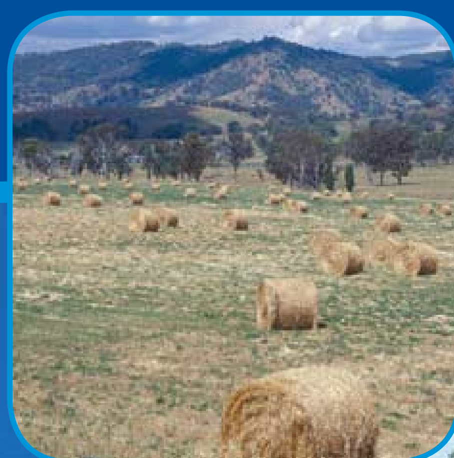
Final proof

The Grassland Society of NSW Inc.

Pastures at the Cutting Edge

Tamworth 2008

23rd Annual Conference



The Grassland Society of NSW Inc.

Pastures at the Cutting Edge

23rd Annual Conference

Proceedings of the 23rd Annual Conference of the Grassland Society of NSW

Tamworth Regional Entertainment & Conference Centre, Tamworth, 21–23 July 2008

Edited by Suzanne Boschma, Loretta Serafin and John Ayres

The Grassland Society of NSW

A unique blend of people with a common interest in developing our most important resource – our Grasslands

The Grassland society of NSW was formed in March 1985. The society now has about 500 members and associates, 75% of whom are farmers and graziers. The balance are agricultural scientists, farm advisers, consultants, and executives or representatives of organisations concerned with fertilisers, seeds, chemicals and machinery.

The aims of the Society are to advance the investigation of problems affecting grasslands husbandry and to encourage the adoption into practice of results of research and practical experience. The Society holds an annual conference, publishes a quarterly newsletter, holds field days, and has established regional branches throughout the State.

Membership is open to any person or company interested in grassland management and the aims of the Society.

ISBN 978 0 7347 1918 8

Layout: Bill Noad, NSW DPI, Dubbo

Cover Design: Linda Dickson, Gecko Photographics, Orange

Citation: Proceedings of the 23rd Annual Conference of the Grassland Society of NSW Inc. Eds SP Boschma, LM Serafin, JF Ayres (Grassland Society of NSW, Orange NSW)

Enquiries and additional copies:

The Grassland Society of NSW, PO Box 471, Orange NSW 2800

Email: secretary@grasslandnsw.com.au

Website: www.grasslandnsw.com.au

Conference sponsors

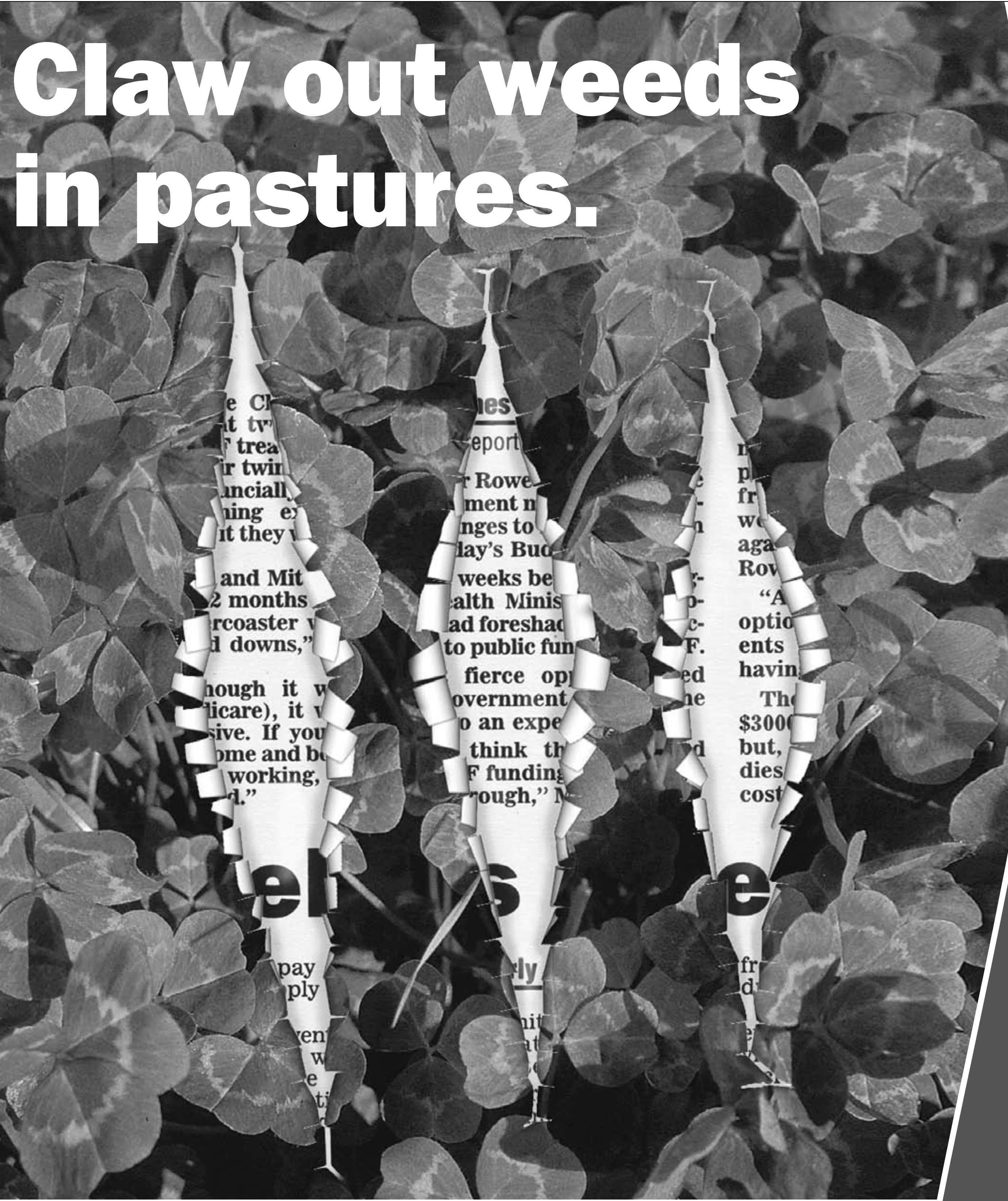
The Executive of the Grassland Society of NSW acknowledge sponsors for their generous support of the Conference. Without this sponsorship in cash and kind it would not be possible to keep the cost of the Conference within acceptable limits.

Premier sponsors

Major sponsors

Corporate sponsors

Local sponsors


Claw out weeds
in pastures.

Contents

Disclaimers

Preface

I extend a very warm welcome to all members attending this 23rd Annual Conference of the Grassland Society of NSW. I would also like to welcome those who are not members of the Society and I encourage you to join us.

This is the second conference of the Grassland Society to take place at Tamworth. This city offers so much to primary producers in cropping, pasture and animal production terms, and provides an ideal venue for everyone to hear, discuss and see 'cutting edge' and topical technology in a relaxed environment.

Plant and animal production depend heavily on new technology to complement sound agricultural science. The Grassland Society is a forum that brings together producers, agronomists, agri-business firms, animal scientists and teachers of agriculture to review and exchange high quality information relevant to grassland farming. The objective is the promotion of animal and plant production systems that embrace improved efficiencies and environmental responsibility. Pastures, both native and introduced, are the powerhouse of agriculture in all forms across Australia. They sustain above ground grazing animals and provide for microbial activity under the ground. In turn, pastures depend on good soil health to maintain production, suppress invasion from unproductive species and protect otherwise bare ground from erosion.

This conference examines the very topical subjects of 'pasture economics' and 'soil health' as these factors relate to grazing animals. The entire program will inspire producers and technologists, within the overall theme of 'Pastures at the Cutting Edge'.

The Organising Committee has put much time and effort into selecting expert speakers who will bring delegates up to date with current aspects of pasture and animal technologies. The conference convener, Loretta Serafin and her team are to be congratulated and thanked for putting together such a stimulating program of formal sessions and paddock tours.

I would like to acknowledge our many sponsors representing the corporate and government sectors who regularly support the Grassland Society. Conferences of this nature do not happen without the substantial assistance of our sponsors. Furthermore, I encourage all conference delegates to visit the well-prepared commercial displays and exhibits. They are full of current information on new pasture varieties, fertiliser products, herbicides and management strategies to assist producers and their advisers. Please take time to talk with representatives of the trade exhibits. They are a valuable source of information and are always happy to discuss product developments with conference delegates.

Finally, I thank all you who are here to enjoy and learn from this conference. The Grassland Society is keen to maintain the high standards of previous years, and we invite suggestions to improve future activities. Please feel free to let any member of the Organising Committee know your thoughts in this regard. After all, the Grassland Society is only as effective as its members and depends on them for continued existence. I also encourage non-members to join and enjoy the many benefits of membership. Application forms can be printed from our internet site: www.grasslandnsw.com.au and are available from the registration desk at this conference.

Best wishes for a most enjoyable conference.

Mick Duncan
President

Invited papers

Pushing the profit drivers for pasture

M. Gout

Productive Pastures Pty Ltd, Gundagai NSW 2722
<mikegout@seedforce.com>

Abstract. *There are many things that livestock producers can do to improve their profitability. Like most agricultural enterprises, much of this will be reliant on favourable weather and prices. There are, however, some simple 'profit drivers' for livestock production from pasture and forage crops. Producers should get these into perspective and work on those with higher potential profits before or whilst focussing on more marginal options. Without feed, there will be no enterprise or higher-cost grain-feeding, so yield is important, but total feed availability is not usually the problem. Better utilisation of existing feed, better grazing management and nutrition to feed more of existing pasture at higher nutritive value will go a long way to increase profit for most producers. Once these are working well, the use of forages or pastures to fill feed-gaps and provide higher weight-gain potential should be considered as part of the farm feed-base. And finally, when looking to sow new pastures or forage, do your homework and find those options that can provide more feed at critical times, better forage quality and lower anti-nutritional factors. All these factors are well proven to drive livestock profitability from pastures. As well as breeding for higher nutritive value, care should be taken to avoid factors that have a negative impact on animal production.*

Introduction

Long term research and development into pasture production has led to steady genetic gains in many long-established pasture species, plus a broad range of new species. These developments have provided current livestock producers continued competitive advantage in their ability to drive productivity of their forage-based production systems. There has been a general premise that as one increases productivity, so will profitability increase. This may not be the case, and the aim of this paper (and the associated Excel session at the conference) is to examine a range of issues that may influence profit so that producers and advisors can focus on the simple 'big ticket' items as opposed to wasting time and resources on less important (profitability-wise) issues.

The other issue that I would like to address is the inclusion of capital costs into the profit equation so that we can clearly separate the real estate gains made by ownership of land for farming, from the returns to funds invested from attempts to profit from use of the land. The biggest complaint from livestock producers would be that they do not have enough pasture available for their stock – or for the stocking rate that they would like to run. What they are in fact saying is that they are faced with seasonal feed shortages due to either the 'normal' pasture supply curve deficits, or deviations from that curve caused by climatic factors such as lack of rainfall, too much rainfall, hotter or colder than normal temperatures or a combination of all of these, for typical season growth.

Another issue for producers is having adequate high quality feed suitable for high rates of live-weight gain or milk production. Feed on offer seems to be suffering from the two main problems, either:

- Low availability
- High availability but poor quality.

The aim of this paper is to identify the key drivers of profit from pastures, review some examples of this from research work, and then to use simple models to highlight the profitability of particular changes in pastures and their management.

Increasing pasture utilisation

In most cases, producers are faced with choices from seed marketers offering them more feed – eg. 10 per cent more feed will deliver extra meat, milk or wool. This may be the case, but may not be what is needed. Apart from well managed dairy farms and a handful of beef producers, lack of total feed is not the issue as pasture utilisation rates will vary from 25–40% for extensive sheep and beef grazing operations (largely set stocked) to 50–65% for intensive fattening (budgeted rotational grazing) operations, to 60–75% for dairy operations with daily rationing of available pasture combined with other feed sources.

So the first area to improve profit from pastures is to increase utilisation. This may require:

- Further subdivision or use of electric fencing

Table 1. The gross revenue from perennial ryegrass cultivars in the Canterbury lamb study (Source: Westwood and Norriss 2001). Year 3 contained data for winter, spring and summer seasons only

Cultivars	Year 1		Year 2		Year 3		Mean	
	Carcass weight (kg/ha)	Gross revenue ($/ha)	Carcass weight (kg/ha)	Gross revenue ($/ha)	Carcass weight (kg/ha)	Gross revenue ($/ha)	Carcass weight (kg/ha)	Gross revenue ($/ha)
Aries HD	510	1275	548	1318	359	896	542	1163
Bronsyn	323	806	374	935	231	577	309	772
Embassy	461	1153	450	1104	337	842	416	1033
G.Nui	313	781	341	813	261	651	305	748
Quartet	537	1343	550	1375	349	873	478	1197
Vedette	441	1101	456	1083	269	673	388	952

- Adjusting stocking rate and enterprise to maximise grazing of peak production periods
- Harvesting of surplus feed to be fed back later in periods of deficit.

Increasing utilisation can have another side-benefit to increasing profitability. By harvesting more feed it will usually be harvested at levels of higher nutritive value offering better meat, milk or wool production per head at the same stocking rate. It will also enable higher stocking rates as more feed will be consumed, so this simple issue can have a multiplier effect on profitability.

Increasing pasture supply

As producers lift stocking rate to increase utilisation it follows that increased yield will provide a greater safety margin to prevent feed-deficits. While this may be the case, if those yield increases are produced at periods of peak pasture supply it may again lead to lower levels of utilisation. In this case, increases in pasture production should be focussed on increasing the production of feed in specific seasons of concern. This may be achieved by:

- Strategic use of nitrogen to boost feed at specific times
- More recently, the use of gibberrelic acid has shown promise on some species during the cool growing seasons
- Use of different cultivars that may provide more feed when you need it
- The use of specific forages or pasture types to change the pasture supply curve on the farm.

Improving nutritive value

Research undertaken by Westwood and Norriss (2000) in New Zealand compared milk production from two perennial ryegrasses (Aries HD and Yatsyn 1), with similar total and seasonal yield characteristics. Aries HD which was selected for higher digestibility, yielded 11.2 per cent and 15.6 per cent more milk solids (MS) per year over each of the two years – 228 vs. 202 kg MS/herd/day year 1 and 340 vs. 294 kg MS/herd/day year 2. This trial provided good evidence that improved nutritive value could improve profitability.

Further trials of perennial grasses by Westwood and Norriss (2001) under lamb grazing highlighted even greater differences between six cultivars. The data reported in Table 1 showed improved returns of up to $562 per hectare from the best compared to the worst performing cultivar and showed some differences between seasons for the various cultivars. Unfortunately, these differences were not able to be partitioned to the specific 'drivers' – tetraploidy increasing water soluble carbohydrates, and utilisation increased digestibility, reduced neutral detergent fibre (NDF) driving intake and lower endophyte levels enabling closer grazing and higher intake. What the trial did achieve, however, was to highlight that yield alone was not the only driver of profitability, despite most forages being marketed on yield data alone. The highest yielding variety from other replicated field trials was not the most profitable.

Further trial data from grazing forage brassicas highlighted the value of adding fibre (when NDF levels are too low for optimum rumen function) to provide increased live-weight gain (Table 2).

With the high costs of animal performance studies and often criticism of the results due to the management practices used, much of the development of forages in various parts of the world is now tested for yield and nutritional value and then evaluated for profitability under animal performance models. Much of USA lucerne breeding involves selection of lines using near infrared spectroscopy screening and then yield and wet chemistry, or *in vivo* testing of elite lines, before entering the data into dairy models to highlight predicted

Table 2. Lamb growth rate and live-weight gain (LWG) on brassica with different fibre sources

Treatment	Growth rate (g/hd/day)	Production (kg LWG/ha)
Pasja + straw	302	520
Pasja	281	484
Pasja + lucerne	244	420

profitability. The benefit of using modelling is that it allows advisors to alter the assumptions by individual enterprises and properties to reflect the varying levels of management.

Research in France by 'RAGT Semences' has developed diploid Italian ryegrass – with the same nutritive value as tetraploids during the cool season, and the summer density and persistence of diploid Italian ryegrass. RGI 542 has been tested under grazing in Australia over the past two years by Seed Force and these trials have confirmed the breeding benefits compared with Australian control varieties, and it has now been commercialised in Australasia as SF Indulgence DipQ. Under animal performance modelling, the higher metabolisable energy (ME), lower NDF (Table 3) and similar yield would deliver up to $500/ha greater returns for milk and up to $300/ha under beef based on various assumptions.

Reducing anti-nutritional factors

Further improvements in animal production have been made possible through a better understanding of other factors having a negative impact on animal production. In the 1990s, two new forage rapes (Arran and Striker) failed to deliver positive animal performance results. They were subsequently found to contain high levels of two alkaloid types (glucosinolates and S-methyl cysteine sulfoxides) that adversely affect intake at low levels and can be toxic at high levels under certain soil nutrition levels.

Table 3. Nutritive value analysis of Italian ryegrass. Data are means of 4 replicates sampled prior to each grazing by beef steers, Gundagai NSW. Feed analysis undertaken by NSW Department of Primary Industries Feed Quality Service, Wagga Wagga

Cultivar	Ploidy	July	August	September	October	December	mean
			Metabolisable energy (MJ/kg DM)				
SF Emmerson	tetraploid	11.63	10.63	10.60	9.73	10.25	10.57
RGI 542	diploid	11.43	10.53	10.65	9.83	10.55	10.60
Feast II	tetraploid	11.48	10.70	10.48	9.65	10.15	10.49
SF Accelerate	diploid	11.33	10.43	10.45	9.73	10.13	10.41
Crusader	diploid	11.30	10.25	10.43	9.53	9.75	10.25
Hulk	diploid	11.40	10.40	10.35	9.28	9.80	10.25
Sonik	diploid	11.10	10.38	10.30	9.50	9.50	10.16
			Crude protein (%)				
SF Emmerson	tetraploid	22.00	21.50	24.1	21.40	24.30	22.66
RGI 542	diploid	23.70	21.20	24.3	23.00	24.10	23.26
Feast II	tetraploid	22.30	19.50	25.1	22.20	24.70	22.76
SF Accelerate	diploid	24.50	21.30	23.8	22.20	24.10	23.18
Crusader	diploid	24.0	23.10	24.5	21.20	22.40	23.04
Hulk	diploid	24.60	21.40	24.3	20.70	22.10	22.62
Sonik	diploid	23.50	21.70	24.5	21.00	22.10	22.56
			Neutral detergent fibre (%)				
Emmerson	tetraploid	32.5	36.3	40.5	48.3	45.0	40.5
RGI 542	diploid	31.0	36.8	41.3	49.3	43.8	40.4
Feast II	tetraploid	30.5	35.8	41.3	49.8	47.0	40.9
SF Accelerate	diploid	31.3	41.3	43.0	51.3	45.8	42.5
Crusader	diploid	34.3	41.8	45.3	54.0	48.5	44.8
Hulk	diploid	35.3	38.8	44.0	51.5	47.0	43.3
Sonik	diploid	34.5	39.5	43.0	52.0	49.8	43.8

The variety Bonar was released in the mid-1990s with lower levels of these compounds and performed better in animal performance trials. Further understanding of these compounds highlighted the ability to minimise their levels in forage brassicas by reducing supply of sulphate and available nitrogen to growing brassica crops.

Research by AgResearch New Zealand identified a number of compounds contained in the fungal endophytes which exist in tall fescue and perennial ryegrass. By identifying endophytes with low or nil levels of some of these alkaloids, they have been able to insert these into existing cultivars to improve animal safety and performance.

Trial work in New Zealand has shown an improvement of 9 per cent for ryegrass containing the AR1 endophyte compared to the same cultivar containing standard wild type endophyte (Table 4)– an increased benefit of $322/ha per year for an increased sowing cost of around $40/ha. Other novel endophytes in perennial ryegrass offer better persistence against pasture pests, but trial data supporting any animal benefits or improved profitability are not yet available.

Improving persistence

This is a difficult trait to prove as there have been few long term (greater than 3 years) trials reported which have measured production and profitability over time. The simple assumption is that if a pasture lasts longer or has a greater plant density at the end of a trial then it should be more profitable over the long-term.

This myth has been popularised by recent survey work highlighting the outstanding persistence of phalaris in long-term pastures. No-one would dispute this outcome, but to extrapolate profitability from persistence is an extremely dangerous exercise.

If persistence is an outcome of low palatability or high levels of anti-nutritional factors, then a long-term pasture based on these characteristics will soon be out-performed by pastures with better milk or meat production capacity even if they have to be re-sown more often. The impact of plant compounds toxic to animals such as endophyte clearly demonstrates this point.

Table 4. Impact of endophyte on milk production and returns

Endophyte	Milk production (kg MS/ha/year)	Milk returns ($NZ/ha)
Standard	847	3,642
AR1	942	3,965

However, if pastures of similar animal performance can offer longer term persistence then this would be a benefit. Consider the example of using highly winter active lucerne to drive yield in winter- rainfall dominant areas. Research has confirmed that the lower-crown, more dormant types will out-perform the more winter-active types in pasture phases in excess of five years. But by sowing a more dormant type with a Mediterranean grass can increase the winter and total production over a highly winter active lucerne alone, and still maintain better lucerne density and stand longevity.

Phalaris should be used as a major component of long-term (breeding) pastures under low management and low utilisation systems. But it can be even more profitable under heavier stocking rates especially during winter as trial work at Glenormiston, Victoria by Reed (1974) and at Cressy, Tasmania (Gout 2006).

However the Cressy data and pasture work in the New England (R. Eccles, personal communication) has highlighted the ability of well managed tall fescue-based pastures in reliable (and in particular summer-rainfall areas) to achieve high animal performance over a number of years that would clearly cover more frequent re-sowing costs. These results are backed up by University of Uruguay trials, that I inspected in 2005, that had achieved beef live-weight gains of 760 kg/ha under low fertility and management, and 1,100 kg/ha under high fertility and management.

In my experience, sowing phalaris with tall fescue can enable medium-term benefits over phalaris alone with phalaris being capable of persisting if tough years or overgrazing thin out the tall fescue. Phalaris will colonise spaces in the sward as will subterranean clover included in the pasture mix.

In general, if persistence gains are possible (but not at the expense of palatability, intake, pasture utilisation, feed quantity and quality), then it is a good benefit and should lead to improved profitability. But persistence gains alone may be at the expense of enterprise profitability.

Dilution of capital costs

Livestock farming has relatively little capital tied up compared to broad-acre farming operations. Operators typically use contracted labour and machinery for key operations, with operator labour, land, shed, yards and livestock as the main areas for investment. Typical economic thought has highlighted the potential to improve profitability by diluting overhead costs over greater stock numbers to reduce per unit costs.

While this is part of the story, focus should be on reducing production-costs by increasing the turn-off of meat, milk or wool from the property to reduce the cost of production of each kg of output.

I have memories of a visit to New Zealand dairy producers in the mid-1990s claiming 85% pasture utilisation, but peaking milk production at 14 L/cow off grass, and wasting energy on relatively high maintenance needs compared to production requirements. The production levels could have been achieved with 25 per cent less stock (and associated capital cost). I met one such producer who had figured it out and dropped from 1,200 to 900 cows to produce the same milk, with 300 cows x 90 MJ x 260 days or 7 million MJ ME saving – about 600 tonne of grain ($250,000) plus 300 cows x $1,700 ($500,000) less capital tied up. Who would not want to improve profit by $250,000 and reduce borrowings by $500,000? The point here is that the focus on pasture utilisation as the main driver of profit had seen the enterprise go over the profitability threshold, and negatively impacted costs of production and return on equity.

The difficulty for meat producers at the current time is that the changing market conditions have not yet signalled any rational reason to grow out stock to higher weights as an alternative to grain-finishing, now that grain costs have 'belted' lot feeders and taken buyers out of the market. Again there is no incentive to buy weaner stock at say $2.00/kg and grow them out at higher maintenance requirements to sell at $1.60/kg. It takes a lot of weight-gain to cover the price loss. The successful trading enterprises of a few years ago can no longer justify buying in stock to improve profitability by grazing the excess spring flush, when they could be sold at similar or higher prices per kg.

But we should examine the impact of land prices and associated pasture options and production possibilities

Table 5. Impact of land values and pasture costs on costs of beef production

	Low value perennial	High value perennial	High value lucerne	High value annual rye	High value rape
Land value ($)	3,000	5,000	5,000	5,000	5,000
Sward life (years)	20	10	6	0.75	0.5–0.67
Capital cost ($)	300	500	500	500	500
Sowing cost ($)	300	350	300	300	240
Annualised ($)	15	18	50	300	240
Maintenance ($)	75	120	120	150	75
Yield (kg/ha)	5,000	8,000	8,000	10,000	8,000
Utilisation (%)	40	60	60	65	70
Feed availability (kg/ha)	2,000	4,800	4,800	6,500	5,600
Capital costs (c/kg)	15	10.4	10.4	7.7	8.9
Annual costs (c/kg)	4.5	2.9	3.5	6.9	5.6
Total costs	19.5	13.3	13.9	14.6	14.5
NDF (%)	50	45	40	40	35[A] with fibre
ME (MJ/kg DM)	9	9.5	10	10.5	12
Daily intake (kg)	7.2	8	9	9	10.3
Daily intake (MJ ME)	64.8	76	90	94.5	123.4
MJ ME for growth	20.8	32	46	50.5	79.4
LWG (g/hd/day)	462	711	1,022	1,122	1,765
Grazing days	365	365	365	210	150
LWG (kg/hd)	168	260	373	236	265
Stocking rate (DSE)	1.5	2.5	2	4	4
LWG (kg/ha)	252	650	746	944	1,060
Estimated FCE	20:1	12:1	10.7:1	8.5:1	7.5:1
Cost of LWG ($)	3.90	1.60	1.49	1.24	1.09

[A]Based on cost of money at 10% pa; Intake based on 1.2 x live-weight/NDF% for an average 300 kg steer; ME for growth based on 44 MJ for maintenance and 45 MJ per kg live-weight gain to see how our costs of production stand up. In general, the production output will determine the contribution of overhead costs to overall costs and it may not be the long term persistent pastures that are the most cost effective – it will depend on the operator and his cost structures. Perennial pastures may have a more significant role for breeding stock and other land health issues.

An analysis of some potential scenarios facing producers on a 'typical' farm with different soil types (and values) and forage options is used as a way of looking at the impact of land values and production systems on the costs of beef production. Table 5 sets up five possible outcomes from a continuum of possibilities to see how some of the factors discussed above might look in terms of setting the feed-base cost for a livestock property.

References

Bluett SJ, Thom ER, Clark DA, Mac Donald KA, Minnee EMK (2003) Milksolids production from cows grazing perennial ryegrass containing AR1 or wild endophyte. *Proceedings of the New Zealand Grassland Association* **65**, 83–90.

Garrett BC, Westwood CT, Nichol WW (2000) Optimising animal production from forage brassicas. In 'Proceedings of the New Zealand Institute of Primary Industry Management Conference.' pp. 61–73.

Gout MJ (2006) Progress with pasture plant breeding. In 'Proceedings of 15th Annual Conference Tasmanian branch of Grasslands Society of Southern Australia.' pp. 62–74.

Nichol WW, Garret BC (2001) Optimising prime lamb production on summer brassica crops. In 'Proceedings of the 6th World Sheep and Wool Congress', CD-ROM, 2001.

Reed KFM (1974) The productivity of pastures sown with *Phalaris tuberosa* or *Lolium perenne*. 1. Pasture growth and composition. *Australian Journal of Experimental Agriculture and Animal Husbandry* **14**, 640–648.

Westwood CT, Norriss MG (2000) Performance by dairy cows grazing two perennial ryegrass cultivars. *Proceedings of New Zealand Society of Animal Production* **60**, 247–252.

Westwood CT, Norriss MG (2001) Liveweight changes in lambs grazing six perennial ryegrass cultivars. *Primary Industry Management* **4**, 31–35.

Factors affecting beef enterprise profitability – experiences from a grazing group in North-West New South Wales

T.M. Farrell

NSW Department of Primary Industries, Narrabri NSW 2390
<tracey.farrell@dpi.nsw.gov.au>

Abstract. *A group of farmers, the 'Narrabri Grazing Group' is addressing how to identify the profit drivers for beef cattle operations in North-West New South Wales. Based on a consideration of enterprise 'strengths, weaknesses, opportunities and threats' together with benchmarking gross margins, the group has short-listed five key profit drivers: early decisions, triggers for actions, resolving management issues, mitigating the feed-gaps, restricted joining and early weaning. The paper also shows the costs and returns structure for farms in the group, and highlights the adverse long-term impacts of drought on subsequent financial performance.*

The 'Narrabri Grazing Group'

The 'Narrabri Grazing Group' was formed in 2001, following participation in a Prograze™ course facilitated by NSW Department of Primary Industries (DPI). The group is currently made up of 16 farming families operating grazing and mixed farming enterprises on a total of some 18,500 ha in the Narrabri district in North-West New South Wales (NSW).

Within the group there is wide diversity in the size of the properties, their stage of development and the goals of the landholders. The group uses farm visits and discussions to find common ground between their different enterprises. Workshop activities revolve around 'SWOT' analyses (enterprise strengths, weaknesses, opportunities and threats) and analyses of gross margins – all in the context of each landholder's goals. Over the years, some of the original members of the group have left, and others have joined the group. Some of the newcomers were already known to the group, while others have been introduced through subsequent Prograze™ courses.

Involvement of NSW DPI staff provides the group with access to technical expertise in cattle markets, pasture agronomy and grazing management. While the meetings are facilitated by NSW DPI staff, a social element has also evolved among the group members, accentuating the openness with which information is shared. Shared information includes i) the short- and long-term goals for enterprises; ii) succession planning; iii) costs (such as replacement stock and pasture inputs); iv) market intelligence (including target markets, selling prices and time of sale); and v) how operations on the farm are undertaken and how decisions to change are made. Not all group members participate in the financial benchmarking. Of the enterprises that do, two are exclusively trading enterprises, six are exclusively breeding enterprises and three have a combination of the two enterprise types. The members that do not contribute their records to analysis, still make a significant contribution to discussions.

Profit drivers derived from benchmarking

At the time the group formed in 2001, the Narrabri district was experiencing below average rainfall after a decade of above average conditions. Properties were fully stocked, the available feed in pastures was running low and reactionary decisions were required. Six years on, benchmarking gross returns (Figure 1) shows the impact of 'forced selling' and utilisation of stored feed reserves during 2001/02 on enterprise profitability in the subsequent years. Decisions driven by drought created problems with herd structure, pasture health and cash flow that have had lasting impacts on profitability. The group have developed and adopted five key management principles to assist 'smoothing-out' the impacts of dry seasons on their profitability.

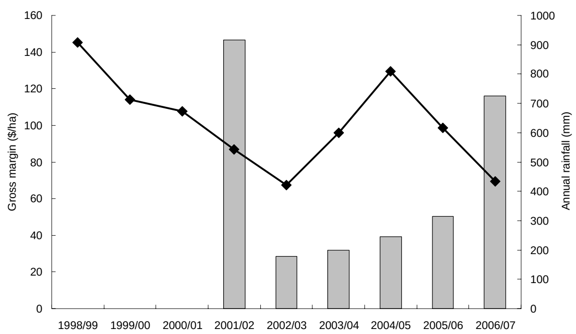


Figure 1: 'Narrabri Grazing Group' average annual gross margin ($/ha) in association with average annual rainfall (mm). Data for 2001/02–2006/07 are means across farms (from group member's records), data prior to 2001/02 are for the town of Narrabri.

1. Early decisions are good decisions

Two fundamental principles accepted by the group are: 'No decision is still a decision' and 'avoid stalling a decision in the hope that seasonal conditions will change'. For example, it can be better to sell early rather than feed growing stock a maintenance ration and miss a key marketing window. While an early decision (such as selling a group of steers into the Meat Standards Australia market at 420 kg rather than into the European Union market at 580 kg) may be a deviation from a medium or long-term goal, the benefits can be a major reduction in short-term costs. This decision can also improve the prospects for pastures to recover, and for resources to become available to assist with other decisions.

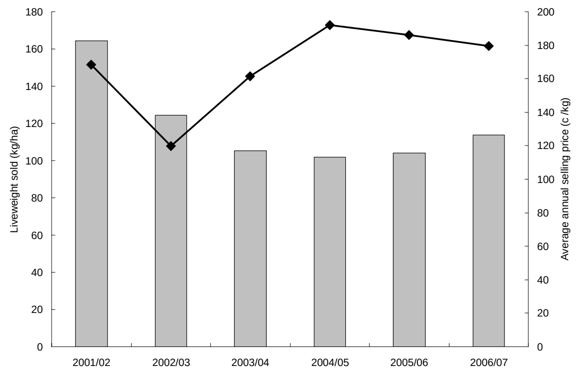


Figure 2: 'Narrabri Grazing Group' average annual production/ha compared to average annual selling prices cents /kg.

