LIVESTOCK PRODUCTIVITY FROM PASTURES

Saint Albert's College, University of New England Armidale

7th–9th June 2016

Australian Grassland Association Inc.

Livestock Productivity from Pastures

Proceedings of an Australian Grassland Association Inc Symposium

Armidale Australia

June 7–9 2016

Editor
Carol Harris

Published by the Australian Grassland Association Inc
Website: www.australiangrassland.org.au

Australian Grassland Association Research Series No. 3 2016

We also acknowledge the contributions of Todd Andrews, *NSW Department of Primary Industries*, Michael Friend, *Charles Sturt University*, Brian Leury, *University of Melbourne*, Tim Pepper, *Heritage Seeds* and David Harbison, *D R Agriculture Pty Ltd*

Citation:
Proceedings of the Livestock Productivity from Pastures Symposium. Editor C. Harris. Australian Grasslands Association Research Series No 3, Armidale 2016 (Australian Grassland Association).

These proceedings were printed by A Betterway to Print Pty Ltd, Glen Innes NSW

Proud sponsors of the Livestock Productivity from Pastures Symposium

CONTENTS

Introduction

Stuart Kemp 1

Paper Abstracts

Seasonal variability

The impact of extreme events in pasture-based dairy systems: a review - J. Chang-Fung-Martel, M.T. Harrison, R. Rawnsley, A.P. Smith, H. Meinke 3

Does establishing lucerne under a cover crop increase farm financial risk? - T.L. Nordblom, T.R. Hutchings, R.C. Hayes, G.D. Li and J. Finlayson 4

An initial investigation of forage production and feed quality of perennial wheat derivatives - M. T. Newell, R.C. Hayes 5

Temporal changes in feed value of temperate perennial legumes - A.W Humphries, H.C. Norman, E. Hulm, S.J. Hughes, T. Rowe, D.M. Peck, P. Vercoe 6

Temporal changes in nutritive value of temperate perennial grasses and herbs - A.W Humphries, H.C. Norman, E. Hulm, S.J. Hughes, T. Rowe, D.M. Peck, K.M. Oldach, P. Vercoe 7

Session Nutritional value

Quantifying the effect of interactions between defoliation interval, defoliation intensity and nitrogen fertiliser application on the nutritive value of rainfed and irrigated perennial ryegrass - K.G. Pembleton, R.P. Rawnsley, L.R. Turner, R. Corkrey, D.J. Donaghy 8

Effect of tiller height on nutritive characteristics of four perennial pasture grasses - B.R. Cullen, D. Bullen, C. Hutcheson, M.H. Deighton, J.L. Jacobs 9

Improving resilience of mixed pastures swards with alternative spatial configurations - R.C. Hayes, G. A. Sandral, G.D. Li, A.D. Swan, A. Price, S. Hildebrand, L. Goward, C. Fuller, C. Lihou, M.B. Peoples 10

Grazing management and new technology

Grazing management of tall fescue-dominant dairy pastures in southern Australia - A.R. Lawson, K.B. Kelly, M.E. Rogers 11

Assessing the productivity and sustainability of grazing management systems - W. Badgery, G. Millar, K. Broadfoot, J. Martin, D. Pottie, A. Simmons, P. Cranney 12

Development of sensor algorithms for intake of pasture by individual grazing cattle - P.L. Greenwood, D.R. Paull, J. McNally, T. Kalinowski, D. Ebert, B. Little, D.V. Smith, A. Rahman, P. Valencia, A.B. Ingham,G.J. Bishop-Hurley 13

Poster Papers

Improving sheep liveweight gains through alternative forages in low rainfall mixed farming systems - B.B. Dzoma, R. Latta 16

Liveweight gain by cattle grazing native pasture or improved pasture sown on rehabilitated mine land – Upper Hunter study - N.W. Griffiths, L.H.McCormick, N.R.Nelson 19

Economic and environmental differences between the nitrogen response functions of different perennial ryegrass cultivars - M.A. Harmer, L. Menhenett, C. Farlow 23

Greater potassium rate increases the biomass of grazing crops, but what about the effects on feed quality? - J. Holland, R.C. Hayes, G. J. Poile, M. T. Newell, M. K. Conyers, A. A. Oates, B. A. Orchard, V. van der Rijt, G. Refshauge 28

Producing store lambs on a Microlaena stipoides dominated pasture – the impact of grazing management and stocking rate - N.P. Linden, M.L. Mitchell, S. Norng, L.L. Slocombe 33

INTRODUCTION

The Australian Grassland Association Inc. (AGA) was established to facilitate the ongoing improvement and development of the pasture industry. We do this through providing a forum which brings together a wide range of industry stakeholders in order to;

- Facilitate the interaction and exchange of ideas and provide an opportunity for research to be presented and published;

- Provide an opportunity for all interested stakeholders to review and contribute to the advancement of pasture based industries through science;

- Consider and discuss the state of the pasture industry and the research needed in order for it to meet the challenges of today and be prepared for the future.

This symposium, “Livestock Productivity from Pastures” will include themes of seasonal variability, nutritional value of pastures, grazing management and new technology for pasture based animal production. In addition, in order to encourage and support early or preliminary research we have included a poster session which gives researchers a chance to test their work with their peers while also allowing attendees to get a first look at research underway.

In a first for an AGA symposium, we have included a field tour and could not pass up the opportunity to visit the innovative ‘SmartFARM’ of the University of New England. This will be a relaxed but informative afternoon with ample opportunity to engage with researchers at the farm and see the latest and greatest.

As with the previous two symposia, we are working with the journal Crop and Pasture Science to ensure that papers presented at the symposium are included in a special issue. In the past our special issues have been highly successful and rank as some of the most viewed online. I am sure that this issue will be no exception.

As with all such events, it takes a team of dedicated, passionate and professional people to put together a successful symposium – and this is no different. I would particularly like to acknowledge the ongoing and enthusiastic efforts of Carol Harris, Mark Norton and Kevin Reed – without which this symposium simply would not exist. Thankyou.

I trust you will have an informative and enjoyable symposium and look forward to meeting you all during the course of the symposium.

Kind Regards,
Stuart Kemp
President
Australian Grassland Association

PAPER ABSTRACTS

The impact of extreme events in pasture-based dairy systems: a review

J. Chang-Fung-Martel[A], M.T. Harrison[B], R. Rawnsley[B], A.P. Smith[C], H. Meinke[A]

[A]Tasmanian Institute of Agriculture, Hobart, TAS 7001: janine.changfungmartel@utas.edu.au

[B]Tasmanian Institute of Agriculture, Burnie, TAS 7320

[C]CSIRO Agriculture, Waite Campus, SA 5064

Abstract: Extreme climatic events such as heat waves, extreme rainfall and prolonged dry periods, are already a significant challenge to the productivity and profitability of dairy systems. In Australia, dairy is primarily pasture-based and relies greatly on the efficient conversion of pastures into milk. Despite projections of more frequent extreme events, increasing temperatures and reduced precipitation, studies on the impact of these extreme climatic events on pasture-based dairy systems remain uncommon. The Intergovernmental Panel on Climate Change has estimated Australia to be one of the most negatively impacted regions projecting production losses of around 16% in the agricultural sector and 5-19% in the south-eastern dairy regions of Australia due to climate change.

Here we review the literature on the impact of climate change on pasture-based dairy systems with particular focus on extreme climatic events. We provide an insight into current methods for assessing and quantifying heat stress highlighting the impacts on pastures and animals including the associated potential productivity losses and conclude by outlining potential adaptation strategies for improving the resilience of the whole-farm systems to climate change. Adapting milking routines, calving systems and the introduction of heat stress tolerant dairy cow breeds are some proposed strategies. Changes in pasture production would also include alternative pasture species better adapted to hotter and drier conditions. In order to develop effective adaptation strategies we also need to focus on issues such as water availability, animal health and associated energy costs.

Key words: temperature-humidity index, milk, cattle

Notes

Does establishing lucerne under a cover crop increase farm financial risk?

T.L. Nordblom[A B] *, T.R. Hutchings[A], R.C. Hayes[A B], G.D. Li[A B] , J. Finlayson[C]

[A] Graham Centre for Agricultural Innovation, Albert Pugsley Place, Wagga Wagga, NSW 2650 Australia

[B] NSW Dept of Primary Industries, Wagga Wagga Ag Institute, Pine Gully Rd, Wagga Wagga NSW 2650

[C] John Finlayson Research Limited, Whangarei, New Zealand

* Corresponding author: tnordblom@csu.edu.au

Abstract: A perplexing question for scientists and farm advisors over the past 80 years in rain-fed crop-pasture rotations has been whether to recommend sowing a perennial pasture either directly or under a cereal cover-crop. A cover-crop provides useful additional income from the sale of grain, but can reduce pasture survival, particularly in less favourable years. This paper is to examine the farm financial risk associated with establishing pastures with or without a cover-crop based on four years data (2008 to 2012) from a series of field experiments along a north-south transect from Ariah Park to Brocklesby, NSW. The Intensive Farming (IF) model was used to analyse these data with information on local weather and price variations. Results showed that i) direct sowing is a more reliable method of establishing lucerne (*Medicago sativa*) pastures than undersowing with a cover crop; and ii) the additional costs of direct seeding are often met by its increased productivity compared with lucerne pastures sown under cover-crops. Pasture total dry matter yield was simulated with a regression model capturing effects of rainfall, sowing date and soil characteristics from the field sites. Given the 1950-2010 rainfall sequence at Coolamon, pasture energy yields calculated for established pastures were greater with direct sowing than undersowing in 40 of those 60 years. Considering all costs, it is concluded that the establishment of lucerne under a cereal cover-crop does increase farm financial risk where stocking rates exceed 10 dse/ha in an integrated cropping/livestock enterprise.

Key words: bioeconomic model, intensive farming model, mixed farming, livestock, cropping, profitability

Notes

An initial investigation of forage production and feed quality of perennial wheat derivatives

M.T. Newell[A], R.C. Hayes[B]

[A] NSW Department of Primary Industries, Agricultural Research and Advisory Station, Binni Ck Rd, Cowra, NSW 2794. Email: matt.newell@dpi.nsw.gov.au

[B] NSW Department of Primary Industries, Wagga Wagga Agricultural Institute, PMB, Wagga Wagga, NSW 2650. Email: richard.hayes@dpi.nsw.gov.au

Abstract: Developing perennial cereals may offer a novel forage source in mixed farming enterprises while improving the sustainability of grain farming. There has been limited analysis of the quality of this forage type and its likely value to mixed grazing/cropping farming systems.This study evaluated the biomass and grain production of 4 wheat *x* wheatgrass hybrid experimental lines under 4 simulated grazing regimes; nil defoliation (grain only; D_0), defoliate once (D_1), defoliate twice (D_2) and defoliate twice followed by a simulated hay cut (D_3), and compared performance to a winter wheat, Wedgetail, and the perennial grass *Thinopyrum intermedium*. Early biomass production of the perennial entries was similar to Wedgetail. Grain yield from Wedgetail was higher ($p < 0.001$) than all other lines except in the D_3 treatment. As defoliation frequency increased, the comparative difference in grain yield between Wedgetail and the hybrid entries decreased, with lines OK72 and 11955 exceeding the grain yield of Wedgetail in the D_3 treatment. Cumulative annual biomass production of the hybrid lines exceeded that of Wedgetail, though the seasonal production differed markedly. Defoliation had little impact on perennial plant survival, however, none of the hybrids could sustain a significant plant population beyond the second summer of the experiment. Yield declines of the hybrid entries was due to increasing plant mortality, rather than a limitation of the germplasm, as all hybrid entries either maintained or increased their grain yield on a per plant basis. In contrast, the perennial grass maintained a constant population for the duration of the experiment. Dry matter digestibility and energy content of all forages tested were high, averaging 80.2% and 13.3 MJME/kg DM, respectively. Crude protein (CP) was higher ($p < 0.001$) in *Th. intermedium* and the hybrid entries with 62% and 25% more CP than Wedgetail, respectively. All cereals had very high potassium:sodium and low calcium:phosphorus ratios which indicated the need to provide mineral supplements to grazing animals to maintain growth rates and manage animal health disorders, similar to conventional grazing cereals. The combination of a perennial cereal/legume intercrop could boost forage quality and reduce the need for supplements in grazing animals.

Key words: *Triticeae* hybrids, *Thinopyrum* spp, mineral content, biomass, forage quality

Notes

Temporal changes in feed value of temperate perennial legumes

A. W. Humphries [A*], H.C. Norman[B], E. Hulm[A], S.J. Hughes[A], T. Rowe[A], D. M. Peck[A], P. Vercoe[B]

[A] SARDI P.O. Box 397, Adelaide South Australia 5000

[B] CSIRO Agriculture Flagship, Private Box 5 Wemberly Western Australia 6913

[*] Corresponding author: alan.humphries@sa.gov.au

Abstract: The temporal distribution of yield and nutritive value of 30 perennial legumes under irrigation and rainfed conditions was measured at the Waite Institute, South Australia. In the first summer, under irrigation, most commercial species had >70% DMD and 20% CP and at the mature growth stage, and decline in digestibility and protein over time and with increasing development stage was relatively low, with DMD of forage declining to an average of 60% with mature seed. *Medicago sativa* (lucerne) had the highest feed value under irrigated and rainfed conditions, with SARDI 7 series 2 producing a total of 20922 kg/ha, 201 MJ/ha of metabolisable energy and 4729 kg CP/ha under rainfed conditions in the second year of the experiment. Lucerne was also the only entry to produce significant quantities of forage in late spring and summer, with 8656−11745 kg/ha (48−60%) of production in summer compared with < 1400 kg/ha in all other entries. The next highest forage legume was *Hedysarum coronarium* (sulla), with cv. Wilpena producing 14957 kg/ha, 144 MJ ME/ha and 285800 CP/ha per year under rainfed conditions, with production dominant in winter through to spring. The persistence of all commercially available entries with the exception of lucerne was poor, highlighting the lack of alternatives to lucerne in this environment. The potential of perennial legumes to modify the diet of livestock to improve productivity and reduce emissions intensity is discussed.

