to seasonal growing conditions and the management of grazing pressure with respect to plant development. Although frost may still be an important factor affecting grain yields, irrigation capability enables low rainfall effects to be removed. It has been well demonstrated that timing of grazing relative to plant growth stage (GS) must be closely managed if subsequent grain yields are not to be compromised. The largest yield reductions have been due to removal of growing points following stem elongation and the greatest increases have been seen where crop lodging was reduced by grazing (Virgona et al., 2006). We observed that limited lodging occurred in the grazed plots, a very useful outcome, and as lambs were removed at GS 30 removal of growth points should not have been a factor influencing the grain yields. Indeed grain yields were higher following grazing than in ungrazed exclosures. In some instances, lighter grazing has been suggested to increase yield by increasing tiller numbers and enabling greater light penetration and increasing net photosynthesis (Davidson et al., 1990). While total DM yields at harvest were numerically greater at the 800kg residual treatments harvest indices were numerically greater for the lower residual treatments. Increased light penetration can encourage weed recruitment, so weed control is important to decrease competitive effects and maintain grain yield.

In summary, grazing resulted in higher grain yields due to frost damage in the ungrazed exclosures. While set stocking to a lower residual produced a reduction in total DM yields at harvest and lesser grain ear density, grain yields were unaffected by grazing method or end grazing residual. It is commonly recommended that grazing cease at Growth Stage 30, when stem elongation starts to occur, and a suitable post-grazing residual be maintained to enable effective restoration of leaf area, in order to maximise grain yields. Leaving residuals of 410, 520 and 940 kg DM/ha did not alter grain yields under irrigation and the conditions of this trial. Indeed grazing to an estimated 0 residual only modestly reduced grain yield.

Gross income from grain production ranged from $980/ha for set stocking to a greater residual up to over $1100 for set stocking to a lower residue, or rotational grazing to a higher residual. These were not statistically significant differences. Additional expenses associated with grazing in comparison with ungrazed crops would include the use of a post-grazing herbicide and possibly the addition of N fertiliser to maintain grain CP concentrations. The yield difference between ungrazed and set or rotational grazing was 0.98 and 1.48 T/ha respectively suggesting that, at a grain price of $230/T, up to $225 to $340/ha could be expended before grazing is uneconomical from a grain value standpoint alone, without accounting for the additional meat income.

4.2.3 Graze and Grain performance

The total gross returns from meat and grain ranged from $1660/ha for the set stocked 800kg residual treatment and the 400kg rotational treatment and up to $1872/ha for set stocking to a 400kg residual. While input costs are also higher, these compare quite favourably to other studies with dual purpose winter wheats which have reported gross margin returns in the order of $500 to $1200/ha from grazing and grain production (Freebairn et al., 2002). Simulations for NSW and the ACT indicate that even with high livestock prices the value of dryland, dual-purpose wheat remained dependant on obtaining high yields and income from grain (L. Salmon, Testing the value of cereal grains and forages in prime lamb grazing systems using decision support tools – a whole farm approach, Research Update – Southern Region (high Rainfall), July/Sept 2004, GRDC website). Given the relatively high quality of most dual-purpose cereal forages, potential grain yields and value will likely play a key role in species and varietal selection for dual purpose graze and grain systems.

The advantages of using dual purpose wheats must be offset against the opportunity cost while the land is fallow or not available for pasture production in current grazing only systems. This cost is minimised where the land is already allocated towards an alternative enterprise and so the capital cost of irrigation infrastructure accrues against the main cash crop e.g. poppies, with cereal grazing 'adding value' to the existing system. Dryland winter wheats have been used for; providing high quality feed during the winter feed gap; paddock preparation for pasture sowing; weed control, finishing stock for particular markets; and silage production (Freebairn et al., 2002). In addition to supporting high animal growth rates and turn-off during periods of traditionally lower supply, potential additional secondary benefits of irrigated, cereal grazing systems include: reduced/lowered water recharge; reduced stubble management costs; increased income diversity from grain and/or hay sales; alleviation of grazing pressure on other native and improved pastures during winter; development of a 'feed wedge' for other livestock outcomes such as preparing ewes for lambing, as well as improving lamb survival and growth; and increased overall property stocking rates and hence pasture utilisation during peak growth periods.