2. Triggering actions

To assist in identifying the opportunities for early decisions, the group uses a process of 'triggers' and 'actions'. Decision plans are developed for a six month period and revisited regularly. The plan outlines 'trigger' points for the enterprise that identifies when a decision needs to be made. For example, if there has been no summer rain by Christmas, the herd should be profiled for 'saleability' versus retaining animals for their 'strategic value' to the business. Where the season remains and dry animals are saleable but of lower strategic value, an early sale (at the opening of the new season market) can prevent difficult feeding decisions.

3. Work *on* the business as well as *in* the business

Group meetings require members to regularly talk through their progress in resolving management issues. By discussing issues within the group, a broader range of information is considered in the decision-making process, and feedback helps to accelerate the implementation of management changes. Farm visits also provide opportunities to see the achievements, over time, of fellow members – this has proven to be a valued source of inspiration and motivation.

In recent years, quite a few members of the group have been fine-tuning the marketing (eg. group marketing, product targeting) of their enterprise's turn-off in order to maximise income per kilogram (c/kg) of beef produced, while stock numbers are low. As can be seen in the summary of production in Figure 2, a near-stable income per kilogram has been achieved, cushioning the impact of lower production. Through selling at 'peaks' in the market and selling animals that meet the market specifications income is being maximised. The group has also come to appreciate the importance of maintaining expenditure on pastures even through dry years to protect productivity (Figure 3).

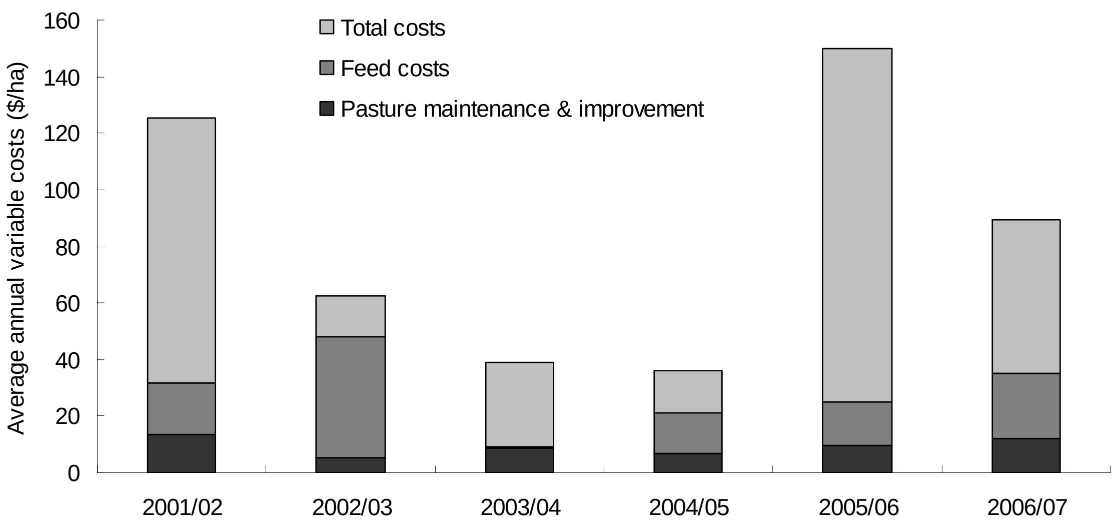


Figure 3. 'Narrabri Grazing Group' average cost structure for beef production.

4. Filling the autumn feed-gap

Autumn is traditionally the driest time of year in the Narrabri region. The availability of feed at this time is essential to keep production timelines on target. The benefits of the combination of pasture improvement, forage crops and supplementary feeding have been determined by members of the group to be essential practices to fill this feed-gap.

While costs such as fertiliser and seed for pastures are considered 'expenses' from an accounting perspective, they have come to be viewed by the group as an investment from a management perspective. From trials (hosted by group members) and confirmed by subsequent experience, some 300-fold increases in dry matter production have been achieved from native grass pastures in the region through the addition of phosphorus and sulphur fertilisers. While the establishment of tropical pastures has proved challenging, the rewards warrant the effort required – in particular, tropical grasses respond to early spring rains and their growing season continues well into autumn. Moreover, the ground-cover achieved with tropical pastures increases the infiltration of storm rainfall into the soil, driving a cycle of higher productivity.

On the basis of the group's experience, key elements of 'best practice' that mitigate the feed-gap include:

- Correcting nutritional differences, despite the expense, are more likely to pay for themselves in dry years than in wet – in dry years, it is even more critical that pastures are able to maximise the dry matter production per millimetre of rainfall
- Soil tests are undertaken before fertiliser programs are commenced – to determine where fertiliser responses are most likely
- The rate at which pastures recover from grazing and from dry seasons impact on the efficiency with which rainfall is used – rotational grazing is effective in enhancing recovery, however, paddock size and location of watering points can interact with the effectiveness of rotational grazing
- In an above average rainfall year, excess feed produced by tropical grasses can produce opportunities for hay-making and seed-harvesting as well as multiple grazing
- Supplementary feeding with white cottonseed enables productivity to be maintained when excess grass feed is produced. The self-limiting nature of this feed type suits the limited availability of labour in most of the enterprises. Co-operative purchasing also assists in acquiring the seed at a competitive price
- Forage crops (oats, forage sorghum, lablab) can be used to meet specific market targets on time.

5. Restricted joining and early weaning

The benefits of setting short joining periods can be realised in the following ways:

- Tighter joining periods mean narrower calving windows – for the smaller enterprises in the group, a narrower calving period leads to improved marketing opportunities as the product to be sold is more uniform
- In dry seasons, shortening the joining period allows for earlier pregnancy testing and prospective culls can be identified earlier
- When conditions remain dry, there is also the option of better management of early weaning because calves are of similar age.

Early weaning of calves at approximately 200–250 kg (rather than 300–350 kg) has been adopted by many in the group to maintain cow condition for the next joining. Managing cows and calves separately reduces energy requirements of the cow by up to 60 per cent. Dry standing feed, that is unsuitable for lactating cows, can be efficiently utilised (with protein supplementation) by dry cows. This limits the need for expensive feeding (fodder crops, grain) to calves with smaller feed requirements. It also ensures that cows are able to produce a calf every 12 months, rather than every 14–16 months.

Conclusions and future directions

Gross margin analyses have provided an insight into how management decisions translate into profitability. However, they only show part of the picture. In 2006/07, some of the group members commenced analysis of total costs of production using the template provide by Meat and Livestock Australia. Over time, availability of these data will provide further insight into the influence of enterprise structure on profitability and provide further fuel for discussion of management direction.

Improved perennial pasture establishment at 'Ruby Hills'

A.D. Burgess

'Ruby Hills', Walcha NSW 2354 <rubyhills@bigpond.com>

Abstract. *The decision making process for the establishment of improved perennial pastures at 'Ruby Hills' is discussed in relation to economic and agronomic strategies.*

Introduction

The decision to establish an improved perennial pasture is never easy because input prices, seasonal conditions and sale prices are all highly variable. The decision to go ahead may also involve factors other than pure economics. I do not purport to know the answer definitively, so I will simply take you through our decision-making process and look at how it has worked financially and strategically for us in recent years. I hope some of my thoughts will be useful in your own decision making process.

To give you an idea of what 'Ruby Hills' is like, I will take you through a few aspects of our business.

Property and grazing business

1. 'Ruby Hills' is located about 15 km west of Walcha on the Northern Tablelands of New South Wales (NSW)
2. Elevation is 1,100 m
3. Average annual rainfall is 800 mm and is summer dominant. We used to believe that good springs were reliable and occurred at least eight out of ten years. This is because our cool climate prevents winter moisture-loss and leads to rapid pasture growth once temperatures rise. That may be in doubt now that we know more about carbon dioxide driving the Southern Annular Mode into positive territory, and the consequent reduction of rainfall from southern weather systems (Climate Change in Australia–CSIRO Technical Report 2007, pp. 27, 106–107)
4. Temperatures range between −15°C and 35°C
5. Property size is 2,100 ha, 50 per cent hilly and 50 per cent arable
6. Soils are trap with some basalt, no granite and a lot of gravelly ridges
7. Phosphorous (P) is adequate for our current production scenario at around 25–30 mg/kg (Colwell) and sulphur (S) levels are good, in the order of 15–25 mg/kg (KCl)
8. Soil pH is quite low at around 4.3–4.5 ($CaCl_2$)
9. Soil tests have revealed variable but elevated aluminium saturation levels ranging from 5–35%
10. Pastures – Microlaena is endemic and old cultivars of phalaris and some aerially sown Demeter tall fescue are well established over the property. We established a new paddock of Jessup MaxP tall fescue in 2003, and another in 2004, and we have sown 25 ha of Quantum II MaxP tall fescue in March this year
11. We employ some winter fodder cropping, mostly using McKellar winter wheat
12. With livestock, our main enterprise is sheep. We have a self-replacing fine-wool flock of 4,000 ewes, a first-cross lamb unit of 1,200 merino ewes and a terminal lamb enterprise of 1,300 first-cross ewes. We breed our own merino rams and sell surplus rams as well. Woolcutters are run on an opportunity basis. We also run a small herd of cows and trade or agist cattle on an opportunity basis
13. Some of the breeding enterprises are under review given the perceived risks associated with climate change
14. Our business plan focuses on 'return on assets' (ROA), rather than productivity as the single biggest economic issue on the farm. The plan also calls for an estimation of our family's economic needs and from there we establish how we are going to generate the cash.

Decision making process

General

We are always looking for ways to grow more feed, or better quality feed without buying more country.

Escalating fertiliser and other input prices mean that instead of an annual blanket fertiliser application across the whole property, we are becoming more targeted in the way we use available resources. We have also identified that blanket application of fertiliser may lead to elevated animal health costs, particularly in relation to scouring due to over-nutrition of merino sheep in some seasons. It is interesting to note that a similar experience was observed on the high input farmlet at the recently concluded Cicerone Project conducted at CSIRO's research farm 'Chiswick' near Armidale, NSW (*Cicerone Project Final Report 2006*, p14). There is also anecdotal evidence that in superfine wool-growing enterprises, wool staple strength is more difficult to manage on highly fertilised pasture than native pasture with lower fertility.

Therefore, we usually have a specific project in mind when taking the decision to establish a new pasture. Examples at 'Ruby Hills' include: achieving joining weight in young females of both species; finishing lambs or steers; adequate nutrition for twin lambing cross-bred ewes. We also believe that there can be a psychological aspect to having an attractive paddock as an oasis near the house, especially during drought.

Successful farming is often a matter of creating opportunities, and we find that having some improved pasture available is often the key to taking advantage of these opportunities as they arise. For example, in January and February 2008, we measured 220 mm of rain. As our livestock numbers were low following years of drought, we decided not to grow a winter fodder-crop because of an abundance of feed and a shortage of spraying contractors. Ironically, shortly after the cropping window had closed, an opportunity presented itself to contract lambs on a forward basis for delivery in the winter, at good prices. Without a crop, that opportunity may seem impossible, but we may nevertheless have the capability to fill these contracts using a high quality perennial pasture.

From a tax perspective, farming businesses have some blurring of the distinction between capital and maintenance costs, allowing full deductibility for many of the inputs into a new pasture in the first year. However, this concession is balanced by the fact that depreciation is not available as a deduction on the outlay in subsequent years. This will be discussed further later in the paper.

While winter fodder crops have their place, especially when feed-grain can be harvested and stored, the recurrent annual overheads of a fodder crop are a big disadvantage compared to a pasture where preparation costs occur once in the long life of a perennial pasture.

Paddock choice

'Ruby Hills' grows a lot of Microlaena, but it can be a two-edged sword. While it survives well in a drought, it also creates a huge problem with seed in our wool when it gets out of control and becomes reproductive. Young sheep in particular have real trouble dealing with the seed and find it difficult to find green leafy material through the long reproductive stems. There is also the problem of them grazing small oases of short feed and becoming wormy as a result. While it would make good sense to have a big mob of cows to keep this under control, these are not always available at short notice immediately following a five-year drought. We have therefore decided to replace some of our Microlaena with new pasture, as a way around the problem.

This year, 2008, has been a big year for seeding Microlaena, however, we were able to wean 3,000 of our merino lambs onto country that had been sown to improved species, and allowed them to find good conditions away from the uncontrolled native grass pasture. It is difficult to quantify what that facility is worth except to say that discounts for seed infestation in otherwise pristine wools tend to be exorbitant wherever possible. In addition, we value very highly merino lambs that are gaining weight post-weaning, so that they can survive our harsh winter with its consequent fodder deficit. Sometimes, if the lambs can be kept on a reasonable plane of nutrition through winter, it is possible to achieve slaughter weights for merino lambs about Christmas time before they cut their teeth.

We have taken the decision to improve our worst arable country rather than our best. This poorer country is mostly the gravelly ridges with high aluminium saturation percentages and low pH. As a result, it struggles to keep 5 Dry Sheep Equivalents (DSE)/ha going in winter. It is often partly infested with bracken fern, which further reduces carrying capacity. As we need to use lime and lots of glyphosate to establish a good fallow, no matter where we plant, the cost to convert either poor or good country to improved pastures is roughly the same. It therefore makes sense to improve both the quality of feed on offer and available grazing area in the one operation. Thus, we get a bigger percentage improvement in the carrying capacity of the poorer country than in the softer more fertile soils once a vigorous (tall fescue) pasture is established. As an added bonus, the bracken fern has been unable to re-establish in that changed environment.

Timing

Decisions to improve pastures are usually made when stock numbers are low, so grazing opportunity cost is also low.

Never try to plant improved pastures when the Southern Oscillation Index (SOI) is negative or heading south. In 2002, in the face of deteriorating conditions and a forecast El Nino, we abandoned pasture establishment and planted a crop of cereal rye in a paddock fallowed for pasture. In economics, they say never fight the Fed; in this game, we say never fight the SOI.

Risks

The risks associated with establishing a new pasture tend to be over-rated. It is not too difficult so long as a few rules are followed:

- A good fallow is essential – generally, three sprays are needed to conserve moisture by controlling both annual and perennial grasses
- Soil-test intended paddocks
- Do not worry too much about a decline in performance from the initial explosive growth of the first year.

In our moderately high rainfall zone, there will inevitably be some degradation of these pastures because of either drought, or periodic failure to add enough fertiliser to the system. We believe that for a couple of reasons that is not necessarily a disaster, and in some cases may even be intentional. For example, during the 2002–2007 drought years, we made the decision to overstock our improved country in order to maintain some ground-cover on the hills. This was because we wanted to prevent erosion from stormwater run-off, but more importantly, to retain the vast amounts of sheep dung which had accumulated on top of the ground and which contained hundreds of thousands of dollars worth of fertility. This caused some degradation of the improved pasture, but we knew that with care, most of it could be resuscitated. If that were not to be the case, we were prepared to replace it.

Because highly improved pastures will eventually succumb to some degradation, it is very important that most of the cost of establishment be recouped early in the life of the pasture. The enormous overhead of the establishment phase needs to be recovered with a large gross-margin enterprise, usually in the first year or two.

From the accountant's point of view, degradation of the pasture can be seen as a kind of depreciation, but it is one that usually is not deducted for tax purposes. However, this is not very significant as we have usually deducted most of the establishment costs at the front-end of the project rather than call it a capital improvement, which can then be depreciated.

We are finding that where the gaps appear in the pasture, they are usually filled with Microlaena or clover in the sward.

Soil chemistry

We have learned that in our environment it is essential to make sure that the soil-tests are done on time, and that the chemistry is understood. For example, the Jessup MaxP tall fescue pasture we established in 2004 would have been a failure unless we had done our homework. The pH was 4.2 and the aluminium saturation was 35%. We therefore knew that it was folly to proceed without at least 2.5 t/ha of lime. In addition, the result has been very rewarding from both the agronomic and economic viewpoints.

As we use exclusively direct-drill technology, we make our lime application about 12 months ahead of planting to allow time for adequate neutralisation to take effect. It is interesting to note that from some of the research conducted by Mick Duncan during an Acid Soils Project at 'Ruby Hills' in 2000–2003, lime application had a large and quick effect on the aluminium saturation, but only a modest impact on pH (M. Duncan, personal communication). When we are spending so much to achieve a good result, taking chances is not an option.

Economics

I would now like to examine a few aspects of the economics of a conversion like the ones we have done in the last few years. As mentioned before, it is possible and desirable to recoup most of the costs in the first year of production, when very high fodder production is achieved. This is also helped by full tax-deductibility in the first year. Our current budget is shown in Table 1.

Of course, it can be argued that this return should be discounted by the value of the existing enterprise (prior to conversion) to obtain the true marginal improvement achieved by investing $726/ha. However, against this we need to consider:

- That a new enterprise has been established where none existed before. It would be nearly impossible to finish these steers on native pasture
- The productivity of the paddock will have been improved for many years to come
- The flexibility of improved fertiliser response has been added in the improved production paddock.

Gross margin for existing enterprise

7 wethers/ha: $252/ha less costs @ $10/head = $182/ha (360 days)
Net increase due to conversion: $526/ha

This represents 72 per cent of the establishment costs, including 180 days of grazing foregone during fallow. This may seem extraordinary, but the last large paddock we attempted, we recouped about 60 per cent of the establishment costs in a short-term profit-sharing deal using agisted steers. Four years, later that paddock is carrying 700 merino weaners and 50 head of yearling cattle where only 400 wethers were run before. In other words, in year four the paddock is about half as productive as it was in year 1, but it is still twice as productive as it was in the years prior to conversion. It would probably be a little better still, if we returned to rotational grazing and added some more fertiliser, rather than set stocking.

Maintenance

It should be remembered that once the pasture is established, it needs some fertiliser to maintain vigour. This is probably a little more flexible than is usually understood for the following reasons. Firstly, the real advantage is that improved species will respond rapidly to fertiliser applications, should an opportunity arise. (We have given this a highly technical name – 'revving it up with a bit of DAP'.) Secondly, survival is often better than casual observation reveals. Once again, as part of the Acid Soils Project (now abandoned by NSW Department of Primary Industries), Mick Duncan established a lime application plot inside (and isolated from) a larger Demeter tall fescue paddock established some 35 years ago. To the casual observer, the plant population in the paddock had declined markedly. However, once grazing in the plot was replaced by mowing, the number of surviving tall fescue plants was a revelation. This observation was supported by a species identification transect in the larger paddock which estimated Demeter tall fescue production at about 1,000 kg/ha which was about half of total production when sampled.

Conclusions

What are the general conclusions that can be reached about our pasture improvement strategies?

Firstly, from the purely financial aspect, ROA across the business may initially fall slightly, which paradoxically appears to be contrary to our business plan. We are not alone in that experience. The financial results obtained by the Cicerone project were similar in that the high input farmlet ended up with the highest production and gross margin of any of the three management systems (*Cicerone Project Final Research Report*, August 2006, p 26). However, production was initially constrained by the large proportion of the farm left unproductive during the establishment of the new pasture. Also, on that farmlet, the capital cost of improvement was not included as part of the gross margin. This serves to reinforce the point that a high gross-margin enterprise is needed initially to pay for the establishment overheads. It is important to include the opportunity cost of fallow in that list of overheads. So why take the risk?

As mentioned earlier, successful farming is often about creating opportunities, and that usually includes flexibility. These improved pastures, once paid for, can be used for a number of strategic purposes and can be 'revved up' or down as the seasons and markets unfold, for a fraction of the cost of initial establishment.

Table 1. Current budget for first 12 months of a new pasture

Costs

Item	Price (Ex GST)	Units	Cost/ha
Lime (spread/t)	$70	2.5 t/ha	$175
Herbicide:			
Roundup Power Max/L	$18	5 L/ha	$90
Surpass/L	$5.5	3 L/ha	$16
Application/ha	$16	3 sprays	$48
Seed/ha	$9.50/kg	19 kg/ha	$180
Fertiliser (40 kg bag)	$54/bag	2.5 bags/ha	$135
Contract sowing	$82/ha	1.0	$82
TOTAL			($726)

Income

Item	Price (Ex GST)	Units	Income/ha
Production: 2.5 steers/ha = 20 DSE/ha (rotational grazing) x 180 days @ 1.0 kg/head/day		450 kg beef/ha	
Sales	$1.75/kg	450 kg beef/ha	$787
Cost of sales and opportunity cost of cattle @ 10%			($79)
NET			$708

Options for managing soil phosphorus supply

A. McNeill

School of Earth & Environmental Sciences, University of Adelaide, South Australia 5005
<ann.mcneill@adelaide.edu.au>

Abstract. *This paper considers potential agronomic strategies to assist in sustainable management of the soil phosphorus resource in Australian farming systems, with an emphasis on material relevant to northern New South Wales pastures. The option most likely to ensure that soluble phosphorus is not a limitation in the system is the import of phosphorus as mineral fertiliser. However, as fertiliser prices rise there is increasing interest in other options, such as composts and biosolids, which can provide some readily available phosphorus as well as organic phosphorus for improving the 'cycling' of phosphorus within the system. Agronomic management to maximise quantity and quality of pasture and crop plant residues also facilitates phosphorus cycling since it builds soil organic matter, but is more effective if there is sufficient and reliable rainfall to drive high dry matter production. Improving the phosphorus-use efficiency of the system by incorporating species into rotation or intercropping systems that are able to access phosphorus from less soluble sources has been successful in other parts of the world, but there is scarce information for such systems in Australia. A long-shot is the seed and soil microbial inoculants to facilitate improved phosphorus uptake that are currently being field tested in Australia. Progress, in selection and breeding for cereal genotypes that are agronomically more phosphorus-efficient, and other plant genotypes that can access less labile phosphorus sources, is gaining momentum but also still remains a long term prospect.*

Introduction

Maintenance of available phosphorus (P) in soil is a problem faced by all growers. This paper discusses potential agronomic strategies to assist in sustainable management of the soil P resource in Australian farming systems, with an emphasis on material relevant to northern New South Wales (NSW) pasture-based systems. Firstly some background information about the P cycle is provided and the role of soil organic matter and microbes is highlighted. Three broad options for P management are considered; (i) importing P as fertilisers, either mineral or organic, (ii) practices for increasing soil P cycling to facilitate release and synchronous uptake of plant-available P, and (iii) approaches for maximising the P use-efficiency of crops and pasture species in the system.

P cycle, soil organic matter, microbes and mycorrhizae

Phosphorus can exist in many different forms in soil (Figure 1), from readily plant-available sources such as mineral phosphate and easily converted labile organic P compounds; to highly insoluble forms including P in some complex organic matter compounds and P 'fixed' by minerals. The soil type (texture and pH in particular) and the organic matter content influence how P behaves in the soil, the pathways it follows and where it ends up. Ultimately the goal of the grower is to maximise P uptake into the plant.

Soil organic matter (SOM) is important for a number of physical, chemical and biological functions. It changes relatively slowly over time but can be increased as long as inputs are greater than outputs ie. more carbon going in as roots and residues than is coming out as respiration. Soil microbes are part of the SOM. A major question concerns how can growers manipulate this tiny but very important 'pool' that contributes to the overall 'health' of the soil, and more specifically is the 'eye of the needle' through which organic matter has to pass in order to produce plant available nutrients such as phosphate (Figure 1).

Another soil microorganism, the mycorrhizae, can contribute to uptake of P by plants, although the process is very complex and the details of the processes involved are still the subject of much research. A range of direct and less direct mechanisms has been suggested including: increased physical exploration of the soil; increased P movement into mycorrhizal hyphae, modification of the root environment; efficient transfer of P to plant roots; increased storage of absorbed P; and efficient utilisation of P within the plant. However, in Australian systems, or at least for crops, it seems that a high level of infection with mycorrhizal fungi does not confer yield benefits and sometimes causes a yield penalty (Ryan et al. 2002; Ryan et al. 2004; Ryan et al. 2005), despite certainly contributing to P uptake (Li et al. 2005; Li et al. 2006; Thompson 1990).

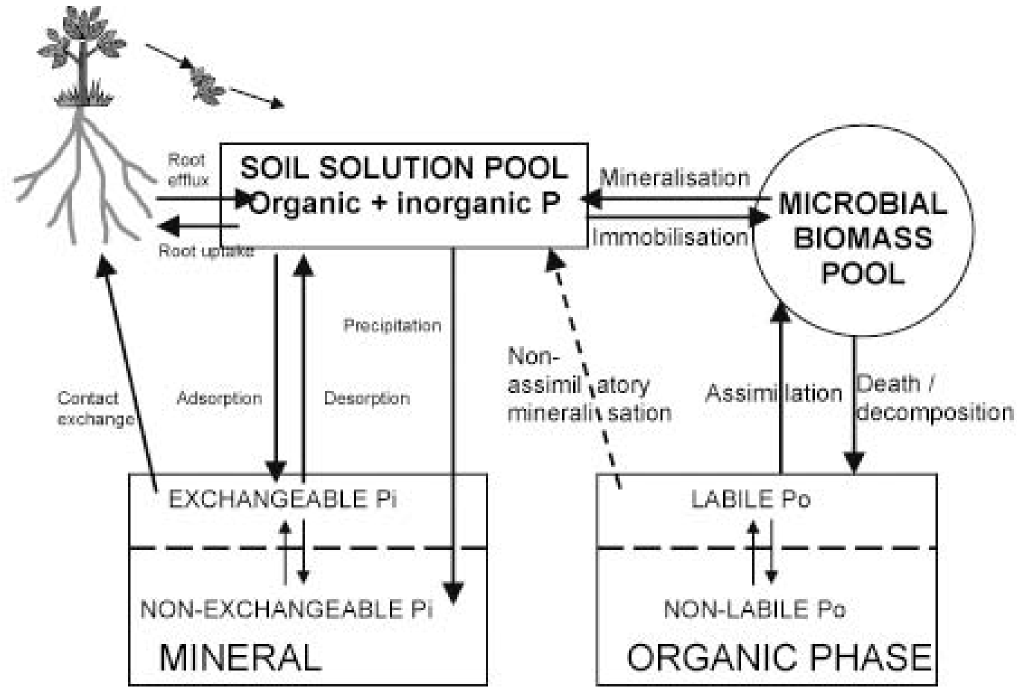


Figure 1. Soil P Cycle – pools and pathways. Modified from: McLaughlin *et al.* (1999).

Fertilisers, manures, composts and biosolids as sources of P

When soluble granular P fertilisers are applied to soil, a large proportion of the P quickly dissolves (within 24 h) but there are many fates for that dissolved P once it gets into the soil solution pool (Figure 1). The concentration of P around the fertiliser granule is high, and P may be lost from the soil solution pool by precipitation reactions, where soluble P combines with other elements in the soil (calcium, aluminium, iron) to produce new solid compounds (Figure 1). Some of these new compounds can eventually dissolve over time, or when a plant root reaches them, to release P into a soluble form again. However, some P compounds can remain very insoluble and are therefore 'locked up' in the non-exchangeable pool (Figure 1) and effectively unavailable for plant uptake. As P moves away from the granule through soil pores it binds to soil surfaces by a process called adsorption. This is where P is attracted to the clay mineral surfaces of soils – some of the P on the surface remains in a plant available form (ie. it can move back into the soil solution pool) but some may be very strongly bound and permanently removed from the plant available pool into the non-exchangeable pool (Figure 1). Crops derive their P from the soil solution that is in equilibrium with the adsorbed P in the soil (this process is called desorption – see Figure 1) and from P compounds that can readily dissolve.

Part of the dissolved P is also incorporated into the soil organic matter by the soil microbial biomass but can be later mineralised to soluble P by other microbial processes or exudates from plant roots (Figure 1). Soil microbes however compete with crop roots for soil solution P (McLaughlin and Alston 1986; McLaughlin *et al.* 1988c). Organic P in soil also exists in forms that

Table 1. Concentration of N, P and K on a dry weight basis in commonly applied wastes or residues [Modified from Gascho (2002) and Pittaway (2002)]

Waste	N (%)	P (%)	K (%)
Livestock manures	1–3	0.4–2	1–2.5
Poultry manures	0.3–5	1–3	1–2
Pig bedding litter	0.3–1	0.05–0.6	0.2–0.7
Plant Residues	1–7	0.1–1.7	0.1–9
cotton trash	1.3	0.45	0.36
peanut shells	0.8	0.15	0.5
cornstalks	0.8	–	0.8
wheat straw	0.3–0.5	0.15–0.26	0.6–1.02
Municipal biosolids	2–9	1.5–5	0.2–0.8
		Mg/L	
Municipal effluents	1.6–2.7	0.2–1.2	1.1–1.7

differ in how they react with the soil solution pool and these are commonly called labile and non-labile pools (Figure 1). When organic fertilisers such as composts, manures and biosolids are applied to soil they contribute P to both the soluble and organic pools, and they can contain considerable amounts of P (Table 1). Grazing animals will also contribute to P cycling via dung and urine, and may concentrate nutrients in 'camp' areas, but further discussion of this is outside the scope of this paper. Data for Australia demonstrates that biosolids can supply P to support crop yields equivalent to that obtained with inorganic P fertiliser (Weggler-Beaton *et al.* 2003) and that biosolids have a residual nutrient value, including P (Pritchard *et al.* 2006). Nevertheless, soluble P availability from organic fertilisers needs to be managed to avoid potential losses and negative environmental impacts (Bell *et al.* 2006).

Increasing P cycling – residues and rotations

Practices that increase organic matter in soil should, generally, increase the capacity to cycle P. Thus, at the Wagga Wagga long term trial site in south-eastern Australia, organic P increased over 24 years in the rotations with a mulched subterranean clover pasture component, especially with direct-drill (Table 2). Losses of organic P were largest (–42 kg P/ha) under continuous wheat with stubble burning and cultivation (Bunemann *et al.* 2006). As can be seen from Table 2, the pattern of changes in organic P in the Wagga Wagga trial caused by agricultural management was closely correlated to changes in organic matter carbon (C). This link between organic C and organic P was also evident in a survey of 10 sites across southern Australia with different land use, including three sites from NSW. The data showed that organic P was highest where organic C input was high, such as under trees or in grassland and pastures, and lowest in wheat-fallow situations particularly with stubble-burning and cultivation.

Concurrent with accumulation of organic P was an increase in P stored in the microbial biomass as shown by the positive correlation between organic P content and microbial P shown in Figure 2. Microbial P is one stage closer to being plant-available P than organic P, and so high microbial P content may reduce the P fertiliser requirements of a soil.

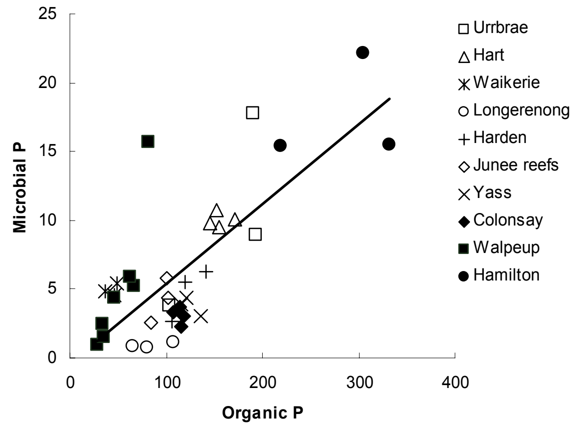


Figure 2. The potential ability of the soil to cycle P (microbial P) increases as organic P increases (From: GRDC Project UA00095 Organic P in Australian Farming Systems, Australian Farm Journal July 2006).

Laboratory studies on low P status alkaline soils from southern Australia (S. Iqbal – PhD thesis in preparation) have shown that addition of mature wheat, pea or canola shoot residues with a wide C:P ratio (from 870:1 to 1,860:1) to a soil low in organic C tends to build up microbial P but without any rapid release of plant-available P. Eventually, after six weeks incubation, there was slow release of available P for the following three months at a rate dependent on the amount and type of C, P and N in the added residue. Incorporation of young shoot material from peas and canola with narrow C:P ratio (from 133–253:1), as might occur where mulching or green-manuring are used, increased microbial P and plant-available P, and resulted in growth and P uptake of wheat similar to that obtained with moderate additions of P fertiliser (4 kg P/ha). Surprisingly, addition of mature canola root material to soil also caused rapid accumulation of plant-available P, highlighting that contributions from roots should not be ignored in P budgets. Further work, combining fertiliser and plant residue additions together, showed that although some P fertiliser is temporarily immobilised as microbial biomass in the presence of residues, there is a net gain in plant-available P compared to unamended soil and treatments with high C:P residues only. However, to obtain a target amount of plant-available P in soil

Table 2. Change in organic P and C in 0–10 cm after 24 years of different rotation, stubble management and tillage treatments at Wagga Wagga

Rotation	Stubble and tillage management	Change in organic P (kg P/ha)	Change in organic C (t C/ha)
Wheat-Lupin	Mulch, 3 cultivations	–13	–4
Wheat-Lupin	Burn, 3 cultivations	–43	–6.5
Wheat-Wheat	Burn, 3 cultivations	–42	–7
Wheat-Subclover	Mulch, direct-drill	+47	+7
Wheat-Subclover	Mulch, 3 cultivations	+5	+2

required more P fertiliser when plant residues with a high C:P ratio were present. Application of P fertiliser alone resulted in three times as much plant-available P than if the equivalent rate of P was added as half fertiliser and half in residues.