Notes

Temporal changes in nutritive value of temperate perennial grasses and herbs

A. W. Humphries[A*], H. C. Norman[B], E. Hulm[A], S.J. Hughes[A], T. Rowe[A], D.M. Peck[A], K. M. Oldach[A], P. Vercoe[B]

[A] SARDI P.O. Box 397, Adelaide South Australia 5000

[B] CSIRO Agriculture Flagship, Private Box 5 Wemberly Western Australia 6913

[*] Corresponding author: alan.humphries@sa.gov.au

Abstract: The temporal distribution of yield and nutritive value of 30 perennial grasses and herbs under irrigation and rainfed conditions was measured at the Waite Institute, South Australia. In the first nine months, grasses and herbs were grown under irrigation and harvested every three weeks for cumulative forage production and nutritive value with increasing plant growth development stages. There were clear differences in digestibility between and within species at different times and in the pattern of digestibility change over time.

Forage yield under rainfed conditions was assessed in the second year to measure the distribution of forage production and identify plants that can extend the growing season or fill autumn to winter feed gaps. Chicory was the highest yielding grass or herb, with cv. Choice producing 15803 kg/ha/yr and 180 MJ ME/ha/yr. Chicory was also the only species to produce significant quantities of forage in late spring and summer, with 11745 kg/ha (56%) and 7661 kg/ha (44%) of their production in summer compared with < 1500 kg/ha in all other entries. The highest yielding grasses were Phalaris with cv. Holdfast GT producing 14400 kg/ha in year 2, Resolute and Freydo Tall Fescue (14000 kg/ha), Dundas tall wheat grass (1200 kg/ha), grazing brome (11200 kg/ha) and prairie grass (10900 kg/ha), which were all superior to perennial ryegrass (Banquet II was the highest cultivar with 6500 kg/ha). Holdfast GT also had higher metabolisable energy at the vegetative stage (10.7) compared with cvv. Advanced AT (10.1) and Australian 2 (10.3).

The potential of perennial grasses and herbs to modify the diet of livestock to improve productivity and reduce emissions intensity is discussed.

Notes

Quantifying the effect of interactions between defoliation interval, defoliation intensity and nitrogen fertiliser application on the nutritive value of rainfed and irrigated perennial ryegrass

K.G. Pembleton[A], R.P. Rawnsley[B], L.R. Turner[B], R. Corkrey[C], D.J. Donaghy[D]

[A] Institute for Agriculture and the Environment, University of Southern Queensland, Toowoomba QLD 4350: Keith.Pembleton@usq.edu.au

[B] Tasmanian Institute of Agriculture, University of Tasmania, Burnie, TAS 7320: Richard.Rawnsley@utas.edu.au, Lydia.Turner@utas.edu.au

[C] Tasmanian Institute of Agriculture, University of Tasmania, Hobart, TAS 7320: Stephen.Corkrey@utas.edu.au

[D] Massey University, Palmerston North 4442, New Zealand: D.J.Donaghy@massey.ac.nz

Abstract: A key goal of temperate pasture management is to optimise the nutritive value and production of pastures. Extensive research has examined the influence of single components such as irrigation, nitrogen (N) fertiliser, and grazing interval and grazing intensity, yet conjecture remains regarding practices that optimise pasture nutritive value. Much of this conjecture relates to interactions between inputs and grazing management. A two year split-split plot experiment was undertaken to investigate these interactions using a perennial ryegrass dominant pasture at Elliott, Tasmania. Irrigation treatments (rainfed or irrigated) were main plots and defoliation intervals (leaf regrowth stages 1-leaf, 2-leaf or 3-leaf) were subplots. Defoliation intensity (30, 55 or 80 mm defoliation height) and N fertiliser (0.0, 1.5 or 3.0 kg N/ha/day) were crossed within sub-subplots. Herbage samples were collected from each plot five times over the experimental period and were analysed for neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude protein (CP) concentrations (%). Metabolisable energy (ME) concentration was estimated from these values. The ME concentration decreased as defoliation height increased for all time points except for in winter. The CP concentration increased with increasing N fertiliser applications in the plots defoliated at the 1-leaf stage, but only occurred as N applications increased from 1.5 to 3.0 kg N/ha/day for the plots defoliated at the 2-leaf and 3-leaf stages of regrowth. Pastures defoliated at the 3-leaf stage had greater increases in NDF concentration with increasing N application rates compared to pasture defoliated at the 1-leaf stage of regrowth, except for in spring. The ADF concentration increased as both defoliation height and interval increased. While defoliating at frequent intervals (1-leaf stage) and lower heights (30 mm) produced pasture of a slightly higher nutritional value, the negative consequences to pasture yield and persistence associated with this practice outweighed any potential benefits to nutritive value.

Key words: grazing management, pasture-based dairy systems, intensive pasture production

Notes

....
....
....
....
....
....
....
....
....
....
....
....
....
....

Effect of tiller height on nutritive characteristics of four perennial pasture grasses

B.R. Cullen[A], D. Bullen[A], C. Hutcheson[A], M.H. Deighton[B], J.L. Jacobs[B]

[A] Faculty of Veterinary & Agricultural Sciences, University of Melbourne VIC 3010: bcullen@unimelb.edu.au;

[B] Agriculture Victoria, Ellinbank Centre, 1301 Hazeldean Road, Ellinbank VIC 3821: matthew.deighton@ecodev.vic.gov.au; joe.jacobs@ecodev.vic.gov.au

Abstract: Intensive dairy rotational-grazing systems aim to rapidly remove pasture on offer in a single grazing, often between milking events. Dairy cows that access the pasture later in the grazing period are likely to consume a sward with different nutritive characteristics to that available pre-grazing. The aim of this study was to quantify the differences in nutritive characteristics in late winter and spring that occur as pasture mass is depleted, using tiller height as a surrogate for pasture mass. Four species were compared: perennial ryegrass (*Lolium perenne* cv. Bealey), cocksfoot (*Dactylis glomerata* cv. Savvy), prairie grass (*Bromus willdenowii* cv. Atom) and tall fescue (*Festuca arundinacea*, cv. Jethro). The study utilised established monoculture swards with four replicates of each species at Ellinbank in west Gippsland, Victoria. Pastures were sampled during the periods 21st July-20th August and 10th November-8th December 2015. Eighty tillers were sampled per plot, dissected into three height categories (0-5, 5-10 and 10+ cm), and dried at 65°C for 72 h. Nutritive characteristics were determined by near-infrared spectroscopy for crude protein (CP, % DM), neutral detergent fibre (NDF, % DM), and dry matter digestibility (DMD). Estimated metabolisable energy (ME, MJ/kg DM) was calculated from DMD values. In all species, CP was higher in the 10+ cm fraction than for other height fractions, while NDF was lowest in the 10+ cm fraction ($P<0.05$). Irrespective of height, ME was highest in perennial ryegrass. Further studies will investigate nutrient selection by grazing dairy cows in these pastures.

Key words: grazing management, selection

Notes

....

Improving resilience of mixed pastures swards with alternative spatial configurations

R.C. Hayes[A], G. A. Sandral[A], G.D. Li[A], A.D. Swan[B], A. Price[A], S. Hildebrand[A], L. Goward[B], C. Fuller[A], C. Lihou[A] , M.B. Peoples[B]

[A] NSW Department of Primary Industries, Wagga Wagga Agricultural Institute, Pine Gully Rd, Wagga Wagga NSW 2650, Australia: richard.hayes@dpi.nsw.gov.au

[B] CSIRO Agriculture, GPO Box 1600, ACT 2601, Australia

Abstract: Maintaining a balance of multiple species in a mixed pasture sward can be challenging, particularly in lower rainfall environments. A series of field experiments was established at 5 locations in the Riverina region of southern NSW to examine the productivity and composition of mixed pasture swards containing lucerne (*Medicago sativa* L.), phalaris (*Phalaris aquatica* L.) and/or an annual legume species mixed together in the same drill row, or spatially separated in alternate (1:1) or double skip-row (2:1) configurations. The relative abundance of the perennial species, lucerne and phalaris, could be increased or decreased by increasing or decreasing the number of drill rows into which they were initially sown. Constraining lucerne growth in lucerne-subterranean clover (*Trifolium subterraneum* L.) swards by confining it to less drill rows increased subterranean clover production with little negative impact on total sward productivity. There was little evidence of negative impacts of alternative spatial configurations on total pasture productivity suggesting that it may present a relatively low risk approach to changing pasture composition. Further research is required to refine pasture sowing configurations, such as defining the optimum row spacing, and to monitor the impact on grazing behaviour and livestock performance.

Key words: Pasture establishment, competition, polyculture, binary mixture, persistence

Notes

Grazing management of tall fescue-dominant dairy pastures in southern Australia

A.R. Lawson, K.B. Kelly, M.E. Rogers

Department of Economic Development, Jobs, Transport and Resources, Tatura, Vic 3616, Australia: alister.lawson@ecodev.vic.gov.au, kevin.kelly@ecodev.vic.gov.au, maryjane.rogers@ecodev.vic.gov.au

Abstract: Tall fescue (*Festuca arundinaceae* (Schreb) Darbysh.) has the potential to become a useful component species of irrigated dairy pastures in northern Victoria due to its high dry matter production compared with perennial ryegrass (*Lolium perenne* L.). However, tall fescue is not widely grown because of the perception that its grazing management is difficult. In October 2010, a tall fescue/white clover pasture was established and border-check irrigated. In September 2011, six grazing management treatments were imposed over three years. Measurements included pre- and post-grazing pasture mass, pre-grazing nutritive characteristics (cut to ground level), botanical composition and plant frequency.

Pasture consumption from the 3-leaf stage (2.5 leaves during spring) treatment was over 3.5 t DM/ha.year (30%) higher than that from the three most frequently grazed treatments. However, the crude protein content was 1 3 %DM units lower when grazed at the 3-leaf stage compared with the two most frequently grazed treatments. There was no effect on either the estimated ME or NDF contents of the pasture on offer. Plant frequency and tall fescue content were reduced and weed content was increased in the most frequently grazed pastures compared to those grazed at the 3-leaf stage, particularly in the third year.

This experiment has shown that a grazing regime for tall fescue based upon the 3-leaf stage appears to be promising because it produced the most DM over the three years of the experiment The major disadvantage of the 3-leaf grazing regime was the need for an extra mowing each year. The practicality of the 3-leaf stage approach to grazing tall fescue needs to be tested at the whole farm level before widespread industry adoption is promoted.

Notes

Assessing the productivity and sustainability of grazing management systems

W. Badgery[A], G. Millar[A], K. Broadfoot[A], J. Martin[A], D. Pottie[A], A. Simmons[A] , P. Cranney[B]

[A] NSW Department of Primary Industries, Orange Agricultural Institute, 1447 Forest Rd, Orange NSW: warwick.badgery@dpi.nsw.gov.au

[B] Central Tablelands Local Land Services, Orange Agricultural Institute, 1447 Forest Rd, Orange NSW

Abstract: Grazing management has been identified as a means of increasing livestock production and improving the composition of perennial pastures. The benefits of intensive rotational grazing have caused much debate, but there has been little research into different methods of implementing these systems. A grazing management experiment was established on a cocksfoot dominant pasture to investigate a range of systems. The treatments covered different stocking rates, paddock numbers and rotation speeds, and a flexible treatment that adjusted grazing time, rest periods and stock numbers for optimal pasture utilisation. Data was collected on pasture characteristics and diet quality that was determined from faecal analysis, animal weight changes and pasture characteristics. Animal production per ha was greatest for fast rotations (56 days rest) at high stocking rates (HSR; 13.6 DSE/ha), but continuous grazing (CG) was equally as productive. While flexible grazing based on the 3-4 leaf-stage was proposed to be the best balance for pasture production and quality, this treatment had lower stocking rates (9.2 DSE/ha) and was not as productive. No treatment negatively impacted pasture composition over the 4-year period. While bare ground was highest for HSR CG, the 30-paddock rotations were able to limit bare ground at the same stocking rate. The results indicated that intensive rotational grazing can be effectively managed using green herbage allowance to budget throughout the year. In spring, green herbage allowance should be based between 1 and 1.5 kg green DM/DSE/da which should be increased up to 5 kg green DM/DSE/day as the quality of green DM decreases, to allow selective grazing to enhance diet quality.

Notes

....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....