Selection of livestock classes for grazing cereals will be determined largely by market opportunities and the short term feed supply situation with regard to alternative options within the enterprise. These might include mid- to late-spring lambs, finishing yearlings into feedlot or medium domestic meat markets and the grazing of lambing ewes and early calving cows.

While this trial involved growing prime lambs and the results can not be directly extrapolated, it is worth considering management of cattle grazing irrigated dual purpose crops. In the US, cattle are predominantly used for grazing wheats rather than sheep, and wheats are often sod sown for winter feed. Horn et al. (1995) grazed steers on hard red wheat forages to GS 30 and reported LW gains of 0.92 kg/d increasing up to 1.08 kg/d with an energy supplement provided at 0.7% of LW. Lippke et al. (2000) grazed steers on irrigated wheat pastures and found that herbage mass below about 850kg/ha dramatically reduced ADG below the 1.44kg/d reported when herbage availability was not limiting. These studies suggest that in steers LWG of 1.1 to 1.4kg/d could be expected from winter wheat pastures, however lower rates of gain, such as the 0.63 kg/d reported by Phillips et al. (2001), can occur when forage availability is limiting.

In Australia, farmer reports from NSW indicated beef growth rates of up to 1.5kg/d, with beef LW gains of 250 to 300kg/ha reported on dual purpose winter wheats (Freebairn et al., 2002). Forage levels greater than 1000kg/ha were not considered to be limiting intake, with residual plant heights of 5 to 10cm and 10 to 20cm for prostrate and erect types respectively resulting in 1000 to 1500kg DM/ha suitable for lactating ewes and finishing steers (Freebairn et al., 2002). These forage availability levels are in broad agreement with the lamb growth rate results we obtained, namely a forage mass above 1000kg is required to maintain growth rates where diet selectivity is compromised.

When grazing cereals with cattle, greater attention may need to be applied to the mineral status of the animals. Hypomagnesaemic tetany (also called wheat pasture poisoning) is seen in late pregnant and lactating cows that have been grazing wheat for more than 60 days and is characterised by low blood concentrations of Ca and Mg (Horn et al., 2005). This class of stock may need to be supplemented to ensure adequate available body reserves of Ca are available in late pregnancy. Cattle are less able to absorb Mg than sheep, and growing cattle may also require higher levels of Ca in forage than are required by sheep (Anon, 2007). In the US, cattle grazing wheats are routinely supplemented with Na and Mg (e.g. Lippke et al., 2000), and growing cattle also require an additional source of Ca where forage concentrations are limiting.

Bloat is another potential problem with grazing of winter cereals in cattle, and studies have shown that monensin and to a lesser extent lasalocid are effective in preventing bloat on wheat pastures (Horn et al., 2005). The addition of monensin (129 to 161mg/d) to a mineral mix has resulted in increased growth rates of steers (260 to 290kg) grazing winter wheat pastures compared to a mineral mix alone (Fieser et al., 2007). Supplemental calcium may also alleviate bloat by increasing rumen motility (Horn et al., 2005).

Another factor that cannot be addressed from the results of the current trial is the relative effect of cattle movement on soil structure within these irrigated systems, particularly where high winter rainfall and water-logging occurs. Extensive pugging is likely to influence subsequent crop growth, and may influence water availability for filling grain kernels. One Australian comparison showed no difference between sheep or cattle grazing winter cereals on their LW gains or later grain yield, suggesting that on-farm stock class feeding requirements or relative meat values should determine stock class choice for these forages (Dann et al., 1983). Further quantification of relative sheep and cattle performance on winter cereals under Australian conditions is required.