Perhaps more applicable to northern NSW is a field study on an acidic soil with high organic carbon (>3.0%) in Canada which specifically measured P mineralisation from root residues of several crops (peas, canola and wheat). The authors concluded that root residues exhibited no tendency to immobilise P although the rate of P mineralisation was less than shoot materials (Soon and Arshad 2002). Residues of mustard or rapeseed varieties high in glucosinolates (Morra and Kirkegaard 2002) could also potentially be used for increasing the suppression of soil-borne diseases and thus maintaining a healthy root system for P uptake. This appears to be possible without undue effects on beneficial soil organisms such as mycorrhizae eg. in a study on Vertosols in south-eastern Australia there was no effect on arbuscular mycorrhiza fungal colonisation of wheat grown in rotation after brassica crops with different levels and types of root glucosinolates (Ryan *et al.* 2002).

Pastures in rotations

Some twenty years ago, tracer studies in annual legume pastures on an alkaline sandy loam soil from the cereal/sheep belt in South Australia showed that P from medic residues accumulated in wheat plant shoots, roots and in soil microbial biomass in similar proportions (6.7, 7.0 and 8.1 per cent of total P added); ie. in one season a total of 21.8 per cent of the residue P became labile or potentially more available to the plants (McLaughlin and Alston 1986). Under field conditions the amount of residue P incorporated into microbial biomass (22–28 per cent) was even greater (McLaughlin *et al.* 1988b) and may be related to the fact that there was a rapid release of soluble P directly via autolysis of the residues upon initial wetting of the soil at the break of the season (McLaughlin *et al.* 1988c). Further work measured the relative uptake of P from fertiliser and medic plant residues in the field and showed that most of the P taken up by a wheat crop originated from historic soil sources ie. not sources from the immediate season's fertiliser or last year's residues (McLaughlin *et al.* 1988a). This underlines the fact that system P fertility is an integration of many years of inputs and that long term P management strategies need to be evaluated to fully understand the sustainability of particular systems. Overall, this work highlighted the contribution that annual legume pastures in southern Australia can make to P cycling in rotations. Studies on P cycling for perennial pastures in Australia appear to have focussed largely on the potential for losses of P (both inorganic and organic) from run-off under high rainfall conditions (Dougherty *et al.* 2008; Melland *et al.* 2008), and these studies emphasise that careful management is required to minimise the risks associated with the maintenance of soluble P in soil for plant uptake using inputs that contain P including those from grazing animals. In relation to pasture management practices and P cycling, there was some interesting work undertaken in sown and native pastures in northern NSW suggesting that over-sowing subterranean clover and applying fertiliser to native pastures markedly improved rates of litter and organic matter decomposition and N recycling (Lodge *et al.* 2006). It is likely that P cycling also increased, although this was not directly measured.

Species that can solubilise P

There are several mechanisms that allow plants to access poorly available inorganic and organic soil-P fractions and thus increase the pool of soil P that contributes to plant P nutrition. Briefly, these include release of protons (H+) or hydroxyl ions (OH−), organic acid anions, increase in reduction capacity and rhizosphere phosphatase activity. A number of crop species used in Australian farming systems are known to excrete P solubilising compounds, especially legumes such as lupin, pigeonpea, chickpea, fababean and peas, lucerne, white clover but also wheat and cocksfoot (Ae *et al.* 1990; Gardner *et al.* 1983; Li *et al.* 1997; Nuruzzaman *et al.* 2006).Other species, such as medics, radish and canola, have been shown to excrete P solubilising substances under P-deficient conditions (Hedley *et al.* 1982; Hoffland *et al.* 1992; Lipton *et al.* 1987; Zhang *et al.* 1997) and might therefore be suited to systems where plant-available P is low. Furthermore, if P is mobilised by plants in excess of their own requirements then it may contribute to the P nutrition of other less P-efficient crops grown in rotation or inter-cropped in the farming system. Reports from field experiments on the P benefits of growing these species in rotations or with inter-cropping in Australia are sparse although over 20 years ago a beneficial effect on P uptake by wheat when grown with lupin in Western Australia was demonstrated (Gardner and Boundy 1983). Seed and soil microbial inoculants that solubilise P and facilitate improved shoot P uptake have been developed in Canada and are currently being field tested in Australia.

Maximising P efficiency

P use-efficiency by crops or pastures in simple agronomic terms can be defined as the amount of shoot biomass per unit of P present in the plant. It represents the integration of plant P uptake from soil and P translocation within the plant, processes that are both extremely complex (Holford 1997). Traditionally, pasture grass species are considered more efficient than pasture legume species at acquiring and using P, both on an individual plant basis and under competition in a mixed sward (Biddiscombe *et al.* 1969; Caradus 1980; Ozanne *et al.* 1976; Ozanne *et al.* 1969). Some years ago, Australian researchers showed stylo was more efficient under low P conditions than white clover (Chisholm and Blair 1988) and later work further identified that some scope existed for selection for P efficiency within white clover accessions, particularly under P stress (Godwin and Blair 1991). However, this does not appear to have been undertaken.

There appears to be a growing consensus that sufficient genotypic variation of P efficiency within cereals exists to warrant breeding efforts. A comprehensive Australian study that screened over 100 cereal genotypes in the glasshouse demonstrated a wide variation in soluble P uptake efficiency (Osborne and Rengel 2002c), as well as in the capacity to use less soluble forms of P such as phytate and iron phosphate (Osborne and Rengel 2002a; Osborne and Rengel 2002b). Rye and triticale appeared more efficient than wheat at taking up and utilising P at low rates of P supply, and in being able to access less soluble forms of P. Work using soils-based screening for P efficiency has also concluded there is germplasm in Australian wheat genotypes that may be valuable for breeding (Liao *et al.* 2004), although these researchers emphasise that breeding for P-uptake efficiency would only be feasible provided the trait is heritable and controlled by relatively few genes.

Another aspect of managing for P efficiency is to consider the plant root system architecture and morphology in relation to the ability to access more P from the soil. Plant root architecture and morphology are important for maximising P uptake, because root systems that have higher ratios of surface area to volume, such as those with long fine roots and abundant root hairs, will more effectively explore a larger volume of soil. Furthermore, a smaller radius of fine roots and root hairs causes a slower decline in P concentration at the root/hair surface, enabling a higher rate of P influx to be maintained, which may also contribute to greater P uptake. Therefore enhancing opportunities for P transport via soil-root contact through growing species or genotypes with greater lateral root formation (Blair and Godwin 1991; Gahoonia *et al.* 1999; Manske *et al.* 2000), longer root hairs (Gahoonia and Nielsen 1997; Gahoonia and Nielsen 2004b), or reduced root diameter (Fohse *et al.* 1991) will give greater potential for increased P acquisition by plants. Agronomic evaluation in the field has been undertaken for barley in Europe demonstrating the efficacy of root traits such as root hair length for increased plant P uptake (Gahoonia *et al.* 2000; Gahoonia *et al.* 1999), as well as sustaining high grain yields under low P conditions (Gahoonia and Nielsen 2004a), although the relationships for wheat were reported as being less clear (Gahoonia *et al.* 1999). These European studies suggest that genetic modification could be used for upgrading P efficiency in barley genotypes, although the time frame is long-term. Currently, these kinds of traits are being investigated for Australian cereal and pasture cultivars but it will be some time before growers benefit from new releases.

Conclusions

Input of soluble P is necessary to sustain productivity in northern NSW pasture-based systems but as mineral fertilisers become more expensive (and sources are depleted) then alternative inputs such as biosolids, composts and manures will become more cost-effective and more attractive to use. These organic fertilisers have additional benefits – they contain other nutrients (N and K) as well as P, and they increase carbon in the soil (improve the organic matter) as well as feeding the soil microbial capacity. However, organic P sources are relatively slow-release and also it is not easy to predict exactly when the soluble P will be released. So, a combination of mineral and organic sources for P is the best option. Currently, sustainable management goals should also consider the use of species in the system that are known to mobilise P from the less available pools and also the tactical use of green-manuring to return high quality residues into the soil if the soluble P pool is depleting. Beyond the horizon in the longer term will be the use of new cultivars that have been modified or bred to be P-efficient, either due to improved root architecture or to enhanced translocation of P into shoots.

Acknowledgements

The author thanks GRDC for funding the project 'Biological Cycling of P in Farming Systems – Towards an Improved Capacity for Managing P Supply to Grain Crops', Petra Marschner and Else Bunemann for their major input to the project, Rebecca Stonor for technical assistance and Chris Penfold for useful discussions.

References

Ae N, Arihara J, Okada K, Yoshihara T, Johansen C (1990) Phosphorus uptake by pigeon pea and its role in cropping systems of the Indian subcontinent. *Science* **248**, 477–480.

Bell MJ, Pu G, Barry G, Want PS, Halpin N (2006) Fate of nutrients applied in biosolids in broadacre cropping systems in Queensland. In 'Proceedings of the AWA Biosolids Specialty Conference III 7–8 June'. Melbourne pp. 1–9.

Biddiscombe E, Ozanne PG, Barrow NJ, Keay J (1969) A comparison of growth rates and phosphorus distribution in a range of pasture species. *Australian Journal of Agricultural Research* **20**, 1023–1033.

Blair GJ, Godwin DC (1991) Phosphorus Efficiency in Pasture Species.7. Relationships between Yield and P-Uptake and Root Parameters in 2 Accessions of White

Clover. *Australian Journal of Agricultural Research* **42**, 1271–1283.

Bunemann EK, Heenan D, Marschner P, McNeill A (2006) Long term effects of crop rotation , stubble management and tillage on soil phosphorus dynamics. *Australian Journal of Soil Research* **44**, 611–618.

Caradus JR (1980) Distinguishing between grass and legume species for efficiency of phosphorus use. *New Zealand Journal of Agricultural Research* **23**, 75–81.

Chisholm RH, Blair GJ (1988) Phosphorus Efficiency in Pasture Species.1. Measures Based on Total Dry-Weight and P-Content. *Australian Journal of Agricultural Research* **39**, 807–816.

Dougherty WJ, Nicholls PJ, Milham PJ, Havilah EJ, Lawrie RA (2008) Phosphorus fertiliser and grazing management effects on phosphorus in runoff from dairy pastures *Journal of Environmental Quality* **37**, 417–428.

Fohse D, Claassen N, Jungk A (1991) Phosphorus efficiency of plants. II. Significance of root radius, root hairs and cation-anion balance forphosphorus influx in seven plant species. *Plant and Soil* **132**, 261–272.

Gahoonia TS, Asmar F, Giese H, Gissel-Nielsen G, Nielsen NE (2000) Root-released organic acids and phosphorus uptake of two barley cultivars in laboratory and field experiments. *European Journal of Agronomy* **12**, 281–289.

Gahoonia TS, Nielsen NE (1997) Variation in root hairs of barley cultivars doubled soil phosphorus uptake. *Euphytica* **98**, 177–182.

Gahoonia TS, Nielsen NE (2004a) Barley genotypes with long root hairs sustain high grain yields in low-P field. *Plant and Soil* **262**, 55–62.

Gahoonia TS, Nielsen NE (2004b) Root traits as tools for creating phosphorus efficient crop varieties. *Plant and Soil* **260**, 47–57.

Gahoonia TS, Nielsen NE, Lyshede OB (1999) Phosphorus (P) acquisition of cereal cultivars in the field at three levels of P fertilization. *Plant and Soil* **211**, 269–281.

Gardner WK, Barber DA, Parbery KG (1983) The acquisition of phosphorus by Lupinus albus L. III The probable mechanism by which phosphorus movement in the soil/root interface is enhanced. *Plant and Soil* **70**, 107–124.

Gardner WK, Boundy KA (1983) The acquisition of phosphorus by Lupinus albus L IV. The effect of interplanting wheat and white lupin on the growth and mineral composition of the two species. *Plant and Soil* **70**, 391–402.

Gascho GJ (2002) Fertilisers, Organic In 'Encyclopaedia of Soil Science' (Ed R. Lal) Marcel Dekker Inc New York. pp. 566–568.

Godwin DC, Blair GJ (1991) Phosphorus Efficiency in Pasture Species.5. a Comparison of White Clover Accessions. *Australian Journal of Agricultural Research* **42**, 531–540.

Hedley MJ, White RE, Nye PH (1982) Plant induced changes in the rhizosphere of rape (Brassica napus var. Emerald) seedlings III. Changes in L value, soil phosphate fractions and phosphatase activity. *New Phytologist* **91**, 45–56.

Hoffland E, Boogaard RVD, Nelemans JA, Findenegg GR (1992) Biosynthesis and root exudation of citric and malic acids in phosphate-starved rape plants. *New Phytologist* **122**, 675–680.

Holford ICR (1997) Soil phosphorus: its measurement, and its uptake by plants. *Australian Journal of Soil Research* **35**, 227–39.

Li CJ, Zhu YG, Marschner P, Smith FA, Smith SE (2005) Wheat Responses to Arbuscular Mycorrhizal Fungi in a Highly Calcareous Soil Differ from those of Clover, and Change with Plant Development and P supply. *Plant and Soil* **277**, 221–232.

Li H, Smith SE, Holloway RE, Zhu Y, Smith FA (2006) Arbuscular mycorrhizal fungi contribute to phosphorus uptake by wheat grown in phosphorus-fixing soil even in the absence of positive growth response. *New Phytologist* **172**, 536–543.

Li M, Osaki M, Rao IM, Tadano T (1997) Secretion of phytase from the roots of several plant species under phosphorus-deficient conditions. *Plant and Soil* **195**, 161–169.

Liao MT, Hocking P, Dong B, Delhaize E, Ryan PR (2004) Screening for genotypic variation in phosphorus-uptake efficiency in cereals on Australian soils In 'New directions for a diverse planet: Proceedings for the 4th International Crop Science Congress'. Brisbane. (Eds DT Fischer, DN Turner, DJ Angus, DL McIntyre, DM Robertson, DA Borrell and MD Lloyd). (The Regional Institute Ltd http://www.cropscience.org.au/icsc2004/poster/2/5/4/697_liaomt.htm)

Lipton GS, Blanchar RW, Blevins DG (1987) Citrate, malate and succinate concentrations in exudates from P-sufficient and P-stressed *Medicago sativa* L. seedlings. *Plant Physiology* **85**, 315–317.

Lodge GM, King KL, Harden S (2006) Effects of pasture treatments on detached pasture litter mass, quality, litter loss, decomposition rates, and residence time in northern New South Wales. *Australian Journal of Agricultural Research* **57**, 1073–1085.

Manske GGB, Ortiz-Monasterio JI, Van Ginkel M, Gonzalez RM, Rajaram S, Molina E, Vlek PLG (2000) Traits associated with improved P-uptake efficiency in CIMMYT's semidwarf spring bread wheat grown on an acid Andisol in Mexico. *Plant and Soil* **221**, 189–204.

McLaughlin MJ, Alston AM (1986) The relative contribution of plant residues and fertiliser to the phosphorus nutrition of wheat in a pasture/cereal system. *Australian Journal of Soil Research* **24**, 517–526.

McLaughlin MJ, Alston AM, Martin JK (1988a) Phosphorus cycling in wheat-pasture rotations. I. The source of phosphorus taken up by wheat. *Australian Journal of Soil Research* **26**, 323–331.

McLaughlin MJ, Alston AM, Martin JK (1988b) Phosphorus cycling in wheat-pasture rotations. II. The role of the microbial biomass in phosphorus cycling. *Australian Journal of Soil Research* **26**, 333–342.

McLaughlin MJ, Alston AM, Martin JK (1988c) Phosphorus cycling in wheat-pasture rotations. III. Organic phosphorus turnover and phosphorus cycling. *Australian Journal of Soil Research* **26**, 343–353.

McLaughlin MJ, Reuter DJ, Rayment GE (1999) Soil testing – principles and concepts. In 'Soil analysis – an interpretation manual'. (Eds KI Peverill, LA Sparrow and DJ Reuter) pp. 1–21. (CSIRO publishing: Collingwood, VIC)

Melland AR, McCaskill M, White RE, Chapman DF (2008) Loss of phosphorus and nitrogen in runoff and subsurface drainage from high and low input pastures grazed by sheep in southern Australia. *Australian Journal of Soil Research* **46**, 161–172.

Morra MJ, Kirkegaard JA (2002) Isothiocyanate release from soil-incorporated Brassica tissues. *Soil Biology and Biochemistry* **34**, 1683–1690.

Nuruzzaman M, Lambers H, Bolland M, Veneklaas EJ (2006) Distribution of carboxylates and acid phosphatases and depletion of different phosphorus fractions in the rhizosphere of a cereal and three grain legumes *Plant and Soil* **281**, 109–120.

Osborne LD, Rengel Z (2002a) Genotypic differences in wheat for uptake and utilisation of P from iron phosphate. *Australian Journal of Agricultural Research* **53**, 837–844.

Osborne LD, Rengel Z (2002b) Growth and P uptake by wheat genotypes supplied with phytate as the only P source. *Australian Journal of Agricultural Research* **53**, 845–50.

Osborne LD, Rengel Z (2002c) Screening cereals for genotypic variation in efficiency of phosphorus uptake and utilisation *Australian Journal of Agricultural Research* **53**, 295–303.

Ozanne PG, Howes KMW, Petch A (1976) The comparative phosphate requirements of four annual pastures and two crops. *Australian Journal of Agricultural Research* **27**, 479–488.

Ozanne PG, Keay J, Biddiscombe E (1969) The comparative applied phosphate requirements of eight annual pasture species *Australian Journal of Agricultural Research* **20**, 809–818.

Pittaway P (2002) Getting the mix right – putting practicality back into composting. In 'Local Global Organics Conference'. Lismore, NSW pp. 69–72. (Biological Farmers of Australia)

Pritchard D, Penney N, Collins D (2006) Biosolids at the farm gate. In 'Proceedings of the AWA Biosolids Specialty Conference III 7–8 June'. Melbourne.

Ryan MH, Derrick JW, Dann PR (2004) Grain mineral concentrations and yield of wheat grown under organic and conventional management *Journal of the Science of Food and Agriculture* **84**, 207–216.

Ryan MH, Norton RM, Kirkegaard JA, McCormick KM, Knights SE, Angus JF (2002) Increasing mycorrhizal colonisation does not improve growth and nutrition of wheat on Vertosols in south-eastern Australia. *Australian Journal of Agricultural Research* **53**, 1173–1181.

Ryan MH, Van Herwaarden A, Angus JF, Kirkegaard JA (2005) Reduced growth of autumn-sown wheat in a low-P soil is associated with high colonisation by arbuscular mycorrhizal fungi *Plant and Soil* **270**, 275–286.

Soon YK, Arshad MA (2002) Comparison of the decomposition and N and P mineralization of canola, pea and wheat residues. *Biology and Fertility of Soils* **36**, 10–17.

Thompson JP (1990) Soil sterilisation methods to show VA-mycorrhizas aid P and Zn nutrition of wheat in vertisols. *Soil Biology Biochemistry* **22**, 229–240.

Weggler-Beaton K, Graham RD, McLaughlin MJ (2003) The influence of low rates of air-dried biosolids on yield and phosphorus and zinc nutrition of wheat (*Triticum durum*) and barley (*Hordeum vulgare*). *Australian Journal of Soil Research* **41**, 293–308.

Zhang FS, Ma J, Cao YP (1997) Phosphorus deficiency enhances root exudation of low-molecular weight organic acids and utilization of sparingly soluble inorganic phosphates by radish (*Raghanus sativus* L.) and rape (*Brassica napus* L.) plants. *Plant and Soil* **196**, 261–264.

Biochar: Potential for climate change mitigation, improved yield and soil health

L. Van Zwieten[A], S. Kimber[A], K. Sinclair[A], K.Y. Chan[B] and A. Downie [C,D]

[A] NSW Department of Primary Industries, Wollongbar, NSW 2477
<lukas.van.zwieten@dpi.nsw.gov.au>
[B] NSW Department of Primary Industries, Richmond, NSW 2753
[C] BEST Energies, Somersby, NSW 2250
[D] University of New South Wales, NSW 2052

Abstract. *There has been a significant increase in scientific, political and media attention on the use of biochar in agriculture and forestry (ABC Catalyst, 2007). The use of slow pyrolysis for generation of renewable energy from waste biomass is now becoming a commercial reality. The bi-product 'biochar' has significant potential for climate change mitigation through the sequestration of carbon in soil (Lehmann 2006), and can deliver improvements in crop yield and soil health. The process has recently been described as a win-win-win situation by Laird (2008) for the reasons mentioned above. This paper will provide a concise situation report on biochar, how it is made, and the results of some of the research conducted by New South Wales Department of Primary Industries in its application in agriculture.*

What is biochar and how is it made?

Biochar is a high carbon bi-product of slow-pyrolysis. Essentially, any biomass can be pyrolysed – that is, heated in the absence of oxygen. However, several key quality parameters of the biochar depend on feed-stock materials and pyrolysis conditions. Feed stocks suitable for biochar include; greenwaste, forestry waste, poultry litter, cattle feed-lot manure, paper mill waste, cane trash, mill mud and bagasse.

Commonly, biomass is heated in a kiln at controlled temperatures ranging from 400–700^{0}C. During this heating, syn gas (similar to town gas) is released from the biomass. A portion of this gas is then recycled to provide thermal energy for the process, with excess syn gas able to be re-directed into the production of renewable energy; either thermal or directly into electricity through a gas engine and generator. High calorific feed-stocks can produce around 1 MW/h electricity per tonne feedstock. Higher temperatures in the pyrolysis kiln generate more energy but the yield of biochar is lower. Typically, a yield of 40–50 per cent biochar is achieved.

Biochars have been produced for New South Wales Department of Primary Industries (NSW DPI) by BEST Energies Australia from a wide range of feed-stocks. What is evident is that biochars differ significantly in their chemical and physical characteristics with changing feed-stocks and processing conditions.

Improvements to soil health through biochar application

The health of soil affects both economic and environmental sustainability of farming systems. Concern about soil health is motivated by present and future interest, in both agricultural productivity and profitability (Sherwood and Uphoff 2000). To test the benefits of biochar on soil health, a number of glasshouse and field trials have been undertaken. NSW DPI currently manages 158 field plots with biochar applications in cropping, pasture and perennial tree crops.

Biochars have a wide range of both chemical and physical characteristics depending on their feedstock and processing conditions. A summary of chemical characteristics of two biochars is provided in Table 1. Generally, biochar alkalinity (measured both as pH and liming equivalents) increases with increasing pyrolysis temperatures, but available nutrients tend to decrease. Higher temperatures give lower total carbon biochars with higher ash contents. As expected, biochars made from manures have higher levels of total and available nutrients compared to woody feed-stocks.

In pot trials, two biochars (poultry litter biochar and green-waste biochar) were mixed into a Krasnozem at the rate of 10 t/ha (assuming incorporation into 0–100 mm profile) for a total of 47 days. Soils were then kept in a controlled temperature incubator at 23^{0}C. Table 2 shows results of the changes in soil properties following incubation with the biochars. Again, it is evident that these contrasting biochars gave very different responses in soil properties. For chemical fertility, it is clear that the poultry litter biochar provided greater benefit initially in terms of supplying higher amounts of available phosphorus (P) and nitrogen (N); and both biochars significantly increased the soil carbon

(C) content. The higher C content biochar resulted in higher soil C analysis. There was little difference in the microbial activity in the soil, measured by the hydrolysis of fluorescein diacetate method, described by Zelles *et al.* (1991).

In a field trial at Wollongbar Agricultural Institute, poultry litter biochar was applied at rates of 0, 5, 10, 20 and 50 t/ha. A sweet corn crop was planted and soil sampling conducted at day 50 of the cropping cycle. Table 3 demonstrates significant improvements in soil chemical properties with increasing biochar rates. Increasing biochar rates have resulted in increases in pH with concomitant increases in cation exchange capacity (CEC) and reductions in available aluminium (Al). Of the nutrients, a very significant increase in crop available P was measured.

In pot trials conducted by Chan *et al.* (2007), biochar derived from greenwaste was shown to significantly improve N fertiliser use efficiency in a hard setting Alfisol. This is particularly relevant as the cost of N fertiliser is likely to rise significantly over the next few years. The biochar also had the benefit of significantly reducing the tensile strength of the soil and increasing its water holding capacity.

Yield increases with biochar application

In December 2007, biochar derived from poultry litter was soil-incorporated at rates of 0, 5, 10, 20 and 50 t/ha and planted with sweet corn in replicated (n=4) plots. Changes in soil chemical characteristics are described in Table 3. The nil treatment plot yielded 16 t fresh weight (FW) cob/ha while the 10 and 50 t poultry litter biochar/ha produced 25 and 35 t cob FW/ha, respectively (Table 4). Plant biomass production also doubled with the highest rate of biochar application.

Table 1. Summary of characteristics of two contrasting biochars (produced by BEST Energies Australia)

	Poultry litter biochar	Green waste biochar
pH (1:5 $CaCl_2$)	13.0	8.1
Colwell Phosphorus (mg/kg)	1700	26
Phosphorus (%)	3.40	0.01
Nitrogen (%)	0.80	0.14
Carbon (%)	27	48
Cadmium (mg/kg)	<1	<1
Acid neutralising equivalent (% $CaCO_3$)	33.0	<0.5

In another field trial with sweet corn, paper mill biochar and poultry litter biochar (both at 10 t/ha) were tested in triplicate in a randomised design with nil treatment control, lime (3 t/ha) and commercial compost at 25 t/ha. All treatments were repeated with and without luxury-rate fertiliser application. The highest yields were observed where biochars were added with fertiliser. However, poultry litter biochar alone out-performed luxury fertiliser treatment, lime amendment and compost amendment. These plots were sown to Faba bean in May 2008.

A pasture trial at Wollongbar has used biochars derived from cattle feedlot and municipal green-waste at 10 t/ha with 2 rates of lime (0, 5 t/ha). Amendments were incorporated into the soil in November 2006 and then sown with Amarillo pinto peanut (*Arachis pintoi*), a tropical legume. Six months later, annual ryegrass was over-sown with two rates of N fertiliser (0, 50 kg N/ha/month) throughout the ryegrass growing season. Over winter–spring the highest DM yields (6.7 t/ha) were harvested from the N fertiliser + cattle feedlot biochar plots. The addition of cattle feedlot biochar increased the yield response to N by 13 per cent. The green-waste biochar did not affect yield. Without N the cattle manure biochar increased N and P uptake by 23 per cent and 36 per cent, respectively.

Potential for climate change mitigation

Climate change caused by increase in the atmospheric concentration of greenhouse gases (GHGs) is predicted to cause catastrophic impacts on our planet (IPCC AR4 2006). This must therefore provide the impetus for action to reduce emissions and increase removal of GHGs from the atmosphere.

Table 2. Summary of soil analysis following 47 days incubation with biochars (at 10 t/ha) in Krasnozem

	Control soil	Poultry litter biochar amended	Greenwaste biochar amended
pH (1:5 $CaCl_2$)	4.8	6.0	4.8
Carbon Dumas (%)	5.1	5.4	6.6
CEC (cmol(+)/kg)	11.3	21.7	13.3
Bray Phosphorus (mg/kg)	15	39	19
KCl extracted NO_3-N (mg/kg)	67	93	67
Microbial activity (mg fluorescein/g dry soil/min)	13.3	12.7	12.3

Table 3. Soil analysis in field rate trial using poultry litter biochar

Biochar rate (t/ha)	pH ($CaCl_2$)	Al (cmol(+)/kg)	CEC (cmol(+)/kg)	Organic C Walkley Black (%)	Total N (%)	Total C Dumas (%)	Bray P (mg/kg)	KCl NH_4-N (mg/kg)	KCl NO_3-N (mg/kg)
0	4.4	1.10	6.5	4.5	0.50	5.3	14.3	3.7	13.5
5	4.6	0.68	7.1	4.5	0.59	6.4	23.3	4.2	10.2
10	4.7	0.43	7.9	4.5	0.54	5.9	41.8	4.7	11.3
20	4.9	0.21	9.2	4.8	0.53	6.0	69.3	5.0	13.2
50	5.9	0.009	15.3	5.2	0.66	7.5	201.0	5.2	14.8

Table 4. Crop responses to increasing rates of biochar application

Biochar rate (t/ha)	Cob weight (t/ha ± std dev)	Plant dry weight (t/ha)
0	16.6 ±4.2	3.3 ±0.6
5	19.8 ±4.8	3.5 ±1.0
10	25.1 ±4.9	4.8 ±0.4
20	25.9 ±7.2	4.6 ±1.4
50	34.7 ±6.6	6.2 ±1.8

Biochar acts in several ways to aid in climate change mitigation. Firstly, the conversion of labile carbons from biological material to stable carbon (biochar) through slow pyrolysis can tie up C in the soil for many hundreds of years (Lehmann 2006). Secondly, biochar in soil has the potential to reduce emissions of non-CO_2 greenhouse gases. The soil is both a significant source and sink for greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Biochar application to soil has been shown to affect C and N transformation and retention processes in soil. These processes along with other mechanisms, as influenced by biochar can play a significant role in mitigating soil GHG emissions.

Recent studies have indicated that biochar reduces N_2O emissions (Yanai *et al.* 2007) and increases CH_4 uptake from soil (Rondon 2006). This could add substantially to the greenhouse mitigation benefit. However, there is currently very limited understanding of the mechanisms through which biochar impacts on fluxes of CH_4 and N_2O. NSW DPI is undertaking several studies to determine the mechanisms of reduced GHG emission from soil using both laboratory and field experimentation.

As biochar has been shown to increase biomass production by crop species, even more C is being taken out of the atmosphere and stored in plant tissue. Apart from obvious economic advantages of improved crop yields, this also increases the amount of waste biomass available for slow pyrolysis and bioenergy production, and increases the amount of biochar available to sequester carbon long-term.

Conclusions

This paper has summarised some of the key benefits of biochar in soil. It is clear that biochar has the ability to significantly: improve crop productivity; increase soil C and soil fertility; improve soil structure (and therefore soil physical properties); sequester C in soil long-term and reduce emissions of non CO_2 greenhouse gases from soil. NSW DPI and BEST Energies Australia are continuing to develop proposals for the commercial production of biochar, and continue to research the benefits of this product for Australian agriculture.

Acknowledgements

The authors wish to acknowledge the financial support of the National Landcare Program through Richmond Landcare and the NSW Climate Action Grant. Work was co-funded by NSW Department of Primary Industries and BEST Energies Australia. The authors wish to acknowledge the assistance of Scott Petty, Josh Rust and Mike Heesom. Barry Outerbridge is especially thanked for providing expert assistance in setting up and maintaining the field site.

References

ABC Catalyst (2007) <http://www.abc.net.au/catalyst/stories/s2012892.htm>

Chan KY, Van Zwieten L, Meszaros I, Downie A, Joseph S (2007) Agronomic values of greenwaste biochar as a soil amendment. *Australian Journal of Soil Research* **45**, 629–634.

IPCC (Intergovernmental Panel on Climate Change) (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (Eds). Published for the IPCC by IGES, Japan.

Laird DA (2008) The charcoal vision: A win–win–win scenario for simultaneously producing bioenergy, permanently sequestering carbon, while improving soil and water quality *Agronomy Journal* **100**, 178–181.

Lehmann J, Gaunt J, Rondon M (2006) Biol-char sequestration in terrestrial ecosystems—a review. *Mitigation and Adaptation Strategies for Global Change* **11**, 403–427.

Rondon MA, Molina D, Hurtado M, Ramirez J, Lehmann J, Major J, Amezquita E (2006) Enhancing the productivity of crops and grasses while reducing greenhouse gas emissions through bio-char amendments to unfertile tropical soils. 18th World Congress of Soil Science July 9–15, Philadelphia, Pennsylvania, USA.

Sherwood S, Uphoff N (2000) Soil health: Research, practice and policy for a more regenerative agriculture. *Applied Soil Ecology* **15**, 85–97.

Yanai IY, Toyota K, Okazak M (2007) Effects of charcoal addition on N_2O emissions from soil resulting from rewetting air-dried soil in short-term laboratory experiments. *Soil Science and Plant Nutrition* **53**, 181–188.

Zelles L, Adrian P, Bai QY, Stepper K, Adrian MV, Fisher K, Maier A, Ziegler A (1991) Microbial Activity in Soils Stored Under Different Temperatures and Humidity Conditions. *Soil Biology and Biochemistry* **23**, 955–962.

Changing 'Glenbrae'

G.S. Ward

'Wooroola', Kelvin Rd, Gunnedah NSW 2380

Abstract. *In 1997 'Glenbrae' was covered with large areas of bare ground. As a result of i) changes in grazing management, ii) deep ripping and iii) seeding with tropical grasses and temperate legumes, the bare areas have become productive again. Results of changes in bare ground along a fixed transect over an 8-year period are presented.*

Introduction

My parents brought 'Glenbrae' in 1994 during a drought. My initial reaction as I was driving up to the old house on the hill was that they were going crazy in their old age – all I could see was bare ground everywhere. The 435 ha property was a worn-out old sheep and farming place with approximately 60 per cent clay pans – hard red pans impenetrable by rain or root. However, one thing which we all liked was that the property was littered with Kurrajongs. Eighty per cent of the property had been ploughed over the years, sown to wheat and oats, so much of the topsoil had been removed by various forms of erosion. What was left had been set-stocked with sheep. Although my parents brought only 40 cows and calves to the property in 1994, there was insufficient feed to sustain them, and the Kurrajongs had to be lopped.