Development of sensor algorithms for intake of pasture by individual grazing cattle

P.L. Greenwood[A,B], D.R. Paull[B], J. McNally[B], T. Kalinowski[B], D. Ebert[A], B. Little[C], D.V. Smith[D], A. Rahman[D], P. Valencia[E], A.B. Ingham[C], G.J. Bishop-Hurley[C]

[A] NSW Department of Primary Industries, UNE, Armidale NSW 2351: paul.greenwood@dpi.nsw.gov.au

[B] CSIRO Agriculture, Armidale NSW 2350: David.Paull@csiro.au

[C] CSIRO Agriculture, St Lucia Qld 4067: Greg.Bishop-Hurley@csiro.au

[D] CSIRO Data61, Sandy Bay Tas 7005: Daniel.V.Smith@csiro.au

[E] CSIRO Data61, Pullenvale Qld 4069: Philip.Valencia@csiro.au

Abstract: Measurements of intake and selectivity of pasture will enable improved precision in livestock and pasture management. These are also important input variables for prediction and simulation models, and allow animals to be ranked on grazing efficiency for genetic improvement. Our objectives are to determine pasture intake and selectivity of individual grazing animals using sensors and wireless sensor networks. We have been developing on-animal sensor devices to classify behaviours specifically associated with consumption of pasture (e.g. grazing, biting, chewing, ruminating) and non-grazing activities (e.g. walking, resting, drinking) for use in pasture intake algorithms. Grazing has been classified using data from inertial measurement units (IMU) with accuracy of >95%. An initial pasture intake algorithm has been established using collar-mounted IMU on 10 Angus steers (mean ± SD live weight 650 ± 77 kg): Pasture dry matter intake (DMI, kg/d) = -4.13 + 2.325 × hours spent grazing/d (P = 0.010, r2 = 0.53, RSD = 1.65 kg DM/d). Pasture DMI for each steer (one steer/≤0.22 ha ryegrass plot) was estimated from the slope (kg DM/d) of the regression of total pasture DM/plot on intake day over an 11 d period. Pasture DM in each plot, commencing with ≤2 t DM/ha/plot, was determined using repeatedly calibrated C-Dax pasture height and Farmtracker electronic rising plate meters. Further development, validation and refinement of intake algorithms is being undertaken under varying pasture conditions using collar, halter, ear tag and leg mounted sensor devices, coupled with established methods for measuring pasture characteristics and grazing intake and selectivity.

Key words: accelerometer, acoustic sensor, magnetometer, GPS, cattle, sheep

Notes

....

Notes

POSTER PAPERS

Improving sheep liveweight gains through alternative forages in low rainfall mixed farming systems

B.B. Dzoma[A], R. Latta[B]

[A] South Australian Research and Development Institute (SARDI), Minnipa Agricultural Centre, South Australia; brian.dzoma@sa.gov.au

[B] Dodgshun Medlin, Swan Hill, Victoria; rlatta@dodgshunmedlin.com.au

Abstract: Livestock producers on the Eyre Peninsula (EP), South Australia (SA) have the proven capacity to sustainably produce sheep as a valuable component of low rainfall mixed farming systems. However, the EP has historically recognised feed gaps which threaten the productivity and viability of sheep enterprises. The introduction of alternative pastures and forage crops to increase the period of availability of highly digestible feed is vital to maintaining the sustainability and profitability of mixed farm enterprises. The aim of this study was to evaluate alternative pasture/forage options with potential to fill the late-spring nutritional feed gap brought about by the senescence of the annual pastures and prior to the availability of crop residues. The study measured feed quality and animal productivity in response to vetch vs self-sown barley crop (Spring 2013) and sulla vs a mature forage barley crop (Spring 2014). Four to 16 month old merino weaners were allocated to treatments for 4 weeks and assessments were done of their respective pasture/forage intake (quality and quantity), and the subsequent response in animal production through liveweight gains. Results showed that pasture intake (kg DM/head/day) and liveweight gain (g/head/day) was higher from the lambs on the better quality forages; vetch and sulla with higher metabolisable energy, protein and digestibility than the barley forage crops.

Key words: feed gap, Eyre Peninsula, mixed farms, alternative forages

Introduction

Sheep are an integral part of low rainfall (<400mm) farming systems in Australia. They act as an alternative enterprise to reduce exposure to risk in poor cropping years; help control weeds and produce income from legume pastures being grown in rotation with cereal crops. The current feeding regime of annual legume pastures (June/July through to October) followed by dry crop residues (available from December through to February) only provides feed capable of supporting animal growth for 7 to 8 months of the year.

Sheep production on mixed farms on the Eyre Peninsula (EP) is limited by feed gaps in late spring, autumn and early winter. Extending the availability of a highly digestible forage supply to the November, December and March to May periods will extend the period of rapid growth rates of young animals, resulting in an earlier turn off prior to the normal annual Mediterranean summer drought when growth ceases. The use of alternative perennial pasture systems, e.g. vetch, sulla or lucerne will increase the period of availability of highly digestible forages into spring and early summer as opposed to the current ley pasture system, and address current nutritive quality issues limiting livestock growth.

A second alternative is that fodder crops (e.g. barley, oats) may be left unharvested at the end of growing season to fill the November/December feed gap. This may be particularly attractive in years with poor finishes as an alternative to harvesting a failed crop. In this context, the aim of this project was to evaluate alternative pasture/forage options with potential to fill in the late-spring nutritional feed gap brought about by the senescence of the annual pastures and prior to the availability of crop residues. The hypothesis was that filling the late spring "feed gap" with highly digestible forages to replace poor quality forages during those periods, will not only improve the availability and quality of grazing resources, but also improve animal productivity and fertility in low rainfall farming systems.

Methods

Replicated field trials were established at Minnipa Agricultural Centre, Minnipa, EP, SA (Lat: 32° 50'11" S; Long: 135°09'05" E) in November 2013 and 2014. The region has an annual average rainfall of 325mm and a growing season average of 241 mm. Total rainfall for 2013 was 334mm, and growing season rainfall was 237mm. The last spring rainfall fell on the 8th of November (16mm) and by that time the vetch and self-sown barley crop growth had already ceased. The trial commenced in November with 200 mixed sex merino weaners (July 2013 drop) at an average liveweight of 28kg. Two replicates were used for each treatment; treatment 1 was placed on an unharvested vetch (*Vicia sativa*) stubble and supplemented by oats grain in a lick feeder. Treatment 2 was placed on an unharvested self-sown barley (Hordeum vulgare) stubble with an annual medic (Medicago spp) pasture residue understory; supplemented by a grain mix of barley and peas in a lick feeder. In 2014, total rainfall was 407mm, and the growing season rainfall was 290mm. spring 2014 was drier, and the last rainfall fell on the 10th of September (9mm). The trial commenced in October with 100 merino ewe hoggets (July 2013 drop) at an average liveweight of 62kg. Two replicates were used for both treatments; treatment 1 was placed on a biennial forage legume, sulla (Hedysarum coronarium) at flowering stage and treatment 2 on a mature unharvested barley crop at growth stage 90.

A total of 5 pre and post grazing samples were collected from randomly selected points within each paddock to estimate available dry matter (DM) and the rate of disappearance. The quality of the different forage components was also estimated through a Feedtest analysis done through Agrifood Technology (Victoria). After 30 days, the animals were taken off their respective treatments and weighed the following morning after an overnight fasting.

Results and discussion

Different stocking rates were used for the two grazing trials because of differences in the available biomass and forage quality. Daily dry matter intake of a 30kg and 60kg growing lamb is 4.7% and 2.8% of live weight respectively (NRC, 1985). Therefore a 30 kg lamb growing at 200 g/day requires 1.3 kg DM/day of forage with 14-16% crude protein (CP) and 10.5-11 MJ/kg DM metabolisable energy (ME), and as a general rule, the pasture or forage that is optimal for finishing weaned lambs should have a DM digestibility of about 70% and have more than 50% green matter (Jolly and Wallace 2007). Estimates of DM disappearance (Table 1) suggest levels of DM loss in excess of potential limits of intake by young merino sheep, therefore we have assumed that a large proportion of the DM loss is associated with trampling and natural breakdown.

The differences between liveweight (LW) gain were highly significant ($P<0.001$) for both grazing trials. For the 2013 grazing trial, the control group grazing the self-sown barley standing crop had an average daily weight gain (ADWG) of 41 g/day over the 30 days of the trial or 1.2 kg LWG, indicative of production performance from a poor quality forage (Table 2). In contrast, the treatment group grazing vetch had an ADWG of 190 g/d over the same period or 5.5 kg LW gain, indicative of better quality feed with adequate CP and energy levels to allow rapid LW gain and shorter time for lambs to reach market specifications.

The 2014 spring LW data indicated a significant response ($P<0.001$) in LW gain and ADWG between the two forage treatments. The hoggets on the barley gained an average of 2.9 kg/head while the hoggets on the sulla gained an average of 5.1 kg/head over the 30 day trial.

Table 1. Forage quantity, quality and utilisation for the four forage treatments

Year	Forage	Stocking Rate (DSE/ha)	Biomass (t/DM/ha)	Disappearance (kg/head/day)	Crude Protein (%)	Digestibility DMD (%)	ME (MJ/kg DM)
2013	Vetch (pods/grain)	4	0.3	1.2	28.9	88.0	12.6
	Vetch (residue)		1.9	1.5	12.9	54.0	7.8
	Oats (grain)			0.25	15.3	78.0	14.0
	Barley (heads/grain)	6		1.3	12.8	80.0	12.6
	Barley (stubble)		0.6	1.3	8.7	60.0	9.4
	Barley (grain)		1.9	0.02	11.3	86.0	13.2
	Field peas (grain)			0.06	26.2	90.0	13.0
2014	Unharvested barley crop	21	3.91	3.66	7.3	75.7	11.4
	Barley grain				11.4	90.0	13.7
	Sulla	15	1.71	3.19	15.3	60.8	8.9

The hoggets on the sulla achieved 85% more ADWG (150.2 g/head/day) than those on the standing unharvested barley crop (81.2 g/head/day). This was largely attributed to the fact that sulla was a green feed with higher crude protein content (18.1%) than the barley crop (7.3%).

Both of the alternative forages (vetch and sulla) trialled in 2013 and 2014 have the potential to be utilised by livestock producers in low rainfall farming systems to improve feed quality and availability during the late spring – early summer feed gap. Vetch is a multi-purpose crop grown mostly as a disease break crop in rotation with cereals on a wide range of soil types from light sands to heavier clay soils, however care must be taken when growing rust susceptible varieties as grazing or feeding hay from rust infected plants may induce abortions in pregnant ewes (GRDC, 2016). Sulla has a high yield potential and is highly palatable with excellent forage and fodder quality and outstanding animal performance, with an added advantage of potentially fixing high levels of nitrogen. It is high in protein and produces condensed tannins which assist in the prevention of bloating in livestock (De Koning *et al*., 2009). Also, sulla is reported to have anthelmintic qualities which may reduce worm burdens and gastrointestinal nematodes as well as reducing faecal egg counts and larval establishment (Wrightson Seeds, 2007). This in turn improves animal health and wellbeing and improves live weight gains.

It is common practice on the EP to offer young growing lambs ring the summer period, and in most cases spilled grain and weed residues are considered to be a valuable component of summer feed. Cereal straw with no grain present, typically has 40–45% digestibility, and at this level, ME is lower than maintenance requirements and stock will require supplementation in order to maintain or prevent loss of condition (Stock Journal, 2016). Therefore,

Table 2. Mean liveweight gains for four forage treatments

Year	Treatment	Post grazing LW (kg)	Total LW gain (kg)	Ave.daily LW gain (g/head/day)
2013	Vetch	33	5.5	190
	Self sown barley	29	1.2	41
		P<0.001	P<0.001	P<0.001
2014	Sulla	68.5	5.1	150.2
	Unharvested forage barley	65.9	2.9	81.2
		P<0.05	P<0.001	P<0.001

failed or substandard cereal crops can be utilised to extend the period of availability of quality fodder without compromising animal productivity.

Conclusion

Historical feed gaps, coupled with seasonal variability, present livestock producers with a challenge to sustainably produce lambs with good marketable weight (40-50 kg liveweight). Therefore adopting alternative forages that have the potential to extend the period of availability of better quality forages and improve animal productivity is key to maintaining the profitability and sustainability of livestock production systems on the Eyre Peninsula and other low rainfall mixed farming systems. Of the forages evaluated, the lambs on vetch (supplemented by oats grain), and sulla resulted in increased liveweight gains and so can be considered as forage options for the period between the senescence of annual pastures and availability of crop residues. This provides producers with an opportunity to sell young sheep at an earlier age, and minimise the risk of overgrazing to protect vulnerable soils.

Acknowledgements

This project is supported by funding from the Australian Government Department of Agriculture – Action on the Ground program (Project Code: AOTGR2-0039 Reducing sheep methane emissions through improved forage quality on mixed farms).

References

De Koning. C, Yates. R and Wurst. M (2009). Sulla (Hedysarum coronarium): Management Package. South Australia Research and Development Institute

GRDC (2016). South Australian sowing guide. What to sow next season: The essential guide to the most suitable varieties. Grains Research and Development Corporation

Jolly S and Wallace. A (2007) Best practice for production feeding of lambs: A review of the literature. Meat and Livestock Australia Final Report, Project SCSB.091.