4.2.4 Presence and significant of internal parasites

Faecal egg counts at the start of grazing indicated only 18% of tested lambs had *Strongylid sp.* infections and only 3% had a *Nematodirus sp.* infection and these were of a low level, in the order of 10 epg. The lambs had come off Feast ryegrass and had been drenched a month previously. Following another Ivermectin drench prior to trial entry within 30 days these incidences had fallen to 12% of lambs recording *Strongylid sp.* and no lambs recording *Nematodirus sp.* infections. Faecal material appeared to be well formed with little evidence of scours and no differences in dag scores at the end of grazing between set-stocked and rotationally grazed plots. Visual examination also revealed no symptoms of worm burdens. The faecal ova counts recorded were unlikely to be at a level affecting production. There was no evidence of anthelmintic drench resistance in these animals or any suggestion in the trial that irrigated winter wheat promoted the build-up of worm burdens following commercial drenching practices. It is recommended that a drenching program be implemented when grazing irrigated winter wheat.

4.2.5 Guidelines for grazing cereals under irrigation

Early crop management
Earlier sowing results in higher DM production but the “vernalisation” response of the variety (cumulative period of low temperature required to initiate flowering) should be recognised. Without a vernalisation response wheat sown early will flower too early with a greater likelihood of frost damage. All winter wheats grown in Tasmania require vernalisation to flower, however there is a limit to early sowing as the vernalisation requirement can be partially met by cold temperatures prior to winter. Obviously some seasons are colder than others resulting in differences in flowering date with the same variety across seasons.

Winter wheat varieties
Trials conducted by TIAR/SFS have demonstrated large differences in the flowering date of winter wheat varieties. The later flowering varieties (e.g. *Tennant*) when sown in May, are also later flowering when sown earlier. Early sowing (e.g. mid March) without grazing will generally result in flowering around 2 weeks earlier than a mid May sowing of the same variety. Grazing delays the onset of flowering by 1½ to 2 weeks. Usually an early sown crop plus grazing will flower several days before a comparable crop sown in May without grazing. Again, this is seasonally dependant, for example in 2008-09 *Mackellar* sown in mid March and then grazed, flowered in early November compared with 7 to 10th November for a May sown crop.

Some general observations are:

- It is not recommended to sow *Mackellar, Brennan* and *Teesdale* before March
- To minimise frost damage, *Tennant* is a more reliable alternative when sowing in February (and possibly January)
- Other wheat varieties with a weaker vernalisation requirement such as *Naparoo* and *Eaglehawk* should not be sown before April.

Irrigation: While dryland dual-purpose crops have traditionally been a profitable enterprise, sowing is dependant on receiving autumn rainfall. Being able to irrigate the crop with a centre pivot in a dry autumn ensures uniform establishment and reliable early growth during a period of warmer temperatures. The amount of water required will depend on rainfall and residual soil moisture. Adequate irrigation will ensure good crop growth, however the risk in most areas of the state is the potential for winter water-logging. On duplex soils in particular, the aim should be to enter winter with minimal moisture in the soil profile so that the soil acts as a sponge over winter.

Fertiliser: Basal fertiliser rates should not vary from grain-only crops, but to maximise autumn growth topdressing of nitrogen may be beneficial where soil N levels are low, e.g. apply 50kg N/ha. In theory higher sowing rates will provide greater DM production but results from trials have been variable. This may relate to the time of sowing with higher growth rates from an early sowing (e.g. March) compensating for lower sowing rates. To assist the recovery of the crop after grazing an earlier application of nitrogen may be useful if soil moisture and temperature conditions are suitable.

Pesticides: Although similar to grain-only crops several issues need to be considered:

- Grazing opens up the crop canopy so that the competitiveness of the crop against germinating weeds is reduced. More effective weed control is therefore required.

- Herbicide resistant annual ryegrass in particular becomes a far greater problem to control.
- The longer growing season is likely to create greater disease problems, in particular Barley Yellow Dwarf virus (BYDV). Insecticides applied to the aphid vector and/or use of the BYDV resistant variety *Mackellar* can alleviate the problem. A higher level of early stripe rust infection has been sometimes observed but in one trial this was removed through grazing. A two spray fungicide program should be sufficient for most crops.