Time to change

My wife and I moved back from North Queensland in 1997. Soon after that, my mother Delsia Ward and I did the Holistic Management course with Brian Marshall. Our whole Nandewar Range Landcare group did this course and it was a real turning point in our lives. It made us start down the road of planned grazing and resting of our pastures. In this system, we manage the worst part of the paddock working on the principle of animals eating a third of the pasture, trampling a third, with a third left behind. We have been using this system ever since. We actually started to focus on what we wanted to grow rather than what we did not want to see growing. The results of this approach are self-supporting – the more you get to grow the more you want to see growing, both in terms of dry matter per hectare and diversity of species per hectare. There is a quote that I remember often… "If you always do what you have always done, then you will always get what you have always got."

When we started our new grazing management practices, we used moveable electric fencing until we decided which way was best to split up our paddocks, and where the troughs should be positioned. We also started to monitor a transect in the worst paddock on 'Glenbrae' with the theory that if we could not make a difference to the hardest and poorest paddock using our grazing management system, then we were wasting our time. The results along the transect showed that we were onto a winner with the amount of bare ground decreasing from 85 per cent in January 1998 to 15 per cent in March 2006 (Figure 1). Plants of all types increased the ground-cover from 3 per cent to 57 per

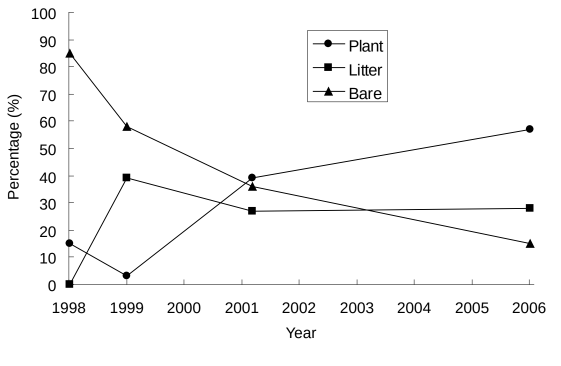


Figure 1. Change in the percentage (%) of plants, litter and bare ground along a fixed transect in a degraded paddock as a result of changes in management imposed from 1998. Assessments were made in autumn.

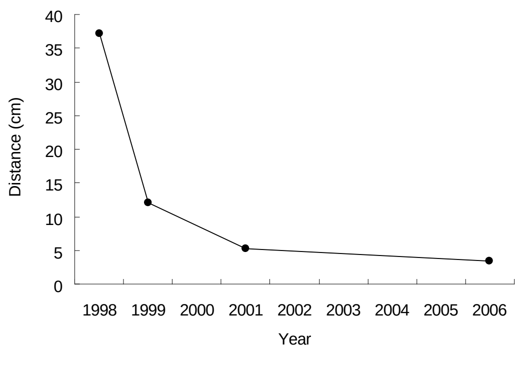


Figure 2. Distance (cm) between perennial plants along a fixed transect since 1998.

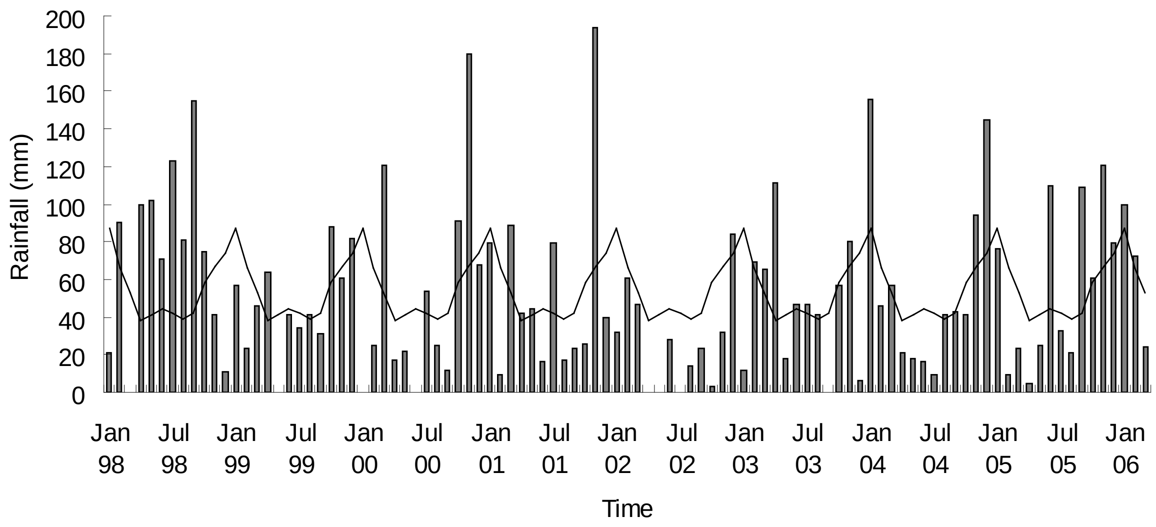


Figure 3. Monthly rainfall (mm, vertical bars) recorded at 'Glenbrae' and long term average for Manilla (122 years, line) from January 1998–March 2006.

cent and the average distance between perennial plants decreased from 37 cm in 1998 to 3 cm in 2006 (Figure 2). This was despite some very dry periods (Figure 3).

We also took photographs from the same position each time we monitored the area. These also show some extensive changes. The first year there was a lot of tap-rooted weeds such as saffron thistles (*Carthamus lanatus*) and Mexican poppies (*Argemone ochroleuca*) and it is a fact that weeds are a sign of soil that is trying to heal itself. The following year there were less weeds and more annual grasses. Every year after that there have been more and more grass species and less weeds. The monitoring area was grazed in the same way as our other paddocks on a rotation – there was no special treatment given.

Our management strategy is to 'manage for what you want to grow, not for what you don't want'. This means that when the cattle have begun to overgraze the fragile areas we move them into another paddock. By doing this we ensure that plants grow and go to seed and the bare ground gets less and less and grass gets thicker and thicker. It is pretty easy if you think about it.

'Glenbrae' was certified organic for about four years between 1998 and 2002 when there was a good premium for organic beef. This is why we went with the low-input system. We are no longer organically certified as there is too much paperwork, auditing and there is no longer a premium for the 60 or so weaners we produce a year. Not having the certification has not changed our management practices and there have been no chemicals or fertiliser applied to 'Glenbrae' since we have began operation. The only change we have implemented has been to grazing management. We did trial fertiliser application on some of the clay-pans prior to 1998 but until you have something growing, fertiliser is ineffective as it just washes away.

We have received some funding from the Liverpool Plains Land Management Committee (LPLMC) to help speed-up the process of getting something to grow on the really bad areas of clay pans. On these areas, we deep-ripped with a dozer which broke up the pans. Yeomans Shankpot seeders were fitted over the top of the rippers, so we ripped and seeded in one pass. The seed consists of a shot-gun mix of tropical grasses, such as purple pigeon (*Setaria incrassata*), Bambatsi panic (*Panicum coloratum* var. *makarikariense*) and green panic (*P. maximum* var. *trichoglume*). Also in the mix were temperate legumes such as lucerne (*Medicago sativa*), arrowleaf clover (*Trifolium vesiculosum*) and subterranean clover (*Trifolium subterraneum*), and sometimes oats (*Avena sativa*). We have tried chisel ploughs and no-till seeders but they do not open the pans enough, and the first rain usually seals over the rip mark again. Ripping with a dozer does leave the paddock very rough but the results are good; being rough it catches grass seed and absorbs all the falling rain. We fence these areas off from grazing for 12 months, sometimes more, depending on the extent of the damage in the area. We leave them until the sown grasses have established and there is a good herbage mass (eg. growth about 1 m high on the tropical grasses). We start crash-grazing until good ground-cover is present and then normal grazing is resumed. A lot of people say that deep-ripping does not work but we have found it effective on red clay pans provided it is followed with good grazing practices. Anyone can get a good germination and grow plants but if the areas are not managed carefully they will soon return to their original state. We have discovered this the hard way by our mistakes on a couple of occasions.

The future

There is no doubt that 'Glenbrae' is a very different property today than it was 14 years ago. As well as changing our grazing management, we have planted 10,000 trees and plan to keep planting for shelter, shade, timber and wildlife habitat. This has presented a bit of a challenge through the dry years but now a large difference can be seen over the whole property. We have just started doing some biological fertiliser trials with the Namoi Catchment Management Authority and LPLMC which will be monitored over the next four years. The results should be interesting. Depending on the results we may choose a higher input system on our next regeneration area. We are one of four properties in our area doing this trial covering many areas including native grass paddocks, worn out farmed red soil paddocks (this is us), pasture-cropped areas and black soil country. Chemical fertilisers will be applied alongside biological products with areas left untreated for comparison. It is an exciting time to be in agriculture with many changes being thrust upon us; some good, some bad.

One thing is for sure, we have to work with nature rather than against it to survive the increasing costs of production that are inevitably heading our way. We all have much more to learn about our soils and how we can improve them to be sustainable.

Profitable pastoral farming through genetic modification: fact or friction?

D.R. Woodfield

AgResearch Grasslands, Private Bag 11008, Palmerston North 4442, New Zealand
<Derek.Woodfield@agresearch.co.nz>

Abstract. *Pastoral agriculture in Australasia faces severe challenges to retain its international competitiveness as a low cost producer of milk, meat and fibre. Our agriculture is based predominantly on introduced forage species that have been domesticated and then sequentially improved by plant breeders. Genetic modification of forage grasses, legumes, herbs and their associated organisms (eg. endophyte and rhizobia) has delivered improvements in annual productivity, seasonality of that production, digestibility, energy content, pest and disease resistance, persistence, water-use efficiency, and in removal of animal health and welfare disorders. The various species and types produced by plant breeders have enabled farmers to optimise and intensify their farming systems so that feed supply better matches feed demand. Intensification will remain a driver of future forage requirements but will face severe environmental and social challenges. Forages that utilise scarce resources such as water and nutrients more efficiently, and that reduce greenhouse gas emissions will be required. In order to deliver these innovations, molecular and conventional breeding approaches must be effectively integrated. Currently, molecular breeding is well resourced but there is a huge gulf in the funding, and even availability, of conventional breeding capability to develop and deliver these forage innovations to the pastoral industries.*

Introduction

Farmers and research funders frequently ask what contribution plant improvement has made to Australasian farming systems and what can it contribute in the future to allow us to remain internationally competitive? The challenge for breeders working on improving their particular crop is to understand the future requirements of their target farming system. Slow adoption of some new varieties has been seen as a failure and funders in Australia have formed 'Pastures Australia' and the Cooperative Research Centres to better focus the forage breeding efforts funded by the industry bodies.

Pastoral agriculture in New Zealand, and to a large extent in Australia, is dependent on exotic species introduced over the past 200 years. Plant breeding has made a significant contribution to the economic growth of our agricultural industries over the past 50 years through domestication, and selection for improved adaptation, of these forage species. Pasture-based industries account for 44 per cent of New Zealand's exports and their contribution to Gross Domestic Product has increased from 13.5 per cent in 1990 to 17 per cent in 2005. This has been achieved despite the removal of agricultural subsidies, increased exposure to global market forces, and substantial shifts in public funding away from plant breeding. Lancashire (2006) estimated that 75 per cent of New Zealand's $14B pastoral export earnings were generated from improved forage species and that overseas germplasm incorporated into New Zealand breeding programs alone contributes nearly $1B annually. The introduction of a new ryegrass technology (ie. AR1 endophyte) alone is estimated to have been worth $74M per year in increased meat and milk production (Bluett *et al.* 2003).

The removal of agricultural subsidies has driven Australia and New Zealand down an intensification pathway to remain economically viable. Intensification and changes away from export of frozen carcasses to products that are processed and exported chilled improved the international competitiveness of the New Zealand sheep industry in the last 20 years. In 2004, 24 per cent more lamb meat was produced in New Zealand than was produced in 1990 despite total sheep numbers decreasing from 60M to 40M in that period. Intensification in the Australasian dairy industry has been even more spectacular (Table 1). The average number of cows per herd has more than doubled in both countries since 1990. While total cow numbers have remained relatively static in Australia, per cow production has increased by 37 per cent. There have also been large increases in per cow production (27 per cent) in New Zealand but by far the biggest change has been the 70 per cent increase in the number of cows since 1990. High exchange rates and high commodity milk prices have further accelerated conversion from sheep to dairying in New Zealand with a drop to 35M sheep predicted by the end of 2008.

Intensification has placed severe pressure on our traditional perennial forages such as ryegrass/clover pastures that have formed the basis of most production systems. Short-term pastures with increased yield

Table 1: Intensification of the dairy industry in Australasia since 1990 (LIC 2007; Dairy Australia 2007)

	New Zealand		Australia	
Year	1990	2007	1990	2007
Number of farms	14,595	11,630	15,396	8,055
Cows (million)	2.31	3.92	1.65	1.81
Average herd size	158	337	107	225
Cows/ha	2.40	2.81	–	–
Production per cow	259 kg MS[A]	330 kg MS	3,781 litres	5,163 litres

[A]Milksolids (fat plus protein) per cow was first measured in 1992/93 season

potential have played a greater role in lamb-finishing and dairy operations, while alternative forage species and supplementary feed-crops are being integrated to fill feed-gaps. The use of nitrogen fertiliser, irrigation (where available) and bought-in feed, has increased dramatically in our farming systems. This has resulted in erosion of the traditional low production cost advantages that we have had over international competitors. Pressure from water restrictions and the rapidly rising input costs associated with fertiliser and supplementary feed will force re-evaluation of these practices in future farming systems.

Plant breeding must play a role in assisting with overcoming the ongoing environmental issues (eg. greenhouse gas emissions, water availability and quality, salinity), economic issues (eg. profitability of pastoral systems and reducing fertiliser and supplementary feed input costs) and social issues (eg. food miles and acceptability of genetically modified foods) that face pastoral agriculture.

Genetic gains in forages

Genetic improvements of about 1 per cent per year for herbage yield, nitrogen fixation, and animal performance have been reported in forage legumes and each one per cent improvement in clover yield has been estimated to be worth more than $20M (Woodfield 1999). Similarly, improvements in herbage yield, rust resistance and heading date of the main forage grasses have also been reported (Easton *et al.* 2002). These improvements are due to selection for improved yield potential and to reducing the effects of yield-limiting factors such as pest and diseases. Improvements in the herbage yield of perennial ryegrass have tended to be slower (0.6 per cent per year for annual yield) than in legumes due to the confounding effects of endophyte. The value of genetic improvements in grass performance to farmers does tend to be greater simply because grass generally contributes around 80 per cent of the diet. The greatest single innovation in forages has been the identification of novel endophytes that have overcome ryegrass staggers and fescue toxicosis (see below). Another important innovation over the past 20 years has been the diversification of ryegrass varieties from persistent perennials through to annual Italian types that offer farmers flexible management options due to differences in heading date and seasonal production characteristics. Tetraploid varieties have become more important and appear to be providing better persistence under Australian conditions (R. Hill, unpublished data).

New varieties of other grasses (tall fescue, cocksfoot, timothy, phalaris, brome) have also been developed. These have found their place in more difficult environments where ryegrass does not persist and/ or in specialist pastures. The recent development of Mediterranean tall fescues has provided a viable alternative to phalaris in drier Australian environments. During the past decade the use of Italian ryegrass, hybrid ryegrass, chicory and forage brassicas in specialist finishing pastures has also increased dramatically.

Annual and perennial legumes are incorporated into pastures to provide nitrogen, and to improve nutritive value and intake rates. More recently, varieties of herbs such as chicory and plantain have been commercialised for their nutritive value. White clover varieties suited to a wide range of environmental conditions and farming systems have been released. These include varieties such as Trophy white clover which maintains better clover content in drought-prone Victorian and New South Wales environments (Ayres *et al.* 2008; Jahufer *et al.* 2008). Selection for increased stolon density has been important in improving the persistence of white clover varieties such as Tribute and Kopu II. Varieties released in recent years have been shown to have better persistence but pasture establishment and management remain the keys to maintaining good clover content even with improved varieties available.

Genetic resistance to pests and diseases are key improvements as it is rarely economic to use chemical controls on-farm. In perennial ryegrass and cocksfoot, selection has been successful in combating the ability of crown and stem rust races to evolve and overcome existing resistance mechanisms (Easton *et al.* 2002). Sources of resistance to three nematode species in white clover have been identified and incorporated into current breeding programs (Woodfield and Easton

2004). The release of a red-legged earth mite resistant subterranean clover (SM029) this year from the National Annual Pasture Legume Improvement Program is a significant innovation for dry-land systems.

Impact of new varieties on animal production

Improvements in the annual and seasonal yield of pastures are vital, but the translation of these improvements into milk, meat and fibre is far more important. Most forage varieties are released into the market based on their agronomic merit without any animal evaluation. The reasons for this are simple; the cost of running these trials is prohibitive for most of the commercial seed companies that currently fund the majority of forage breeding in Australasia. Despite this constraint, a number of new forage varieties have been evaluated in grazing trials. The results of these trials can be inconclusive, showing little impact of a component product in the overall system. Poor results can be due to performance gains observed in small scale plots not translating into similar gains when evaluated in paddock-scale grazing trials or they can be due to poorly planned and executed grazing trials that do not allow the benefits to be captured. Decision rules about stocking rates, use of supplementary feed, and the timing and duration of grazing can all influence the final outcomes. Despite these difficulties a number of technologies have produced strong results in grazing trials (see below). The ultimate test for any technology is always whether it fits into whole-farm systems and improves profitability.

Optimisation of the grass-endophyte association in ryegrass and tall fescue has provided productivity gains in both sheep and cattle. Varieties with novel endophytes retain protection against a range of damaging pasture pests (eg. Argentine stem weevil, black beetle, pasture mealybug, root aphids) while alleviating ryegrass staggers (eg. AR1), reducing the severity of ryegrass staggers (eg. AR37) and overcoming fescue toxicosis (eg. Max Q™, MaxP™) by eliminating the toxic alkaloids. Extensive trialling has shown that animals grazing ryegrass pastures containing AR1 endophyte are free of staggers and produce more meat (47–108 g/head/day more) and milk (9–14 per cent) than animals grazing ryegrass containing the wild-type endophyte (Woodfield and Easton 2004). AR1 is now the industry standard and is present in most modern ryegrass varieties.

AR1 has provided resistance to Argentine stem weevil and pasture mealy bug but has shown more susceptibility to black beetle and root aphid than the wild-type endophyte in Northern New Zealand and Southern Australia. A recently released ryegrass endophyte, AR37, overcomes these pest susceptibilities but is not completely animal safe. Animals grazing AR37 have exhibited occasional staggers events, but they are generally short in duration and animals recover rapidly when transferred to other feeds (Fletcher 2005). Perennial ryegrass swards with AR37 produced about 17–36 per cent more herbage dry matter (DM) than ryegrasses containing either AR1 or wild-type endophyte (Hume *et al.* 2007). AR37 had its greatest DM advantage in summer and autumn. Grazing trials with AR37 are underway in New Zealand and Australia. Preliminary data after 18-months under dairy grazing in the Waikato suggests that milk yield with AR37 may be slightly lower than the animal safe AR1 but better than the wild type endophyte, although to date these differences are not significantly different over the full lactation. Importantly, the agronomic advantages in terms of tiller density and persistence were clearly evident after the recent drought. Ryegrass staggers has been observed with the wild-type endophyte but not with AR37 (Easton *et al.* 2007).

MaxP™ (called Max Q™ in USA) endophyte in tall fescue has also provided increased animal performance in comparison to tall fescue with wild-type endophyte. The live-weight gains are similar to those achieved with endophyte-free material but without sacrificing persistence (Bouton 2007). Economic returns were estimated to be between US$36 and US$55 per cow per year in Southern USA (Bouton 2007). Tall fescues containing MaxP have been used successfully for several years in Australia.

Diploid ryegrasses with sugar levels that are comparable to the levels normally found in tetraploids are being marketed in Australasia. There has been substantial variation in the animal performance response reported from a range of European and New Zealand trials with high sugar grasses (reviewed by Edwards *et al.* 2007). The most favourable results in milk and meat production have been in United Kingdom trials where these grasses were developed. Under New Zealand conditions a three-year dairy trial found no milk production response in spring although a 10 per cent increase in milk yield was found in one of the two autumn periods (Cosgrove *et al.* 2007). Increased animal production has been attributed to improved protein utilisation with less nitrogen excreted in urine. Expression of the 'high sugar' trait is not consistent, and is dependent on environment, as maximum expression is associated with cool night temperatures (Edwards *et al.* 2007). Further increases in sugar level will be achieved and higher and more stable expression may provide reliable animal productivity gains.

The improved persistence of new white clovers has provided substantial increases in beef production in south-eastern USA (Bouton *et al.* 2005). Pastures containing Durana white clover had 35 per cent more clover than the control pastures with Regal white clover, and cattle live-weight gains were 100 per cent and 83 per cent greater with Durana than the Regal control in endophyte-infected (E+) and endophyte-free (E–) tall fescue swards, respectively (Bouton *et al.* 2005). Increases in legume content in Australian and New Zealand pastures can provide similar animal performance benefits, with the optimal clover content for milk yield shown to be in excess of 50%.

Importance of introduced germplasm and ecotype collections to developing locally adapted varieties

Germplasm is the lifeblood of the pastoral industries. Introductions of new overseas germplasm and collections of ecotypes adapted to local environmental stresses have both contributed to genetic improvement of our forages. Perennial ryegrass and white clover are good examples of this. Initial introductions of both species from Europe were made into New Zealand prior to 1820 and by 1912 the majority of the seed used in New Zealand was locally produced. Initial breeding in the 1930s began by identifying the best naturalised ecotypes identified and these were re-selected over the next 30 years to produce Ruanui ryegrass and Huia white clover. These adapted ecotype varieties were shown to have superior performance to the best European varieties highlighting the power of the local environment to concentrate the best genes. The identification of the Mangere ryegrass ecotype in the late 1960s led to the development of Nui and Ellett ryegrasses. These varieties have had a profound impact on ryegrass breeding as they have formed the basis of all ryegrass breeding pools in Australasia. The incorporation of north-west Spain germplasm over the past decade has been equally important providing better winter growth, rust resistance and improved forage quality in varieties such as Impact, Tolosa, Bealey and Banquet (Stewart 2006).

Locally adapted ecotypes have been important in developing white clover varieties for marginal environments. Durana (southern USA tall fescue belt), Prestige and Tahora (moist New Zealand hill country), and Nomad (dry New Zealand hill country) are all successful varieties based on collected ecotypes. In Australia, the introduction of overseas collections led to the release of Siral (Algeria) and the widely used Haifa (Israel). Subsequent breeding efforts have combined Mediterranean, Southern European and local ecotypes to develop superior varieties such as Tribute and Trophy. Incorporation of Mediterranean germplasm has provided improved winter-activity in several species including ryegrass, tall fescue, cocksfoot, phalaris and white clover.

The next frontier will be in better utilising the genetic resources that sit within the wild relatives of our major forages. The majority of these related species have poor agronomic value but contain genes for useful traits such as drought tolerance, salinity tolerance, pests and disease resistance, establishment vigour and forage quality. New clover hybrids between white clover and several wild relatives are being assessed to identify perennial drought tolerant material for zones that are traditionally the domain of annual legumes.

There are many potential forage species sitting in our gene banks that with intensification and climate change represent a significant opportunity. A change in focus is required as current breeding and agronomy efforts are concentrated around a few economically important species. The chronic instability and low funding of underpinning genetic resources research and field breeding represents a major threat to the future viability of Australasia's pastoral industries. The value of new germplasm to the industry is unequivocal and we must work within international treaties and biosecurity constraints to maintain access to new germplasm. The reality is that breeding programs with elite germplasm will be strongly positioned to help the pastoral industries remain competitive and to deliver innovations that arise from biotechnology and genomics.

Future direction of conventional and molecular breeding

Molecular biology and genomics research in Australia and New Zealand offer considerable promise; the problem is that in forages, they have been long on promise and short on outcomes over a 20-year investment period! Undoubtedly there are target traits that require molecular approaches, unfortunately too often investment has been made into traits that could have been more developed by conventional means had the resources been made available. A case in point is virus resistance in white clover. More than 20 years effort has produced transgenic white clovers with resistance to white clover mosaic virus, alfalfa mosaic virus, and clover yellow vein virus. Transgenic plants have been field tested in New Zealand and Australia but they have not yet been commercialised. Given the current opposition to even simple technologies such as Round-up Ready alfalfa and a very costly regulatory framework, it is unlikely that we will see them in the foreseeable future either. The sad part is that good sources of natural genetic resistance exist to at least two of these viruses, and had even a fraction of the investment been put behind a conventional breeding effort then commercial varieties would already be available to farmers.

Molecular efforts need to focus on challenges that are beyond conventional breeding. Stable increases in expression of forage quality components such as lipid and condensed tannins, and increases in digestibility through modification of fibre composition are all areas that could provide quantum industry benefits within the next decade. Beyond that horizon, forages that utilise scarce resources such as water and nutrients more efficiently, and that reduce greenhouse gas emissions will be required. Climate change predictions indicate more variable rainfall and more frequent and severe droughts in many of our main pastoral environments. Germplasm with better water-use efficiency will be critical to deal with moisture constraints.

In order to deliver these innovations, molecular and conventional breeding approaches must be effectively integrated. Currently, molecular breeding is well resourced but there is a huge gulf in the funding, and even availability, of conventional breeding capability to develop and deliver these forage innovations to the pastoral industries. Public plant breeding has increasingly concentrated on a core group of economically important forages (ryegrass, tall fescue, white clover, red clover, lucerne and forage brassicas) where there is strong partnership with industry. In Australia, there is reasonable breeding capability working in species for the drier environments, but there is a scarcity of capability in species for the higher rainfall zones. The converse is true in New Zealand. In both countries, however, many of the existing plant breeders will reach retirement age in the next 10 years and training of new breeders is very low. Increasingly, Australian pasture requirements will be met by international breeding groups who specialise in a particular species or genus. The combined impact of a stringent regulatory environment together with poor integration of molecular and breeding capability is that Australasia's primary industries are likely to be followers rather than leaders in capturing the economic benefits that can be delivered from genetically modified crops.

The biggest gains from the genomics investment to date have been in the expansion of knowledge about genome structure and function, and in the development of better tools that plant breeders can use. High density genetic maps have been developed for white clover, red clover and perennial ryegrass that open the door for cost-effective marker-assisted selection, introgression of traits from wild relatives, and dissection of complex traits. The first forage varieties developed through application of these tools are currently undergoing seed multiplication in New Zealand.

References

Ayres JF, Caradus JR, Murison RD, Lane LA, Woodfield DR (2008) Grasslands Trophy – a locally adapted white clover for dryland environments. In 'Proceedings of the 23rd Annual Conference of the Grassland Society of NSW.' (Eds SP Boschma, LM Serafin, JF Ayres) (Grassland Society of NSW Inc.: Orange) pp. 116–119

Bluett SJ, Thom ER, Clark DA, Mac Donald KA, Minnee EMK (2003) Milksolids production from cows grazing perennial ryegrass containing AR1 or wild endophyte. *Proceedings of the New Zealand Grassland Association* **65**, 83–90.

Bouton JH (2007) The economic benefits of forage improvement in the United States. *Euphytica* **154**, 263–270.

Bouton JH, Woodfield DR, Hoveland CS, McCann MA, Caradus JR (2005) Enhanced survival and animal performance from ecotype-derived white clover cultivars. *Crop Science* **45**, 1596–1602.

Cosgrove GP, Burke JL, Death AF, Hickey MJ, Pacheco D, Lane GA (2007) Ryegrasses with increased soluble carbohydrate: evaluating the potential for grazing dairy cows in New Zealand. *Proceedings of the New Zealand Grassland Association* **69**, 179–185.

Dairy Australia (2007) Australian dairy industry in focus 2007. Melbourne, Australia.

Easton HS, Amyes JM, Cameron NE, Green RB, Kerr GA, Norris MG, Stewart AV (2002) Pasture plant breeding in New Zealand: where to from here? *Proceedings of the New Zealand Grassland Association* **64**, 173–179.

Easton HS, Thom ER, Bluett SJ, Hume DE, Popay AJ (2007) Endophyte technology for dairy pastures. In 'Proceedings of the Australasian Dairy Science Symposium, September 2007, Melbourne.' pp. 293–306.

Edwards GR, Parsons AJ, Rasmussen S (2007) High sugar grasses for dairy systems. In: Meeting the challenges for pasture-based dairying. In 'Proceedings of the Australasian Dairy Science Symposium, September 2007, Melbourne.' pp. 307–334.

Fletcher LR (2005) Managing ryegrass-endophyte toxicoses. In '*Neotyphodium* in Cool-Season Grasses'. (Eds CA Roberts, CP West, DE Spiers) pp. 229–241. (Blackwell: Ames, IA)

Hume DE, Ryan DL, Cooper BM, Popay AJ (2007) Agronomic performance of AR37-infected ryegrass in Northern New Zealand. *Proceedings of the New Zealand Grassland Association* **69**, 201–206.

Jahufer MZZ, Clements R, Durant R, Woodfield DR (2008) Evaluation of white clover commercial cultivars and experimental synthetics in South west Victoria. *Australian Journal of Experimental Agriculture* (submitted)

Lancashire J (2006) The value of exotic germplasm to the NZ livestock industry. *Grassland Research and Practice Series* **12**, 5–9.

Livestock Improvement Corporation (2007) New Zealand dairy statistics 2006–2007. Hamilton, New Zealand. 44p.

Stewart A (2006) Genetic origins of perennial ryegrass (Lolium perenne) for New Zealand pastures. *Grassland Research and Practice Series* **12**, 55–62.

Woodfield DR (1999) Genetic improvements in New Zealand forage cultivars. *Proceedings of the New Zealand Grassland Association* **61**, 3–7.

Woodfield DR, Clifford PTP, Baird I, Cousins GR, Miller JE, Widdup KH, Caradus JR (2003) Grasslands Tribute: a multi-purpose white clover for Australasia. *Proceedings of the New Zealand Grassland Association* **65**, 157–62.

Woodfield DR, Easton HS (2004) Advances in pasture plant breeding for animal productivity and health. *New Zealand Veterinary Journal* **52**, 300–310.

Pastures for animal production: Understanding the challenges

C.T. Westwood

Strategic Bovine Services, 9 Victoria Avenue, Barooga NSW 3644
<charlottew@dairydocs.com.au>

Abstract. *Tropical and temperate pastures provide a low-cost and effective feed-base for almost all New South Wales livestock enterprises, yet significant constraints limit the potential performance and profitability of such systems. Total dry matter yield and the proportion of dry matter yield utilised remain the most common factors that constrain productivity. Management strategies that address these challenges remain the most appropriate and rewarding ways to lift profitability for most livestock producers. Where a system is already being managed for optimal harvest of dry matter yield, opportunities exist to manipulate ways to improve feed conversion efficiency. This paper explores potential nutritional constraints for pasture-fed sheep and cattle and highlights opportunities to improve feed conversion efficiency through pasture management and the use of complementary supplements.*

Introduction

The use of grazing sheep and cattle to harvest pasture in situ remains the cornerstone of the simple, low-cost animal production systems of New South Wales (NSW). These systems are characterised by a diversity of grass/clover and herb blends, ranging from native pastures to tall fescue, phalaris and annual and perennial ryegrass pastures, with pastoral systems dictated by environmental and climatic constraints, stock types and management techniques.

Most traditional pasture-based systems are characterised by the synchrony of peak demand by stock with the peak periods of pasture growth. The simplicity and efficiencies of a supply-demand driven pastoral system are tempered by the challenges of matching pasture supply with animal demand. Inconsistent pasture production as a result of drought, hot or cold climatic conditions, and limitations of soils, drainage and pasture species reduces the effectiveness with which animals may be reliably sustained by pasture. Nutritional imbalances associated with pasture, including high or low levels of structural and non-structural carbohydrates, crude protein, trace elements and minerals and the presence of anti-nutritional compounds can limit the performance of grazing sheep or cattle.

A growing number of traditionally lower input NSW beef systems are now strategically incorporating supplementary feeds into pasture-based systems, recognising the potential vulnerabilities and inefficiencies of pastures as an ideal feed for cattle.

This paper will identify practical opportunities to optimise the productivity of cattle and sheep within pastoral based systems.

1. Quantitative aspects of feeding sheep and cattle on pasture

Within temperate regions of NSW, the generally favourable climate promotes the growth of highly digestible, high crude protein (CP) pastures for the cooler months of the year, particularly between the months of April and October. Tropical species of pasture offer greater challenges, being characterised by a lower CP, less digestible sward that is less favourable for efficient animal production.

While extremely cost competitive, the potential disadvantages of pasture-based systems are numerous. Inadequacies and potential constraints of grazing vs. more intensive management systems, including feed-lotting, are summarised in Table 1.

2. Productivity by NSW pasture-fed sheep and cattle: potential inefficiencies

Potential live-weight gain and reproductive performance of pasture-fed sheep and cattle are often below genetic potential, and are lower than those reported for animals offered high quality supplements and/or full total mixed rations (TMR).