NRC (1985). National Research Council. Nutrient requirements of sheep (6th edn). Subcommittee on Sheep Nutrition, Committee on Animal Nutrition, Board on Agriculture, National Research Council. (National Academy Press: Washington, D.C., USA)

Stock Journal (2016). In the business of sheep: Plan ahead to close feed gaps. Thursday February 25, 2016

Wrightson Seeds (2007). Forage focus: Sulla – the wonder legume

Notes

Liveweight gain by cattle grazing native pasture or improved pasture sown on rehabilitated mine land – Upper Hunter study

N.W. Griffiths[A], L.H.McCormick[B], N.R.Nelson[C]

[A] NSW Department of Primary Industry, Tocal Agricultural Centre, Paterson NSW 2421: neil.griffiths@dpi.nsw.gov.au

[B] Agronomist, Manilla NSW 2346 (formerly NSW DPI): mccormicklester@gmail.com

[C] Neil Nelson Agvice Pty Ltd, Singleton NSW 2330: neil@neilnelsonagvice.com

Abstract: Three comparison sites in the NSW Hunter Valley had pastures monitored and cattle weighed seasonally. Cattle were steers introduced as weaners and grazed for 12 to 18 months before sale. Each site used randomly allocated steers with common breeding and background. Stocking rate was the same for each treatment at each site. Pastures were a diverse mix of species. The rehabilitated mine land was dominated by the introduced species, Rhodes grass (*Chloris gayana*) with green panic (*Megathyrsus maximus*) and kikuyu grass (*Pennisetum clandestinum*) also common. The native pasture was dominated by redgrass (*Bothriochloa* spp.), wiregrass (*Aristida ramosa*), *Sporobolus* spp. and Queensland bluegrass (*Dichanthium sericeum*). Soil tests indicated that fertility was similar on each paired study site. Steers were moved in a simple two or three paddock rotation after each weighing. Results to date show that steers grazing rehabilitated mine land gained an average 77kg/head more weight than those on the native pasture, analogue sites and botanical composition across the sites has been maintained during the study.

Key words: botanal, biomass, coal mining, rehabilitation, analogue

Introduction

In the Hunter Valley of New South Wales, coal mining companies control large areas of land (over 60,000 ha of agricultural land in 2013). By 2013 a total of 9,145 ha of mined land had been rehabilitated in the valley with 18,283 ha disturbed by mining but not yet rehabilitated. In 2013 a further 1,148 ha was newly disturbed while new rehabilitation had commenced on 962 ha (NSW Minerals Council).

There has been ongoing discussion in the community about how effective mine site rehabilitation is and whether it is possible to return mined land to previous levels of productivity. To help inform this discussion three study sites have been established to compare beef cattle production from rehabilitated mine land and adjacent native pasture which represents what the land was like prior to mining. The primary objective of these studies was to investigate the question "Can rehabilitated mine land sustainably support productive and profitable livestock grazing"?

Sites used in these studies were rehabilitated after open cut coal mining fifteen to thirty years previously using standard practices from that time (W.Baxter pers. com.). After mining the sites were rehabilitated and sown to a pasture mix comprising Rhodes grass cv. Pioneer (*C. gayana*), green panic (*M. maximus*), lucerne (*Medicago sativa*), couch grass (*Cynodon dactylon*), medic (*Medicago* spp.) subterranean clover (*Trifolium subterraneum*) and white clover (*T. repens*). The native pasture comparison sites reflect the original pastures of the area and are separated from the rehab sites by a fence or road.

Methods

Site description

Three sites were monitored, each site comprised a rehabilitated mine site and an adjacent native pasture analogue site of the same area. The mine sites were rehabilitated at least 15 years ago. This has allowed the sown pasture to establish and stabilise.

Site 1 (-32.499560, 150.990693) Singleton, NSW. Comprises two 20 ha paddocks each for rehabilitation and analogue.

Site 2 (-32.364081, 150.836125) Muswellbrook, NSW. Comprises three 10 ha paddocks each for rehabilitation and analogue.

Site 3 (-32.373304, 151.020559) Liddell, NSW. The initial trial at this site (2012 – 2014) used two 36 ha paddocks each of rehab and analogue. A second trial at the same site (2014 – 2015) had a reduced area of 25 ha per paddock.

Soils

Top soil (0-10 cm) was sampled and analysed over the 0-10 cm profile at the beginning of the studies.
Table 1 Soil Analysis (0-10cm depth) results at three trial sites in the Hunter Valley NSW at the commencement of the grazing study

Cattle

Steers were vaccinated, drenched and ear tags applied for identification before introduction to the study sites as weaners. No supplementary feeding was undertaken. Sites 1 and 2 used Angus steers (sourced from different herds at each site). At each site steers were randomly allocated to the sown rehabilitation pasture or native pasture treatment with 10 steers in each. At site 3, 30 Charbray steers were allocated to each treatment in the first trial; 20 per treatment in the second trial. See Table 2 for cattle weights.

Pastures

Pastures were monitored for herbage mass and botanical composition. At sites 1 and 2 a botanal (Tothill *et. al*.1978) (Powells 2015) was assessed at approximately six week intervals. Botanals used 3 random 1000m transects at in each paddock with sampling every 20m. Site 3 used 2

Table 1 Soil Analysis (0-10cm depth) results at three trial sites in the Hunter Valley NSW at the commencement of the grazing study

Site	pH ($CaCl_2$)	Phosphorus (Colwell mg/kg)	Cation exchange capacity (cmol(+)/kg)
Site 1 Analogue	5.7	6.0	17.4
Site 1 Rehab	6.8	31.0	14.4
Site 2 Analogue	5.5	7.0	13.2
Site 2 Rehab	7.8	5.0	32.4
Site 3(1) Analogue	4.7	7.0	5.8
Site 3(1) Rehab	6.1	11.0	12.9
Site 3(2) Analogue	4.7	14.0	5.5
Site 3(2) Rehab	5.9	17.0	12.9

fixed transects of 100 metres per paddock with sampling points every 5 metres, assessed seasonally.
Fertiliser was used when mine sites were initially rehabilitated but no fertiliser had been applied for at least 10 years except for the second study at site 3 when fertiliser was applied to both rehabilitation and analogue on 10 June 2014, at the same application rate (single superphosphate at 125 kg/ha).

Results

Cattle
Steers grazing on the rehabilitated mine land gained an average 77kg/head more weight than steers grazing native pasture analogue comparison areas (table 2). This result was associated with a greater pasture availability on the rehabilitated land (Table 2).
Soil Analyses
Soil analyses indicated the rehabilitated land was less acidic than the analogue undisturbed sites (Table 1). Phosphorus (Colwell P) was medium at site 1 rehabilitation, low at site 1 analogue, low at both site 2 areas and slightly higher in the rehabilitation area than the analogue paddock at the site 3. The relatively low soil phosphorus levels are typical in the area. The topdressing of superphosphate to both site 3 areas in 2014 increased the soil phosphate level in both native and improved treatments and encouraged more legume growth.

Pastures
Pasture measurements at site 1 (Figure 1) show that analogue pastures have more species diversity but less herbage mass available for grazing than the pastures on rehabilitated mine sites. The “native” pastures were dominated by redgrass, wiregrass, Queensland bluegrass and Sporobolus species with The rehabilitated pasture was dominated by Rhodes grass.

Conclusions

Comparison across three sites in the Upper Hunter Valley has shown that steers grazing rehabilitated mine land have achieved growth rates equal to or well above steers grazing adjoining undisturbed native pastures. Tropical pasture grasses sown into the rehabilitated sites were able to provide higher pasture productivity than many of the native species.

Soil analyses indicated rehabilitated land typically was less acidic than undisturbed topsoil, had higher CEC and similar, or higher phosphorus levels.

Legume content varied between sites, with one trial site having both treatments (rehabilitated and native) top-dressed with superphosphate, resulting in a greater contribution of white clover, medics and subterranean clover.

Table 2. Cattle weight gain comparing rehabilitated mined land and native pasture analogue at three sites in the Hunter Valley NSW.

Site	Area (ha)	Numbeer of steers	Days in study	Average start weight (kg/ha)	Average end weight (kg/ha)	Weight gain (kg/hd)	Weight grain per day (kg/hd/day)	Weight gain kg/ha
Site 1 Analogue	40	10	551	358	611	253	0.46	63
Site 1 Rehab	40	10	551	344	764	420	0.76	105
Site 2 Analogue	30	10	581	275	537	262	0.45	87
Site 2 Rehab	30	30	581	278	586	308	0.53	103
Site 3(1) Analogue	72	30	533	418	597	179	0.34	75
Site 3(1) Rehab	72	30	533	406	662	256	0.48	107
Site 3(2) Analogue	49	20	383	319	548	229	0.60	94
Site 3(2) Rehab	49	20	383	316	562	246	0.64	100

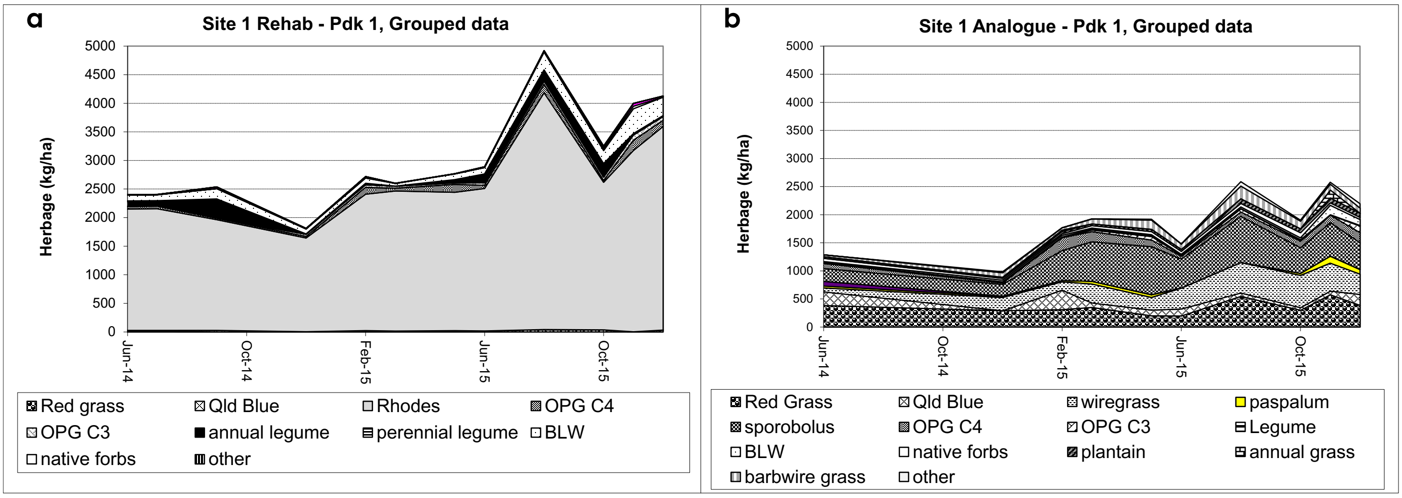

Figure 1. Pasture species diversity at a) Site 1 Rehab and b) Analogue Site

Pasture grass composition did not change any more than the normal seasonal variation and ground cover remained above 70 percent throughout the studies.

Tropical perennial pasture grass species used in mine rehabilitation are suited to the soil conditions at these sites and the stop/start growth periods associated with variable rainfall. Ground cover, an important component of grazing management with variable rainfall, was maintained throughout the study.

The study across the three sites provide strong evidence that with successful rehabilitation, selection of species and pasture management, rehabilitated mine land can be used for profitable grazing.

Acknowledgments

These studies were organised through the Upper Hunter Mining Dialogue and are supported by the NSW Department of Primary Industries and Division of Resources and Energy, ACARP (the Australian Coal Industry's Research Fund), Glencore, Rio Tinto, and BHP Billiton. We especially want to acknowledge input into the studies from Jo Powells, Harry Rose, David Deane, Bill Baxter and Luke Stevens. Study site 3 was supported by Glencore (Coal Assets Australia), and conducted by Neil Nelson Agvice P/L with co-operation of Colinta Holdings P/L. The input of Terry Launders, Rob Slaughter and Nigel Charnock is gratefully acknowledged.

References

Anon, http://www.nswmining.com.au/dialogue/rehabilitation-reporting

Powells J (2015) The sustainability and productivity of grazing on rehabilitated mine land in the Hunter Valley. Mine land Rehabilitation Conference, Singleton (The Tom Farrell Institute, University of Newcastle.)

Tothill JC, Hargreaves JNG, Jones, RM, McDonald CK (1992) BOTANAL – a comprehensive sampling and computing procedure for estimating pasture yield and composition. I. Field sampling. CSIRO Australia, Division of Tropical Crops and Pastures. Tropical Agronomy Technical Memorandum No. 78.

Notes

Economic and environmental differences between the nitrogen response functions of perennial ryegrass cultivars.

M. Harmer[A], J. Sewell[A], L. Menhenett[B] and C. Farlow[B]

[A] PGG Wrightson Seeds Research, Leigh Creek Research Station, Leigh Creek, VIC 3352: mharmer@pgwseeds.com.au and jsewell@pgwseeds.com.au

[B] Incitec Pivot Fertilisers Limited, Level 8/28 Freshwater Pl, Southbank, VIC 3006: Craig.Farlow@incitecpivot.com.au and lee.menhenett@incitecpivot.com.au

Abstract: Nitrogen (N) fertiliser is an important input in perennial ryegrass (*Lolium perenne* L.) systems for both economic and environmental reasons. A large body of perennial ryegrass N response data contributes to current recommendations, but owing to when the experiments were completed, the responses were for now outclassed cultivars. Might modern perennial ryegrass have different response functions and as a consequence, different profit maximising N rates and environmental risk profiles? Eight perennial ryegrass cultivars ranging from those which contribute to historical datasets, European and contemporary commercial cultivars to an experimental cultivar (potentially available to producers in the 2020's) were used in this experiment. Each cultivar was tested at 5 N rates; 0, 20, 40, 80 and 160kg N/ha per harvest. A single late spring harvest was analysed from an economic perspective. Old cultivars were found to exhibit a typical diminishing marginal return while the newer cultivars, on average, behaved linearly in the N range examined. New cultivars had a commensurately higher profit optimising N rate. Analysis of a winter harvest demonstrated cultivars vary significantly in their N uptake at all rates including 0 and 160kg N/ha. Given prior work demonstrates N uptake is inversely proportional to N leaching risk, newer cultivars with higher yields in winter may reduce this risk. The data indicates that for producer profits to be maximised, N use recommendations may need updating to reflect contemporary cultivar performance. Collection and analysis of more data is required to determine if cultivar specific responses exist and should be reflected in N use recommendations.