Crop management during grazing: Winter wheat should not be grazed until plants have a sufficiently strong root system. Test this by simulating a grazing animal by pinching the top leaves of plants between the thumb and forefinger and twisting. If the leaves break off rather than pulling the plant out of the ground the crop can be grazed.

Pre-grazing animal management: With high stocking rates coinciding with a wet environment, internal parasites are a potential problem when grazing irrigated winter cereals. It is recommended that effective drenching is used prior to livestock being grazed on these crops. As clostridial diseases, like pulpy kidney, are a potential problem on these feeds, it is strongly recommended that livestock be vaccinated with a 6 in 1 prior to grazing. Nitrate poisoning is also a potential issue when hungry livestock are put on short regrowth wheats, so precautionary vaccination against enterotoxaemia is indicated (Freebairn et al., 2002).

Where livestock are coming off a poorer quality feed, such as hay, or a markedly different type of feed source, an adaptation period to the cereal forage diet will allow the rumen to adjust. Giving the stock access to the crop for a few hours each day and then increasing the time spent on the crop over a 7 to 14 day period is one way to adapt the animals. Alternatively provision of some good quality roughage will assist in adapting animals to the change in feed. While provision of poorer quality hay may result in extended grazing periods, it would also likely result in reduced crop grazing time and potentially reduced stock performance. Feeds low in DM can cause scouring as the animal tries to get rid of excess water in its diet; this is normal and shouldn't affect growth rates. While grazing stock may get most of their water requirements from the feed, it is important to also provide clean drinking water.

Selection of stocking rate is important to make the most of available feed, to achieve good lamb growth rates, and to meet market specifications. Individual lamb daily LW gain declines as feed on offer decreases. Winter wheat grazing trials have shown that a SR of 20 x 40kg lambs/ha maintains forage at around 1500 kg DM/ha; 30 lambs/ha reduced 1800 kg DM/ha to 500 kg/ha residual in 56 days; a SR of 40 lambs/ha took 42 days to reach 500kg/ha; and in the current trial 35 lambs/ha reduced 1900 kg to 400 kg/ha in 30 days. Patch-grazing may result if stocking rates are too low and so larger paddocks can be fenced to improve evenness of grazing pressure. Setting SR will also depend on marketing considerations, such as LW targets and optimum marketing periods.

Animal management and health during grazing: The highest LW and grain production levels were noted for set stocking to a 520kg DM residual and for rotationally grazing to a 940kg DM/ha residual at Zadoks GS 30, however this trial has shown no significant differences in LW produced per hectare or grain production between set and rotationally grazed systems. Our data would indicate that for a SR of 35 to 40 lambs/ha a forage availability of 1100 kg DM/ha would produce an average LW gain of 200 g/d and that a minimum of 550 kg/ha is needed to maintain lamb LW. The linear decline in growth rate with feed availability indicated that lamb growth rates were maintained at high levels when FOO was above 1000 kg DM/ha and it is recommended that lamb LW is monitored more closely once feed on offer falls below 800 kg DM/ha. Grazing to a 400 to 500 kg DM residual may depress nutritive value of the remaining forage, this was about 2 to 3 cm in height under our trial conditions (Figure 9).