Beef cattle that grow more quickly are more efficient than those growing more slowly because faster growth rates 'dilute' the fixed costs of maintenance over a proportionately greater weight gain. For example, a 200 kg live-weight beef heifer has a daily energy demand for 33.7 mega joules of metabolisable energy just for maintenance requirements – that is, this energy intake will just cover her daily requirements to survive with no weight-gain (Table 2). If the 200 kg heifer is offered poor quality pasture and grows at 350 g/day live-weight, her fixed maintenance costs are being 'diluted' down

Table 1. Advantages and disadvantages of grazed pasture systems, NSW style versus Total Mixed Ration (TMR) systems for feed-lotting

Factors	NSW pastoral systems	Feed-lotting
Manure disposal and spreading	None	Extensive disposal facilities required
Capital investment	Can be minimised	Can be significant
Working expenses	Can be minimised	Can be significant
Metabolic cost of walking and grazing	Can be an important cost for lower stocked properties with expectations for high per head productivity	Lesser for feedlot situations
Vulnerability to external market forces	Less directly affected by prices of forages, grains but vulnerable to fertiliser, herbicide etc costs.	Vulnerable to market volatility (forage, grain and protein meal prices)
Per head performance (weight gain etc)	Will be limited by nutritional and intake variation	Can be increased to approach limits of genetic capacity
Protection from adverse conditions	Limited unless irrigated	Better (in most cases) but still vulnerable to drought affecting supply and price of purchased feeds and stock
Harvest and storage of forages	Minimal required, *in situ* grazing efficient, however wide range of pasture utilisation between systems	All forages stored
Vulnerability to effects of climate on forage growth	Vulnerable if supplementary feeds not in system	Less vulnerable on short term basis but vulnerable to forage and grain prices influenced by drought
Losses associated with forage storage	Can be significant (shrinkage losses for silage and at feed out) but lesser proportion of total diet consumed	Can be significant (shrinkage losses for silage and at feed out). Losses high relative to total diet consumed
Control of nutrient profile of daily diet	Large variation in nutrient profile of pasture, day to day/season to season	Less variation in silages/concentrates as feed base
Dry matter intake	Can be unpredictable; often restricted by supply, not need	Known and consistent within small limits
Dietary palatability	Inconsistent, uncontrolled	Can be controlled
Anti-nutritional factors associated with each system	Phalaris staggers, endophyte (perennial ryegrass); Fusarium; nitrates	Silage/grain associated mycotoxicoses; nitrates in stored feeds

over 350 g of live-weight. That is, 78.7 per cent of her daily energy needs are being used simply to survive. Conversely, if the same heifer is being fed a better quality pasture, is being offered more kg dry matter (DM) and grows at 950 g/day, her 'fixed' costs of maintenance are diluted down over more live-weight gain.

3. Animal production from pasture: key factors involved

Several aspects of the nutritional profile of pasture may limit the productivity and performance of pasture-fed stock. The more important limiting aspect of pasture as a complete feed for cattle and sheep is the inconsistency between pasture DM supply versus DM demand.

(a) Control of feed demand

The annual feed demand for a pasture-based system is defined by the following:

(i) Stocking rate – Animals per hectare (expressed as DSE/ha) is a key determinant of DM demand. Inappropriately low stocking rates can equate with low DM demand, and the potential for pasture wastage, unless surplus grass is conserved. High stocking rates can be extremely efficient, provided individual animal productivity (weight-gain, wool production and/or reproductive performance) is not compromised.

(ii) Calving or lambing date – Different properties are characterised by a range of calving or lambing patterns, which makes any general comparisons or recommendations difficult. Generally, the peak demand for a property is matched with the peak supply of feed. A later than planned start to calving or lambing and an inappropriate calving/lambing spread will mean greater difficulty with matching feed supply with demand, particularly for properties with short growing seasons. Strategic use of supplements may allow earlier calving

Table 2. Daily mega joules of metabolisable energy (MJME) requirements for a 200 kg live-weight heifer gaining weight at a range of different daily live-weight gains (between 350–950 g/head/day), and the percentage of energy needed for live-weight gain (expressed as a total of daily energy intake)

	Predicted live-weight gain (g/head/day)				
	350	500	650	800	950
MJME for maintenance	33.68	33.68	33.68	33.68	33.68
MJME for live-weight gain	9.10	13.31	17.73	22.37	27.25
Total daily MJME intake	42.78	46.99	51.41	56.05	60.93
MJME for weight gain (as % of total MJME)	21.3	28.3	34.5	39.9	44.7

or lambing, to take advantage of a better matching between peak supply of pasture and peak demand by stock.

(iii) Per head feed demand – The daily nutrient demand by individual animals is a key determinant of the total demand for DM. In turn, the daily nutrient demand is set by your ambitions for 'per head performance' and productivity for finishing lambs or young cattle, and the physiological state of animals (eg. pregnant or lactating).

(b) Pasture production and harvest

The basic requirements for pasture growth include the correct balance of soil nutrients (nitrogen, phosphorus and potassium), soil pH, temperature, moisture and soil drainage and solar radiation. Not all pasture that is grown is harvested by animals or conserved; the balance is lost from the system by death and decay. Best-practice pastoral farming should aim to optimise:

- *Pasture grown* – through 'top-shelf' agronomic practices (including appropriate plant nutrition) and by controlling variables such as moisture through irrigation where possible, and the selection of the appropriate pasture species and cultivars for that system.
- *Pasture harvested* – influenced largely through grazing management and by stocking rate, utilising stock and areas out for cropping, 're-grassing' or forage conservation. Poor pasture utilisation remains one of the key constraints that limits the effective conversion of pasture DM to live-weight gain.

(c) Net herbage production

Net herbage production is the balance between new growth and senescence of older tissues (Figure 1).

For cattle grazing ryegrass, pasture mass must be maintained between 1,400–2,800 kg DM/ha, and preferably between 1,500–2,500 kg DM/ha (Holmes *et al.* 2002) to optimise net pasture production. Target pasture heights are lower for tall fescue 'cattle pastures'

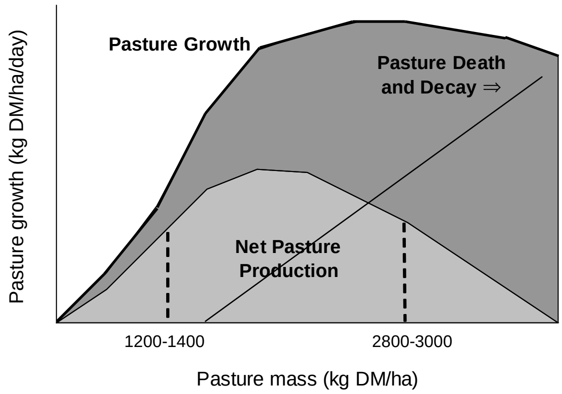


Figure 1. Net pasture production from a cattle-grazed perennial ryegrass pasture, as influenced by pasture death and decay (Adapted from Langer, 1990).

and are dependent on the time of the year because lower residuals are required to ensure removal of seed heads and to optimise pasture quality.

(i) Allowing pastures to go rank – Grazing any grass when the lower leaves are being lost through death and decay is one of the key reasons contributing to the sub-optimal profitability of pastoral farming. Loss of green material in the base of the sward equates to net loss of DM; a deterioration of pasture quality and poor conversion of DM to live-weight gain. In most cases, developing strategies to improve the utilisation of pasture by grazing animals is the most immediate and likely to improve profitability for any pastoral system. Other unwanted outcomes from allowing pasture to become tall and rank include:

- Higher pasture mass causes a lower density of tillers, with the average size of tiller larger than for more intensively grazed swards. Clover populations may be reduced at a higher pasture mass due to shading
- Poor harvesting efficiency – tall rank pastures become clumpy and sheep particularly will not utilise these well. Even for cattle, tall pastures are harvested inefficiently because the pasture is not

easily removed during grazing equates to more residual grass remaining

- Poor palatability – palatability of the grass component of tall swards is poorer than short better quality pasture.

Accumulation of seed heads may increase problems of:

- Poor pasture quality
- Ergot infection of grass seed heads and associated risks of ergot toxicity
- Greater risk of endophyte toxicity for older cultivars of perennial ryegrasses
- Seed drop by potentially unwanted grass species.

(ii) Low pasture mass

- Tiller density is increased by grazing pastures to low post-grazing residuals provided the sward is not overgrazed
- Grazing of grasses to inappropriately low residuals will reduce plant reserves of water-soluble carbohydrates, reduce root development and the production of new shoots, and potentially decrease net DM production
- Overgrazing opens up a sward, increasing challenges of broad-leaf weeds and unwanted grass species
- Grazing to low post-grazing residuals may increase intake of some anti-nutritional factors. Ingestion of the perennial ryegrass endophyte toxins ergovaline, lolitrem B and other endophyte alkaloids are greatest in the base of the sward (Fletcher 1998).

(d) Helping animals to manage grass quality within the optimum grazing horizon

Higher stocking rates, either by running more DSE/ha, or by cropping more areas or taking surplus pasture out for silage or hay, favour improved grass quality through improved utilisation of the sward. In some situations, it will be necessary to control surplus pasture, even for higher stocked properties by buying in additional stock or conserving some surplus as hay or silage where topography permits.

Care is needed when using valuable stock classes to clean up stemmy very poor quality pastures during spring months when grasses are heading. For example, if spring-joined beef cows are used to clean up rank stemmy tall fescue pastures, 'in-calf rates' are likely to end up below target. In many cases, it is better to conserve a surplus of poor quality pasture as silage or hay (and accept that the quality will not be much good) rather than forcing high value or vulnerable stock to clean paddocks out.

4. Grazing systems and sheep and cattle nutrition: a practical 'boots on' approach

For most pastoral producers, the principles of advanced ruminant nutrition have been, and for many will remain, irrelevant. Animal live-weight gains are typically low, well below the genetic capability of the animal. Animal production often has a greater relationship to soil type, environment, pasture species, pasture cultivars and to the vagaries of climate than to the application of an advanced knowledge of animal nutrition. In many cases of sub-optimal pasture nutrition and poor live-weight gain per hectare, basic fundamentals including simply growing and harvesting (utilising) more DM should be addressed well before seeking resolution of the specific nutritional constraints of pasture. A small but growing number of producers are applying more advanced feed and animal management techniques to pasture-based systems in order to significantly improve productivity.

(a) The challenges of meeting the nutritional demands of pasture-fed stock

As discussed previously, grazed pasture in most localities is rarely available in consistent quantities throughout the season. Deficits in supply of DM must be met by appropriate supplementation, in combination with appropriate pasture management, agronomy and fertiliser to maximise net herbage production. Individual farmer choice and circumstance will determine stocking rate and hence availability (or not) of surplus pasture to be carried over as hay or silage to supplement periods of inadequate growth. Where annual feed demand exceeds the ability of the farm to grow the total required DM, off-farm feed must be sought, giving opportunity to choose feeds most appropriate to complement pasture or stock must be removed. Purchased and/or stored feeds can be readily tested for nutrient composition, feed value and relevant physical and chemical characteristics. Provided harvesting, manufacturing, storage, handling, transporting and mixing management are appropriate or relevant, composition for most feeds will remain stable as tested.

Grazed pasture can change in composition throughout the day. Such changes are insignificant to the average ruminant – total DM intake is most often the first limiting factor on animal performance, not minor changes in nutritional composition. Pasture composition throughout the area available to graze will also change. Legume-to-grass ratios vary, as do grass species. Any feed testing samples of pasture will be specific to that sample only, and are often not representative of the pasture intake by all animals. The practicality and economics of testing numerous pasture samples throughout the day, everyday, is unrealistic. To a limited extent, pasture management (especially manipulation of rotation length, strategic use of N fertiliser, varying pre- and post-grazing levels when rotationally grazing) can be used to optimise consistency of pasture, but a degree of variability remains.

(b) Maximising dry matter intake

For feed lots, TMR are formulated to optimise DM intake. For pasture systems, the management of both pasture and animals must be fine-tuned to maximise intake for pasture-fed animals. Pasture is not a nutrient-dense feed, and as grazed is sometimes of very low DM per cent, particularly over the winter and spring. To optimise nutrient intake from pasture, animals must consume huge volumes of wet feeds. During periods of rapid growth, especially in spring and autumn, pasture DM per cent may be as low as 10–15% wet weight for high quality, well managed temperate pastures. Total mixed rations can be formulated at 40–60% DM, necessitating a much lower dietary wet weight intake. For wet pasture, stock must take more mouthfuls, often in more energy demanding circumstances, to obtain equivalent DM intakes.

Optimising DM intake in grazing animals requires excellent animal management to ensure that motivated stock want to, are able to, and can process high volumes of wet pasture. Pasture must be presented to the animals in such a manner as to enable maximum 'swallowable' bite sizes, collected in minimum time, for maximum hours per day. Deficiencies in animal management can frequently be 'hidden' by excellent ration formulation in a TMR feedlot situation. Deficiencies in animal management in a grazed situation result in significantly lower nutrient intake and/or excessively high rates of condition loss.

(c) Dry matter intake challenges for pasture-fed dairy stock

Dry matter intake is calculated as:

$$\text{Dry matter intake} = T \times R \times S$$

Where T = time available for grazing; R = bites per unit time; S = average bite size

(i) T or time available for grazing – Adverse weather conditions can limit the time spent grazing. Sheep and cattle huddling for shelter in driving rain, for example, may spend less total time grazing but need to meet higher maintenance requirements. Conversely, stock that seek shade under hot conditions or spend considerable time walking to sources of stock water have a reduced grazing time.

(ii) R or bites per unit time – This is influenced by feed or pasture characteristics and by animal factors. Leafy, high digestibility dense pasture is quickly collected – bite numbers per minute can be equal to that for TMR fed stock on a feedlot, provided bite size does not limit speed and ease of swallowing. Most cattle TMRs consist of food particles of less than 25 mm in length – pasture as grazed can be of significantly longer length, impeding the ability of some cattle to quickly propel each bite down the oesophagus.

- It is unlikely that low DM% pasture *per se* limits performance, but to collect 10 kg DM of wet grass may necessitate a wet volume intake of 100 kg of 10% DM pasture. Cattle do adapt to high wet volume diets by better and bigger rumen capacity.
- As pasture ages or enters the reproductive stages, shear time may increase, slowing the rate of collection, and decreasing the number of bites per unit time, compromising performance. Shortening rotation length, strategic N use or removal of some feed to be conserved may aid intake. Surface moisture on external leaf surfaces can change the coefficient of friction, and hence slow down bite rate via slower swallowing times. This has implications for ruminants grazing in wet weather, when energy requirements are likely to be increased, or following heavy dew.
- Animals must also be managed to want to eat that extra mouthful. Clinically or sub-clinically ketotic animals (ewes pre-lambing, beef cows after calving) and/or rumen acidotic animals have depressed appetites – they take less bites per unit time, and eat for less total time.

(iii) Average bite size (S) – Average bite size will primarily be influenced by pasture length. Long pasture does not, however, guarantee maximum bite size, especially where the proportion of stalky material is high. Collecting handfuls of grass is a practical method of determining the average sheer height and 'ease' of collection by cattle. Try wrapping pasture around your fingers and tearing off the pasture – this is exactly how cattle need to graze, by tearing pasture off with their tongues (compared with sheep that graze by biting off pasture). Cattle grazing tougher pasture frequently need to 'tug' –slowing rate of bites, and the bite size collected may be less than optimum.

Short pasture (less than 15–20 cm for cattle) may restrict bite size, there being physically less material available to collect – this can be of consequence when having to compromise between short pasture to maintain quality (eg. tall fescue that is heading) and optimal per head animal productivity.

Pasture plant and leaf density will influence final bite size as well as bite rate. In some poor quality, low-density pastures, animals have to take more steps between bites and each bite collected may contain less material, limiting total DM intake.

(d) 'Balancing' some specific nutritional challenges of pastures

While there is much debate on the potential performance limitations placed on grazed sheep or cattle by changes and deficiencies in the nutritional composition of pasture diets, the opportunity to fine-tune or to 'rebalance' dietary intake is limited for most producers.

In a high performing TMR fed feed-lot animal, rumen function and live-weight gain potential are optimised by ensuring a constant supply of feed to the animal with a consistent known nutritional composition, chosen to stimulate maximum potential production. Even when the nutritional deficiencies of pasture are known, and can be supplemented by offering other feeds (eg. silage or grain), what is actually in the rumen at any given time may have little resemblance to the ration as formulated. True TMR diets are impossible to mimic if grazed pasture is a significant proportion of the total diet. Complementary feeding by offering supplements to pasture-fed sheep or cattle is targeted at improving total DM and nutrient intake, encouraging better rumen function, enhancing animal health and grossly balancing nutrients at a rumen level.

(i) Crude protein (CP) and amino acids

Too much CP – Sheep and cattle reared on high quality grazing systems develop a tolerance for high intakes of highly degradable dietary CP. Rather than limit the CP intakes, it is more economical and practical for producers to enhance 'capture' of CP by providing more dietary starch and sugars, thus producing more microbial protein, less ammonia or to dilute total dietary CP intake by using low CP feeds as part of the diet. This is of particular relevance when transitioning sheep or cattle off poor quality, low protein summer pastures onto post-autumn break 'flush' feed. The amino acid profile of pasture might not be considered optimal for maximum live-weight gain but realistically, amino acid nutrition is of limited relevance for pasture-fed cattle and sheep. Total CP intake over the summer when pasture quality is poor is more likely to constrain animal productivity than deficiencies of specific amino acids. Exceptions may include intake of sulphur- (S) containing amino acids for wool production, due to the requirement for S-containing amino acids during wool growth.

Insufficient CP – More commonly for young sheep or cattle on poorer quality summer grass-dominant pasture, CP deficiency may constrain potential live-weight gain. Older sheep and cattle have lesser requirements for CP and better tolerate pastures that contain low levels of CP. For young sheep and cattle, the financial benefits of supplementing a poor quality pasture with a high CP supplement (eg. concentrate that contains canola or soybean meal), or summer crops where climate is favourable must be evaluated on a cost-benefit basis. Under some circumstances, urea can be fed to sheep and cattle, however, care is needed with the delivery of urea (ideally urea needs to be blended with a carbohydrate source such as grain or molasses to improve the utilisation of urea and to reduce risk of urea toxicity). Expectations of animal productivity from urea-supplementation should be considerably lower than for animals supplemented with sources of true proteins.

(ii) Non-structural carbohydrates – Non-structural carbohydrate (NSC) is often the second most significant limiting nutritional factor in pasture-fed, high performance sheep or cattle, after total DM intake. On high quality, N boosted/high CP pasture, a significant amount of dietary N is lost via degradation to ammonia because of a lack of complementary intake of NSC. Consequent conversion to urea is energy-demanding, further exacerbating loss of live-weight gain potential. Rapidly fermentable sources of NSC such as cereal grains or molasses may contribute to lowered rumen pH, particularly if the supplement is fed out only two to three times per week. Sub-clinical acidosis can depress total DM intake, impair rumen function (particularly cellulose and hemicellulose digestion), and reduce feed conversion efficiency. Pasture intake falls, and substitution can occur (substitution means wastage of pasture when supplements are fed). Of concern is the possibility that rumen acidosis may also contribute to a greater incidence of lameness in cattle (Westwood *et al.* 2003). Depression of rumen pH is most commonly attributed to high concentrate and poorly designed TMR diets, but the potential for pasture-only diets to cause sub-acute acidosis should not be ignored. As previously mentioned, anything that depresses the appetite in sheep or cattle operating on a less than perfect diet will have significant effects on performance.

(iii) Fibre – Neutral detergent fibre (NDF) levels in pasture vary with climate, season, species and cultivar composition, grazing management and fertiliser regime. For maximum live-weight gain and production potential and high DM intake, pasture management aims to provide highly digestible, leafy, 'easy-to-collect' feed. By its very nature, such pasture may have inadequate physically effective NDF (peNDF) for cattle (and occasionally sheep), characterised by less cud-chewing (fewer than 45 chews per cud for cattle), lower rumen scores and loose faeces. Where CP levels are also high, dung may be extremely fluid, dark and bubbly. Excessively loose faeces are unacceptable in cattle for which there is a high live-weight gain expectation. Lengthening the rotation length or supplementation with long stem fibre (eg. hay, cereal straw) may be necessary to improve rumen pH and function. Use of

buffers and rumen modifiers with supplementary feed may help.

(iv) Macro and trace minerals and vitamins – As well as variability of macro-nutrients, the mineral and vitamin content of pasture is inconsistent. Concentrations of minerals and the presence of other antagonistic factors that impede uptake and the absolute DM intake combine to determine actual mineral availability. For most sheep and cattle fed sufficient quantities of leafy pasture, macro, trace mineral and vitamin deficiencies are rarely directly limiting on live-weight gain or milk production. Limitations can occur on very poor quality grass dominant summer pasture and are influenced by soil type and previous fertiliser history. The low phosphorus concentration of tropical grasses and legumes are well known, particularly for mature and stemmy tropical pastures. Other nutritional attributes of tropical pastures may limit productivity, for example, low concentrations of calcium in tropical pastures vs. temperate pastures, however, high performance stock classes with an above average demand for calcium (eg. lactating dairy cattle) are unlikely to be wholly reliant on tropical pastures as a high substantial proportion of the diet. Conversely, magnesium concentrations are lower in temperate than tropical pastures and supplementation of pregnant or lactating beef cattle with magnesium is often appropriate. As performance expectations increase; especially for extremely rapid live-weight gain, production requirements for minerals do become more significant. Feed and animal levels can be tested, monitored and adjusted as per the National Research Council (NRC) 'Nutrient Requirements of Sheep' or the NRC 'Nutrient Requirements of Beef Cattle', with recommendations as appropriate.

(v) Anti-nutritional factors – Anti-nutritional factors present in pasture do directly limit performance. The perennial ryegrass-associated fungal toxins (lolitrem B, ergovaline, sporidesmin) have significant effects on production, animal health and profitability where older cultivars of perennial ryegrass form the feed-base for pasture-fed sheep and cattle. Phalaris staggers remains a risk factor for sheep grazing phalaris. Nitrate toxicity is a risk factor for cattle and sheep grazing annual pastures sown for winter feed production.

Conclusions: lifting per head productivity for pasture-fed sheep and cattle

The significance of pasture quality as a potential limiter for animal productivity is largely influenced by a producer's expectation of per head and per ha productivity. Too many NSW properties are growing insufficient DM per ha and are under-utilising pastures grown, and these two key factors dictate both per head and per ha live-weight gain. For many producers, it is more important to consider ways to grow more forage (kg DM/ha) and to harvest/utilise more of the DM grown. Better NSW producers achieve 70 per cent utilisation or more of pasture grown, with benefits of better live-weight gain per hectare and improved per head performance due to better pasture quality. Gains occur through improved pasture management, control of stocking rate and optimum pasture mass (DM/ha).

Opportunities exist for producers who are already achieving excellent pasture DM production and utilisation to improve per head productivity by complementary feeding – that is, supplementing high performance pastures with relatively small quantities of supplements, including extra starch to increase the daily energy intake, or fibre to improve rumen function on high quality lush pasture. Understanding the nutritional constraints of pastures throughout the year is the key to the development of strategic use of complementary supplementation. The realisation of profit from such opportunities relies on a presumption that the DM yield and utilisation (harvest) of pasture is already at optimal levels and profit is sensitive to both supplementary feed prices and cattle or sheep sale prices.

Conversely, changes to pasture management can often be relatively simple and cost-effective to implement, such that pasture utilisation can be improved. All production systems should critically evaluate DM grown and harvested per ha and seek efficiencies in this area. For specific stock classes at times of the year when they are rewarded by sufficiently high premiums, additional benefits may be gained from complementary feeding.

References

Fletcher LR (1998) Endophyte on the dairy farm, is it a problem? In 'Proceedings of the 15th Annual Seminar of the Society of Dairy Cattle Veterinarians of the NZ Veterinary Association'. (Convenor W. Webber) pp. 119–132. (Rotorua, New Zealand)

Holmes CW, Brookes IM, Garrick DJ, MacKenzie DDS, Parkinson TJ (2002) Milk production from pasture: Principles and practices. Massey University. Palmerston North, New Zealand.

Langer RHM (Ed.) (1990) 'Pastures: their ecology and management'. (Oxford University Press: Auckland, New Zealand)

Nelson CJ, Moser LE (1994) Plant factors affecting forage quality. In 'National Conference on Forage Quality, Evaluation and Utilisation'. (Ed. GC Fahey) pp. 115–154. (American Society of Agronomy, Inc.: Wisconsin)

Van Vuuren AM, Tamminga S, Ketelaar RS (1991) *In sacco* degradation of organic matter and crude protein of fresh grass (*Lolium perenne*) in the rumen of grazing dairy cows. *Journal of Agricultural Science* **116**, 429–436.

Westwood CT, Bramley E, Lean IJ (2003) Review of the relationship between nutrition and lameness in pasture-fed dairy cattle. *New Zealand Veterinary Journal* **51**, 208–218.

Towards a tropical grass package for northern New South Wales

S.P. Boschma and L.H. McCormick

NSW Department of Primary Industries, Tamworth Agricultural Institute, 4 Marsden Park Road, Calala NSW 2340 <suzanne.boschma@dpi.nsw.gov.au>

Abstract. *Tropical grasses are suited to large areas of northern New South Wales and are increasing in usage due to their adaptability, persistence, ability to respond to summer rainfall, and capability of producing large quantities of forage. Despite growing awareness of these advantages, there has been reluctance for more widespread adoption of tropical pastures in north-west New South Wales for a number of reasons, most of which can be overcome by development of an 'agronomic package'. This paper describes the components of a package drawing on known information and recent research; knowledge gaps requiring further attention are highlighted.*

Introduction

Large areas of the North-West Slopes of New South Wales (NSW) have a history of cultivation and many of the lighter soil types have become unproductive because of low fertility, poor soil organic matter and deteriorating soil structure. Permanent pastures are an effective means of ameliorating these soils and restoring productivity (Whitbread *et al.* 1996).

The North-West Slopes of NSW offers a unique and challenging environment for perennial pastures. It is unique in that the region has a summer dominant rainfall distribution, but effective winter rainfall, making it potentially suitable for both summer and winter growing species. The challenge is for species to persist, therefore, temperate grass species need to be summer-dormant (S.P. Boschma *et al.*, unpublished data) while tropical species need to be frost-tolerant (McCormick *et al.* 1998). Traditionally, temperate grasses have been recommended for this region, however, producers report that temperate pastures do not persist (Reeve *et al.* 2000). Recent research confirms the poor persistence of current varieties (S.P. Boschma *et al.*, unpublished data) making them uneconomical (Scott *et al.* 2000). By contrast, there are tropical grass pastures in the region which are over 35 years old and still persisting.

Tropical grasses were first evaluated in northern NSW in the 1950s (Johnson 1952; Buckley 1959). The potential for tropical grasses was recognised and their use recommended in pasture mixtures, but poor seed availability and pursuit of grain farming meant that adoption was low. On the North-West Plains, species evaluation was conducted in the 1970s (Watt 1976) and establishment methods investigated in the 1980s and 1990s (Bowman 1990; Campbell *et al.* 1993). In the 1990s, a range of grass species and cultivars were evaluated in NSW at over 20 sites from Forbes in central NSW to the Queensland border and west from the Great Dividing Range to Walgett (McCormick *et al.* 1998). More recently, studies conducted near Manilla on the North-West Slopes highlighted the superior persistence and production potential of tropical grasses compared to the temperate grasses (S.P. Boschma *et al.*, unpublished data).

Some producers have been successfully using tropical grasses in their systems for many years (viz. Murray 2004), but it is only in the last five or so years with dry conditions and stop-start seasons that tropical grasses have shown their advantage as a responsive and persistent option. While many producers have shown an interest in tropical grasses, there has been a reluctance to sow them, thereby curtailing widespread adoption. A series of workshops to investigate producer perceptions of tropical grasses identified quite a number of barriers (L.H. McCormick, unpublished data) with the common concerns including difficulty to establish, poor forage quality, previous bad experiences and a general lack of information. While there were suitable grasses ready for adoption, there was no 'agronomic package' to assist producers.

A comprehensive package needs to cover five areas: species options, establishment, maximising herbage production, grazing management and impacts on animal production. To date, only some of the components of the package for tropical grasses have been developed. The aim of this paper is to report details of components of the tropical grass package which have been developed, discuss components currently under development and identify gaps in knowledge requiring further work.

The 'right species'

Through the 1990s, an evaluation of tropical grasses was undertaken across northern NSW at sites representing a range of soil types, rainfall and altitude (McCormick *et al.* 1998). These experiments consisted of 34 entries representing nine species; viz. Rhodes grass (*Chloris* *gayana*), panics (*Panicum* spp.), creeping bluegrass (*Bothriochloa insculpta*), bahia grass (*Paspalum notatum*), forest bluegrass (*Bothriochloa bladii* ssp. *glabra*), digit grass (*Digitaria eriantha* ssp. *eriantha*), purple pigeon grass (*Setaria incrassata*), buffel grass (*Cenchrus ciliaris*) and birdwood grass (*Cenchrus setiger*).

Results from this study showed the adaptability of tropical grasses in our environment, and that cultivar performance was more closely related to soil type and pH and less to rainfall and latitude. However, rainfall was obviously an important factor, especially for the 300 mm rainfall zone where buffel grasses were the best adapted (McCormick *et al.* 1998). A summary of the adaptation of grass species to soil type is shown in Table 1.

Gatton panic (*Panicum maximum*) and Petrie green panic (*P. maximum* var. *trichoglume*) did not perform well in this evaluation, however, recent research in northern NSW has identified a number of lines with superior persistence and herbage production compared with the current cultivars (Harris 2008). A number of *P. coloratum* types have also shown promise (Harris 2008). The promising lines of *P. maximum* and *P. coloratum* will be evaluated under grazing with the best performing lines being developed for commercial release from 2011.

Commercial practice shows that tropical pastures are commonly sown as a mixture of grass species and cultivars across a range of soil types. Mixtures have the advantage of different species finding their own niche within the variation that exists in a paddock. For example, Premier digit grass on medium soils, Bambatsi panic (*P. coloratum* var. *makarikariense*) on heavier water-logged prone soils, and Katambora Rhodes grass to fill the gaps between plants. However, the disadvantage of mixtures is that competition can occur between species, sometimes to the detriment of one or more in the mix.

Work at Tamworth found Katambora Rhodes grass was highly competitive in an establishing pasture, with the ability to out-compete both Premier digit grass and Bambatsi panic even at a low plant proportion of 25% (G.M. Lodge and S.P. Boschma, unpublished data). The seedling vigour and spreading habit of Katambora Rhodes grass allowed establishing plants to spread quickly, potentially swamping other seedlings in an establishing pasture. Katambora Rhodes grass seedlings are so competitive that in a study assessing the ability of individual cultivars to compete with common grass weeds, Katambora Rhodes grass was equally competitive as liverseed grass (*Urochloa panicoides*) and more competitive than awnless barnyard grass (*Echinochloa crus-galli*) (G.M. Lodge and S.P. Boschma, unpublished data). While Rhodes grass has a role in mixtures, viable seed numbers should not exceed 20 per cent of the total, otherwise it will out-compete the other sown species.

Planning and preparation before sowing

Pasture establishment is a 'numbers-game' dependent on germination of the seed, emergence of the seedling and its survival as a juvenile plant. The aim when establishing a tropical grass pasture is to achieve a plant population of about 10 plants/m^2 (W.J. Scattini, personal communication). Key elements of planning and preparation for sowing centre around weed control and sourcing high quality grass seed.

Table1. Tropical grass species and cultivars suitable for light, medium and heavy soils in northern NSW (McGufficke and McCormick 2008)

Light soils	Medium soils	Heavy soils
	Soil groups and pH range	
Sands, sandy loams; pH <5.0–7.0 ($CaCl_2$)	Clay loams, silty clay loams; pH 5.0–7.0 ($CaCl_2$)	Red/grey clays, black earths; pH 6.0–8.0 ($CaCl_2$)
	Species and cultivar	
Lovegrass (*Eragrostis curvula* type conferta) cv. Consol Digit grass (*Digitaria eriantha* ssp. *eriantha*) cv. Premier Rhodes grass (*Chloris gayana*) cv. Pioneer and Katambora Forest bluegrass (*Bothriochloa bladii* ssp. *glabra*) cv. Swann Buffel grass (*Cenchrus ciliaris*) cv. America and Gayndah	Digit grass cv. Premier Forest bluegrass cv. Swann Creeping bluegrass (*Bothriochloa insculpta*) cv. Bisset Rhodes grass cv. Katambora Purple pigeon grass (*Setaria incrassata*) cv. Inverell[A] Panic (*Panicum coloratum* var. *makarikariense*) cv. Bambatsi[A]	Purple pigeon grass cv. Inverell Panic cv. Bambatsi Bluegrass (*Dicanthium aristatum*) cv. Floren Buffel grass cv. Biloela[B]

[A]Performs with higher nutrition
[B]Flood free areas

Weed control

Weeds typically have vigorous seedlings, short life cycles and the ability to set large quantities of seed which can survive in the soil for years. Sown perennial species, by comparison, tend to be less vigorous and are sown at low rates compared to the seed-bank of weeds likely to be present. Control of the main annual summer-grass weeds, liverseed grass, awnless barnyard grass and stink grass (*Eragrostis cilianensis*) is essential, requiring control for two years prior to sowing to reduce the seed-bank to minimal levels. In an experiment conducted near Manilla, two years of annual grass weed control were necessary to reduce the grass weed seed-bank to low levels (15 seeds/m^2). By comparison, controlling weeds for only one summer, or the spring prior to sowing, resulted in 1,650 and 5,500 seeds/m^2 in the seed-bank, respectively (G.M. Lodge, unpublished data). Bambatsi panic sown at 4 kg/ha (bare seed, adjusted for germination) is equivalent to sowing about 400 germinable seeds/m^2. At this sowing rate, Bambatsi panic seed numbers are in the minority unless there has been two years of weed control.