Key words: marginal cost, genetic gain, regulation, endophyte

Introduction

Nitrogen (N) use on perennial ryegrass pasture has both economic benefits and environmental consequences. The importance of the benefits of N use is evidenced by the large body of historical research that contributes to current recommendations (Eckard 1999, Gourley *et al*. 2016 and Stott *et al*. 2016) and the volume of nitrogen fertiliser utilised by farmers. The environmental aspects of N use are increasingly well researched. As a company who breed and market improved perennial ryegrass and market and advise on fertilisers (PGG Wrightson Seeds Ltd and Incitec Pivot Fertilisers Ltd respectively), we were intrigued by the possibility that improvements in cultivars of perennial ryegrass may have consequence for both the economic and environmental aspects of N fertiliser use.

The role of N within pasture systems was thoroughly researched and reviewed in the 1990's as part of the Best Management Practices for Nitrogen in Intensive Grazing Systems project (Eckard 1999) which published guidelines suggesting the application of no more than 50kg N/ha per application to maximise economic efficiency, and no more than 200kg N/ha/year to minimise adverse effects on clover.

A more recent review of Australian pasture N response experiments aggregated data into seasonal and regional response functions (Gourley *et al*. 2016), made accessible to farmers via an interactive marginal costs analysis based decision support tool (Stott *et al*. 2016). This is a step forward from old recommendations that list linear responses, albeit recommending ceiling applications of 50-60kg N/ha. While the economics of this approach are sound (diminishing marginal returns and varying pasture price and utilisation) and the analysis is based on a large data set, the overwhelming majority of trials contributing to this decision support tool were completed prior to the 1990's (C Gourley personal communication 2013). As such, the majority of data contributing to industry best practice guidelines can only represent response functions of 'Australian' ecotypes of perennial ryegrass, as these were all that was available in Australia at the time. These 'Australian' ecotypes are in fact naturalised Northern European ryegrasses, examples of which include the ecotypes Victorian and Kangaroo Valley, most often containing standard endophyte (SE). As a result of their European origin 'Australian' ecotypes are winter dormant, with naturalisation to the Australian environment favouring plants which in comparison to modern cultivars (discussed below) could be described as semi-summer dormant, with comparatively poor late spring, summer and autumn growth.

In the late 1990's, pasture seed companies began offering Australian farmers ryegrass with germplasm from North West Spain (Stewart 2006) with improved autumn, winter, late spring and summer growth. This type of germplasm now occupies all top positions in cultivar evaluation schemes in environments comparable to Australia's (Dairy NZ 2016).

There is a knowledge gap regarding the N response functions of modern perennial ryegrass cultivars which vary from old cultivars and amongst themselves in seasonal growth potential. From an economic perspective our primary concern is the response function's slope. If breeding has increased this, then farmers may be able to capture additional profits by increasing N application in some seasons. Inversely, should breeding have decreased the slope of response functions, current recommendations may lead farmers to use too much N. Risk to the environment via leaching of N is strongly negatively correlated with pasture N uptake (Moir 2013). The increased growth of modern cultivars in winter may allow production to be increased via an increased N rate, while risk to the environmental is held constant. If we proceed to advise and regulate N use in the absence of this knowledge, we may unnecessarily constrain productivity as the genetic potential of perennial ryegrass performance improves over time. If our hypothesis that improvements in perennial ryegrass genetics are of economic and environmental consequence is true, it may be that N use guidelines and N use regulation should take into consideration the cultivar sown.

Methods

The experiment was sown at Leigh Creek, near Ballarat, Victoria (37°33' S, 143°57'E, altitude 575 m, mean annual rainfall of 847 mm). The soil is a deep red Krasnozem weathered in-situ from basalt, select chemical characteristics of soil between 0 and 10 cm below ground level include pH (H2O) 5.3, electrical conductivity (Saturated extract) 1.0 dS/m, Olsen P 37 mg/kg, Colwell potassium 320 mg/kg and sulphate sulphur (KCl40) 7 mg/kg. The trial site was sown to lupins (*Lupinus angustifolius*) in the autumn of 2013. These and any weeds were sprayed out with glyphosate (1,620 g/ha) in spring 2013, cultivated and the site chemically fallowed with glyphosate until May 2014 when the trial was sown.

To determine if a change in cultivar response to nitrogen has occurred as a result of breeding, historical and modern perennial ryegrass cultivars with vastly divergent seasonal growth potential were selected. The early maturing diploid ecotype Victorian SE and very early maturing cv. Fitzroy SE (bred from Kangaroo Valley germplasm) were sown to represent historical naturalised Northern European germplasm whose response to N determines current N use recommendations. The European diploid cv. Aberdart AR1 was included to represent material bred in Europe and sold to Australian and New Zealand farmers. The modern diploids cv. Ultra AR1 and cv. One50 AR37 and modern tetraploid cv. Base AR37 were included to represent contemporary Australasian bred cultivars with a range of yield potential (Dairy NZ 2016). To determine the effect of the AR37 novel endophyte at the trial location, Base AR37 seed was incubated following a proprietary procedure to generate an endophyte free line. An elite experimental tetraploid PGWLp AR37 was trialled to represent cultivars producers may have available to them in the near future.

The experiment was a randomised block design with three replicates. Two nitrogen management regimes were implemented. The first regime had all N rates (0, 20, 40, 80 and 160 kg N/ha) applied to all cultivars at every second harvest (to prevent the potential accumulation of N confounding response functions) and the second regime has 20, 40, 80 kg N/ha applied to Base AR37 and ecotype Victorian every harvest. A replicate of Base AR37 was also fertilised with 40 kg N/ha in the form of Green Urea (a urease inhibitor coated urea) and these results will be reported elsewhere. Nitrogen fertiliser was applied post-harvest by hand as pre-weighed amounts of Urea. Periodic basal fertiliser application of a specifically designed blend of nutrients ensured that other nutrients were non-limiting.

Yield was determined by full plot harvest of all forage above 50 mm from ground level and the collection of sub-samples for dry matter determination and nutritive analysis (not reported). Harvests occurred when the most advanced cultivars in the trial were observed to reach the three leaf stage as this has been shown to optimise pasture production (Fulkerson and Donaghy 2001) and nitrogen use efficiency (Rawnsley *et al*. 2014 and Staines *et al*. 2011). Environmental parameters were available from a nearby government weather station (BOM No.087014) and soil moisture and temperate were logged under select plots using Watermark® soil moisture sensors at 10, 20 and 30 cm depths. Irrigation supplemented rainfall as required. Deep soil N was measured twice per year (10, 20 and 30 cm) under all Victorian SE and Base AR37 plots (not reported). Spatial variation was accounted for using ASReml (VSN International 2016) with cultivar/N rate combinations fitted as fixed effects. Response functions were fitted using CurveExpert Professional (Hyams 2016). As at March 2016 there were 11 harvests following an N application. Collection of data is expected to continue until autumn 2017 when approximately 20 harvests and associated N uptake, soil N, nutritive analysis and environmental data will require in-depth analysis from an economic and environmental perspective. For brevity, only two harvests are discussed here. The economic discussion is framed around a late spring response and the environmental discussion around a mid-winter response.

Results and discussion

At all harvests thus far we have identified significant differences between cultivars.

Nitrogen use economics

The 2 December 2015 harvest (after 44 days of regrowth) is utilised in this discussion of economic implications. A range of biologically sensible response functions were found to well model individual cultivar data. A number of cultivars were better modelled by the Hill equation (a dose response [DR] function) than the commonly used Mitscherlich function. The DR-Hill function was better able to account for the lack a response which was often observed between the 0 and 20kg N/ha treatments, which is consistent with reports of unreliable responses at low levels on N input (Eckard 1999). Some newer cultivars demonstrated essentially linear responses at this harvest with no indication of diminishing returns, i.e. PGWLp Ar37 (r^2=0.94) Base Nil (r^2=0.88) and Ultra Ar1 (r^2=0.96).

Until multiple harvests are available to develop seasonal specific response functions, we will avoid cultivar specific conclusions. We will however compare 'old' cultivars influencing current recommendations (Victorian SE and Fitzroy SE) with 'new' locally bred cultivars (Base Ar37, Base Nil, PGWLp Ar37, One50 Ar37 and Ultra Ar1), to determine if profit maximising N rate varies with the type of cultivar.

The Hill-DR model was most appropriate for 'old' cultivars (r^2=0.93) at the 2 December 2015 harvest, realistically capturing the minimal response observed between both 0 and 20kg N/ha and 80 and 160kg DM/ha, see Figure 1. If the price of N is taken to be 140 c/kg N and the value of grown forage 25 c/kg DM, N use should increase so long

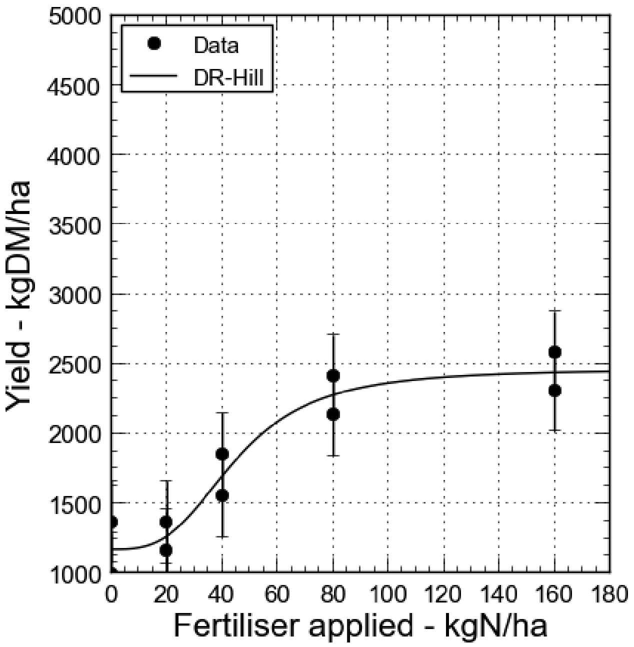

Figure 1. Old cultivar model

as the observed response to additional N (the slope of the response function) is greater than 5.6 kg DM/kg N (140 c/ kg N / 25 c/kg DM), i.e. so long as the marginal cost of additional feed grown is less than its value. 'Old' cultivars reached this profit maximising point at approximately 82 kg N/ha.

Figure 2 presents a linear regression (r^2=0.92) fitted to all 'new' cultivar data from the 2 December 2015 harvest. Models that could account for a diminishing marginal return were no better fit. The slope of the linear regression was 13.9 kg DM/kg N and there is no evidence of a diminishing marginal return in this aggregated 'new' cultivar data, suggesting the economic optimum of this particular dataset lies beyond 160 kg N/

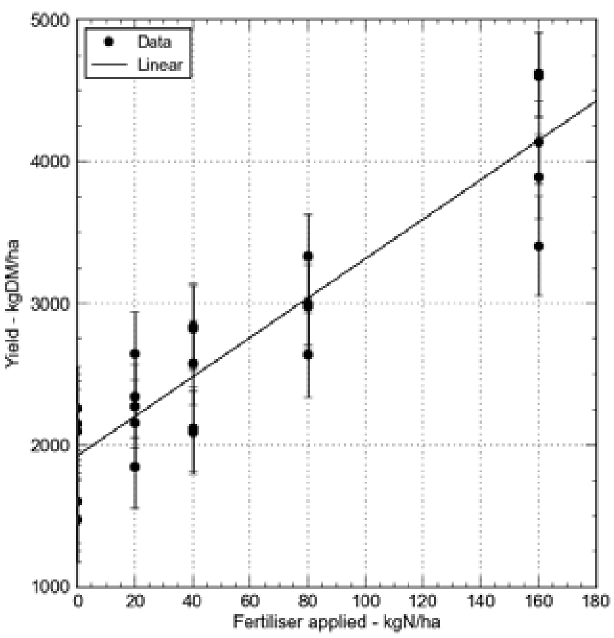

Figure 2. New cultivar model

ha. To our knowledge, this is the first time two distinctly different nitrogen response functions have been identified in different types of cultivars within the one trial. This suggests the hypothesis of our work may be correct, and different types of perennial ryegrass do indeed have different N response functions in some seasons. More data is required to determine if differences at a cultivar level (i.e. between modern cultivars) are significant. A single outlier was identified in the 'new' data (Base AR37, 80kg N/ha and 5,270kg DM/ha) and omitted. This did not materially affect the conclusions drawn, i.e. that the slope of an appropriate response function remained above 5.6 kg DM/kg N at 160kg N/ha.

Environmental perspective

The most relevant harvest thus far from an N leaching perspective occurred on 18 August 2015 after 85 days of winter regrowth. Figure 3 presents the nitrogen uptake in foliage at 0 and 160 kg N/ha. Cultivars differed significantly in their ability to uptake nitrogen through winter, with the highest uptake under both 0 and 160 kg N/ha occurring in PGWLp AR37 and the lowest in the European and naturalised northern European cultivars. Even in winter at Ballarat when mineralisation is low, cultivars with poor growth potential were unable to uptake all mineralised nitrogen in their foliage, i.e. they took up less N than PGWLp Ar37 at 0 kg N/ha.