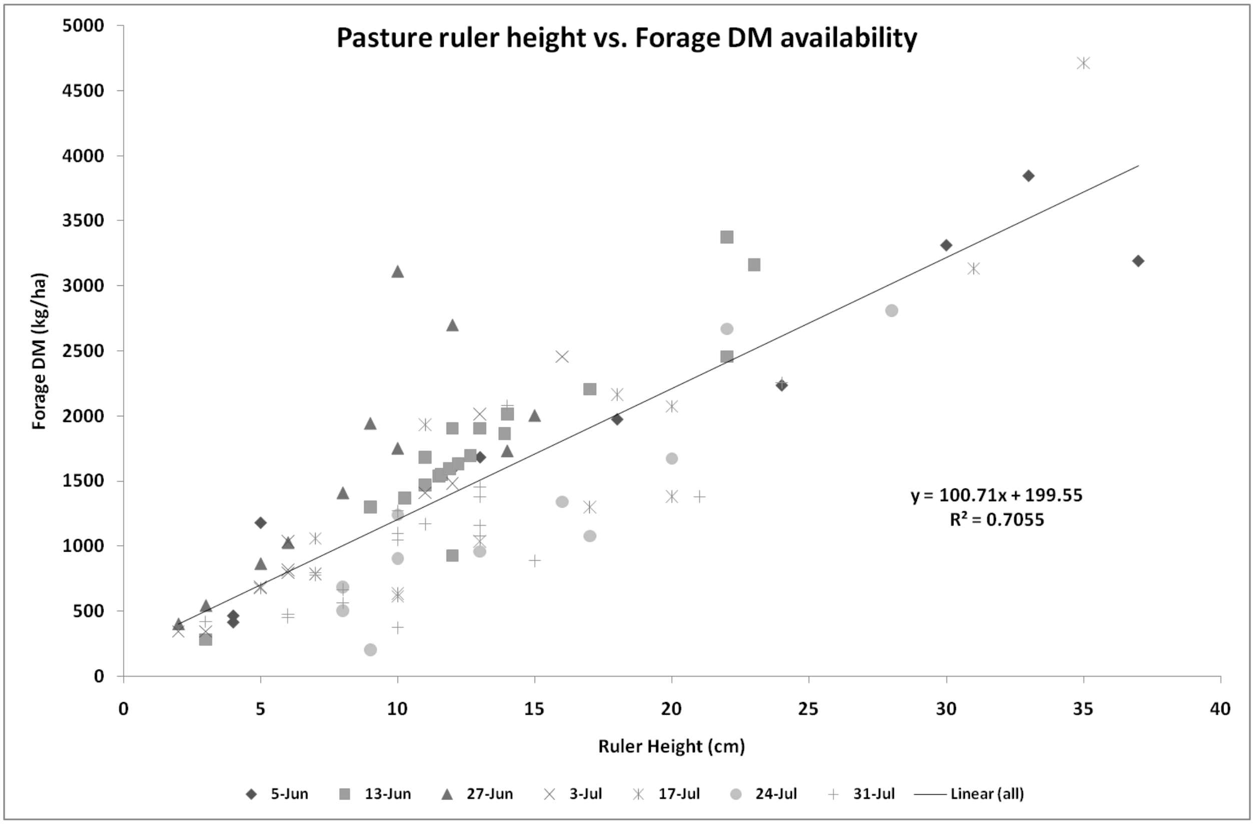

Figure 9. Pasture ruler height (cm) multiplied by 100 and then adding 200 gives the approximate kg of DM available under the conditions of this trial.

Winter wheats have excessive amounts of potassium, are marginal in magnesium and are deficient in sodium. Imbalances of sodium and potassium reduce the absorption of magnesium in the rumen. Therefore it is recommended that grazing stock be supplemented with magnesium and sodium. A loose mix of 1:1 magnesium oxide and salt provided at 20 grams per lamb per day in half-drums produced normal blood sodium and magnesium concentrations after 28 days of grazing for lambs on winter wheat in Tasmania. Ca supplements may also be required for growing cattle. If rain is expected then these supplements should be under cover, or have adequate drainage holes to allow water to escape the supplement containers. Vitamin D may also be an issue for lambs grazing green oats for extended periods during winter, however any Ca deficiency would also need correcting before a response to Vitamin D would be seen (Anon, 2007).

Footrot may also emerge as a problem under wet conditions and lambs with impaired mobility will not perform as well as unaffected animals. Facilities for the treatment of footrot should be available in the event a problem develops. Foot-bathing with a 10% zinc sulphate solution proved effective in controlling a minor footrot problem. Livestock should also be monitored for the incidence of bloat.

To ensure maximum grain production animals must be removed from the wheat crop before the plant switches from a vegetative to reproductive (seed development) phase. This is when the main stem with an already developing ear begins to elongate and move above the soil surface. Further grazing will remove this growing point and potentially reduce grain yield. On the Zadoks cereal growth stage key this is referred to as GS30.