Seed quality

Poor establishment is often blamed on insufficient rainfall or sowing too deep, however, seed quality can be variable and the possible cause of poor establishment in many cases. Knowing the purity and germination percentage of the seed purchased is important. A bag of seed can include weeds, inert material such as trash, empty florets, and dead and viable seed. A seed purity and germination test from a National Association of Testing Authorities (NATA) accredited laboratory will identify the species (desirable and weeds) present in the seed sample tested, their proportions, the proportion of inert material and germination rate of each of the desirable species. With seed costs ranging from \$18–40/kg it is important to 'get what you pay for'.

Low germination percentage means that sowing rates need to be increased to ensure a high number of viable seeds, while weed contamination could be introducing weeds that might negatively impact on farm productivity and animal health. Seed-coating is common in tropical grasses, but sowing rates do need to be increased for the additional weight of the coating which can be as high as 80 per cent. There are no published data from field studies to indicate that seed-coating assists emergence or establishment. However, seed-coating has the advantage of assisting seed-flow through a planter and therefore more accurate seed placement is possible.

Some species have seed dormancy mechanisms meaning that they need to be stored for a period of time or treated before they will germinate. These dormancy mechanisms are either based within the embryo or in the structures covering the embryo (Adkins *et al.* 2002). Dormancy involving chemical inhibitors in the seed embryo is strongest in freshly harvested seed, decreasing with age (Harty *et al.* 1983). Species vary in dormancy (Table 2) and establishment can be affected if dormant seed is sown. Storing seed for 12 months overrides the dormancy mechanism in most grasses. Work at Tamworth has shown that Katambora Rhodes, Premier digit grass, Swann forest bluegrass (*Bothriochloa bladii* ssp. *glabra*) and Bambatsi panic do not have any post-harvest dormancy either as bare seed or in the floret (G.M Lodge, unpublished data).

Factors to consider at sowing

Sowing time and depth

A suitable sowing time for successful establishment is dictated by considerations of soil temperature and the

Table 2. Dormancy of tropical grass species available in NSW (Sources: Anon 2007; G.M. Lodge, unpublished data)

Species with known post-harvest dormancy	Species which do not have post-harvest dormancy
Mitchell grass (*Astrebla lappacea*)	Rhodes grass[A] (*Chloris gayana*) diploids eg. cv. Katambora
Creeping bluegrass (*Bothriochloa insculpta*)	Digit grass (*Digitaria eriantha* ssp. *eriantha*)
Buffel grass (*Cenchrus ciliaris*)	Bambatsi panic (*Panicum coloratum* var. *makarikariense*)
Rhodes grass[A] (*Chloris gayana*) tetraploids eg. cv. Callide	Forest bluegrass (*Bothriochloa bladii* ssp. *glabra*)
Bluegrass (*Dicanthium aristatum*)	
Lovegrass (*Eragrostis curvula* type conferta)	
Panic (*Panicum maximum*)	
Green panic (*Panicum maximum* var. *trichoglume*)	
Paspalum (*Paspalum dilatatum*)	
Bahia grass (*Paspalum notatum*)	
Kikuyu (*Pennisetum clandestinum*)	
Setaria (*Setaria sphacelata* var. *sericea*)	
Purple pigeon (*Setaria incressata*)	

[A]Rhodes grass can be either diploid of tetraploid. Seed of the diploids has little or no post-harvest dormancy while seed of the tetraploids may not reach maximum germination for 3–6 months, and sometimes up to 18 months post-harvest (Cook *et al.* 2005).

time of year when the likelihood is highest of receiving at least 50 mm of rain over 2–3 days. Optimum emergence is dependent on correct sowing time and sowing depth. Tropical grasses have different soil temperature requirements for germination and emergence. For example, the minimum soil temperature (at 9 am) at the optimum sowing depth for buffel grass is 13°C, Rhodes grass 14°C, Bambatsi panic and bluegrass 17°C and purple pigeon grass 25°C (McCormick 2004).

A study at Tamworth showed that emergence of tropical grasses was high from December through to March (G.M. Lodge, unpublished data), however, sowing late in summer can affect the ability of establishing plants to survive winter. In a separate study conducted near Tamworth (M.A. Brennan *et al.*, unpublished data), five species were sown in November, January and March. Plant frequency was measured after sowing in May (prior to the first frost) and in September (when growth recommenced). There was little change in plant frequency for the November and January sowing, indicating excellent winter survival. However, plant frequency fell by up to 70 per cent for the March sowing. Spring herbage production of the grasses sown in March was also reduced by 50–99 per cent the year after establishment (M.A. Brennan *et al.*, unpublished data). Studies conducted near Walgett also found significant plant losses during winter (Bowman 1990).

Summer rainfall on the North-West Slopes and Plains typically falls in high intensity storms preceded and followed by high temperatures. This results in the soil surface wetting and drying quickly, often within 24 hours on lighter soils, which is inadequate for germination. Tropical grass seeds have the ability to imbibe water then dry again without loss of germinability provided the radical has not emerged. This is termed hydropedesis (Watt 1978). The advantage of hydropedesis is that the seed has been ‘primed' and will germinate sooner than if it has not been wetted previously. While tropical grasses have this ability, the use of ground-covers (such as cereal crops) and practices which help retain surface soil moisture (such as minimum-till) assist establishment especially during years with marginal conditions for pasture establishment.

Tropical grass seed size is variable but generally small, therefore, sowing depth is crucial with the optimum depth varying with species and soil type. In a study conducted at Tamworth (G.M. Lodge, unpublished data), seedling emergence was highest for the smaller seeded cultivars such as Premier digit grass, Katambora Rhodes grass and Floren bluegrass (*Dicanthium aristatum*) at 10 mm sowing depth, while Bambatsi panic (with a larger seed) was able to emerge from up to 50 mm depth. Seedling emergence from seed placed on the soil surface was poor except during spring when day-time temperatures were lower. From December, evaporation rate is high so it is difficult to keep the soil surface wet for a sufficient period to allow germination.

Tropical grasses are commonly sown with conventional cultivation practices into a fine seed-bed. Direct-drilling is also affective if there is good seed-soil contact and the seed is placed at the optimum depth. Direct-drilling into a cereal stubble can be effective, however, drilling into areas which have not had any preparation (eg. a degraded pasture) can be high risk, and not recommended for a number of reasons, including competition from weeds and the existing pasture, poor stored soil-moisture and poor seed-bed produced by the drill. Where depth is difficult to control, sowing the seed on the surface and incorporating with a small chain and press-wheel can provide soil-cover and contact for the seed. Establishment from aerial seeding into stubble before or after harvest has proven unreliable (Campbell *et al.* 1995).

Factors to consider post-emergence

Post-emergent herbicide options

Controlling grass weeds in an establishing grass pasture is not possible, reinforcing the need to control grass-weeds prior to sowing. However, broadleaf weeds can be controlled post-emergent, once the pasture has developed secondary roots (about 4–6 leaf stage). Unfortunately, there are no chemicals currently registered in NSW to control broadleaf weeds in tropical grass pastures. In January 2008, a range of herbicide options for control of broadleaf weeds in establishing tropical grasses was assessed. This study evaluated 20 herbicide treatments and identified 11 which gave effective broadleaf weed control, with little damage (<20% reduction in herbage production) to the establishing pasture. A permit is currently being sought for those chemicals which showed the most potential.

Management during the first year

Guidelines for the grazing management of tropical grasses in the establishment year are largely drawn from knowledge of temperate pastures and farmer experience. The limits for grazing in the first year have not been studied in NSW, however, this will be an area for future research.

Since tropical grasses grow at a much faster rate, it is contended that there is more flexibility with the management of tropical grass pastures in the establishment year. In favourable years, light grazing can encourage tillering and greater seed production in an establishing pasture. However, letting grasses flower before the first frost to allow regenerative buds to form at the base of the tillers is recommended. If temperate legumes are to be over-sown in the autumn following grass establishment, the bulk of grass material needs to be removed by grazing to open the sward for legumes to germinate.

Beyond the first year

Two of the greatest attributes of tropical grasses is their ability to persist once established and their ability to produce large quantities of herbage following rainfall. Studies conducted in the Tamworth area over the last three years have been monitoring the effects of nitrogen (N) fertiliser and defoliation intensity on herbage production and forage quality (S.P. Boschma, unpublished data), and the soil water use of tropical grasses. The following information is based on results from this study.

Herbage growth and forage quality

Tropical grasses begin active growth in September–October as day temperature starts to rise. Growth rate continues to increase, peaking during summer before declining over autumn and ceasing when frosts commence.

During the summer, growth of tropical grasses is commonly restricted by a lack of N, rainfall and/or sub-soil moisture. In the Tamworth area, Premier digit grass and Katambora Rhodes grass have had growth rate recorded as high as 160 and 175 kg DM/ha/day, respectively, when N was applied, while growth rate without N was 45 and 20 kg DM/ha/day, respectively (S.P. Boschma, unpublished data).

Addition of N increases herbage production, even during periods of below average rainfall. In the 2006–07 growing season, rainfall for the period October–April was 150 mm below the long term average (340 mm), yet the addition of 100 kg N/ha increased herbage production by 23 per cent and 56 per cent for Premier digit grass and Katambora Rhodes grass, respectively. In comparison, during the peak growth period when above average rainfall was received (December 2007–February 2008), the application of 100 kg N/ha resulted in 14,500 and 8,300 kg DM/ha for Premier digit grass and Katambora Rhodes grass, respectively; compared to 4,700 and 2,000 kg DM/ha where nil N was applied.

There was a herbage production response to the addition of most rates of N, however, the greatest increase per unit of N applied was with 50 kg N/ha (additional 6,000 kg DM/ha compared to nil N) for Premier digit grass with production plateauing at about 250 kg N/ha. In contrast, Katambora Rhodes grass continued to increase to the highest rate of N applied (300 kg N/ha). Herbage production was higher when the tropical grasses were cut every 6 weeks compared to every 2 weeks, however, the percentage of stem and dead material was higher and forage quality lower.

Tropical grasses have lower forage quality than temperate grasses at the same growth stage, however, it is important to appreciate that their growth patterns are contrasting, and comparisons of quality need to account for these contrasting growth patterns. For example, during summer, when tropical grasses are actively growing, temperate species are relatively dormant with little or no green leaf and therefore their quality can be lower. Likewise, during cool season months, while temperates are actively growing and vigorously producing high quality green leaf, tropicals are generally dormant, presenting low quality senesced leaf for grazing.

It is important when comparing tropical grasses with alternative forages [eg. sorghum (Sorghum bicolour x *S. sudanense*) and lucerne (*Medicago sativa*)], to do so at the same time of year. The Tamworth study recorded green Premier digit grass leaf (two weeks regrowth) with a crude protein (CP) level of 18.5% and metabolisable energy (ME) of 9.6 MJ/kg DM (Table 3). The quality of Katambora Rhodes grass was lower with 16.5% CP and 9.1 MJ/kg DM ME. These values rank tropical grasses lower than lucerne but higher than sorghum.

To maximise animal production, the pasture needs to be managed to maintain a high proportion of green leaf as it has the highest quality of all plant fractions. The addition of N increases forage quality because it promotes 'leafiness'; similarly, regular defoliation increases forage quality because it promotes growth of

Table 3. Forage quality of Premier digit grass and Katambora Rhodes grass cut every 2 and 6 weeks with either 0 or 100 kg/ha N applied (S.P. Boschma, unpublished data)

	Premier digit		Katambora Rhodes	
	0 kg N/ha	100 kg N/ha	0 kg N/ha	100 kg N/ha
	Crude protein (%)			
2 weeks	15.3	18.5	12.7	16.5
6 weeks	13.6	15.5	13.4	15.2
	Metabolisable energy (MJ/kg DM)			
2 weeks	9.3	9.6	8.6	9.1
6 weeks	9.1	9.1	8.9	8.6

new green leaf. Management practices that maximise green leaf production and minimise stem and dead material, improve forage quality and therefore increase grazing value and animal production.

The upright growth habit of tropical grasses and high levels of CP (where N is applied) allow grazing animals to increase their intake compensating for lower ME levels. Cattle growth rate of 0.7–0.9 kg/head/day is generally achieved and growth rate of 1 kg/head/day has been recorded (McCormick 2004).

After the establishment year, the pasture can be grazed once growth recommences and herbage mass reaches 1,500–2,500 kg DM/ha depending on livestock enterprise. During periods of good rainfall and nutrition, high pasture growth rate can result in herbage production surpassing animal intake (unless stock numbers are increased). During such times, rotationally grazing a smaller area and maintaining the herbage mass between 1,500–3,000 kg DM/ha (McCormick 2004) with a shorter grazing interval will help maintain a higher proportion of green leaf and maximise animal production.

Legume compatibility

For transitional temperate/tropical environments as occurs in north-west NSW, temperate legumes are a cost-effective means of supplying N for the long term productivity of a tropical grass pasture. Subterranean clover (*Trifolium subterraneum*) is commonly used, broadcast during autumn after the pasture has established. Biserulla (*Biserulla pelecinus*) and serradella (*Ornithopus* spp.) have been used successfully on lighter sandy more acid soils, while lucerne has been used in higher rainfall areas. Careful management is essential to minimise selective grazing of the legume and to ensure regeneration of the annual legume. Also, to ensure maximum regeneration of a winter annual legume, tropical grass pastures need to be grazed so that the sward is opened to allow annual legumes to germinate. Further research is required to identify legumes (tropical and temperate) adapted to northern NSW which would be persistent and productive in tropical grass pastures.

The amount of N fixed by legumes in a pasture is related to the quantity of herbage produced by the legume. As a guide, subterranean clover in a grazed pasture may produce around 2,000 kg DM/ha of herbage. Assuming legumes fix 20–25 kg shoot N/1,000 kg DM produced (Peoples and Baldock 2001), this is equivalent to 40–50 kg N/ha fixed by the legume.

Water-use and species selection

Tropical grass species have varying plant root depth and efficiency by which they convert water into forage. A study near Tamworth monitored Premier digit grass, Katambora Rhodes grass and Swann forest bluegrass with a number of other treatments including lucerne, forage oats (*Avena sativa*), forage sorghum and a native pasture (predominantly redgrass (*Bothriochloa macra*), bluegrass (*Dichanthium sericeum*) and wallaby grass (*Austrodanthonia bipartita*) cv. Bunderra). Of the sown perennial grasses, Premier digit grass had the highest herbage production and water use efficiency (16.1 t DM/ha and 32.4 kg DM/ha/mm, Murphy *et al.* 2008a), but Katambora Rhodes grass had a greater rooting depth (1.6 m vs. 1.2 m, Murphy *et al.* 2008b).

Lucerne is well known for producing a lot of herbage under moist soil conditions, but with a dry profile growth stops until further rainfall is received. Katambora Rhodes grass acts similarly, however, it is unable to respond quickly once rainfall is received because during extended dry periods the runners die back to the crown. In comparison, Premier digit grass is able to respond quickly and with great efficiency once rainfall recurs.

This has implications for the persistence of these species in a mixture and also for preferred location in the landscape. In areas where maximum soil drying is required (but not waterlogged areas), Katambora Rhodes grass is effective. However, for maximum herbage production, better response following rainfall and therefore better continuity of feed, Premier digit grass is a better option. Katambora Rhodes grass is commonly considered to be less drought-tolerant. This could partly be due to its slow recovery after a dry period, allowing other species to respond to rainfall, and potentially shading-out the slower growing Katambora Rhodes grass plants. It is noteworthy from the Tamworth study that N application resulted in Katambora Rhodes grass plants using the stored soil water quicker, and being drought affected quicker than plants which had less N. Premier digit was not affected like this.

More work to be done

The agronomic package for tropical grasses is not complete. More work needs to be done on grass/legume compatibility, grazing management for persistence, strategies to use the huge quantities of feed produced and applications in grazing systems. Some of these will be addressed in research planned to commence in 2009.

Conclusions

There is potential in northern NSW to increase grazing performance and at the same time to restore degraded land with tropical pastures. Encroaching climate change and the need to accumulate more carbon will make the use of tropical grasses attractive. However, for widespread adoption of tropical grasses in northern

NSW, an 'agronomic package' is required detailing species options, guidelines for pasture establishment, maximising herbage production, optimal grazing management for persistence and sustainable animal production. Development of this package has commenced and the completed components are summarised in this paper. The ongoing development of additional components of the package are planned to commence in 2009.

Acknowledgments

The recent research conducted in northern NSW is part of a project funded by the Future Farm Industries Cooperative Research Centre (formerly Cooperative Research Centre for Plant-based Management of Dryland Salinity) and NSW Department of Primary Industries. This project led by Dr Greg Lodge also involves Dr Sean Murphy, Fiona Scott and the authors of this paper. Technical support by Mark Brennan, Brian Roworth, Peter Sanson and Ivan Stace throughout this project is greatly appreciated. Stuart Squires, Chris Bowman and Dr Sally Muir are also recognised for their role in promotion and extension of these results.

References

Adkins SW, Bellairs SM, Loch DS (2002) Seed dormancy mechanisms in warm season grass species. *Euphytica* **126**, 13–20.

Anon (2007) International Rules for Seed Testing. Edition 2007. (The International Seed Testing Association: Bassersdorf, Switzerland)

Bowman AM (1990) Rehabilitation of degraded pastures and abandoned cropland in semi-arid New South Wales. Final report for the Australian Wool Corporation, Wool Research & Development Council. NSW Agriculture & Fisheries, Walgett.

Buckley KS (1959) Plant testing for soil conservation at Inverell. *Journal of Soil Conservation of NSW* **15**, 227–245.

Campbell MH, Munnich DJ, Bowman AM (1993) Rehabilitation of degraded native pasture and croplands for grazing in the semi-arid summer rainfall pastoral zone. Final report to Australian Wool Research and Development Corporation. NSW Agriculture, Orange.

Cook BG, Pengelly BC, Brown SD, Donnelly JL, Eagles DA, Franco MA, Hanson J, Mullen BF, Partridge IJ, Peters M, Schultze-Kraft R (2005) Chloris gayana. In 'Tropical Forages: an interactive selection tool'. [CD-ROM] (CSIRO, DPI&F(Qld), CIAT and ILRI: Brisbane, Australia) or http://www.tropicalforages.info/key/Forages/Media/Html/Chloris_gayana.htm

Harris C (2008) New *Panicum* cultivars on horizon for northern New South Wales. In 'Proceedings of the 23rd Annual Conference of the Grassland Society of NSW, Tamworth'. (Eds S.P. Boschma, L.M. Serafin, J.F. Ayres) (Grassland Society of NSW Inc.: Orange). pp.114–115

Harty RL, Hopkinson JM, English BH, Alder J (1983) Germination, dormancy and longevity in stored seed of *Panicum maximum*. *Seed Science and Technology* **11**, 341–351.

Johnson A (1952) Sown pastures for Inverell, Moree and Boggabilla Districts. *The Agricultural Gazette of NSW* **63**, 343–366, 410–414, 418.

McCormick LH, McGufficke BR, Harden S, Ross BA (1998) Subtropical grass evaluation for pastures in northern NSW. In 'Proceedings of the 9th Australian Agronomy Conference, Wagga Wagga'. http://www.regional.org.au/au/asa/1998/1/028mccormick.htm

McCormick LH (2004) Managing the pasture phase as a high value crop. In 'Proceedings of the nineteenth Annual Conference of the Grassland Society of NSW'. (Eds SP Boschma, GM Lodge) pp. 93–98. (Grassland Society of NSW Inc: Orange)

McGufficke BR, McCormick LH (2008) Tropical grasses for inland NSW. *NSW Department of Primary Industries Primefact* (in press).

Murphy SR, Lodge GM, Brennan MA (2008a) Water use indices of tropical perennial grasses in a temperate environment. In 'Proceedings of the XXI International Grassland Congress – VIII International Rangeland Congress', 29th June–5th July 2008, Hohhot China'. (in press.)

Murphy SR, Lodge GM, Brennan MA (2008b) Plant root depth of tropical perennial grasses in a temperate environment. In 'Proceedings of the XXI International Grassland Congress – VIII International Rangeland Congress', 29th June–5th July 2008, Hohhot China'. (in press.)

Murray S (2004) Successful use of sub-tropical grasses on-farm. In 'Proceedings of the 19th Annual Conference of the Grassland Society of NSW'. (Eds SP Boschma, GM Lodge) pp. 23–27. (Grassland Society of NSW Inc: Orange)

Peoples MB, Baldock JA (2001) Nitrogen dynamics of pastures: nitrogen fixation inputs, the impact of legumes on soil nitrogen fertility, and the contributions of fixed nitrogen to Australian farming systems. *Australian Journal of Experimental Agriculture* **41**, 327–346.

Reeve IL, Kaine G, Lees JW, Barclay E (2000) Producer perceptions of pasture decline and grazing management. *Australian Journal of Experimental Agriculture* **40**, 331–341.

Scott JF, Lodge GM, McCormick LH (2000) Economics of increasing the persistence of sown pastures: costs, stocking rate and cash flow. *Australian Journal of Experimental Agriculture* **40**, 313–323.

Watt LA (1976) Evaluation of pasture species for soil conservation on cracking black clays – Gwydir district, northwestern New South Wales. *Journal of Soil Conservation Service of NSW* **32**, 86–97.

Watt LA (1978) Some characteristics of the germination of Queensland blue grass on cracking black earths. *Australian Journal of Agricultural Research* **29**, 1147–1155.

Whitbread AM, Lefroy RDB, Blair GJ (1996) Changes in soil physical properties and soil organic carbon fractions with cropping on a red brown earth soil. In 'Proceedings of the 8th Australian Agronomy Conference, Toowoomba.' pp. 582–585.

Experiences with the establishment and grazing of tropical grasses on the North-West Slopes of New South Wales

L.E. Bowman

'Springfield', Manilla NSW 2346
<bowmanluke@bigpond.com>

Abstract. *'Springfield' is a beef cattle operation running breeding cows and growing the progeny through to feedlot weight. Trade cattle are also bought and taken through to feedlot weight. Temperate grasses have been planted in pasture mixes over the years with limited success, as persistence has been a big problem. Our goal is to establish a pasture that gives us performance as well as persistence. The tropical grasses we have planted thus far seem to be giving us both performance and persistence.*

Outline of the farming system

I have been running 'Springfield' and 'Red Hill' together in conjunction with my father, Graham Bowman, for the past eight years. These properties cover approximately 2,400 ha. We are located on the upper slopes of the North-West Slopes and Plains between Barraba and Manilla. Our elevation ranges from 500 m to 800 m and average annual rainfall is between 650 mm to 700 mm. It is a beef cattle operation running predominately 650 Angus and Angus-cross cows whose progeny is destined for the feedlot and domestic markets. We also have scope in our operation to trade cattle when the opportunity arises.

The soils on 'Springfield' and 'Red Hill' are predominately clay-loam, high in phosphorus but with low sulphur levels. Fertiliser history on pastures on the properties includes the application of SF45 every 2–3 years, and other necessary applications of nitrogen (N) fertiliser on improved pastures as required.

Experience with temperate pastures

Typically, temperate pastures have been introduced to paddocks after 3–4 years of grazing-oats. Generally a lucerne/clover mix was planted under a cereal cover-crop, or a lucerne/clover/phalaris mix was planted after a summer-fallow. Germination was often good and the pastures performed well for 2–5 years.

With the lucerne/clover mix, after some years, lack of ground-cover was causing sheet erosion and damaging our soils. Lucerne plants were diminishing and native grasses were starting to establish themselves. With the lucerne/clover/phalaris mix, phalaris was not persisting and was unable to make it through the dry times, and then we ran into the problem (as with the lucerne/clover mix) of lack of ground-cover resulting in sheet-erosion. During the 5–10 year age of the pasture, native grasses, mainly wire grass and red grass were establishing back into the pasture and starting to dominate.

Fletcher MaxP tall fescue has also been planted and it is persisting well. However, we are getting only limited grazing from it as rainfall events have not favored its growing-season since it was planted.

Experience with tropical pastures

In 2005, a paddock was selected to plant tropical grasses after hearing some good results from Lester McCormick's (NSW Department of Primary Industries) trials. This paddock was selected because it was probably the worst paddock on the property and was very susceptible to sheet-erosion. The paddock had gone through the lucerne/clover phases where it experienced terrible sheet-erosion and was at the end of a four-year grazing-oat phase, with the last year being locked up for harvest of grain. Tropical grasses were drilled into the oat-stubble after the grain was taken off and before a predicted rainfall event. Problems arose with establishment of these pastures as volunteer oats and barnyard grass out-competed any tropical grass.

This pasture was left till the beginning of the next summer and sprayed out and planted again – this time establishment was successful. The pasture has performed well and established on the sheet-erosion areas of the paddock. In the sheet-erosion areas, there has been an increase in the number of plants per square metre, and organic matter is starting to build up in those areas giving us more ground-cover. In the areas with better soil fertility, the pasture is well established and early indications show it is getting thicker.

Establishment of tropical pastures

The best establishment technique for tropical grasses we have found so far is explained below:

- Plant into an oat-crop stubble that has been grazed so that there is no oat seed left behind, but there is sufficient stubble retention to protect the soil and prospective plants

- Control summer weeds 2–3 years before the pasture is to be planted
- Plant when the soil temperature is a stable 20°C (around October–November), or otherwise the appropriate temperature for the species to be planted.

Different seed depths and ground disturbance were trialed with high disturbance and shallow seed depth creating the best establishment in our soils. The ground can set very hard so there needs to be sufficient tilth for the seedling to get started. Our planter is based on the soil-flow system as it seemed to show the best results with the harder setting soils. The planter is a John Shearer Trashworker (chisel plow) with a 50 mm spear point, a deep banding fertiliser-boot and a shallower adjustable seed-boot where fertiliser can also be placed with the seed. A Garnelle in-frame press wheel is used to firm the seed and gain soil-seed contact.

We have used bare seed and had trouble with the flow of the material through the seeder, so a blend (1:1) of seed and fertiliser was used which rectified the problem. Since then, we have been using coated seed and have had good results. When planting, the spear point of the planter is put in at a depth of 75 mm to 100 mm and 70 per cent of the fertilizer is placed at the bottom of the trench. Some 30 per cent of the fertiliser and the seed are placed just in front of the press wheel and pressed into the soil so they do not get too much soil cover (0–10 mm is desirable). The seed then is ready for when it rains, and if you get a heavy rainfall event after planting, soil may wash into the seed trench but not give the seed so much soil cover that it hinders germination.

The most successful species have been Katambora Rhodes grass and Premier digit grass. A mix of Premier digit grass, Katambora Rhodes grass, Bambatsi panic, Gatton panic and Bisset bluegrass have been sown at rates of 10 kg/ha of treated seed.

Nitrogen applications in grass pastures

Nitrogen has been applied annually to the tropical grass pastures in the form of urea at a rate of around 50 units of N per hectare. This has given us good results and boosted growth dramatically. The application of N was not undertaken this year due to the prices, and established tropical grass pastures fell short in dry matter and feed quality.

Efforts have been made to broadcast subterranean clover into the pasture to fix some of the N required. This has had limited results as rainfall has been the limiting factor. Before broadcasting subterranean clover you must have the canopy of the pasture opened up to allow the clover to germinate. Sowing a summer-legume like burgundy bean will be something we will try in the future.

Some facts of relevance from NSW Department of Primary Industries are:

- Compared with using nil N, 50 kg N/ha gave the highest increase in herbage production for Premier digit grass (147 kg herbage/kg N/ha) (S.P Boaschma, personal communication)
- Subterranean clover in a grazed pasture produces approximately 2 t herbage/ha/year – that is equivalent to about 40–50 kg N/ha for the tropical grasses (Boschma and McCormick 2008).

Animal performance from tropical grasses

Animal performance has been good with the rates of growth a little less than 1 kg/head/day. This is a little lower than growth rates from temperate pastures and legumes, but the tropical pasture is able to hang on for a longer period of time. I am able to use tropical grasses when legumes have a risk of bloat in cattle, this still gives me a pasture with good performance. When the period of bloat-risk has passed, I am then able to put cattle on the temperate legumes.

The future

We will be trialing organic and biological ways to provide soil fertility. Composts and organic minerals will be used to provide the pasture with its nutrients. Companion planting with summer-legumes will be something else we will pursue.

Conclusions

Tropical grasses have a place in our pasture program because of their performance and persistence. When establishing tropical grasses, attention must be give nto correct sowing time, weed control (24 months in advance) and sowing depth. These factors along with a little moisture should produce a robust pasture. When established, a lack of N is the main factor limiting performance.

References

Boschma SP, McCormick LH (2008) Towards a tropical grass package for northern New South Wales. In 'Proceedings of the 23rd Annual Conference of the Grassland Society of NSW'. (Eds SP Boschma, LM Serafin, JF Ayres) pp. 51–57 (Grassland Society of NSW Inc.: Orange)

Pastures in the high rainfall zone – their anticipated responses to climate change and their role in minimising net farm greenhouse gas emissions

D. Alcock[A] and R.S. Hegarty[BC]

[A]NSW Department of Primary Industries, Cooma NSW 2630
<douglas.alcock@dpi.nsw.gov.au>
[B]NSW Department of Primary Industries Beef Industry Centre, Armidale NSW 2351
[C]Current address: Grasslands Research Centre, Palmerston North, New Zealand

Abstract. *The projected climate change to a significantly warmer and perhaps drier New South Wales by 2050, gives notice that grazing enterprises will need to adapt to this climate in order to remain productive. It is likely that most pasture systems in higher rainfall zones of New South Wales will respond to reduced rainfall and increased temperature with a shortened growing season and therefore a smaller proportion of the year in which highly digestible feeds are available. Higher atmospheric CO_2 concentration can serve to increase both plant growth and also to increase water use efficiency which may serve to offset some of the negative effects in environments where fertility and soil moisture are not over-riding factors. Wider use of drought adapted species, particularly C4 plants and invasion of C4 weed species into existing pastures can be expected. As plans for an emissions trading system in Australia become a reality, it is likely that the costs of emissions along with potential offsets from mitigation will lead to restructuring of grazing enterprises. Details of the response of pastures to climate change are evaluated and the likely impact on productivity in the high rainfall zone modelled. The role of pastures in reducing emissions and sequestering carbon is also considered as part of managing net emission from the farm.*

Introduction

Climate change is increasingly a topic of concern to livestock producers in Australia, because of the potential physical impact on the biology of the production system, and the inevitable economic impact of an Emissions Trading Scheme (ETS). 2007 was the warmest year on record for New South Wales (NSW) and the Murray-Darling Basin and was the seventh consecutive year of below average rain for the state (BoM 2008). While this is clearly a time of drought, climate change is likely to make such periods both longer and more severe than we have previously experienced. The median projected climate change for NSW by 2050 (using mid-range emissions estimates) indicates this trend will continue, with an increase in mean annual temperature and evapotranspiration, but reduced annual rainfall (CSIRO and BoM 2007).

The productivity and ecological changes within Australian pasture ecosystems arising from such climatic change are only just being explored (Hall *et al.* 1998; Pittock 2003; Harle *et al.* 2007; Hacker *et al.* 2007). Economic implications of changing productivity and land use, as well as of including agriculture in carbon markets are now being evaluated (Gunasekera *et al.* 2007). The determination that the national ETS should include agriculture (Garnaut 2008) is pivotal in placing the grazing industries in the context of Australia's other greenhouse gas (GHG) emitting industries. While points of obligation and allocation in a national ETS remain to be determined, there is much effort being expended to evaluate the implications of climate change and an ETS for farmers individually (Keogh 2007), the NSW extensive industries as a whole (Hacker *et al.* 2007); and to build a national (agricultural) carbon accounting system (NCAS) that can accommodate management and mitigation options (Brack *et al.* 2006).

In comparison to rapid policy change, biological change in the paddock appears slow, however, the projected climate change means that graziers must be prepared to adapt to changed climate. The major contribution of enteric methane to Australian agricultural GHG emissions is apparent (Gunaskera *et al.* 2007) but the scope for grazing lands to sequester atmospheric carbon in regrowth, in new forests and especially soil carbon is not well quantified. Scientists are striving to review the response of plants to elevated CO_2 (Morgan 2005) and changed climate (Campbell *et al.* 2000; Hughes 2003) but also anticipate how this will affect the wider grazing system (Harle *et al.* 2007). System models estimating impacts of management decisions on net greenhouse gas emissions from farms are evolving (McKeon *et al.* 1993; Howden *et al.* 2003b; Alcock and Hegarty 2006; Johnson *et al.* 2008), but are not fully developed for all gases. This paper seeks to look at the relationship between pasture production and a changing climate in two ways. Firstly, to report the likely impacts of climate change on pasture productivity and composition in NSW into the future, and secondly, to consider how pasture production in a grazing system can be managed to minimise the net GHG emission from the enterprise.