Moir (2013) found N uptake of different species was strongly negatively correlated with leaching loss under high N loads (300 and 700 kgN/ha) and suggested that different species posed different leaching risks. We identified variation between cultivars in their ability to uptake N in winter under relatively high N loads (160kg N/ha). As such, leaching risk from urine patches is also likely to vary with the cultivar sown. The challenge then becomes predicting maximum N uptake in an affordable manner. We identified a strong linear correlation (r^2=0.91) between N uptake of cultivars at 160 kg N/ha and their growth at 80 kg N/ha, which happens to be approximately the N input or Australia's and New Zealand's cultivar evaluation schemes, which aim for full replacement. This relationship may prove useful should regulatory N loss models wish to account for cultivar sown by utilising existing data.

Conclusion

The response of perennial ryegrass pastures to N is of significant economic and environmental consequence. Too little N and producers will fail to maximise profits, too much N and producers also fail to maximise profits whilst increasing the chance of negative externalities. While current N use recommendations are based on sound economics and science, the data used to derive those recommendations was collected on now outclassed cultivars. Current recommendations may therefore inadvertently constrain profitability. We undertook an N response trial testing cultivars that contributed to current N recommendations and contemporary cultivars. At a single late-spring harvest, response functions of older cultivars were best described by a dose response model which explained poor responses at low and high N rates. The response of aggregated modern cultivar data was best described as linear. Profit maximising N rates

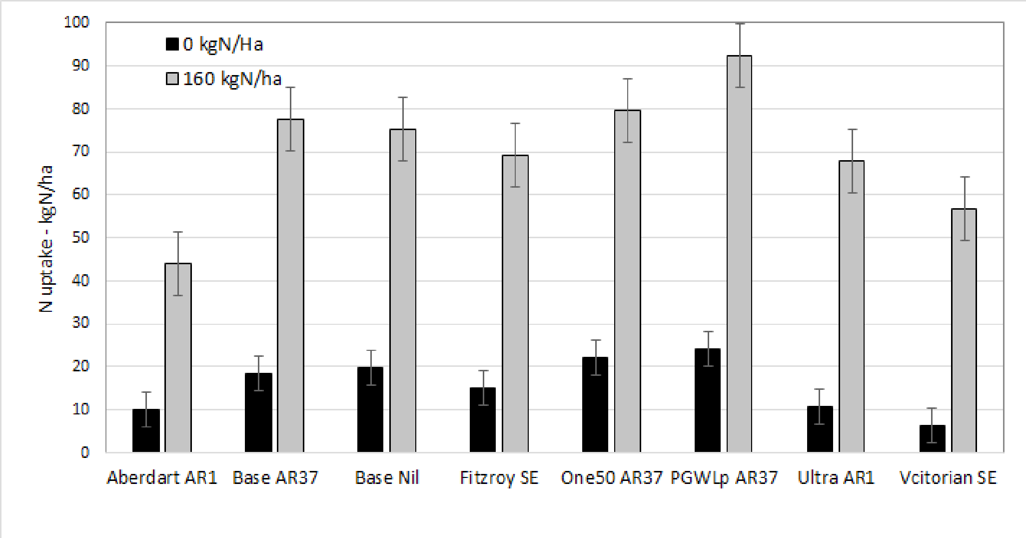

Figure 3. Nitrogen uptake, 18 August 2015

differed between new and old cultivars. We also

demonstrate some but not all newer cultivars take up more N in their foliage during winter. This increase in uptake is explained by increases in winter yield. We confirm our hypothesis and demonstrate an understanding of differences between cultivar's N response functions may aid profits and better inform efforts to manage environmental risk. Further harvests will be completed and along with forage N%, forage quality, soil moisture and environmental data, will be analysed to better understand season specific N response functions of the different types of perennial ryegrass (perhaps even different cultivars) and the practical economic and environmental implications this has in different farming systems.

Acknowledgments

We would like to thank: the research staff at PGG Wrightson Seed's Ballarat research facility for assisting with the considerable field work required to complete this trial; the management of IPF and PGW who had the foresight and appetite for risk required to fund this work; and the various experts in state and levy funded organisations who provide us advice on protocols, a sounding board for ideas and encouragement.

References

ASReml. (2015) Hemel Hempstead: VSN International Ltd
CurveExpert Professional. (2016) Madison: Daniel Hyams
Eckard R (1999) Best management practices for nitrogen in intensive pasture production systems. Melbourne: The University of Melbourne and Ellinbank: Natural Resources and Environment.

Dairy NZ. (2016) Forage Value Index. Available at http://www.dairynz.co.nz/feed/pasture-renewal/select-pasture-species/about-fvi/ (Accessed 15 March 2016)

Fulkerson WJ, Donaghy DJ (2001) Plant-soluble carbohydrate reserves and senescence — key criteria for developing an effective grazing management system. *Australian Journal of Experimental Agriculture* **41**, 261-
275.

Gourley C, Chia K, Hannah MC, Awty IM (2016) A calibrated model for predicting pasture yield response to nitrogenous fertiliser. Manuscript in preparation.

Moir JL, Edwards GR, Berry LN (2013) Nitrogen uptake and leaching loss of thirteen temperate grass species under high N loading. *Grass and Forage Science* **68**(2), 313-325.
Rawnsley RP, Langworth AD, Pembleton KG, Turner LR, Corkrey R, Donaghy DJ (2014) Quantifying the interactions between grazing interval, grazing intensity, and nitrogen on the yield and growth rate of dryland and irrigated perennial ryegrass. *Crop & Pasture Science* **65**(8), 735-746.

Stott K, Malcolm B, Gourley C (2016). The dairy nitrogen fertiliser advisor- a tool to predict optimal N application rates in grazed dairy pastures. 60th AARES Annual Conference, Canberra, ACT 2-5 February, 2016.

Staines M, Morris R, Casson T, Bolland M, Russell B, Guthridge I, Lucey J, Bennet D (2011) Nitrogen for intensively grazed dairy pastures. Bulletin 4815, Western Australian Department of Agriculture and Food.

Stewart AV (2006) Genetic origins of perennial ryegrass (*Lolium perenne*) for New Zealand pastures in New Zealand. *In* 'Proceedings of the 13th Australasian Plant Breeding Conference', Christchurch, New Zealand, 18-21 April.

Notes

Greater potassium rate increases the biomass of grazing crops, but what about the effects on feed quality?

J. Holland[A,C], R.C. Hayes[A], G. J. Poile[A], M. T. Newell[B], M. K. Conyers[A], A. A. Oates[A], B. A. Orchard[A], V. van der Rijt[A], and G. Refshauge[B]

[A] NSW Department of Primary Industries, Wagga Wagga Agricultural Institute, Pine Gully Rd, Wagga Wagga NSW 2650, Australia: richard.hayes@dpi.nsw.gov.au

[B] NSW Department of Primary Industries, Agricultural Research and Advisory Station, Binni Ck Rd, Cowra, NSW 2794. Email: matt.newell@dpi.nsw.gov.au; gordon.refshauge@nsw.gov.au

[C] Present address: James Hutton Institute, Invergowrie, Dundee DD2 1DA U.K.: jonathan.holland@hutton.ac.uk

Abstract: A field experiment was established near Breadalbane, NSW, to examine the effect of increasing rates of potassium (K) fertiliser on the forage attributes of grazing cereals grown on a soil traditionally used for permanent grazing. Rates up to 100 kg/ha of K were applied to limed and unlimed plots, and the biomass of wheat and triticale was compared over the first 19 weeks following sowing. Productivity and response to K fertiliser was significantly greater in triticale than in wheat which was slower to develop, and there were few effects of K fertiliser on the forage quality of either crop. The addition of K fertiliser led to an increase in the concentration of K in the crop herbage with a resulting increase in the K:Na and tetany indices. The K:Na ratio was excessive under all K-fertiliser regimes, including the nil control, relative to established benchmarks and more than doubled with increasing K rates. The implication is that livestock with a high demand for Ca and Mg (growing stock and late pregnant and lactating breeders) are at risk of hypomagnesemia and hypocalcaemia when grazing forage cereals unless mineral supplements are provided ad libitum. However, reducing K fertiliser inputs does not alleviate the need for mineral supplements for grazing livestock, meaning that K fertiliser should be applied to optimise productivity of grazing crops and that mineral supplements be provided ad libitum as a matter of course when crops are grazed by livestock. Research remains ongoing to further evaluate the response of the cereals to lime and K fertiliser over a longer timeframe.

Key words: livestock health, mineral profile, grazing crops, biomass, grass tetany

Introduction

Potassium (K) is an essential nutrient for plant growth and it is often required in large quantities by field crops. It is also of key importance to the nutrition of grazing livestock. High K concentrations in forage, particularly when associated with low sodium (Na) concentrations, are known to inhibit magnesium (Mg) absorption in the rumen leading to a higher risk of nutritional disorders such as hypomagnesaemia (Masters 2015; Masters and Thompson 2016). High dietary K intakes also lead to reduced calcium absorption (Bhanugopan *et al*. 2015), which leads to higher risks for hypocalcaemia. Concurrently, increasing forage K is also associated with reductions in forage Mg and Na concentrations (CSIRO 2007). For farmers looking to optimise the performance of grazing cereals, this potentially presents a conundrum. On the one hand they aim to optimise crop productivity, which on low-K soils may mean the addition of K fertiliser. However, increasing K availability in the soil will likely lead to increased K availability in the herbage of grazing cereals, potentially increasing the vulnerability of grazing livestock to nutritional disorders associated with high K concentrations. The present study is one of the first to examine the change in the feed quality and herbage mineral profile of dual-purpose grazing cereals with the addition of K fertiliser. The study also examines the early response of dual-purpose wheat and triticale to additions of K fertiliser on a responsive soil.

Methods

A field experiment was conducted near Breadalbane (34° 46'S 149° 29'E), NSW. Agricultural land use in this high rainfall region is predominantly grazing (sheep and cattle) with an increasing interest in dual purpose crops to augment existing grazing enterprises (Dove et al. 2015). The paddock on which this experiment was conducted was sown in 2014 to a commercial crop of wheat as part of the farmer's plan to incorporate grazing crops into his enterprise. The soil was acidic in the surface with low levels of K in the surface 0.3 m (Table 1) and was classified as a Yellow Sodosol (Isbell 1996). A Colwell phosphorus (P) of 36 mg/kg in the top 0.1 m of soil reflects a long history of single superphosphate application onto prior pastures.

The experiment used a split-split-plot design that included two crop species, wheat and triticale, and four K fertiliser rates all with and without the addition of 1 t/ha agricultural lime, replicated 4 times. Plot size was 10 x 2 m. Agricultural lime (NV 98%) was applied by hand and incorporated into the top 0.1 m soil one week prior to sowing. Wheat cv. Revenue was sown at 100 kg/ha and triticale cv. Endeavour was sown at 88 kg/ha on 18 March 2014 at rates calculated to achieve similar plant densities.

Table 1. Initial soil chemical properties at experimental site before treatments were applied.

Soil depth (cm)	exch. K (mg/ kg)	pH (CaCl2)	EC (µS/cm)	S-KCl40 (mg/ kg)
0-10	47	4.63	133	21
10-20	20	4.57	33	6
20-30	23	4.54	28	6

The K was applied as potassium chloride (KCl) by hand on 1 May 2014, after the crop had emerged, at the following rates: K0 = control (nil K fertiliser), K1 = 25, K2 = 50 and K3 = 100 kg K/ha.

Di-ammonium phosphate fertiliser was applied at sowing to all plots at rates calculated to deliver 20 kg P and 50 kg N/ha. Additional nitrogen was top-dressed during the growing season with two split applications of urea calculated to deliver 85 kg N/ha. Crop establishment density was assessed 6 weeks after sowing by counting the number of seedlings in 4 x 1 m drill rows. The first dry matter biomass sample was taken on 29 July 2014 by cutting 4 x 1 m drill rows per plot at ~20 mm above the soil surface. Samples were dried at 70ºC for 48 hours and weighed and ground through a 1 mm laboratory mill. Concentration of cations (Na, K, Ca, Mg) was analysed after HNO3 digestion using Atomic Absorption Spectrometry. Total plant N and P content was determined following Kjeldahl digestion. Samples were also analysed for feed quality attributes using near-infrared reflectance spectroscopy (NIRS; MPA, Bruker). Concentrations (%) of neutral detergent fibre (NDF), acid detergent fibre (ADF), crude protein (CP), inorganic ash (ASH), organic matter (OM), dry organic matter digestibility (DOMD), dry matter digestibility (DMD), water soluble carbohydrates (WSC) and metabolisable energy (ME) were determined by scanning the ground plant tissue material and relating them to established calibration relationships supplied the NSW Department of Primary Industries Feed Laboratory, Wagga Wagga. Mineral balance ratios were calculated for the tetany index (% potassium * 256) / (% calcium * 499 +% magnesium * 823) and the ratios (%:%) of K:Na and Ca:P.

Data was analysed with a 3-way analysis of variance in Genstat 17 (VSN International Ltd, Hemel, Hempstead). Treatment structure was Crop x Lime x K with blocking structure Replicate (Rep)+Rep.Mainplot+Rep.Mainplot. Subplot. The calculated K:Na data were transformed at the plot level prior to analysis to normalise the distribution of residuals. Back transformed data are presented. All effects are reported at the 5% level unless stated otherwise.