Post-grazing crop management: As grazing can open up the forage canopy and let more light reach the ground there is the potential for significant weed recruitment to occur after grazing. It is recommended that herbicides be applied after stock removal to control weed recruitment, particularly that of ryegrass which can reach high densities if uncontrolled. Army worms should also be controlled to reduce crop losses. With-holding periods should be observed if chemical application occurs while livestock are still grazing the forage to minimise subsequent residues in meat products.

Interactions of grazing management decisions (such as residual DM levels) on plant development and frost incidence is a factor affecting grain yields that requires consideration under Tasmanian conditions. Susceptibility to disease during the extended growing season for dual purpose cereals is another. In some studies, grazing has tended to reduce grain protein levels, possibly due to a reduction in N available for grain fill. It has been thought that this reduction might be alleviated by a post-grazing or pre-flowering N fertilisation, however the cost: benefit of this strategy should be considered carefully.

5 Success in Achieving Objectives

The objectives of this project were to quantify lamb and grain performance on irrigated dual purpose wheat and evaluate in agronomic, animal health and economic terms, set-stocked & rotational grazing systems and 2 end-grazing residuals for lamb performance. These objectives were achieved successfully as outlined in this report. Larger farm systems studies are needed to quantify all the secondary benefits of these winter cereal grazing systems, and to confirm that the findings of this small plot trial hold under property-scale commercial conditions. There may be benefits to a rotational system that are not captured by the 0.2ha plots used. While not a component of the field trial, the potential for cattle production was also examined, and an evaluation of the significance of internal parasites undertaken. The final section of this report contains some guidelines for grazing cereals under irrigation systems based mainly on the results from the trial.

6 Impact on Meat and Livestock Industry – now & in five years time

To the best of our knowledge, direct comparisons of animal production and grain yields between rotational and set-stocking management systems have not been investigated for dual-purpose cereals in temperate Australia. Based on the lamb performance results to date there does not appear to be any advantage in implementing a rotational grazing system compared to set-stocking at the stocking rates and post-grazing residuals used here. There may be advantages when residual levels are low of set-stocking in terms of maintaining LW gain and forage use efficiency through selective grazing, however the rotational grazing system also produced similar LW and grain production levels and financial income levels, and has advantages for achieving even forage utilisation patterns.

Two extension events have been held and the results of the trial presented to over 80 participants, with 80% of participants at the field day in 2008 considering that the information presented was of value to their businesses and all of these indicated that they would use it in their farming operations. Indeed anecdotal evidence is that some dual purpose winter wheat plantings occurred in early 2009 on the basis of that field-day. Information sharing and discussion opportunities were also delivered.

Looking forward over the next 5 years, this project will provide producers with basic quantitative knowledge under Tasmanian conditions of performance levels and management considerations to assist them to confidently manage grazing of winter cereals under irrigation. Specifically the production and economic benefits arising from both rotational vs. continuous grazing systems and information on the crucial decision about the timing of livestock removal to maintain grain yield.

7 Conclusions and Recommendations

In conclusion, while grazing did elevate grain yields over ungrazed areas, there were no clear advantages in rotational grazing over set stocking under the conditions of this trial. The greatest LW production per hectare, best feed conversion efficiencies and financial returns were achieved when set stocking to a lower residual and for rotational grazing to an 800kg residual. It was demonstrated that feed availability drives growth rates, and so maximum animal growth rates are achieved when more than 800 kg of forage is available. There are likely to be advantages of rotational grazing to manage grazing pressure across larger paddocks. There were no differences in grain yields, or quality between grazing systems. Greater grazing pressure encouraged weed competition and so effective control of ryegrass post-grazing is important.

In terms of recommendations for research for grazing management of dual–purpose cereal crops under irrigation in southern Australia the following areas are indicated:

- timing of grazing initiation relative to crop DM accumulation and growth stage for optimising animal LW production
- farming systems studies to quantify the secondary benefits of these dual-purpose grazing systems, including management of cattle grazing and rotations at commercial scales
- physiological drivers of feed intake control on these high quality feeds given the importance of feed availability
- inclusion of legumes into plantings
- post-grazing management, including fertilisation to offset animal related nutrient removal.

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