Pasture responses to climate change in NSW

Projections of climate in NSW to 2050 reveal changes in total rainfall, rainfall distribution, temperatures and potential evapotranspiration relative to present characteristics (Figure 1). These climatic changes and elevated CO_2 concentrations will mean that pastures will be in a new microclimate by 2050 relative to what they are today, so a change in the pasture ecosystem can be expected. Some of the changes expected are outlined below. Reviews assessing pasture and grazing responses to climate change are available (Campbell *et al.* 2000; Morgan 2005; Smith *et al.* 2008).

Growing season and pasture growth

Early models of the Queensland grazing system on native pastures indicated that increased CO_2, together with warmer conditions would increase pasture growth and live-weight gain of grazing animals, but when accompanied by reduced rainfall (as now projected for NSW), reduced annual pasture growth (Howden *et*

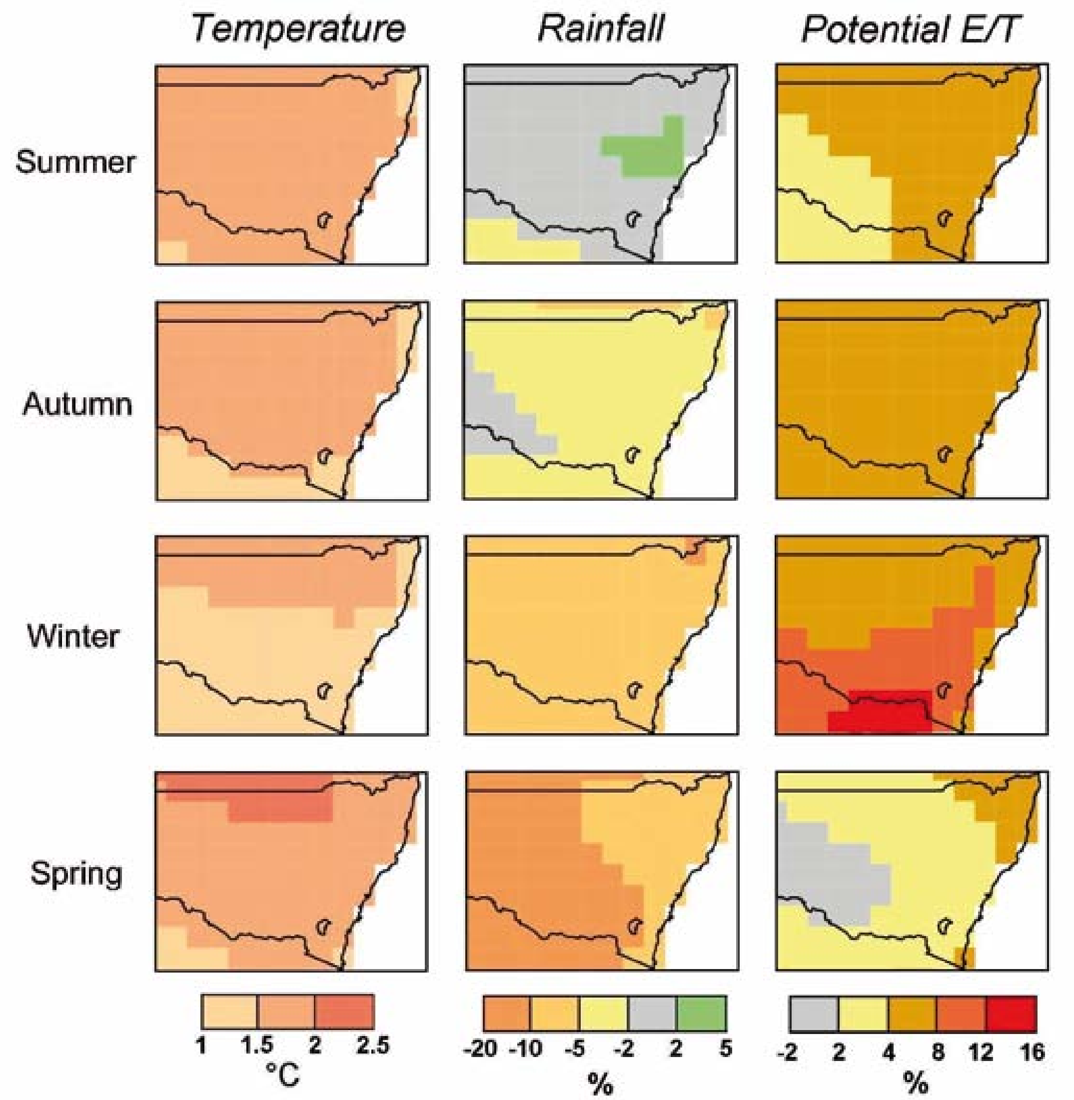


Figure 1. Best estimate of change in seasonal rainfall, temperature and potential evapotranspiration in NSW in 2050 assuming a medium emissions scenario. Change in projected parameters is given for 2050 relative to the period 1980–1999 (referred to as the 1990 baseline for convenience) and takes into account consistency among climate models. Individual years will show variation from this average. The 'best estimate' is taken as the mid point (50th percentile) of the spread of results from a range of global circulation models used to predict future climate. The medium emissions scenario refers to scenario A1B, from the IPCC Special Report on Emission Scenarios. Data are sourced from http://www.climatechangeinaustralia.gov.au/nswactevap17.php.

al. 1999a). We have used GrassGro (Freer *et al.* 1997, Moore *et al.* 1997) to simulate the productivity of a fine wool merino enterprise grazing an annual grass pasture at Cowra, NSW. GrassGro models the production of pasture and the performance of grazing livestock based on the impact of daily time-step weather data. Simulations were run using historical weather data from 1963–2002 and the same pasture system with synthesised weather data for mid-range projections for the climate in 2030–2069 (CSIRO 2001). The magnitude of the seasonal temperature and rainfall changes are shown in Table 1. This approach allows the impact of changed seasonal weather patterns and seasonal pasture growth to be accounted for.

Figure 2 shows the median pasture growth rates for the historical and future 40 year period and indicates that climate change may lead to a shortening of the growing season (the period where median growth rate exceeds 10 kg dry matter (DM)/ha/day) from 32 weeks to 26 weeks. The peak growth rates also appear reduced but in this case CO_2 fertilisation effects have not been accounted for and could potentially offset this effect. In a recent assessment of the likely impacts of climate change on the Australian wool industry to 2030, Harle *et al.* (2007) considered literature regarding the moderating effects of higher CO_2 levels on plant water-use efficiency. Overwhelmingly this literature points to enhanced plant growth under high CO_2, especially in water limited situations, presumably as a consequence of increased water use efficiency due to decreased stomatal conductance. Furthermore, modelling of C3 photosynthesis indicates that the thermal optimum for CO_2 assimilation may rise under elevated CO_2 (Sage and Kubien 2007) due to a shift in the relative photosynthetic limitations, assuming no other factors are limiting photosynthetic rate. However, while elevated CO_2 could offset the reduction in growth rate shown in Figure 2 it is unlikely to substantially ameliorate the impact of a shortened growing season.

Table 1. Average change to historical Cowra weather data projected for 2030–2069, expressed relative to 1963–2002 data

Season	Temp change (°C)[A]	Rainfall change (%)[A]	Evaporation (mm/day)[B]
Summer	2.4	109	Estimated using corrected historical data for each season
Autumn	2.4	109	
Winter	2.0	92	
Spring	2.6	92	

[A]Temperature and rainfall change after CSIRO 2001
[B]Historical data was corrected using proportional increase in calculated EPan (FAO–56) for both historical and projected temps, solar radiation and constant wind; after Allen *et al.* (1998).

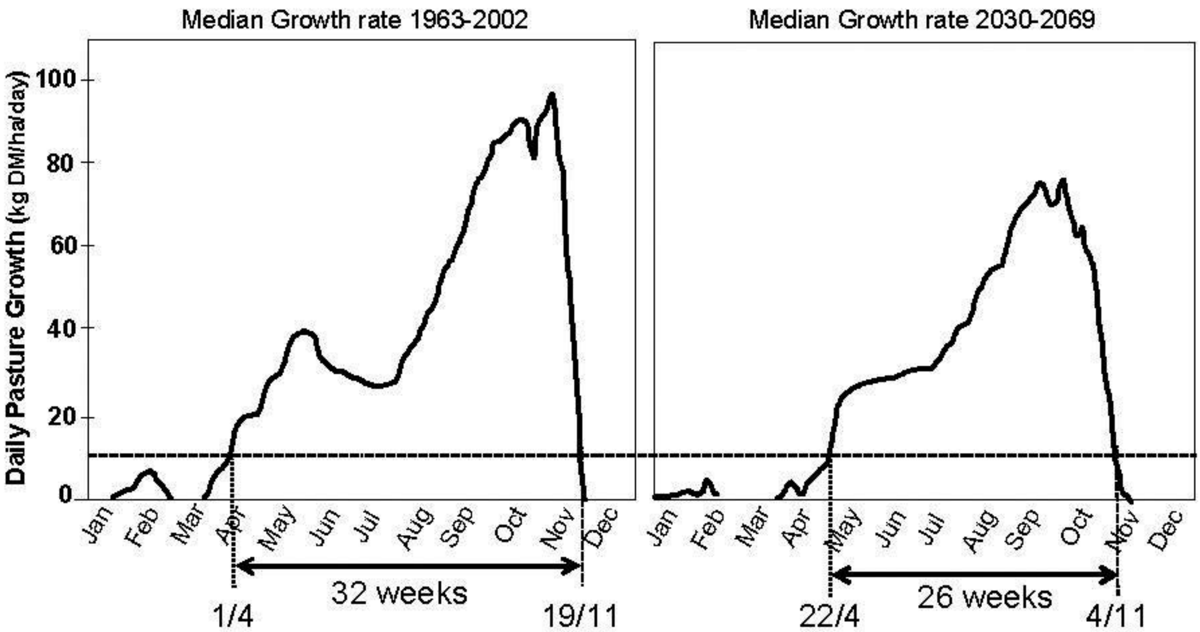


Figure 2. Effect of projected climate change on growing season length of annual grass based pasture at Cowra NSW as simulated using GrassGro 2.5.1.

Table 2. Effect of projected climate (2030–2069) on stocking rate and economic output of fine wool Merino enterprise relative to 1963–2002 climatic conditions

	1963–2002	2030–2069	Reduction (%)
Sustainable stocking rate	7 ewes/ha	5 ewes/ha	28
Average GM	\$472/ha	\$302/ha	36
Average Profit[A]	\$382/ha	\$212/ha	44

[A]Assumes overheads costs @ \$90/ha

It is clear by comparing systems in a variety of climates that overall pasture utilisation rate is largely limited by length of growing season rather than by annual dry matter production, yet overall carrying capacity is affected by both season length and pasture productivity (Alcock 2006). In this simulation by relating herbage mass to ground cover and assuming a farm management objective to maintain summer/autumn ground cover above 70 per cent for at least 8 years in 10 (Warn *et al.* 2005), GrassGro indicates that Cowra will experience a reduction in sustainable carrying capacity from 7 ewes/ha to just 5 ewes/ha (Table 2).

These results assume the absence of adaptive management but this modelling approach may allow us to test the effectiveness of potential adaptation strategies in the future. Changing lambing times or the age at sale of young stock might help bring feed requirements back in line with the feed supply, especially if winter growth rates are increased due to CO_2 fertilisation.

Change in pasture species mix

In theory the impact of warming on a pasture ecosystem can be equated to moving the production further north to a drier, warmer climate. Howden *et al.* (2003b) indicated a 1°C change would be equivalent to relocating Melbourne to Wagga Wagga (NSW) under current conditions. In NSW there is also a shift in the seasonality of rainfall with latitude, in general moving from slightly winter dominant to a summer dominant pattern. In addition to rainfall, plant growth is photoperiod responsive (relative seasonal daylight hours) which will remain the same under a global warming scenario. For this reason it is not reasonable to expect that pasture ecosystems in a locality will automatically be suited to a locality further south as warming progresses. The most up to date climate change impacts are illustrated for Cowra in Figure 3. It can be seen that while the projected temperature data for Cowra overlays historical data for Coonabarabran quite well, Cowra's projected rainfall will remain non-seasonal compared with the summer-dominant pattern for Coonabarabran.

The most anticipated compositional change has been a shift in the C3:C4 species balance toward C4 species, due to changes in rainfall, temperature and extreme weather events (Howden *et al.* 1999b). While C4 are less responsive to elevated CO_2 (review: Sage and Kubien 2003), higher temperatures are considered likely to give C4 grasses a competitive edge as in previous world

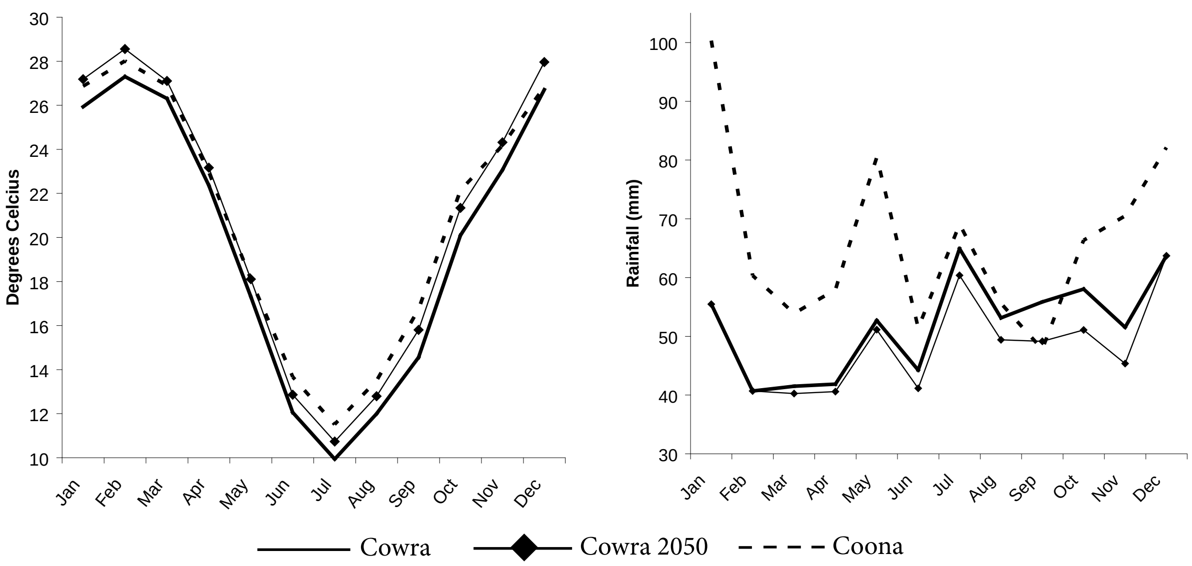


Figure 3. Historical lagged daily temperature and monthly rainfall (1980–1999) for Cowra and Coonabarabran compared to projected future climate parameters for Cowra (2050).

warming events ('t Mannetje 2007). Modelling by Howden *et al.* (1999b) for the C3:C4 balance in tropical Queensland suggests the isoline for where equal populations of C3 and C4 plants exist, will be moved south 100 km by a temperature rise of 3°C, and 250 km when combined with a doubling of atmospheric CO_2. While the warmer/seasonally drier scenario anticipated for NSW is consistent with inducing a shift to C4 species and C4 weed invasion as is being reported in Europe ('t Mannetje 2007), the non-seasonal to winter dominant pattern of rainfall in the southern half of the state may serve to limit this shift. Conversely, active management of pastures using such tools as grazing timing and intensity, pasture sowing and even fire, provide a rapid and powerful capacity to manage the C3:C4 balance in pasture, in ways that could readily reverse or accelerate climate-induced shift as desired.

It should also be remembered that C4 pasture plants are generally frost sensitive and the effect of climate change on frost risk is not as great as the effect on average temperature. In areas where frost is frequent (more than 40 frosts per year) the reduction in frost is only half the reduction that would be indicated by the average temperature increase (CSIRO and BoM 2007). This is the result of drier cool seasons and longer periods between rainfall events leading to more frequent 'clear sky' nights which offset the average temperature rise.

Pasture competitiveness and plant survival will also reflect differential species responses to elevated CO_2, microclimate changes and extreme weather events. In any one year, chamber studies of pastures under high CO_2 concentration revealed changes in the proportions of biomass contributed by component species (Morgan *et al.* 2004). Across years, CO_2 has been thought to change species balance by increasing flower number and seed number (review: Jablonski *et al.* 2002) but Australasian studies suggest this is a limited impact in native pastures. Free air CO_2 enrichment studies in open paddocks with elevated CO_2 in Australia's tropics, Tasmania and in New Zealand have been conducted (eg. Hovenden *et al.* 2007). These studies have found increased recruitment of some species due to increased seed production (Edwards *et al.* 2001) but germination does not appear to be affected. In Tasmania, where both CO_2 and temperature have been increased in small plots of natural temperate grassland (Hovenden *et al.* 2007), only five of the 23 species reported showed an effect of CO_2 or temperature on the percentage of plants flowering. In some years and some species, the number of inflorescences/plant produced was increased by CO_2 but most species showed no response.

Higher CO_2 alone may be expected to promote legume growth more than grasses (Picon-Cochard *et al.* 2004; Lilley *et al.* 2001), but given the drier winters and springs predicted for NSW in 2050, these effects may be negated by moisture stress. Importantly, higher evapo-transpiration and longer intervals between rainfall events (CSRIO and BOM 2007) in autumn may increase the risk of poor establishment of annual clovers.

Pasture quality

For a given species, dry matter digestibility may decrease with elevated CO_2 concentration (Morgan *et al.* 2004) or increase (Picon-Cochard *et al.* 2004), and results are likely to be confounded with time of cut relative to maturity and species, with little local research to report. Climate induced changes in digestibility are most likely to arise from accelerated maturation due to shorter growing season and a change in species balance due to CO_2 availability and microclimate. In general, a shift from C3 to C4 species would contribute to a decrease in both herbage digestibility and crude protein which would limit animal performance by comparison with current C3 dominant pasture systems. Importantly reductions in pasture quality will lead to higher methane output per unit of product from grazing animals, increasing the cost to grazing enterprises of any future ETS.

Pests

Just as changed climatic conditions will re-establish a new balance of C3 and C4 plants in each region, so local balances of plant, insect and microbial pests and diseases can be expected to change over time (Hughes 2003). Invasion with C4 weeds and pastures into C3 dominated pastures can be expected as outlined (Sage and Kubien 2003). CO_2 fertilisation studies have shown part of the species change with warming and CO_2 in Tasmania is greater presence of some weeds (Williams *et al.* 2007) in pastures.

Pasture management as a tool to reduce climate change

So far we have portrayed pastures only as structures responding to changes in CO_2 and to the temperature and rainfall of the environment in which they grow. It is equally true to assess pastures as agents influencing the net balance of greenhouse gas emissions leaving a farm. The example of Keogh (2007; p12) depicts that on a 'typical' southern NSW mixed farming enterprise (5,000 breeding ewes, 700 ha of cropping), 58 per cent of emissions are enteric methane and 31 per cent arise from nitrogen in soils and fertiliser.

Pasture management is a key tool in giving flexibility for the producer to move the balance between emissions and productivity. Alcock and Hegarty (2006), again using Grassgro to simulate a Cowra lamb producing property, were able to show that progressive pasture improvement (from annual pastures, low soil fertility) to fertilised perennial pasture (*Phalaris aquatica* plus 25 per cent legume), could give producers the option to:

- Maintain equal farm profit but graze a smaller area and reduce enteric methane emissions (from 5.3 to 3.0 t enteric methane/year)
- More than double farm profit but graze a smaller area and, maintain equal methane emissions
- Maximise gross margin (raised from $139 to $525/ha), improve all the grazing area and substantially increase enteric methane production.

These simulations did not include possible nitrous oxide loss from improved pastures, but as indicated by Keogh (2007), this is a minor source in extensive grazing systems. It should also be noted that current costs for pasture establishment exceed $300/ha (M. Keys, personal communication) and the cash-flow implications of development may mean that while cash-flow is enhanced the development as a whole may not break even for at least seven years.

Pasture management can also influence enteric methane, nitrous oxide and soil carbon losses by a range of other means as outlined below:

Pasture species

While the rumen digestibility of a plant affects the level of intake and methane loss/unit intake, (Hegarty 2001), specific non-fibre components of the plant can also affect methane production and potentially nitrogen excretion and volatilisation from paddocks. Examples of these are condensed tannins and organic acids.

Condensed tannins in species such as *Lotus* spp, have potential to reduce emissions by both reducing enteric methane and reducing loss of dietary nitrogen in urine. While it is recognised that condensed tannin activity varies among sources, tannins in pasture have typically reduced enteric methane emissions (Waghorn 2008). This is often achieved without compromising productivity and may be associated with other productivity benefits such as reductions in internal parasitism, susceptibility to bloat and urinary nitrogen, the latter possibly associated with lower N_2O emissions. (review: Mueller-Harvey 2006).

Many pasture species contain low levels of carboxylic acids such as the tricarboxylic aconitate and/or dicarboxylic malic and fumaric acids that can accumulate under some conditions (Stout *et al.* 1967). Some of these acids are known to be readily reduced to propionate upon entry to the rumen, thereby reducing hydrogen available for methane production (Lopez *et al.* 1999). Malate concentrations in lucerne may be up to 7.0 per cent of DM, so are at levels of organic acid believed sufficient to reduce methane production but these levels decline with maturity and vary with cultivar (Callaway *et al.* 1997). Recent studies of methane production by cattle consuming lucerne chaff showed daily emissions consistent with those predicted by published equations, indicating no evidence of lucerne chaff being a low methane-potential forage (R.S. Hegarty, unpublished data).

Grazing management for soil carbon sequestration

Soil carbon accumulation is one of the ways that graziers hope to be able to reduce net farm emissions or provide emission offsets for sale off-farm. Despite this, Australia has not agreed to Section 3.4 of the Kyoto protocol, thereby excluding Australia from including soil carbon in claimed sequestration (see Keogh 2007; p 11 for explanation). Nonetheless, there is enthusiasm for external schemes in their infancy which may enable landowners to be rewarded for increased soil carbon (eg. Jones 2007; Carbonlink 2008).

The principles of managing pasture to optimise residual sward state and grazing frequency are well established (Parsons and Chapman 2000) but their practical application in optimising animal management for productivity on-farm remains a topic for debate. The ramifications of pasture management on soil carbon accumulation have less data to support decision making, but the principles of plant growth used in optimising grazing frequency are instructive. Sources of soil organic matter include root dry matter, root exudates, leaf litter and the microbes associated with their decomposition. In pastures grazed to a low leaf area index (by intense grazing), there will be a low root mass and low litter loss into the soil. In pastures that are allowed to mature towards their ceiling yield, both root mass and litter mass will be maximised. Correspondingly, providing nutritional support to enable rapid pasture growth will be critical to active soil carbon (C) accumulation. Simply reverting cultivated land to unmanaged grassland led to only 30 kg C/ha/year (Burke *et al.* 1995), whereas converting crop-land to managed pasture typically accumulates at ten times this rate (~300 kg C/ha/year; Post and Kwon 2000). This should however be put into the context of grazing system emissions. For example, the GrassGro simulation of the Cowra based grazing system (descried previously in this text) indicates an average methane output of 64 kg/ha/yr (at a global warming potential of 21 times CO_2, this is equivalent to 1.34 tonnes of CO_2 emissions). Consequently, that land system would have to sequester an extra 365 kg of extra soil carbon per year to fully offset the methane emissions resulting from the introduction of livestock.

Species diversity also appears important to maximise soil carbon accretion, with accretion being greater for mixed swards than their component species grown in monocultures including C4 grasses and legumes (Fornara and Tilman 2008). In native species, differences in fine root (FR) production between Kangaroo grass (*Themeda triandra*; 17 g FR/pot/year) and Wallaby grass (*Austrodanthonia racemosa*; 4 g FR/pot/year) are apparent (Guo *et al.* 2005) and may also reflect their relative usefulness in building soil carbon.

While the scale and recognition of carbon sequestered under pastures remains to be defined in Australia, soil carbon sequestration must be seen in the context of concomitant farm GHG issues, some of which are listed below:

- Any continuously managed system will reach carbon equilibrium
- Rapid plant growth by which atmospheric CO_2 is sequestered will be dependent upon high nutrient and water availability. Forecast NSW climate change will periodically diminish pasture growth so even higher levels of inputs (with inherent potential nitrous oxide loss) may be required in periods when soil moisture and temperature are not limiting if overall pasture productivity is to be maintained or improved in the future
- Pastures are primarily grown for grazing, so pasture management (species, fertilising and grazing strategy) for minimising enteric methane production may not maximise soil carbon accretion or farm profit
- Benefits of adequate soil carbon include contributing to soil aeration, moisture holding capacity and exchangeable nutrient retention which may support enterprise profitability far more than the dollar value of the carbon itself.

As a land use change option, replacement of grazing systems (with their high enteric methane release) by alternative enterprises such as forestry has been considered, and large areas of grazing land have been converted to plantation forestry. Reversion of native pasture (*Thermeda triandra*) to radiata pine plantation has led to substantially greater accrual of above-ground carbon (in trees relative to grass) but reduced the soil carbon pool (Guo *et al.* 2008). Other avenues of sequestration which do not exclude grazing should be considered. Pyrolysis of organic materials to produce biochar is one option that can be expected to provide sequestered carbon (in the char) and enhance the biological and biophysical properties of soils to promote pasture growth. In pot trials, biochar has been shown to increase cation exchange and field capacity while lowering tensile strength of the soil (Chan *et al.* 2007). While not yet commercially available, such results suggest biochar may have benefit as a soil ameliorant in both sandy as well as heavy clay soils.

Conclusions

By 2050, it is likely that NSW grazing enterprises in the high rainfall zone will encounter a shorter growing season in a warmer drier climate with a substantially reduced spring rainfall. Pollution of the atmosphere with GHGs will carry a direct or indirect cost to the enterprise and be part of the business calculation, as will potential returns from trading away the value of carbon sequestered on-farm. Pastures will provide a vital tool in optimising the financial viability of the farm. They will provide a food source for livestock, and their area, composition and management will be optimised to reduce GHG emissions from the stock grazing them; they will be a bank of carbon, either sequestered by plants into the soil or introduced as non-degradable carbon such as biochar. As such, the changing climate provides a bright future for the purposeful establishment and management of pastures as an underpinning component in the farming system.

References

Alcock DJ (2006) Using grazing systems modelling to assess economic, production and environmental risks to aid in selecting appropriate stocking rates. *Australian Journal of Experimental Agriculture* **46**, 845–849.

Alcock D, Hegarty RS (2006) Effects of pasture improvement on productivity, gross margin and methane emission of a grazing sheep enterprise. *International Congress Series* **1293**, 103–106.

Allen RG, Pereira LS, Raes D, Smith M (1998) Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56.

BoM (2008) Annual climate change summary for New South Wales. http://www.bom.gov.au/climate/current/annual/nsw/summary.shtml downloaded 28/04/08

Brack C, Richards G, R Waterworth (2006) Integrated and comprehensive estimation of greenhouse gas emissions from land systems. *Sustainability Science* **1**, 91–106.

Burke IC, Lauenroth WK, DP Coffin (1995) Soil organic matter recovery in semiarid grasslands: implications for the conservation reserve program. *Ecological Monographs* **5**, 793–801.

Callaway TR, Martin SA, Wampler JL, Hill NS, Hill GM (1997) Malate concentration of forage varieties commonly fed to cattle. *Journal of Dairy Science* **80**, 1651–1655.

Campbell ND, Stafford Smith DM *et al.* (2000) A synthesis of recent global change research on pasture and rangeland production: reduced uncertainties and their management implications. *Agriculture, Ecosystems and Environment* **82**, 39–55.

Carbonlink (2008) http://www.carbonlink.com.au/farmers/cells/index.htm downloaded 30/04/08.

Chan KY, Van Zwieten EL, Meszaros I, Downie A, Joseph S (2007) Agronomic values of greenwaste biochar as a soil amendment. *Australian Journal of Soil Research* **45**, 629–634.

CSIRO (2001) Climate Change Projections for Australia. CSIRO Atmospheric Research, Victoria. Sourced 06/05/08. http://www.dar.csiro.au/publications/projections2001.pdf.

CSIRO, BoM (2007) Climate change in Australia – technical report, CSIRO. Downloaded 02/05/08. NSW maps sourced from http://www.climatechangeinaustralia.gov.au/nswactevap17.php

Edwards G, Clark H, Newton P (2001) The effects of elevated CO_2 on seed production and seedling recruitment in a sheep-grazed pasture. *Oecologia* **127**, 383–394.

Fornara DA, Tilman D (2008) Plant functional composition influences rate of soil carbon and nitrogen accumulation. *Journal of Ecology* **96**, 314–322.

Freer M, Moore AD, Donnelly JR (1997) GRAZPLAN: Decision Support Systems for Australian Grazing Enterprises-II. The Animal Biology Model for Feed Intake, Production and Reproduction and the GrazFeed DSS. *Agricultural Systems* **54**, 77–126.

Garnaut (2008) http://www.garnautreview.org.au/CA25734E0016A131/WebObj/MicrosoftWord-GarnautClimateChangeReviewInterimReport_ExecutiveSummary_-Feb08/$File Sourced 25/04/08.

Gunasekera D, Ford M, Tulloh C (2007) Climate Change: issues and challenges for Australian agriculture. *Australian Commodities* **14**, 493–515.

Guo LB, Halliday MJ, Siakimotu SJM, Gifford RM (2005) Fine root production and litter input: Its effects on soil carbon. *Plant and Soil* **272**, 1–10.

Guo LB, Cowie AL, Montagu KD, Gifford RM (2008). Carbon and nitrogen stocks in a native pasture and an adjacent 16-year-old *Pinus radiata* D. Don. plantation in Australia. *Agriculture Ecosystems & Environment* **124**, 205–218.

Hacker R, Bowman A, Fairweather H, Hailstones D, Hegarty R, Holzapfel B, Sinclair K, Williamson W (2007) Climate change impacts and priority actions in the agriculture sector: Background paper. Paper presented to NSW DPI Priorities Actions for Climate Change Workshop, October 2007.

Hall WB, McKeon GM, Carter JO, Day KA, Howden SM, Scanlan JC, Johnston PW, Burrows WH (1998) Climate change in Queensland's grazing lands: II An assessment of the impact on animal production from native pastures. *Rangeland Journal* **20**, 177–205.

Harle KJ, Howden SM, Hunt LP, Dunlop M (2007) The potential impact of climate change on the Australian wool industry by 2030. *Agricultural Systems* **93**, 61–89.

Hegarty RS (2001) greenhouse gas emission from the Australian livestock sector: What do we know, what can we do? http://www.greenhouse.gov.au/agriculture/publications/livestock.html downloaded 01/05/2008

Howden SM, McKeon GM, Walker L, Carter JO, Conroy JP, Day KA, Hall WB, Ash AJ, Ghannoum O (1999a) Impacts on native pastures in south east Queensland, Australia. In 'Global Change Impacts on Australian Rangelands'. Working paper series 99/09 8–22.

Howden SM, McKeon GM, Carter JO, Beswick A (1999b) Potential global change impacts on C3-C4 grass distribution in eastern Australian rangelands. In 'Proceedings of the VI International Rangeland Congress' People and Rangelands: Building the future'. (Eds. D Eldridge, D Freudenberger) pp. 41–43. (VI International Rangeland Congress, Inc.: Aitkenvale, Qld)

Howden SM, Stokes C, Ash AJ, MacLeod ND (2003a) Reducing net greenhouse gas emissions from a tropical rangeland in Australia. In 'Proceedings of the VIIth International Rangeland Congress'. (Eds. N Allsopp, AR Palmer, SJ Milton, KP Kirkman, GIH Kerley, CR Hurt, CJ Brown) pp. 1080–1082.

Howden M, Hughes L, Dunlop M, Zethoven I, Hilbert D, Chilcott C (2003b) Climate change impacts on biodiversity in Australia. Outcomes of a workshop sponsored by Biological Diversity Advisory Committee 1–2 October 2002. http://www.environment.gov.au/biodiversity/publications/greenhouse/pubs/greenhouse.pdf downloaded 01/05/08.

Hovenden MJ, Wills KE, Vander Schoor JK, Chaplin RE, Williams AL, Nolan MJ, Newton PCD (2007) Flowering, seed production and seed mass in a species rich temperate grassland exposed to FACE and warming. *Australian Journal of Botany* **55**, 780–794.

Hughes L (2003) Climate change and Australia: trends, projections and impacts. *Australian Ecology* **28**, 423–443.

Jablonski L, Wang X, Curtis P (2002) Plant reproduction under elevated CO_2 conditions: a meta-analysis of reports on 79 crop and wild species. *New Phytologist* **156**, 9–26.

Johnson IR, Chapman DF, Snow VO, Eckard RJ, Parsons AJ, Lambert MG, Cullen BR (2008) DairyMod and EcoMod: biophysical pasture-simulation models for Australia and New Zealand. *Australian Journal of Experimental Agriculture* **48**, 621–63.

Jones C (2007). Australian soil carbon accreditation scheme. In 'Managing the carbon cycle, Katanning workshop'. http://www.amazingcarbon.com/What%20are%20Soil%20Credits.pdf downloaded 30/04/08.