Results and discussion

Wheat and triticale established at similar plant densities (129 plants/m2). Early crop growth, sampled 19 weeks after sowing and 13 weeks after K-fertiliser application, was significantly greater in the triticale plots (average 3.15 t/ha) compared to wheat (2.27 t/ha; P<0.01). The triticale at this time was at early stem elongation (Zadok growth stage 31) and more advanced than the wheat which was at the late tillering stage (Zadok growth stage 28). There was a positive biomass response to K fertiliser in the triticale but no response was observed in the wheat (Figure 1). Most of the response at this time was observed in the K1 treatment, perhaps indicating that demands of K in the first 3 months of crop growth at this site were met by the lower K application rate.

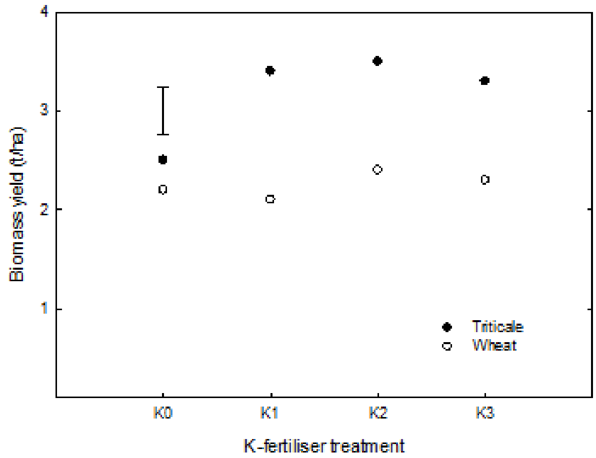

Figure 1. Biomass yield (t/ha) of wheat and triticale 19 weeks post sowing grown with the addition of 25 (K1), 50 (K2) and 100 kg/ha (K3) of additional potassium, compared to the nil control (K0). Error bar: l.s.d.$_{0.05}$.

Few significant 2- or 3-way treatment interactions were observed in the herbage quality and mineral composition of biomass at the first sampling (P>0.05). Wheat biomass was significantly higher in crude protein, metabolisable energy, dry matter digestibility and water soluble carbohydrate while triticale biomass had higher inorganic ash and fibre contents (P<0.001). There was no effect of K fertiliser on feed quality, although there was a non-significant trend of increasing inorganic ash content with increasing K rate (P=0.17). Differences in the mineral profiles of the two crops are presented in Table 2. Triticale had a significantly higher K concentration and lower Na concentration, resulting in a K:Na ratio that was approximately double that of wheat herbage. Triticale also had a slightly higher tetany index compared with wheat.

The addition of K fertiliser led to an increase in the concentration of K in the crop herbage with a resulting decrease in the concentrations of Ca and Mg. Concentrations of Na were also numerically lower as K rate increased, although differences were not significant (P=0.17). The significant increase in K and the declining trend in Na concentrations resulted in the K:Na index more than doubling between the nil and K3 treatments (Table 3).

As dietary concentrations of K increase, less Mg is absorbed, particularly when forage Na is low. As the K:Na ratio increases, ruminal absorption of Mg is impaired (Suttle 2010) leading to higher risks of hypomagnesemia. In cattle, an indicative threshold for the K:Na ratio is 6 - 7:1, but an equivalent threshold has not been established for grown sheep (Masters and Thompson 2016). It is known, however, that supplementing weaned lambs grazing high K:Na cereal crops with salt and Causmag® (MgO) leads to improved growth rates (Dove & McMullen 2009). In the present study, the K:Na ratio was excessive in all treatments including the control, but the Ca and Mg

Table 2. The significance levels and average feed quality attributes of wheat and triticale biomass sampled 19 weeks post sowing

Feed quality and mineral variables	Crop species	Wheat		Triticale
Metabolisable Energy (MJ/ kg DM)	**	14.7		13.7
Acid Detergent Fibre (%)	**	17.3		21.6
Neutral Detergent Fibre (%)	*	37.8		41.4
Crude protein (%)	ns		15.8	
Dry Matter Digestibility (%)	**	87.1		82.1
Water Soluble Carbohydrate (%)	*	36.8		30.5
Inorganic Ash (%)	*	7.4		8.0
N (%)	ns		2.39	
P (%)	ns		0.25	
K (%)	*	1.44		1.63
Ca (%)	ns		0.42	
Mg (%)	ns		0.14	
Na (%)	*	0.03		0.02
Tetany Index	***	1.3		1.4
K:Na[1]	*	49.1		99.8
Ca:P	ns		1.68	

[1]Data back-transformed; ns = not significant; * $P < 0.05$; ** $P < 0.01$; *** $P<0.001$

concentrations remained adequate, except for the K3 treatment. In the K3 treatment, the concentration of K, Ca and Mg depart such that the tetany index approached threshold levels (2.2) that indicate an elevated risk of hypomagnesemia (Kemp and t'Hart 1957).

Lime increased crop biomass by 10% (P=0.09) but had few effects on early herbage mineral concentrations and feed quality. This could be associated with the relatively short period of time that had elapsed between application and the sampling of herbage (20 weeks), given the low solubility of lime (Scott et al. 2000). Nevertheless, lime increased the P concentration of crop herbage to 0.26% compared to 0.24% in the nil lime plots (P<0.05).

Conclusions

Under all K-fertiliser regimes including the nil control, the K:Na ratio exceeded the level after which Mg absorption becomes impaired. While the concentration of forage Mg and Ca were adequate, it is highly likely that absorption in the rumen will be impaired. The implication is that livestock with a high demand for Ca and Mg (growing stock and late pregnant and lactating breeders) may have animal health issues when grazing such forages unless mineral supplements are provided ad libitum. As the K-applied increases, the absorption of Mg, Ca and Na will be increasingly constrained and risks to grazing livestock not supplied with mineral supplements will increase. However, reducing K fertiliser inputs does not alleviate the need for mineral supplements for grazing livestock, meaning that K fertiliser should be applied to optimise productivity of grazing crops provided mineral supplements are available to grazing livestock. Analysis from the present study remains ongoing as it would be premature to draw too many conclusions on the effects of lime on mineral nutrition of grazing cereals given that there were few immediate effects of lime on early crop growth and herbage content at this site. Further research is warranted to quantify effects of potassium fertiliser on livestock production, particularly in relation to absorption of minerals such as Mg and Ca in different classes of livestock.

Acknowledgments

The authors are very grateful to the farmer Mr Chris Kilby for providing access to land for this experiment and for his ongoing cooperation. We also must thank Mr James Cheetham (Delta-Ag, Harden) for his constant support and helpful agronomic advice. Mr Richard Meyer (NSW DPI) analysed the forage biomass samples for a suite of feed quality variables in the Wagga Wagga Feed Quality Testing Laboratory. Financial support for this work was provided by Australian growers through a grant from the

Grains Research and Development Corporation and the NSW Department of Primary Industries.

References

Bhanugopan, M. S., Fulkerson, W. J., Hyde, M. & Fraser, D. R. (2015). Effect of dietary potassium supplementation on the calcium absorption capacity in the rumen and abomasum and fractional excretion of urinary minerals in sheep. *Animal Production Science* **55** (4): 508-514

CSIRO (2007). 'Nutrient requirements of domesticated ruminants'. (CSIRO Publishing: Collingwood)

Dove, H., Kirkegaard, J. A., Kelman, W. M., Sprague, S. J., McDonald, S. E. & Graham, J. M. (2015). Integrating dual-purpose wheat and canola into high-rainfall livestock systems in south-eastern Australia. 2. Pasture and livestock production. *Crop and Pasture Science* **66** (4): 377-389

Dove, H. & McMullen, K. G. (2009). Diet selection, herbage intake and liveweight gain in young sheep grazing dual-purpose wheats and sheep responses to mineral supplements. *Animal Production Science* **49** (10): 749-758

Isbell RF (1996). 'The Australian Soil Classification'. Melbourne: CSIRO.

Kemp, A, 't Hart, JL (1957) Grass tetany in grazing milking cows. *Netherlands Journal of Agricultural Science* **5**, 4-17.

Masters, D. G. (2015). Mineral nutrition of sheep: new insights into interactions when grazing vegetative crops. *Animal Production Science* **55** (10): 1215-1216.

Masters, D. G. & Thompson, A. N. (2016). Grazing crops: implications for reproducing sheep. *Animal Production Science* **56** (4): 655-668

Scott BJ, Ridley AM and Conyers MK (2000). Management of soil acidity in long-term pastures of south-eastern Australia: a review. *Australian Journal of Experimental Agriculture* **40** (8): 1173-1198.

Suttle, N. F. (2010). 'Mineral Nutrition of Livestock, 4th Edition'. (Wallingford: CAB International)

Table 3. The significance levels and average mineral content (g/ kg DM) for crop biomass grown on plots with nil (K0), 25 (K1), 50 (K2) and 100 kg.K/ha (K3) applied 13 weeks prior to sampling

Mineral variables	K rate	K0	K1		K2	K3	l.s.d.$_{0.05}$
N (%)	ns			2.39			
P (%)	ns			0.25			
K (%)	***	1.01	1.41		1.66	2.06	*0.146*
Ca (%)	***	0.50	0.45		0.40	0.32	*0.044*
Mg (%)	***	0.16	0.15		0.13	0.11	*0.013*
Na (%)	ns			0.03			
Tetany Index	***	0.69	1.08		1.44	2.18	*0.232*
K:Na[1]	***	44.2	57.9		82.8	113.1	
Ca:P	***	1.99	1.82		1.62	1.27	*0.186*

[1]Data back-transformed; ns = not significant; * P < 0.05; ** P < 0.01; *** P<0.001

Notes

Producing store lambs on a *Microlaena stipoides* dominated pasture – the impact of grazing management and stocking rate

N.P. Linden[A,D], M.L. Mitchell[A,D], S. Norng[B], L.L. Slocombe[C,D]

[A] Department of Economic Development, Jobs, Transport and Resources, 124 Chiltern Valley Rd, Rutherglen, VIC, 3685, Australia; nick.linden@ecodev.vic.gov.au

[B] Department of Economic Development, Jobs, Transport and Resources, 32 Lincoln Square North, Parkville, VIC, 3053, Australia;

[C] Department of Economic Development, Jobs, Transport and Resources, 915 Mount Napier Rd, Hamilton, VIC, 3300, Australia

[D] Future Farm Industries CRC, The University of Western Australia, 35 Stirling Highway, Crawley, WA, 6009

Abstract: The production of lambs from native grass dominated pastures in south-eastern Australia is being considered for some sheep enterprises. To determine the effectivenes s of producing lambs on native pastures, a large scale grazing experiment on *Microlaena stipoides* dominated pasture, was conducted at Chiltern, Victoria, over three lambing seasons. The site consisted of twelve 3 ha plots, fenced and allocated to the treatments, according to topography and location, within the landscape. Merino ewes were joined to terminal sires with lambs sold at weaning. The four treatments consisted of 1) high stocking rate, tactical rotational grazing, 2) high stocking rate, rotational grazing, 3) high stocking rate, set stocked, and 4) low stocking rate, set stocked. For the set stocked treatments, in two out of three years higher stocking rates gave greater lamb production per hectare than lower stocking rates. Rotationally grazed treatments with higher stocking rates did not always exhibit increased lamb production per hectare, compared to set stocked treatment with lower stocking rates. This was due to a trend whereby lower stocked treatments exhibited increased per head animal performance. The most profitable lamb production system will be one that balances animal performance from a lower stocking rate with greater lamb production per hectare of the higher stocking rate.

Key words: live weight, native pastures

Introduction

Native pastures in southern Australia have traditionally been used for wool production from Merino wethers. Native pastures, defined as any pasture where native grasses are the main perennial component (Crosthwaite and Malcolm 2001),occupy about 3.1 million hectares (22%) of the agricultural area of south-eastern Australia (Hill *et al*. 1999). Much of this area has soils that are shallow, low in phosphorus (P), acidic (pHCaCl$_2$ < 5.5) and are considered non-arable (Simpson and Langford 1996); therefore are unsuitable for the sowing of introduced species.

There has been an increase in the production of store lambs from joining merino ewes to terminal sires. However, there is limited information available in the literature on lamb production from native pastures . Rotational grazing of native (Michalk *et al*. 2003) or introduced (Saul *et al*. (2011) pastures has inconsistently resulted in higher lamb live weights or total kg of lamb/ha, despite higher stocking rates, when compared to continuously grazed treatments. This is in agreement with a review by Briske *et al*. (2008) who found that in 92% of 38 studies there was no increase in per head animal performance from rotational versus continuous grazing, and that in 84% of 32 studies there was no increase in production per unit area.

This experiment was conducted as part of the EverGraze® project (Avery *et al*. 2009). It was hypothesised that: (1) rotational grazing would not necessarily result in increased lamb production; and (2) that lambs stocked at a lower stocking rate would have higher per head, but lower per hectare production than lambs stocked at higher stocking rates.

Methods

Experimental design and treatments
The experiment was conducted between 2008 and 2011, over three lambing seasons. The site was located in south-eastern Australia, Chiltern, Victoria (S36°12’, E146°35’), with an annual median rainfall of 682 mm.

Within an area of native pasture (approximately 81 ha), twelve 3 ha plots were fenced and allocated to the treatments, according to topography and location, within the landscape. The four treatments consisted of 1) High Stocking rate, tactical Rotational Grazing (HSxRGt) - Simple four sub-plot rotation (as HFxRG); with the exception of lambing to marking, when animals are set stocked, 2) High Stocking rate, Rotational Grazing (HSxRG) - Rotational grazing using 4 sub-plots, grazed for 2 weeks and rested for 6 weeks, 3) High Stocking rate, Set Stocked (HSxSS), and 4) Low Stocking rate, Set Stocked (LSxSS). The pasture was predominately Microlaena (*Microlaena stipoides* [Labill.] R.Br) (40% DM) based but also included sweet vernal grass (Anthoxanthum odoratum L.) (26% DM), silver grass (Vulpia sp. K.C. Gmel.) (8% DM), pigeon grass (*Setaria* sp. P.Beauv.) (8% DM), wallaby grass (*Rytidosperma* spp. Steud.) (5% DM), fog grass (*Holcus lanatus* L.) (4% DM), spear grass (*Austrostipa* spp. S.W.L.Jacobs & J.Everett) (4% DM), sorrel (*Acetosella vulgaris* Fourr.) (4% DM) and subterranean clover (*Trifolium subterraneum* L.) (1% DM).

In years 1 and 2 stocking rates were 2 and 3 ewes/ha for the low and high stocking rate treatments respectively, in year 3 in response to summer rain and feed on offer, stocking rates were lifted to 3 and 5 ewes/ha.

Animal production

Large framed, dual-purpose Merino ewes, on their second parity at the start of the experiment, were used for Years 1 and 2. In Year 3, younger replacement ewes of the same bloodline were used. Ewes were allocated to the treatment balanced for pregnancy scanning results. At lambing; birth weight, sex, birth status (single or multiple), dead or alive and dam were recorded. All live lambs were ear tagged, with individual numbers and live weights recorded at marking (approximately 1 to 2 weeks after completion of lambing) and every 2 to 4 weeks thereafter, until weaning when sold at an average age of 12 weeks.

Statistical analysis

Lamb birth, marking, weaning weights and average daily growth rate were calculated on a per plot basis and presented on a per head basis. Weaning weight data was also presented on a per ha basis. This was calculated from the total weights for all the lambs in each plot expressed as kilograms per hectare. These data were calculated for each year independently.

Table 1 Average lamb birth, marking, weaning weights (kg) and ADG (average daily growth rate g/day) for LSxSS, HSxSS, HSxRG and HSxRGt (where LS is lower stocking rate, HS higher stocking rate, SS set stocked, RG rotationally grazed, RGt tactical rotational grazing).

Treatment	Birth	Marking	Weaning	ADG
Year 1				
LSxSS	5.4	12.7	32.2	330
HSxSS	5.5	13.9	34.0	346
HSxRG	6.1	13.8	32.4	323
HSxRGt	5.4	12.5	30.6	285
LSD (5%)	0.81	3.55	9.42	95.8
Year 2				
LSxSS	5.9	20.9	42.2	326[a]
HSxSS	5.3	18.7	37.1	282
HSxRG	5.1	16.7	35.9	274[b]
HSxRGt	5.5	17.7	35.9	271[b]
LSD (5%)	0.86	4.34	6.48	44.9
Year 3				
LSxSS	4.4	10.4	31.7	239
HSxSS	4.7	10.6	31.0	229
HSxRG	4.6	11.0	28.3	203
HSxRGt	4.4	11.0	29.4	208
LSD (5%)	0.64	2.15	3.93	31.2

Within a year means with different letters are significantly different at P = 0.05

For each year, lamb birth, marking, weaning weights and average daily growth rate were analysed in REML as opposed to the standard ANOVA, due to the complex data structure when lambs were grouped by sex, birth type and plots. The model fitted was treatments + sex + birth type. Per ha lamb production data for each year was analysed using ANOVA appropriate for a completely randomised design (CRD), with a permutation test using the default 9999 iterations. All statistical analyses were performed in GenStat 15 (Payne *et al*., 2010).

Results

Lamb live weight and per ha production

There were no effects of treatment on lamb live weight gain in Year 1. Lambs on LSxSS grew faster ($P < 0.05$) than those on HSxRGt in year 2; and faster than HSxRG in years 2 and 3 (Table 1). There were no significant treatment effects on birth, marking or weaning weights in any year. At the higher stocking rates of HSxSS, HSxRG and HSxRGt lamb weaning weights were not significantly affected by the grazing management strategy.

The amount of lamb produced per hectare was greater ($P<0.05$) in HSxSS than LSxSS in Years 1 and 2, and tended to be greater in Year 3 (Table 2). In Year 1, HSxSS had greater ($P<0.05$) per ha production than HSxRG and HSxRGt, but was not repeated in subsequent years. In Year 3 there were no significant treatment differences in per ha lamb production.

Discussion

Grazing Management

The hypothesis that rotational grazing would not necessarily improve lamb production was supported in the years in which this experiment was conducted. There were no significant differences in lamb growth rates between HSxSS, HSxRG and HSxRGt; however, there were only differences in amount of lamb produced (kg) per hectare in some years. Our findings of no improvement in animal production associated with different grazing management regimes of native pastures has also been reported for a native pasture (*Bothriochloa macra*) (Roe *et al*. 1959), and introduced species phalaris (Chapman *et al*. 2003) and subterranean clover (Lloyd Davies and Southey, 2001). Lloyd Davies and Southey (2001) found grazing management had no significant impact on the percentage of lambs reaching 30 kg (the considered marketable live weight target) or carcass weight produced (kg/ha). We found that in two out of three years, HSxSS tended to have higher lamb weaning weights than either of the rotationally grazed treatments.

The HSxSS treatment tended to produce more lamb per hectare in all experimental years, and had significantly greater lamb production than HSxRG and HSxRGt in Year 1. These findings are in agreement with Michalk *et al*. (2003), who reported that tactical grazing reduced lamb production (kg/ha) compared to continuous grazing, of native pastures. In that study, tactical grazing of native pastures included a period of deferment over summer, as well as reduced stocking rates at a winter DM threshold of

Table 2 Lamb produced (weight, kg) per hectare in years 1, 2 and 3 at weaning for LSxSS, HSxSS, HSxRG and HSxRGt (where LS is lower stocking rate, HS higher stocking rate, SS set stocked, RG rotationally grazed, RGt tactical rotational grazing).

Treatment	Year 1	Year 2	Year 3
LSxSS	96.3[a]	49.3[a]	69.6
HSxSS	136.8[b]	91.1[b]	84.8
HSxRG	106.7[a]	77.9[b]	89.7
HSxRGt	114.9[a]	87.1[b]	90.1
LSD (5%)	18.71	14.74	35.06

Within a year means with different letters are significantly different at P = 0.05

1000 kg DM/ha. It is possible, that the reported decrease in per ha production of tactically grazed treatments was in response to a reduced stocking rate associated with experimental triggers, as per head production was in fact slightly higher in tactically grazed treatments.

The results indicate that within the confines of this experiment, there is little benefit from a livestock production perspective, in rotationally grazing native pastures. As previously described, animal production on a per hectare basis is potentially increased in the set stocked regimen. The results presented show no difference in lamb weaning weights, and inconsistent differences in production, between set stocked and rotationally grazed production systems at the same stocking rate. While there were variable differences in lamb production from set stocking compared to rotational grazing under this management structure, it does not follow that the same relationship will hold for a different rotational system. Under a different rotational grazing system based on plant lifecycle and animal requirements (as opposed to a time based rotation), rotational grazing may prove to be more advantageous as it may allow for an increase in stocking rates, thus improving pasture utilisation.

The finding that there was no significant increase in lamb production associated with rotational grazing is in agreement with our first hypothesis.

Stocking rate

In partial contrast to our second hypothesis, lambs from LSxSS did not have significantly heavier weaning weights than lambs from the higher stocked treatments. However, the higher stocking rates of HSxSS resulted in HSxSS having significantly ($P<0.05$) greater levels of lamb production per ha than LSxSS in Years 1 and 2. Given the higher stocking rate treatments did not see a reduction in per head live weights of lambs, may be indicative that our rates were set too low and failed to fully test the system, and while it was not measured, it is likely that there has been a low level of pasture utilisation. In this case the potentially considerable costs associated with establishing infrastructure needed for rotational grazing, beyond that needed for fencing to land capability would not have been warranted.

While it would be preferable to test a greater number of stocking rates, and thus generate a response curve, the ability to test more than two stocking rates within the context of a paddock scale research project, on a commercial property was not possible. Logistics and cost constraints dictated that within the experimental methodology only the two stocking rates outlined could be tested.

While the use of higher fertiliser inputs is a viable means of increasing farm profitability through increased carrying capacity (Crosthwaite and Malcolm 2001), it is not without the added costs associated with the additional fertiliser and may suffer a period of short term operating loss, while stocking rates are increased. While supported by higher fertiliser applications, GrassGro modelling of higher stocking rate systems on native pastures (data not presented) indicates a greater requirement for supplementary feeding, associated with increased periods of reduced pasture cover .

Our second hypothesis was partially supported by our findings. While lambs from low stocking rate treatment did not have greater weaning weights than those from high stocking rates, in Years 1 and 2 per ha production of HSxSS was greater than that of LSxSS. However, the rotationally grazed treatments of HSxRG and HSxRGt did not consistently offer significantly greater per ha performance than LSxSS .

Conclusion

That there was no significant increase in lamb production associated with rotational grazing is in agreement with our first hypothesis. In partial contrast to our second hypothesis, the lower stocking rate did not significantly increase per head animal performance, however, in agreement with this hypothesis, lamb production in HSxSS was greater than that of LSxSS in two of the three years. The rotationally grazed treatments of HSxRG and HSxRGt did not consistently offer significantly greater overall animal performance than LSxSS.

Despite there being no treatment effects on lamb weaning weights, the experiment does show that it is possible to produce acceptable store lambs from a native pasture system. This is in agreement with both Michalk *et al*. (2003) and Holst *et al*. (2006) who found that lambs produced on native pasture systems were unable to reach a target carcass weight of 18-22 kg and that while lambs reached 33-36 kg at weaning, due to nutritional limitations it was not possible to get them to slaughter specifications.

Acknowledgements

The authors acknowledge the financial support of both the Victorian Department of Economic Development, Jobs, Transport and Resources; and the Future Farm Industries CRC, which provided funding for the research project. EverGraze is a Future Farm Industries CRC, Meat and Livestock Australia and Australian Wool Innovation research and delivery partnership.

References

Australian Code of Practice for the care and use of animals for scientific purposes (2004). Available at https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/ea16_animal_code.pdf

Avery A, Saul G, Behrendt R, Friend M, Mitchell M, Virgona J, Badgery W, Lodge G (2009) EverGraze – Right plant, right place, right purpose. *In* 'Proceedings of the 50th Annual Conference of the Grasslands Society of Southern Australia: Take up the Challenge. Geelong, Victoria'. (Grasslands Society of Southern Australia Inc).

Briske DD, Derner JD, Brown JR, Fuhlendorf SD, Teague WR, Havstad KM, Gillen RL, Ash AJ, Williams WD (2008) Rotational grazing on rangelands: Reconciliation of perception and experimental evidence. *Rangeland Ecology & Management* **61**, 3-17.

Chapman DF, McCaskill MR, Quigley PE, Thompson AN, Graham JF, Borg D, Lamb J, Kearney G, Saul GR, Clark SG (2003) Effects of grazing method an fertiliser inputs on the productivity and sustainability of phalaris-based pastures in western Victoria. *Australian Journal of Experimental Agriculture* **43**, 785-798.

Crosthwaite J, Malcolm B (2001) Farm scale economics of native grasses. *In* 'Proceedings of the second national conference of the native grasses association, Dookie College' 27th-28th September 2001. University of Melbourne, Institute of Land Food Resources: Dookie College).

Hill MJ, Vickery PJ, Furnival EP, Donald GE (1999). Pasture land cover in eastern Australia from NOAA-AVHRR NDVI and classified Landsat TM. *Remote Sensing of Environment* **67**, 32-50.

Holst PJ, Stanley DF, Millar GD, Radburn A, Michalk DL, Dowling PM, Van de Ven R, Priest SM, Kemp DR, Payne RW, Murray DA, Harding SA, Baird DB, Soutar DM (2010) 'GenStat for Windows (13th Edition).' (VSN International: Hemel Hempstead, UK)

Lloyd Davies H, Southey IN (2001) Effects of grazing management and stocking rate on pasture production, ewe live weight, ewe fertility and lamb growth on subterranean clover-based pasture in Western Australia. *Australian Journal of Experimental Agriculture* **41**, 161-168.

Michalk DL, Dowling PM, Kemp DR, King W McG, Packer IJ, Holst PJ, Jones RE, Priest SM, Millar GD, Brisbane S and Stanley DF (2003) Sustainable grazing systems for the Central Tablelands, New South Wales. *Australian Journal of Experimental Agriculture* **43**, 861-874.

Payne RW, Murray DA, Harding SA, Baird DB, Soutar DM (2010) 'GenStat for Windows (13th Edition).' (VSN International: Hemel Hempstead, UK)

Roe R, Southcott WH, Newton Turner H (1959) Grazing management of native pastures in the New England region of New South Wales. 1. Pasture and sheep production with special reference to systems of grazing and internal parasites. *Australian Journal of Agricultural Research* **10**, 530-554.

Saul G, Kearney G, Borg D (2011) Pasture systems to improve productivity of sheep in south-western Victoria 2. Animal production from ewes and lambs. *Animal Production Science* **51**, 982-989.

Simpson P, Langford C (1996) Whole-farm management of grazing systems based on native and introduced species. *New Zealand Journal of Agricultural Research* **39**, 601-609.

Notes

Notes

Notes

AUSTRALIAN GRASSLAND ASSOCIATION INC.

www.australiangrassland.org.au