Keogh M (2007) The new challenge for Australian agriculture: How do you muster a paddock of carbon? Discussion paper (Australian Farm Institute Ltd.: Surry Hills, Australia)

Lilley JM, Bolger TP, Peoples MB and Gifford RM (2001) Productivity and nitrogen dynamics of pasture under warmer, higher CO_2 conditions. In 'Proceedings of the Australian Agronomy Conference'. http://www.regional.org.au/au/asa/2001/p/16/lilley.htm#P2_79

Lopez S, Newbold CJ, Bochi-Brum O, Moss AR and RJ Wallace (1999) Propionate precursors and other metabolic intermediates as possible alternative electron acceptors to methanogenesis in ruminal fermentation in vitro. *South African Journal of Animal Science* **29**, 106–107.

McKeon GM, Howden SM, Abel NOJ, King JM (1993) Climate change: adapting tropical and subtropical grasslands. In 'Grasslands for our world'. (Ed. MJ Baker). pp. 426–435. (SIR Publishing: Wellington, New Zealand)

Moore AD, Donnelly JR, Freer M (1997) GRAZPLAN: Decision Support Systems for Australian Grazing Enterprises-III. Pasture Growth and Soil Moisture Submodels and the GrassGro DSS. *Agricultural Systems* **55**, 535–582.

Morgan JA (2005) Rising atmospheric CO_2 and global climate change: responses and management implications for grazing lands. In 'Grasslands: developments, opportunities and perspectives'. (Eds SG Reynolds, J Frame). pp 235–260. (FAO and Plymouth, UK: Science publishers inc.)

Morgan JA, Mosier AR, Milchunas DG, LeCain DR, Nelson JA, Parton WJ (2004) CO_2 enhances productivity, alters species composition and reduces digestibility of shortgrass steppe vegetation. *Ecological Applications* **14**, 208–219.

Mueller-Harvey I (2006) Unravelling the conundrum of tannins in animal nutrition and health. *Journal of the Science of Food and Agriculture* **86**, 2010–2037.

Parsons AJ, Chapman DF (2000) The principles of pasture growth and utilisation. In 'Grass, its production and utilisation'. 3rd Edition (Ed. A Hopkins) pp. 31–89. (Blackwell Science Ltd.: Oxford)

Picon-Cochard C, Teyssonneyre F, Besle JM, Soussana AF (2004) Effects of elevated CO_2 and cutting frequency on the productivity and herbage quality of a semi-natural grassland. *European Journal of Agronomy* **20**, 363–377.

Pittock B (2003) Climate change: An Australian guide to the science and potential impacts. Australian Greenhouse Office, Canberra ACT, Australia. pp.112–113.

Post WM, Kwon KC (2000) Soil carbon sequestration and land-use change: process and potential. *Global Change Biology* **6**, 317–327.

Sage RF, Kubien DS (2003) Quo vadis C4? An ecophysiological perspective on global change and the future of C4 plants. *Photosynthesis Research* **77**, 209–225.

Sage RF, Kubien DS (2007) The temperature response of C3 and C4 photsynthesis. *Plant, Cell and Environment* **30**, 1086–1106.

Smith P, Martino D, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Sirotenko O, Howden M, McAllister T, Pan G, Romanenkov V, Schneider U, Towprayoon S, Wattenbach M, Smith J (2008) Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society of London: Biological Science* **363**, 789–813.

Stout PR, Brownell J, Burau RG (1967) Occurrences of trans-aconitate in range forage species. *Agronomy Journal* **59**, 21–24.

't Mannetje L (2007) Climate change and grasslands through the ages: an overview. *Grass and Forage Science* **62**, 113–117.

Waghorn G (2008) Forages with condensed tannins for methane mitigation. In 'Proceedings of the XXI International Grassland Congress - VIII International Rangeland Congress', 29th June–5th July 2008, Hohhot China'. In press.

Warn L, Webbware J, Salmon L, Donnelly JR, Alcock D (2005) Analysis of the profitability of sheep wool and meat enterprises. Final report for Project 1.2.6 (Sheep CRC).

Williams AL, Wills KE, Janes JK, Vander Schoor JK, Newton PCD, Hovenden MJ (2007) Warming and free-air CO_2 enrichment alter demographics in four co-occurring grassland species. *New Phytologist* **176**, 365–374.

Defining the northern New South Wales feed-year and mitigating feed-gaps

A.J. Lockyer

Landmark, Corner of Bourke & River Streets, Dubbo NSW 2830
<amanda.lockyer@landmark.com.au>

Abstract. *Northern New South Wales grazing systems are characterised by a shortage of pasture from May to September. There are a number of different options available to cope with this feed-gap, with their suitability depending on the enterprise. The tablelands region of northern New South Wales is particularly prone to pasture shortages during winter. These can be managed by de-stocking all but essential breeding stock during winter, and timing lambing and calving to occur around or slightly before the spring pasture flush. The spring pasture flush of both quantity and quality feed then coincides to better meet peak nutritional requirements of grazing animals. Any supplementary feeding programs should be carefully assessed to ensure that they are providing the nutrients that the pasture is lacking. Forage crops such as oats should also be considered as a viable option to fill the feed-gap due to its moderate to high nutrient content and comparably high growth rates over the winter months.*

Introduction

Northern New South Wales (NSW) is famous for its super-fine wool, large grazing enterprises and very cold winters (in particular in the Northern Tablelands). Northern NSW consists of the Northern Tablelands and North-West Slopes and Plains. The area has a diverse range of grazing enterprises including fine wool, prime lambs, beef cattle production and cropping in the North-West Slopes and Plains. The pastures consist of both native and improved. Climate including rainfall, evaporation and temperature determine the type of pastures that can be effectively grown and utilised by grazing animals. Picking the right pastures, managing them effectively and filling feed-gaps are all important parts of running a successful grazing enterprise.

The focus of this paper is on the Northern Tablelands as it has the greatest expression (with its very cold winters) of the feed-gap, however, the principles and strategies described are applicable to those other regions of northern NSW.

It is estimated that 50 per cent of pastures on the Northern Tablelands are native (Alford *et al.* 2003) with improved perennial pastures probably making up less than 30 per cent. These native pastures can be further divided into un-fertilised, fertilised and native pastures with some introduced legumes and grasses.

Soil types in the Northern Tablelands have a major influence on the types of pastures that can be grown. The basalt soils are highly fertile and lend themselves to the improved annual and perennial species such as phalaris, cocksfoot, ryegrass, tall fescue and red and white clovers. The granite-based soils are more suitable for the native pastures that have evolved on these soil types such as kangaroo and wallaby grass. Some of the improved temperate grasses such as cocksfoot and white and red clovers will also grow on these granite soils.

Temperature and rainfall are also major determining factors on the type of pastures that can be grown. They also contribute to major feed-gaps in grazing enterprises. By putting together growth-rates and growth patterns of the pasture species in your enterprise, you can effectively plan for feed-gaps and use pasture surpluses more efficiently.

Understanding pasture growth and defining the feed-year

To get a good understanding of your pasture system, it is important to get an idea of what your pasture growth rates are across the year and across pasture species. There are a large number of factors that influence pasture growth. Some of these include species (temperate or tropical, native or introduced), fertiliser history, temperature and rainfall. Monitoring pasture growth-rate on your farm allows you to do pasture budgets to identify feed surpluses and gaps. By identifying feed-gaps in advance it enables you to plan your strategy to get through this period. Strategies may include de-stocking, culling surplus animals (ie. dry animals) or changing the timing of calving or lambing to alter the feed demand profile to better suit feed supply. Pasture budgeting is a management tool that helps producers map the feed-year and manage pasture shortages and surplus.

Estimated growth rates over a 12 month period of both native (Figure 1) and temperate perennial grass and clover pastures (Figure 2) on the Northern Tablelands clearly show a defined 'winter feed-gap'. Northern NSW has a large number of frosts resulting in low ground

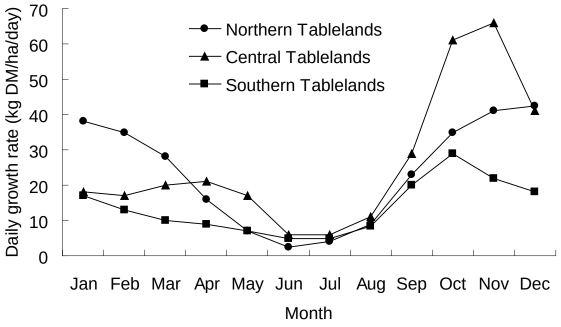


Figure 1. Estimated pasture growth rate of Microlaena/ clover pastures on the NSW Tablelands (Source: Alford *et al.* 2003).

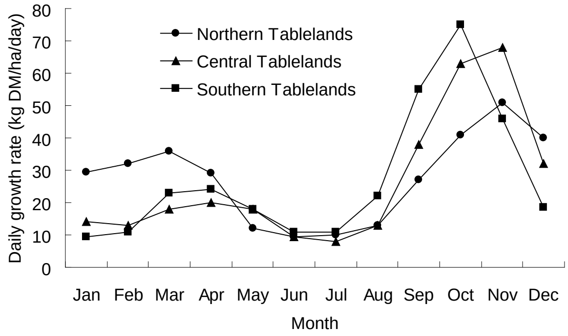


Figure 2. Estimated pasture growth rate of temperate perennial grass and clover pastures on the NSW Tablelands (Source: Alford *et al.* 2003).

temperature which contributes to low growth-rate in winter. Growth-rate can fall below 10 kg DM/ha/day from May to September for the native grasses, and below 20 kg DM/ha/day for the temperate perennial grass and clovers. This winter feed-gap is one of the main challenges for grazing enterprises in northern NSW.

Growth rates of these pastures are at their highest levels from September to December with growth rates above 30 kg DM/ha/day for the Microlaena/clover pastures and 40 kg DM/ha/day for the temperate perennial grass and clover pastures. Growth-rates steadily decline from December through until May due to high evaporation rates in the summer.

Pasture quality also tends to be higher during spring where there are high levels of green leaf in the pasture resulting in high energy, protein, digestibility and low fibre. As there is a bulk of feed grown in the spring much of this feed is carried into summer and autumn, however, as it matures it becomes less digestible and lower in energy and protein. Effectively managing spring growth and utilising this feed while it is at its optimum for animal performance gives the best returns in grazing enterprises.

Ayres *et al.* (2000) looked at temperate perennial pastures (tall fescue, phalaris, perennial ryegrass, cocksfoot, white clover and red clover) for weaner cattle in Glen Innes. Results from the trial led them to characterise the feed-year into three distinct phases. They are as follows:

- Spring primary growth
  High availability of green leaf
  High digestibility (80–85%)
  Very high levels of nitrogen (N) (30 g N/kg DM)
- Summer-autumn secondary regrowth
  High availability of green leaf
  Moderate digestibility (65–70%)
  Moderate levels of N (15–20 g N/kg DM)
- Winter dormancy
  Low availability of green leaf (750–1,500 kgDM/ha)
  High digestibility (75–80%)
  High levels of N (20–30 g N/kg DM)

Dicker *et al.* (2000) looked at weaner growth rates in the Northern Tablelands over a three year period (with no supplementation) and found that growth rate was seasonal, as we would expect. Live-weight gain ranged from less than 0.5 kg/hd/day during winter to 0.8 kg/ head/day during spring, while the summer/autumn gain was 0.3–0.7 kg/head/day.

Management practices for improving animal production

Filling the feed-gap

There are a number of options available for filling the winter feed-gap. The most suitable strategy or strategies will be determined by individual farms and their livestock enterprises. Some of these options include making silage or hay from surplus pasture in the spring, planting forage crops such as oats, wheat, barley or triticale that have active growth over the winter months and buying supplementary feed including hay, silage, grain (pellets) and whole cottonseed.

Shifting feed demand

Another management option other than filling feed-gaps is shifting feed demand to better match pasture growth. Feed demand will vary over the year according to stock numbers and physiological state of the animals. Pregnant and lactating animals have higher requirements for both dry matter (DM) and nutrients. Autumn lambing or calving is not advisable in the Northern Tablelands because the cows/ewes reach their peak nutrient requirements when feed supply is at its lowest. To meet animal requirements, a high level of supplementary feeding will be necessary. The vast majority of enterprises in northern NSW lamb in the late winter and spring and calve mid- to late-winter.

Forage crops

Planting forage crops to provide a good quality body of feed in the winter is a good way of filling the winter feed-gap. Forage oats has been a popular choice in the past, but more grazing enterprises are looking towards alternative species such as barley, triticale and winter wheats.

'Prograze' (Anon 2006) estimates the growth rates for forage oats in an average Northern Tablelands season to be 27 kg DM/ha/day in April, falling to 19, 18 and 19 kg DM/ha/day in May, June and July, respectively, increasing to 29 kg DM/ha/day in August and 47 kg DM/ha/day in September. These growth rates are higher than the temperate pastures and native pastures shown in Figures 1 and 2, making it a viable alternative to fill the winter feed-gap. It is worthwhile to look at figures from the North West-Slopes and Plains to compare figures between pastures and forage crops to help fill feed- gaps.

Forage crops can be locked up to make good quality cereals and hays that can be fed during the next winter or feed gap. Dual purpose forage crops can be grazed initially and then locked up and harvested for grain. The grain is particularly useful for feeding pre-lambing ewes or weaners. Another option once the grain has been harvested is to bale the crop stubble. The stubble can provide an effective fibre source whilst grazing lush pasture, clovers and cereal crops. Crop scours can be a major loss of production in grazing systems.

Hay and Silage

Hay and silage are essential tools in a grazing enterprise. In situations when there are low levels of DM in the paddock, a roughage source is needed to ensure optimal rumen function. Hay and silage can be used for maintenance or growth, depending on the quality, or can make up the roughage component of a grain-based ration.

Making hay and silage can be used as a pasture management tool to utilise feed surpluses. By taking a paddock out of production or by shutting up an area not needed for grazing, good quality hay or silage can be made and utilised at a later date. The remaining pasture will be of better quality due to higher grazing pressure and less time for the pasture to decline in quality.

Pasture supplementation

It is rare in a grazing enterprise that pasture will contain all nutrients that the animals require. By identifying the nutrient requirements of the livestock classes throughout the year and then comparing it with what is available from the pasture enables you to determine what nutrients are lacking for optimum production. Too many feeding programs are used because of 'tradition' or what the neighbour uses rather than looking at what is lacking and then determining how best to satisfy the requirements.

Conclusions

To get the most out of grazing systems in Northern NSW, it is essential to get a good handle on the growth rates of the pastures in your system throughout the year. This can then be matched to animal demand and feed-gaps can be identified. Filling the feed-gap can include supplementation depending on what is deficient (ie. DM, protein or energy) or shifting feed demand by de-stocking or changing your lambing and calving patterns.

References

Alford A, Griffith G, Davies L (2003) Livestock Farming Systems in the Northern Tablelands of NSW: An Economic Analysis. Economic Research Report No 12, NSW Agriculture, Orange, October. http://www.dpi.nsw.gov.au/research/areas/health-science/economics-research/reports/err12

Anon (2006) Prograze™ Profitable Sustainable Grazing. NSW Department of Primary Industries, Seventh Edition, March 2006.

Ayres JF, Dicker RW, McPhee MJ, Turner AD, Murison RD, Kamphorst PG (2001) Post-weaning growth of cattle in northern New South Wales 1. Grazing value of temperate perennial pasture grazed by cattle. *Australian Journal of Experimental Agriculture* **41**, 959–969.

Dicker RW, Ayres JF, McPhee MJ, Robinson DL, Turner AD, Wolcott M, Kamphorst PJ, Harden S, Oddy VH (2001) Post-weaning growth pathways for cattle in Northern New South Wales 2. Growth pathways of steers. *Australian Journal of Experimental Agriculture* **41**, 971–979.

'The business of growing a meal' – the application of new pasture varieties and management practices for intensive beef production

G.R.T. Lord

'Branga Plains', Walcha NSW 2354
<brangaplains@bigpond.com>

Abstract. *This paper outlines the planning and operation of producing beef cattle, including supplying 110 head per month of finished animals to a retailer. The focus has been consumer-based breeding of cattle utilising tools such as 'Breedplan'. The pastures are all introduced species based on phalaris, cocksfoot, tall fescue and various strains of legumes. Pastures are rotationally grazed and well fertilised with phosphorus, sulphur, nitrogen and molybdenum.*

'Branga Plains' is located on the southern end of the New England Tablelands in New South Wales at approximately 1,250 m above sea level. The property is 4,300 ha with predominately basalt and trap soils receiving an average rainfall of 900 mm.

The operation is 100 per cent beef cattle. In the past eight years we have moved from a long tradition of selling weaners at an annual on-property sale in autumn, to retaining and value-adding all steers and surplus females. This program of breeding all replacement animals is fully integrated with finishing stock and direct-marketing.

We moved from a commodity focus to a consumer focus with the implementation of a retail alliance in Sydney to supply 12 months of the year. This program has presented a set of production challenges. It requires the merging of agronomic functions, most of which we can measure to help make our operation more efficient. New technology within our industry has generated opportunities to advance production in the animal and plant fields. The Australian beef industry has developed probably the best genetic evaluation program in the world in 'BreedPlan'. Using 'Estimated Breeding Values' (calculated by BreedPlan) has enhanced our ability to select bull 'genetics' to breed cattle with improved performance. This will allow us to maximise gains that have been made in pasture production.

Supporting our breeding and finishing program has involved realigning some paddock fence lines to facilitate efficient use of labour and plant production. A central laneway services the more intensive pasture paddocks. We consider this system along the lines of a grass feedlot. Our breeding herd is a segment of the factory type arrangement we hope to develop and maintain as part of our philosophy. A functionally efficient breeding herd has to be driven by fertility, which demands a reasonably constant supply of nutrition. The key profit drivers for this system are high weaning percentages of calves with optimum growth, carcass traits and eating quality.

Measuring performance is dependent on a good recording system. This has been enhanced by the implementation of the National Livestock Identification System. This system gives us the advantage of having regular recording of weight gains and feedback on individual animals. Our system is dependent on the Meat Standards Australia (MSA) grading system as it gives us an independent assessment of our product. The science behind this system is based around consumer acceptance, and compliance is normally influenced by management practices that include nutrition. The concept of producing a graded product dovetails our animal and pasture production.

Different categories of cattle have to be catered for with different qualities of nutrition. We have designated areas in a tier system for breeding cattle, growing cattle and finishing cattle. With favourable seasons we would certainly like to see these areas overlap. The traditional 'shotgun mixes' of phalaris, cocksfoot, demeter fescue and various clovers have served us very well on the majority of 'Branga Plains'. With an annual fertiliser program topping up a phosphorous deficiency, and with the addition of sulphur (and on a periodic basis molybdenum), these pastures support our breeding herd very well. This program is normally supported with the annual application of around 75 kg/ha/yr of blended fertiliser products. Grazing management has proven to be a major contributor to the quality of the pasture with noticeable differences in plant population and ground coverage. This has been helped by subdividing paddocks and increasing water points.

Supplying a market on a fortnightly basis with a continuous number of cattle has given us a regular cash flow and a challenge to submit cattle of consistent quality. When we first started this alliance around eight years ago we were excited because we had the numbers and the genetics to undertake such a commitment. We also thought we had good enough pastures to ensure we could supply, with the help of some supplementary feeding. However, we have also had to experience rising feed costs which compromises the costs of production.

We started a pasture improvement program using so called 'high performance' species by upgrading into the new models like Quantum fescue, Lincoln rye, Astred red clover, Matua prairie grass, Puna chicory and a mixture of white clovers. This mix was planted in early February and was in production by the middle of May and is still going well today. We have since moved onto a program utilising tetraploid ryegrasses (both Italian and long rotation) with a two to three year retention. These grasses have given us excellent winter production and with their late flowering have continued to perform well into summer. One of the benefits of a 'break up' crop such as ryegrass is that it allows us to target weeds and undesirable grasses with a couple of chemical cultivations. Following the ryegrass, we are then planting tall fescues such as Advance and Quantum II with clovers, chicory and plantain. Outside normal New England tradition, we are also trialling annual clovers and so far they look spectacular.

Maintaining the productivity of these pastures requires several management inputs both financial and mechanical. During the growing season we are applying up to three topdressings with nitrogen (N) based fertilisers (at around 50 kg N/ha) along with our annual spreading of a phosphorous blend in the spring. An important ingredient is the input that we rely on from our agronomists. We have installed a stock watering system to facilitate rotational grazing. This consists of solar powered submersible bore pumps and troughing to enable us to run temporary electric fences to split paddocks into manageable areas and promote non-selective grazing. The palatability of the new pastures has promoted good utilisation of the whole area. However, to ensure an even sward we follow the cattle with a mulching slasher to 'top' each field as part of the rotation. This process also assists in the control of weeds such as scotch thistles.

The challenge of supplying about 110 head per month directly to our retailer is contingent on weight gain and carcass quality. The weight gain factor has been addressed by the use of good pasture and fertiliser allowing our genetics to express themselves with daily weight-gains in the vicinity of 1.8 kg/day during the warmer months. When these pastures are at the least fibrous stage, we give the animals access to straw in hay self-feeders. The critical control point of eating quality is monitored by the MSA grading system with factors such as weight-for-age, meat colour, fat cover included in our producer feedback with all these traits nutritionally based. Individual animal identification on all animals gives us a constant monitoring system of animal and paddock performance with frequent updating from weighing cattle on a regular basis. Collection of these data has reinforced the fact that increasing productivity from our pastures has outweighed re-pasturing costs with larger numbers of animals coming off a selective area. Our calculations would suggest that we are producing upwards of 850 kg of beef per hectare from our intensive areas.

We are committed to, and enjoy supplying consumers with a product that satisfies their expectations of a more consistent eating experience, and we feel this will no doubt lead to producing cattle that are more profitable.

The challenges that confront our industry are becoming quite evident at the moment, and they are being driven from both inside and outside our country. The US Government's decision to mandate ethanol production coupled with unfavourable seasonal conditions in a lot of countries (including our own) has put pressure on our intensive grain feeding industries. The situation has arisen that we now have competition between the feedlot industry, food industry and the ethanol industry for grain and grain-growing country. In the US, we have seen the price of corn doubling in price in the last two years, which not only challenges the feedlot industry but all intensive livestock industries. We are constantly being made aware of the threat that climate change poses, and now we have high input-costs such as herbicides, fertilisers and fuel. Hopefully the answer will be in grass production of our red meats with the constant research and development of better pastures, because this where Australia has a definite advantage.

'Art and science' – producing high quality forage-based feed for intensive dairy production

J.L. Drury

'Emmie-R Farms', Attunga NSW 2345
<emmie-rfarms@bigpond.com>

Abstract. *Dairy cows of today need a high performance ration to meet the rigours of high production, reproduction and health. High quality pasture is finding a different role to what was traditionally seen, with changes required persistently to fit a fine balance of meeting the cow's nutrient requirements effectively, economically and in an environmentally sustainable way.*

Introduction

'Emmie-R Farms' is a 300 cow dairy operation producing around three million litres of milk per annum. The farm consists of 134 ha of land area purchased in December 2004. The property at that time was used as a mixed farming operation with no pasture improvement and minimal fertiliser inputs.

The farm has been transformed into a high-input/high-output dairy operation where home-grown forages drive the profitability and production output of this system. High quality pastures form the base to the ration for a high production dairy herd. This grass-base is balanced by corn silage, cereal grains, protein meals, pasture silage and straw.

Background

Jamie was born and bred on the family farm. Jamie studied at the University of New England where he completed a Bachelor of Science degree, majoring in Chemistry and Bio-Chemistry. He also completed a post-graduate year in Animal Nutrition and Agriculture and Resource Economics. In 1996, Jamie returned to the family farm where he purchased cattle, leased a neighbouring farm and formed a partnership with his parents. Over nine years, herd numbers and farm area were expanded to milk 180 cows on 105 ha.

This farm on the North Coast, near Taree, was on the lower Manning floodplain with an average annual rainfall of around 1,000 mm. This rainfall was traditionally summer-dominant but during the late 1990s to the time of moving farms, the rainfall pattern tended towards drier summers and wet autumn/winter periods along with rainfall becoming far more sporadic. With increases in stocking rate, production and variability of feed due to rainfall variability, a move was made towards more supplementation along with continued use of high quality ryegrass/clover pastures. This system was developed extensively during the period of Jamie's involvement with the operation at Taree.

The move

Jamie's father was ready to retire, so in 2005, a sheep and irrigation property was purchased at Tamworth for conversion to a dairy. Consequently, the family farm at Taree was sold and Jamie and Michelle Drury started a new adventure on the other side of the ranges.

The dairy facilities consist of a double 15 Boumatic Grandprix Rapid Exit Parallel Parlour and a 300 cow feed-pad with self-locking head locks. The existing shearing shed has been converted for calf rearing facilities.

The irrigation is made up of two Valley centre pivots covering 66 ha plus side roll and hand shift irrigation. A two-pond effluent system treats waste from the dairy facility with treated effluent being injected into pivots along with 'fertigation'.

Currently the feed mixing/conservation areas are being developed with the mixing area. Four 1500 tonne silage pits are being completed together with new hay sheds and commodities storage are being constructed over the next 12 to 18 months.

Cow production

The rolling herd average of 10,500 L of milk at 4.0% fat and 3.3% protein compares favourably to a district average of 7,500 L at 3.7% fat and 3.2% protein. This level of production is achieved by feeding a partial mixed ration of soda wheat, barley malt combings, corn silage, barley straw and ryegrass/legume silage. This partial mixed ration is balanced to complement the availability and quality of ryegrass/clover pastures. By balancing this ration correctly, we can increase pasture intake by cows along with overall dry matter (DM) intake to drive production higher.

Pastures and cropping

Pastures are sown from the last week in February starting on the irrigation area so that it can be watered if needed. We aim to complete sowing by mid-April at the latest. Unfortunately, with the lack of rainfall in autumn this year, we have only recently completed our sowing on the dry-land areas.

The pasture mix consists of a tetraploid ryegrass (Feast II, Winter Star II) at 30 kg/ha and annual clovers (Arrowleaf clover, Sardi and Turbo Persian clover, Alexandria burseem clover) at 4 kg/ha. The varieties used in each area are chosen on seeding date, ie. the short rotation varieties are sown in areas that will be cropped in summer with longer rotation varieties sown on the balance of the area.

A pre-plant fertiliser application consists of 300 kg/ha of sulphate of ammonia, 2.5 t/ha lime (every second year) and 50 kg/ha of Granulock 15 at sowing. The pasture is topdressed with urea and effluent-water as needed. Effluent-water is preferred for a number of reasons. Firstly, it is a readily available resource that is a by-product of our farming system. It offers a good balance of nitrogen (N), phosphorus and potassium to our pastures along with improving microbial functions in the soil, and lastly (and most importantly) it is significantly cheaper than any other fertiliser.

We aim to provide between 40 and 50 kg of N/ha between every grazing to achieve maximum yields.

Rotation length varies from 24–28 days in autumn to 40–45 days in winter, and shortens to 14 days in spring.

The short rotation varieties are sprayed out around the last week in September to allow for ground preparation for a corn crop to be planted during the first week in October. The timing of this will vary with soil temperature needing to be at 16°C to sow, but we aim to have the corn sown within 10 days of spraying out the ryegrass. A pre-plant fertiliser application of 300 kg/ha of urea and 300 kg/ha of potash is used along with 125 kg/ha of Granulock 122 at sowing. A further 80 to 100 kg/ha of N is applied during the growing season through the pivots. Sowing in early October allows for a target harvest date of around the end of January. This then allows for approximately three weeks until ryegrass is sown again, giving a total fallow/lay 'off-time' of less than four weeks for the year for the irrigation area.

The dry-land areas are sown to a longer rotation cultivar of tetraploid ryegrass (Feast 2). This year, the late spring/early summer rainfall meant that these pastures continued to grow well into early 2008. Heat and weed infestation reduced the productivity of the pastures with the dry-land area sprayed in January and left fallow ready for direct-drilling in autumn. The same pre-plant fertiliser is used as for the irrigation area with follow up N application dependent upon moisture, but the aim is to be as close to the irrigated area as we can.

Weed control

In our initial year, we had a significant weed burden. In that year we sowed grass-only pastures to give us cheap and effective weed control. The following years have resulted in minimal spray requirements for winter weeds.

When we are grazing, there is a considerable juggling act between fertiliser, irrigation, grazing and weed control. We have found that if we do the first three things very well, then there is little need for sprays to be used for weed control. Most weeds will be grazed and when sufficient nutrients are used to push the pasture along, then the weeds are generally killed out.

The use of summer-cropping has significantly reduced all weeds. Our ryegrass/clover pastures, grown after a corn crop have no weeds to be controlled – this comes about due to the management practice of cutting silage prior to a corn crop early in the season. Any weeds that survive through the winter grazing/fertiliser program are harvested for a silage cut in spring before any seed-set. Paddocks are then sprayed with 'Roundup' and cultivated for corn. A pre-emergent spray of Dual and Atrizine are used for grass and broadleaf weed control in the corn crop. These young weeds have a significant detrimental effect on young corn taking nutrient and water, and consequently affecting the overall yield and quality of our corn silage.

Our principal of weed control is based around the fact that weeds will only grow when there is a lack of competition; hence, we work very hard to make sure they do. This in turn gives us a larger proportion of home-grown feed which drives our profitability.

Pasture and crop production

The greater the amount of pasture DM produced on-farm and the higher the quality of this feed, the greater the profitability we can achieve. This principal is born about by the fact that the higher the quality (in terms of palatability, digestibility, acid and neutral detergent fibres, starch, protein profiles, sugars, fats and amino acids) of our forages all have a significant effect, not only on production but on the other inputs required to balance these forages for the required production level. Purchased feeds are more expensive and less predictable in some cases, and thus reduce the potential profitability. Having said that, we still require certain amounts of grain and commodities to balance the ration for high production levels and cow health and reproduction.

We aim for pasture DM yields, at present, of greater than 35 t DM/ha on our irrigation area with this target increasing to above 40 t DM/ha by the end of 2009. Currently, this is achieved by corn yields of 23–25 t DM/ha and ryegrass yields up around 15 t DM/ha. The increases in overall yield will be achieved by ongoing improvements to soil health and nutrition and increased efficiencies in harvest for our ryegrass.

Currently all ryegrass is grazed by the milking herd. We have found over the last two years that we are starting to have significant compromises between what is agronomically correct for ryegrass defoliation and what cows can physically harvest. We are finding that we need to graze at the two-leaf stage rather than the preferred three-leaf stage for maximum ryegrass yields. We are currently investigating the economics of alternatives such as 'cut-and-carry' for some of this production during winter. Excess feed in spring is conserved as silage, to be fed out in the total mixed ration through summer, and also to balance rations through autumn and winter during any wet periods if we cannot graze.

Repeatability

The pasture component of this system has been repeated at two other farms where our heifers are contract reared. In both these operations, a proportion of the irrigation area has been sown to a semi-permanent pasture mix of Feast II ryegrass, red and white clovers (USA Red red clover, Haifa white clover), chicory and lucerne (WL 925HQ lucerne). The balance of the irrigation areas are sown to a tetraploid ryegrass and annual clovers. Dry-land areas are sown to a similar mix with early paddocks (early March sown) having 10 kg/ha oats included. Excess spring growth is purchased as silage with some hay being made to supplement the heifers in feed-gaps.

One of these properties, 'Wingara', where our in-calf heifers are run, has been contracting our heifers for approximately 18 months. The farm consists of 80 ha – 35 ha irrigation, 35 ha dry-land and the 10 ha balance of laneways and lay-off areas. Last year, the average number of heifers run on this block was between 90–100 550 kg heifers with a peak of 140 in spring. We also cut the entire irrigation area for silage once in spring, and a second cut of hay and silage was taken off the irrigation area in November. A 7 ha block of lucerne is used for hay production only, except for one grazing during winter. This represents a significant increase in the previous enterprise of fattening 30–40 steers on oat-crops!

These systems are based on maximising the inputs available. The climate in Tamworth allows for production of both summer and winter crops. Ryegrass/clover based pastures are selected for winter cropping as they are high production, high quality feed for grazing livestock. We are currently considering/trialling some winter cereals for use on our dry-land area for cutting for silage.

Annual ryegrasses are selected in preference to perennials due to their higher production and hence better water- and nutrient-use efficiency. The cost of re-sowing each year is far out-weighed by the significant increase in production. The other consideration is the low water-use efficiency of ryegrass over the summer period.

Corn has proven to be one of the most water-use efficient crops we can grow. Corn grows a large amount of DM over the summer period and is also a complementary feed for ryegrass pasture or silage.

Ryegrass typically has good energy, with low starch, high protein and high digestibility (and can be low in fibre). Corn silage complements this by being low in protein, good effective fibre with high energy and high starch levels to complement the ryegrass. Both feeds also have similar digestion times which gives an efficiency of nutrient use and hence an increase in production. These two feeds are then balanced by adding some straw (for effective fibre) and cereal grains and protein meals (to increase ration density and balance the nutrient profile) to achieve a balanced ration for high production.

Conclusions

Many farmers do a good job in certain areas of their operation. At 'Emmie-R Farms' we try to extend the boundaries of what can be achieved. We do this by looking at what we do well and trying to do better, along with bringing in expertise to balance what we do so as to achieve the best out of the inputs available to us. The nice thing is that we all have this option available to us.

Contributed papers